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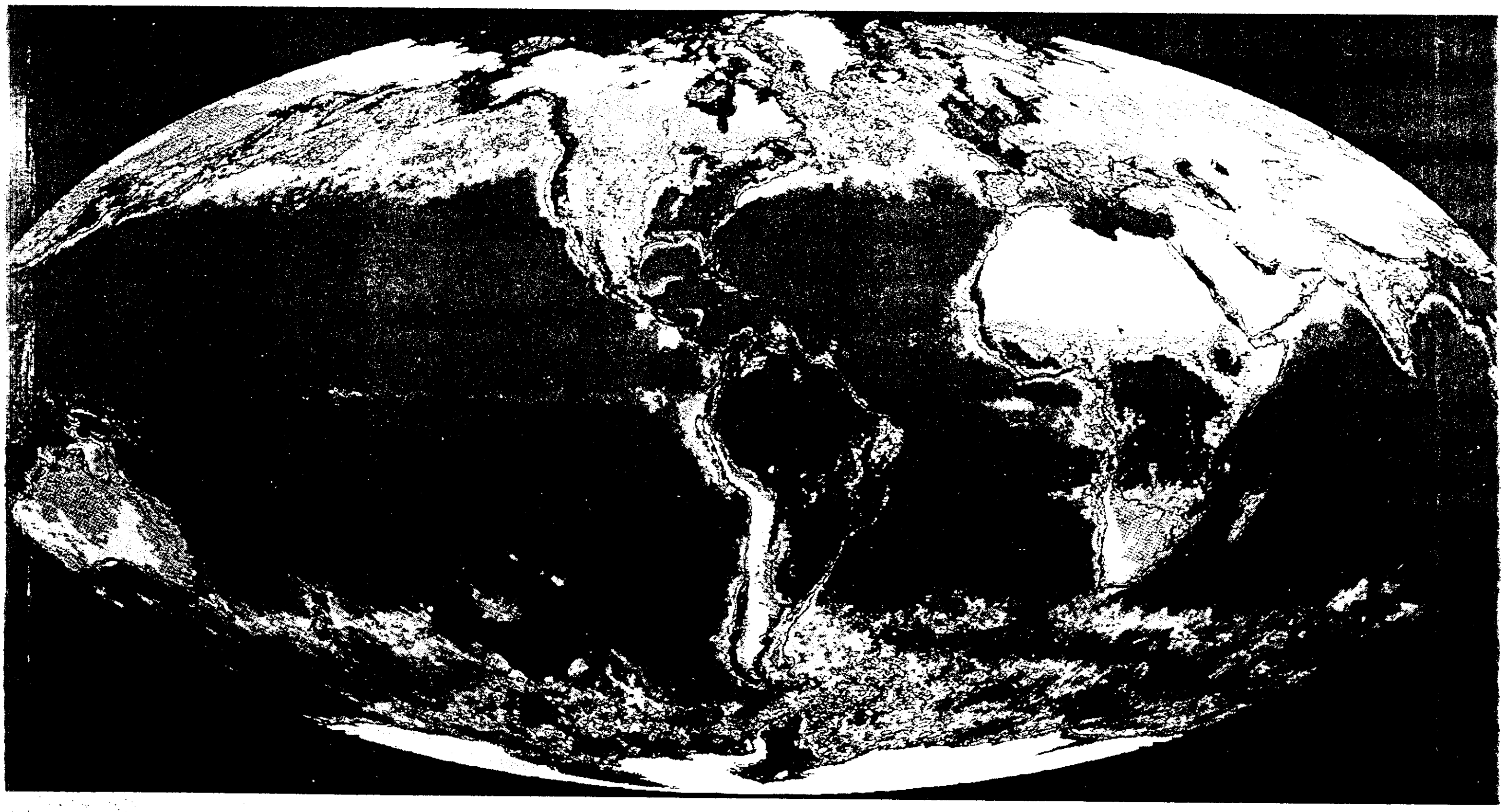
# SEMINARS

## of the United Nations Programme on Space Applications



Selected Papers on Remote Sensing, Satellite Communications and Space Science

1996

United Nations

Office for Outer Space Affairs
United Nations Office at Vienna

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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 developing country access 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 seventh 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 is comprised of selected papers presented at the 1995 activities of the Programme on Space Applications that illustrate the issues related to the use of space technology for development, especially through management of natural resources and the environment, and to meet communications needs. The scope of the publication extends from a general overview of international cooperation in space activities and the role of the developing countries in this area, to more specific areas of applications of space technologies, including the use of remote sensing for resource management in Africa., and Asia, and the use of advanced satellite communications systems for health care and education. 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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# THE CHALLENGES OF SPACE TECHNOLOGY - POSSIBILITIES TO ENHANCE THE QUALITY OF LIFE*

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## INTRODUCTION

Humanity, whose ancestry can be traced across whole geological eras into a creature not greater than a diminutive rat and whose intellectual powers began to be strikingly prophetic only during the last ice-age, deserves the generic title that it has given to itself *'Homo Sapiens,'* the wise. From the beginnings in East Africa about five million years ago, humans have vigourously pursued the struggle for dominating the world and improving living conditions. While the initial stages were marked by the struggle against the vagaries of climate, a new culture based on agriculture and domesticated animals was originated in the rich and fertile river valleys. From this economic foundation came a population explosion and the first cities, intercultural trade, colonization and the ideas of empire and conquest.

While primitive humans were happy when their basic needs were met using whatever was available in nature, the increasing demand on resources along with the instinct to improve living conditions forced successive generations to use their intelligence and skill. The quest for scientific exploration paved the way for significant advances in science and technology which were effectively utilized for the betterment of humanity or improving the quality of life. Among the scientific developments of the 20th century, the development of space technology and applications stands out as one of humanity's most momentous achievements. It has enriched the scientific knowledge, provided scintillating experiences of the Moon, improved human connectivity, provided the capability to extract valuable information on weather and climate which was hitherto unavailable, enabled the extraction of vital details on the Earth's resources on a continuous basis for sustainable resource development, and so on. Apart from the memorable experiences of space exploration, the major causal factor for the uniqueness of space technology is its inevitable role in addressing those issues that are of direct relevance to humanity. As the poet Xenophanes said 2,500 years ago, "The gods did not reveal to men all things in the beginning, but in the course of time, by searching, they find out better."

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* This paper, which was presented at the United Nations/IAF Symposium on "Space Technology for Health Care and Environmental Monitoring in the Developing World," held at Oslo, Norway, 28 September - 1 October 1995, does not necessarily reflect the views of the United Nations.

## QUALITY OF LIFE - ITS MANY DIMENSIONS

The concept of quality of life is as varied as the individuals in a society and as complex as the human body. For primitive humans, for whom quality of life was nothing but meeting basic needs, that standards of measurement of social well-being as well as the means to improve the quality of life has undergone dramatic changes. If quality means a characteristic, innate or acquired, that, in some particular way determines the nature and behaviour of a person, there are a number of individualistic, societal and environmental factors that affect the quality of life. (See Figure 1.) Although people differ in the goals that they would set for development, some are virtually universal. These include a long and healthy life, education, access to the resources needed for a decent standard of living, political freedom, guaranteed human rights and freedom from violence. Improving the quality of life is thus a process that enables humans to realize their potential, build self-confidence and lead lives of dignity and fulfillment.

### THE INDICATORS

A look at the global scenario brings out wide variations in the quality of life due to varied reasons, ranging from cultural and socio-political factors to environmental and technological constraints. But there are certain indicators which help us to assess the level of development as well as to arrive at the critical issues that need to be addressed towards ensuring a better quality of life.

#### The Pressure of Population

The world's population doubled from 2.5 billion to 5 billion between 1950 and 1987 and is expected to reach 6.4 billion by 2000. In other words, the world's population of 300 million in the first century might have increased by more than 21 times by the beginning of the 21st century. Accordingly, there has also been a tremendous increase in the urban population. By 1970, the number of people living in urban settlements had reached 1.35 billion and United Nations estimates and projections set the figure at 3.2 billion in 2000, which means that half of humanity will live in cities by the end of the century. Besides the adverse impact of the increased anthropogenic activities, the resource requirements for meeting basic human needs will be exerting tremendous pressure, especially on the scarce resources of the developing nations. For each 1 per cent growth in population, it is estimated that at least 3 per cent of GNP is needed as a "demographic investment" to expand the infrastructural stock. One of the major reasons for the backwardness of most of the developing countries is the lack of necessary infrastructure. Coping with the future infrastructural requirements calls for tackling inefficiency and waste, both in investment and in delivering services, and opting for modern technologies that can reach more people with less ground infrastructure by a cost-effective and timely manner.

#### Economic Development

Economic growth is an important component of development, though it cannot be a goal in itself. The wide-ranging disparities in the living standards of the people in the developed and developing nations can be mainly attributed to the lack of economic development. In 1991, 84.7 per cent of global GNP and 84.2 per cent of world trade was controlled by the richest fifth, as against 1.4 per cent of the GNP and 0.9 per cent of world trade handled by the poorest fifth. A look at the total domestic savings and investment in these two groups also reveals a similar disparity. Likewise, the average real GDP per capita in terms of purchasing power in the developing countries is around $2,700 which is just 1/6th of that in the industrialized countries. When we consider the absolute poverty levels rather than average GDP per capita, the situation is more revealing. For example, in the least developed countries, 71 per cent of the rural population and 31 per cent of the urban population live in absolute poverty. Thus, along with the efforts to increase the availability of goods, improving the purchasing power of the poor needs to be addressed, as only then can an improvement in quality of life be achieved.

Education

The catalytic role of education in improving the living standards of people is an accepted fact. Least developed countries with literacy rates of 20-30 per cent have a national per capita gross income of less than $200 per year. On the other hand, in developed countries where the literacy rate is more than 95 per cent, the average annual per capita GNP is $18,000. Similarly, a look at female literacy rates, along with infant mortality rates, life expectancy and levels of development also brings out the inevitable role of education in the overall development of a nation. (See Figure 2.) For example, the average number of children per uneducated woman in Brazil is 6.5 whereas women with secondary education have only 2.5 children. In Liberia, women who have been to secondary school are 10 times more likely to use family planning services. Another study in four Latin American countries has shown that education was responsible for a 40-60 per cent decline in female fertility. A recent study by the International Food Policy Research Institute reveals that if men and women had education and access to agricultural inputs such as fertilizer and technologies, gains in agricultural output would be substantial. Thus, education plays a significant role in improving the quality of life and facilitating the overall development of a nation.

Health Care and Sanitation

One of the major reasons for the poor quality of life in the under-developed societies is the lack of proper health care and sanitation. For example, in least developed countries, only 54 per cent of the population has access to health services. Similarly, the number of people per doctor in industrialized countries is 390 as against 6,670 in developing countries and in the least developed countries only 30 per cent of births are attended by health personnel. It is then quite natural that the maternal mortality rate in developing countries is about 20 times higher than that in the developed world.

The lack of adequate health services in most of the developing countries is further complicated by unhygienic living conditions and poor sanitation. On an average, 60 per cent of the rural population in developing countries and only 30 per cent in least developed countries have access to safe water. In addition, infectious diseases continue to act in synergy with the risks created by crop failure, an uneducated at-risk population and the lack of public sanitation. Such diseases are a major cause of human illness on our planet. Malaria alone infects more than 200 million people. A list of diseases which are largely spread by insect vectors is given in Table 1. As each of these vectors requires specific kinds of ecologies to support it, tracking these ecologies and identifying areas of maximum risk is of paramount importance. Besides, imparting health consciousness to the poor and uneducated can greatly improve the existing scenario. To cite an example, the Tanzanian radio study campaign had been highly successful in imparting health awareness. The evaluation of this campaign has shown that not only did the target group participate in weekly discussion meetings but it also learned about health practices and participated in various actions, including the digging of 750,000 latrines.

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Table 1: Insect-borne diseases

| Disease | People Affected (millions) | People at risk (millions) | Number of countries affected |
|---|---|---|---|
| Malaria | 270 | 2,100 | 103 |
| Schistosomiasis | 200 | 600 | 76 |
| Lymphathitic filiarasis | 90 | 900 | 76 |
| River blindness | 17 | 90 | 34 |
| Chagas disease | 16-18 | 90 | 21 |
| Leishmaniasis | 12 | 350 | 80 |

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Food Security

The struggle against hunger has been the biggest challenge since the origin of humanity. According to recent estimates, 31 per cent of the people in developing countries are in absolute poverty whereas it is 64 per cent in least developed countries. Though the dependence on agriculture is much less pronounced in the industrialized countries, they have been quite successful in improving agricultural productivity through better management practices and by adopting a scientific approach. On the other hand, the contribution of agriculture to the national GDP is very high in most developing countries (See Figure 3). While agricultural contributes less than 5 per cent to GDP in most of the high-income economies, the figure is more than 25 per cent in 35 out of 41 low income countries. Bringing cultivable wastelands under agriculture and improving productivity through scientific approaches appears to be the only option to ensure food security, especially in most of the developing nations.

Improvements in agriculture also call for effective utilization of water resources. In most countries, irrigated agriculture accounts for the biggest share of water and amounts to approximately 70 per cent of world water withdrawal. While the irrigated land area, which has almost tripled in the last four decades, supplies one-third of the world's food, less than 40 per cent of the water supplied for irrigation contributes to the growth of crops. Added to this enormous waste are the problem of waterlogging, salinity/alkalinity, etc. Thus, a lot of improvement is called for in the management of land and water resources, if we are to ensure food security for the world's growing population.

Environmental integrity

For a very large number of the poor who depend on the resources of their immediate environment, poverty has been compounded by environmental degradation. Not only does the natural resource base of the immediate environment provide their basic requirements, it is also the basis of their livelihood and security. The challenge of poverty and the challenge of environment are therefore not two different challenges but two facets of the same challenge.

A clean and safe environment not only ensures a better life today, but also forms the foundation for a sustainable future (See Figure 4). The unsustainable consumption of resources to satisfy the increasing needs of an exponentially growing population is already exerting tremendous pressure on our fragile environment. There are widespread symptoms of environmental degradation, seen all over the world in the form of degraded lands, depleted ground water levels, decreased agricultural productivity, global warming and changing climate, increasing health hazards due to pollution from various sources, etc. Thus, any development not in tune with the environment can no longer be tolerated. Conservation-based development must include deliberate actions to protect the structure, functions and diversity of natural systems. Accounting for natural resources, periodic monitoring and assessment of the environmental impact of human interventions are essential, and the initiation of preservation and conservation measures are essential for ensuring that we live within the carrying capacity of planet Earth.

While a clean environment may be well within our hands, humanity has not been highly successful in ensuring protection from natural disasters and environmental hazards. According to the International Federation of Red Cross and Red Crescent Societies, the major causes of deaths from natural disasters between 1967 and 1991 were droughts (1.3 million), cyclones (0.8 million), earthquakes (0.6 million) and floods (0.3 million). But if all disaster incidents are considered, nearly 1,400 flood events were reported during the above period. Accordingly, the economic damage from such disasters increased from $10 billion in the 1960s to nearly $100 billion in the 1980s. Added to the loss of lives and economic damage is the hardship suffered by the affected peopled and relief operations. A coordinated effort by various agencies along with proper warning, monitoring and management can only reduce the effect of the havoc caused by disasters.

The quality of life of an individual is also dependent on a number of factors which affect the intrinsic qualities. These vary from entertainment to enrichment of knowledge and connectivity to peace of mind. In other words, there may be one goal but many indicators. There are many critical issues that need to be addressed to transform our societies to better living environments as well as to enable happy life. The significant developments in science and technology provide effective tools to address these issues. Space technology, one of the latest but very powerful additions in the saga of achievements resulting from humanity's relentless pursuit of scientific explorations, has emphatically proved its capability in improving the quality of life all over the world.

## SPACE TECHNOLOGY - A HARBINGER OF CHANGE

The direct benefits of space technology have been in the areas of communications, education, health, entertainment, meteorology, resource inventory, monitoring and management, disaster warning and management, enrichment of knowledge and development of science and technology, thus addressing most of the crucial issues towards enhancing the overall quality of human life. (See Figure 5.)

### Global Connectivity

Since the root cause of the growth of human intelligence and civilization is non-genetic transmission of experience and knowledge from one generation to successive generations, the role of satellite communications is extremely crucial. Satellite communications, with its inherent flexibility, distance insensitivity, ability to reach even the most remote location and, above all, its low cost and timeliness, has already revolutionized the global communication scenario. Starting with a small, 240 channel capacity, 39 kg Intelsat-I (Early Bird) Satellite in 1965, which ushered in the age of operational satellite communication service on a global basis, the variety and the quantum of services available now have increased many fold. (See Table 2.) There are now international, regional and domestic networks offering a large variety of services both for communication and broadcasting. The satellite channel capacity has increased from the 240 voice channels of Early Bird to around 30,000 voice channels1/ This dramatic growth has not only ensured initially "international connectivities" and later "regional connectivities" and "national connectivity," but have led to the introduction of "roof-top connectivity" and "personal connectivity". The "mass connectivity" through the inherent broadcast capabilities of the satellite made them most attractive for TV distribution and broadcast services. The ability of satellite payloads to address weather parameters offers the operational framework to provide "environment connectivity" for collecting meteorological and other environmental data from dispersed locations over land and sea to a central point. Maritime satellite service has now become an established means of communication to ships on high seas. Very soon, the aeronautical mobile satellites service will provide "mobile connectivity" for people on the move either on land, sea or air. The "emergency connectivity" is an important humanitarian service to people in distress and communication satellites are the indispensable tools ensuring connectivity even in the case of disasters.

Table 2: Number of transponders

| | 1980-85 | | 1990-95 | | 2000-2010 | |
|---|---|---|---|---|---|---|
| | Global | India | Global | India | Global | India |
| Voice | 200 | 10 | 1,100 | 60 | 4,736 | 68 |
| TV | 40 | 4 | 450 | 9 | 2,592 | 41 |
| Video Conferencing | 2 | - | 60 | 2 | 500 | 12 |
| Data transmission | 30 | - | 390 | 1 | 2,702 | 21 |
| TOTAL | 272 | 14 | 2,000 | 72 | 10,530 | 142 |

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Having developed over seven generations of satellites in just three decades, Intelsat has made great contribution to ensure "international connectivity" by operationalizing more than 900 earth stations located in over 180 countries. Through its 20 satellites it provides global telephony, telex and data audio services in addition to video and audio programme exchanges. Regions having close socio, economic and political relations realized the benefits of satellite communications and established systems, such as, Eutelsat-1, Eutelsat-2, Arabsat, etc., to have "regional connectivities". Even though, satellite systems were initially envisaged for international systems, many countries realized the usefulness of satellite communication systems to meet their domestic communication requirements as well. While 14 countries have their own satellites, more than 40 countries have leased space segment capacity from Intelsat and have set up their own domestic communication network. These national systems have revolutionized the communication scenario in their respective countries. For example, since its introduction in 1983, the utilization of India's INSAT has grown multi-fold. (See Figure 6.) Today, with over 200 earth stations in its telecom network, it provides about 4,500 circuits on 170 routes to large, medium and small earth stations ranging from 3 m to 11 m in diameter.

The Effective Isotropic Radiated Power (EIRP) of satellites has also been steadily going up and it is now approaching 40 dBw in C-band and exceeds 55 dBw in Ku band.

As a result, there has been remarkable expansion in the use of Very-Small Aperture Terminals (VSATs) ensuring worldwide "roof-top connectivity." Due to the broadcast nature of satellite systems all over the world, the majority of satellite capacity is being used for television transmissions, ensuring mass connectivity to the extent that capacity originally planned for telecommunications is being used for television transmissions. For example, the most visible impact in India due to the introduction of INSAT has been in the field of television. From about

20 television transmitters in the country before 1983, the Doordarshan network today consists of more than 700 transmitters linked by the satellite and covers more than 65 per cent of the land and 85 per cent of the population. The sense of togetherness and participation brought in by this capability is one of the most important achievements of space technology. The emerging satellite-based hand-held telephony service is an important step towards global personal communications for voice and low bit rate data communications. The era of low Earth orbit (LEO) satellites at an altitude of 700-1400 kms is likely to ensure worldwide "personal connectivity." Future systems for communications and broadcasting will make great contributions by ensuring (i) growth of Public Switched Telephone Network (PSTN), (ii) expansion of broadcasting networks including private and regional networks, (iii) growth of business communications, (iv) improved personal communication services, (v) better social, educational and developmental networks and (vi) mobile satellite services. With this great potential, communication satellites offer valuable services of connectivity at all levels and one cannot remain isolated in this transformed "Global Village."

Imparting Education and Training

Experiments carried out by many countries have found that satellite-based distance education systems have undoubtedly become one of the most efficient and cost-effective tools for disseminating knowledge and awareness through (i) rural education; (ii) developmental education; (iii) adult education; (iv) continuing education directed at specific groups and augmentation of university and formal education. To take an example, China has been able to establish a large distance education delivery system beginning with the Satellite for Health and Rural Education (SHARE) which was supported by an Intelsat programme in 1985. This is one of the world's largest distance education delivery systems and it was established in a short period of time because of the deliberate policies and strategies followed by the Chinese Government.2/ China's Central Radio and Television University (CRTVU) provides their programmes in a national satellite network and plays a vital role in the country's education system, particularly for those who have failed to gain access to schools, colleges and universities. The system provides post-secondary degrees in agricultural, vocational and technical education for young people in rural areas, and, by offering continuing education for factory employees, companies and enterprises. CRTVU also trains teachers, technicians and administrative staff and conducts education research. The provincial RTVUs are responsible for detailed educational programmes and professional courses for local needs. It has made a great contribution towards imparting awareness and skills, with which China is realizing its goals for planned development.

Similarly, the Palapa system in Indonesia has proved to be a cost-effective means for distributing centrally-produced programmes to local rebroadcasting stations spread over 8,000 islands. The Satellite Instructional Television Experiment (SITE), conducted jointly by India and the United States in 1975-1976, is yet another a major milestones in the application of space technology for providing programmes aimed at development, viz., agriculture, health, nutrition, family planning, etc. A substantial amount of time was also devoted to educational programmes for children between the ages of 5 and 12 years. It was hailed as "the greatest communication entertainment in history" through innovative use of the most advanced technology to tackle the problems of development in some of the least developed and poorest parts of India. SITE used the United States ATS-6 satellite to broadcast television programmes.

The satellite-based interactive training course for trainers, conducted in India in February 1991, was found to be encouraging. The research study revealed that, compared to face-to-face instruction, this training was viewed by most trainees as a better and effective approach in covering a large number of geographically scattered trainees in a limited time. The "talk-back terminal" (enabling a return voice link via satellite apart from reception of the television signal) wherein the uplinking of the recorded television programmes for undergraduate students was also attempted. The recorded programmes were received and rebroadcast by the full television network as part of the usual countrywide classroom broadcasts. Special arrangements were made for interaction at eight specific locations, via satellite (using the talk-back terminal) at two, and at the other six by the normal public switched telephone network. The system was configured in such a way that the questions from any location were hooked back in to the broadcast and hence audible to all viewers. Thus, while questions could only be asked by the students in the eight pre-determined locations, all viewers could hear the questions and hear/see the replies. Such various participation will increase viewers' interest and attention and hence learning. While these experiments demonstrated the importance and efficiency of adopting such an interactive system for rapid dissemination of education, eradication of illiteracy as a goal requires the regular operational use of satellites to effectively disseminate culture and region specific information to each of the individual language groups and regional entities.

Telemedicine

It has been 25 years since NASA positioned three satellites, the Advanced Telecommunication Satellites (ATS) -1, -2 and -3, in geosynchronous orbit and provided the first telemedicine test bed for remote health care delivery. While there have been a number of pilot programmes in telemedicine since then, in recent years the improvements in telecommunication technology and information systems have resulted in a dramatic increase in the number of telemedicine programmes worldwide. The application of telemedicine offers certain advantages in terms of cost effectiveness and improved care to remote areas, disaster sites or inner-city urban populations. Linking remote locations to an urban medical centre provides an opportunity for specialist consultations that might not be otherwise possible. Thus, telemedicine can reduce critical delays in health care delivery by expanding access to underserved locations.

One of the most remarkable telemedicine services was observed in 1988 when Soviet Armenia experienced a massive earthquake that killed 2,500 people, caused many more casualties and destroyed much of the infrastructure of that republic, including the health care delivery systems. The medical communities of both Soviet Armenia and the United States were connected in what was called the Telemedicine Spacebridge to Armenia. The results of this effort indicated that interactive consultation by remote specialists can provide valuable assistance to on-site physicians and favourably influence clinical decisions in the aftermath of disasters. As a result of the success of the spacebridge to Armenia, the first international telemedicine programme, known as the Spacebridge to Moscow, was launched under the auspicious of the United States-

Russian Joint Working Group on Biomedical and Life Support Systems. Four participating medical institutions in the United States and one in Russia were linked via satellite. (See Figure 7.) A two-way video/two-way audio satellite communication system was established utilizing the Western Satellite Data Relay Network (WSDRN; Loutch) satellite, a Russian military satellite used for communications with the Mir space station, and NASA's Lewis Research Center in Cleveland, Ohio. Spacebridge to Moscow has not only offered real-time medical services to millions of sufferers, but has also firmly established the need and utility of a worldwide operational telemedicine service.

Encouraged by the services and overall impact of the Spacebridge to Moscow and earlier similar experiments in Alaska, the Northern territories of Canada, the Australian outback, Arizona, etc., Debakey Enterprises is setting up telemedicine systems in Mexico, the Russian Federation, Turkey, and the United Arab Emirates. All of them will be fully operational in another few years. Examples of other major projects already undertaken include (i) Project SHARE (described above), which provides video transmission capacity for humanitarian purposes via Intelsat satellites to 20 projects and 43 countries, and (ii) the remote clinical communication system, a portable telemedicine system used by the United States Army during its operations in Croatia and Somalia. By providing the low cost antennas and VSATs with standard television receivers, teleservices available from communication satellites offer the best solutions to widely and effectively transmit information on health care, hygiene, nutrition, environmental cleanliness, family planning and agricultural practices to remote and rural areas. Such information can lead to a substantial improvement in the quality of life, especially in developing countries.

Ensuring Food Productivity

Since there is no option except to produce more and more food from the increasingly fragmented and fragile land which has a finite carrying capacity which cannot be stretched beyond a certain limit, the strategy for achieving enhanced food production must aim at developing and disseminating environmental friendly agricultural packages ensuring optimal employment, income and agricultural productivity from units of land, water and energy. The concern of increasing agricultural productivity becomes more severe because the scope for increasing areas under cultivation is rather limited and if there is an expansion of agricultural activities, it will cause sharp conflicts with other sectors, especially forests and agriculturally unsuitable lands, causing more rapid land degradation. While a substantial increase in agricultural productivity can be achieved by (i) improved land and crop management technology, (ii) improved crop vanities, (iii) increasing irrigation facilities, (iv) greater use of fertilizers, and (v) adopting integrated pest management, the realization of these goals are possible only when there is a reliable data base on the existing land use, land capability classification, acreage under various crops, soil types and soil moisture, hydrogeomorphology, surface/subsurface waterbodies and agrometeorological parameters.

Building the Basic Life Support System

A holistic approach, coupling improved agricultural productivity with appropriate conservation of land and water resources, is called for in order to build an ecological foundation of resource bases. In the quest for ensuring food security with environmental integrity, the basic life support systems such as land, water, flora, fauna and the atmosphere are to be protected and enriched. Satellite remote sensing offers the potential for developing and conserving these elements simultaneously.

Preventing Land Degradation

A scientific land management strategy calls for a detailed data base on land capability identifying the unsustainable, marginally sustainable, conditionally sustainable and prime land for the intensification of agricultural production. Remote sensing has been operationally providing these spatial information in many countries. For example in India, using satellite remote sensing, 13 categories of wastelands, amounting to 54 million hectares, have been identified, almost half of which could be reclaimed for the extension of agricultural activities. Lands thus identified for immediate reclamation are scrublands, gullied/ravined areas, marginally salt affected lands and areas under shifting cultivation which with the application of appropriate agricultural practices and conservation measures could be made agriculturally productive to augment total food production. Likewise, satellite remote sensing has been used to map the current land use at the microlevel in order to identify areas under single-crop, double-crop and residual fallows. This information could be gainfully used to determine the cropping intensity and to explore the dormant potential for increasing agricultural production. Increasingly, satellite data are being used for preparing reconnaissance level soil maps showing soil associations and land capability units that are agroclimatically coherent and have common characteristics (slopes, soil depths, textures, water holding capacity). Such maps could be used to identify areas for developing locale-specific cropping patterns which are agro-climatically more suitable.

Conserving Water Resources

The availability of adequate soil moisture at critical periods of crop growth is extremely important in determining final crop production. In this context, inventory, monitoring and management of both surface and groundwater resources play a crucial role in agriculture management. The repetitive coverage provided by satellites has been widely used for mapping and monitoring the extent of surface water bodies/reservoirs and for reliable estimation of storage capacity of the reservoirs and its changes over the years, thereby facilitating optimal scheduling of irrigation. Similarly, by identifying hydrogeomorphological features, satellite remote sensing has been found to considerably narrow down the areas for ground water exploration. A classic example is India's National Technology Mission on Drinking Water under which hydrogeomorphological maps showing ground water prospect areas have been prepared using space imagery of 1:250,000 scale. Based on statistics of over 2 lakhs borewells dug with the help of remote sensing, it has been observed that the success rate of finding water has increased to 92 per cent compared to 45 per cent achieved using purely conventional methods.

Also crucial is the management of water resources in the dryland tracts of the tropical countries where the temporal and spatial distributions of rainfall is highly uneven. Coupled with the higher temperature regimes and evapotranspiration rates, the need for harvesting of runoff and recharging of underground aquifers in tropical countries assumes paramount importance. In this context, satellite remote sensing plays a unique role towards ***in situ*** soil moisture conservation through efficient watershed management. Preparation of hydrogeomorphological maps to delineate watersheds, drainage patterns, suitable sites for impounding water and recharging of aquifers has now become possible with the imagery obtained from space. Remote sensing based methodology has been adopted to prioritize the watershed for taking up soil conservation programmes. Using such an approach, priority delineation has been carried out in various watersheds around the world.

Satellite-based glacier inventories have been found to be very promising for planning and operating mini- and micro-hydroelectric stations. Models based upon the areal extent of seasonal snow have been developed to predict snow-melt runoff into the Bhakra reservoir in India. Identification of waterlogged areas in the command areas of the irrigation projects and inventory of croplands and cropping patterns have facilitated efficient water use and thereby increased the cropping intensity in major irrigation commands of the country.3/

Preserving flora and fauna

Towards efficient forest management, satellite remote sensing inputs are used operationally in (i) periodical forest cover estimation, identification of deforestation and afforestation; (ii) assessment of timber volume and growth; (iii) regular monitoring of forest stresses due to disease, insect infestation, forest fires; and (iv) regular monitoring of habitats to identify conservation needs. The adoption of this technique during the past few decades has provided a new thrust in this area of making available quantitative means for monitoring the growth and degradation of natural forestry, deforestation linked soil erosion and sediment load into rivers and watersheds, depletion of biodiversity, natural flora and fauna, underground water recharge and green-house gases. Even the coarse resolution meteorological satellite payloads, particularly the NOAA/AVHRR, have greatly helped in studying vegetation dynamics in relation to climate changes at regional and continental levels on a gross basis. The Normalized Difference Vegetation Index (NDVI) derived from NOAA/AVHRR data, which is well correlated with vegetation parameters such as green leaf biomass and green leaf areas, has been successfully used to classify eight major global vegetation types of the world and derive their individual primary productivity, which varies between 1.2 $kg/m^2$ per year in the case of deciduous forests to 2.2 $kg/m^2$ per year in tropical forests. The use of high-resolution imagery such as that obtained from Landsat, SPOT, and IRS satellites obviously has a greater advantage in providing basic discrimination of vegetation types with much higher levels of accuracy.

High-resolution imagery has been used in Brazil to study the deforestation that significantly influences the global warming phenomenon and the accompanying loss of biodiversity. The Brazilian Institute of Space Research (INPE) estimated accurately the total deforestation areas and rate of deforestation in the Brazilian Amazon. By using Landsat data, the government of Brazil was able to implement effective measures which helped to reduce the rate of deforestation. (See Figure 8.) 4/ Similarly, in India the results of forest mapping using

IRS and Landsat data showed 2 per cent annual deforestation between 1972 and 1982. Regular monitoring of forest cover once every two years and subsequent afforestation measures have reduced the deforestation rate to 0.08 per cent per year. Thus, monitoring of deforestation by logging, fuelwood use and shifting cultivation by using satellite data has prompted many countries to institute protection measures and to implement various reforestation and afforestation programmes.

Disaster Management

Space-based systems provide valuable inputs to disaster management communities before, during and after a disaster event. (See Figure 9.) They are the only tools available for disaster management which remain unaffected by the impact of disasters. Various kinds of satellites with capabilities for communication, meteorology and remote sensing are contributing substantially towards disaster management in the form of preparedness, prevention and monitoring. (See Table 3.)

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Table 3: Sequential Groups of Emergency and Disaster Management Phases

| PHASE | TIME |
|---|---|
| PREPAREDNESS | |
| vulnerability analysis | long before |
| hazard/risk zoning | |
| pre-disaster planning and mitigation | |
| PREVENTION | |
| observation, detection and prediction | before, immediately |
| early warning | before |
| MONITORING | |
| emergency relief | during |
| damage assessment | during/immediately after |
| rehabilitation | immediately after |
| reconstruction | immediately after |
| post-disaster planning | after |

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The unique capabilities of remote sensing satellites to provide comprehensive, synoptic and multi-temporal coverage of large areas at regular intervals and with quick turn around times have been valuable in the continuous monitoring of atmospheric as well as surface parameters attributed to natural disasters. On the other hand, the capabilities of communication satellites have significant potential for real-time dissemination of information and early warning, data transfer and relief operations. They have been used individually during recent disasters and have been included in regional or national disaster management systems. The advent of VSATs, Ultra Small Aperture Terminals (USATs) and phased array antennas have further enhanced these capabilities. Fixed Satellite Service (FSS) capabilities are now available worldwide through international systems such as Intelsat or Intersputnik, regional systems like Eutelsat, Arabsat and national systems like Anik, Palapa, Insat, etc. Satellite mobile services for emergency plans are also already operational in many countries. Internationally, the COSPAS-SARSAT system could provide alert services for disasters occurring anywhere in the world.

Space-based technologies are therefore assisting humanity to overcome a number of limitations and to correct certain infrastructural weaknesses, provided that proper technical and managerial solutions are adopted and user communities are in a position to implement them. Earth observation satellites are providing unique inputs to monitor meteorological phenomena, soil and vegetation, geomorphological studies, integrating land use and hazard maps, movement of tectonic plates and the status of land and water resources of a region. These inputs, backed by appropriate groundtruth measurements, are effectively employed to carry out vulnerability analysis and evolve long-term strategies for disaster management.

On the other hand, communications and Earth-based transmissions of weather forecasts and advance warnings of severe weather will minimize the loss of life and damage and facilitate timely and effectively rescue and rehabilitation of affected populations, especially to those entities/groups/persons who are located in remote, rural and underdeveloped areas. They also provide communication support for administrative actions for emergency preparedness. One such example is the unattended, locale-specific Disaster Warning System (DWS), which is used to disseminate cyclone warning messages to the areas likely to be affected. India has been using this indigenously developed system, through INSAT, since 1985. At present, the receive terminals are installed in Indian coastal regions. The cyclone warning messages are generated from the Cyclone Warning Centre (CWC). The special feature of this system is the selective addressing of the receivers. The present receive terminal consists of a 3 m diameter antenna and a receiver. The receiver is activated and a siren is sounded as an alert by detecting the code related to the specific receiver. This is followed by a warning message repeated several times to alert the people in the affected areas. If the cyclone deviates from the course, the CWC can direct the warning to another area and in fact give out different warnings to different locations.

The system has proved its efficacy in the successive cyclone seasons over the past decade. For example, prior to the development of the system, a November 1977 cyclone killed about 10,000 people when it hit the South Andhra coast near Nizampatnam in southern India. In contrast, the May 1990 cyclone which hit the Andhra Coast near Machilipatnam, resulted in less that 1,000 deaths, primarily due to the timely warnings given to the villages by the effective functioning of Cyclone Disaster Warning System, established along the southeastern coast of India. The system helped the government to evacuate over 170,000 people, thus saving thousands of lives and livestock in this area. It is estimated that over 20,000 people would have lost their lives during the disaster has the warning system not been in place.

Drought Management

Satellite data are also being utilized effectively for combating drought, at both the short- and long-term strategic levels. Short-term strategy includes early warning, monitoring and assessment of drought, whereas long-term strategies are aimed at drought mitigation measures through reservoir management, water harvesting structures, soil and water conservation, cropping pattern optimization, etc. Satellite derived vegetation indices, area averaged surface temperature and remotely sensed inputs in mapping and monitoring of land use/cover soil, geologically geomorphological features, environment impact studies, etc., could be integrated with socio-economic and demographic information through Geographic Information Systems (GIS) in order to arrive at suitable strategies for drought management. These drought management packages essentially aim at event modifications which could address efficiently meteorological, hydrological and agricultural droughts.

Satellite derived vegetation indices (VI), which are sensitive to vegetation stress, are now being continuously used to monitor drought conditions on a real-time basis, thus helping decision makers to initiate strategies for recovery by changing cropping patterns and practices. The use of meteorological satellite data to assess the spatial and temporal inadequacies of rainfall at critical crop stages and subsequent assessment of crop status/condition based on VI anomalies provide an excellent drought monitoring mechanism. However, spaceborne measurements must be integrated with computed aridity anomaly based on field measurements of rainfall and crop calendars to bring out fortnightly/monthly drought conditions of a region. The integration of VI with other relevant field data can be used to explain the extent of variation in drought characteristics which is evaluated based on meteorological drought indices such as, the Crop Moisture Index, Drought Severity Index or the Hydrologic Deficit.

Quite a few developing countries are using space-based measuring instruments to assess and monitor drought conditions. For example, in Africa NOAA-AVHRR data are used to estimate the vegetation conditions, with the help of the African Real-Time Environmental Monitoring Information System (ARTEMIS). ARTEMIS regularly distributes data products describing rainfall probability and actual precipitation derived from Meteosat and also timely information on crop conditions and food shortages due to droughts, desert locusts, etc., through NOAA-AVHRR derived Normalized Difference Vegetation Index (NDVI). The early drought warning system in Malaysia relies primarily on the Agro-Ecological Zonation and Agricultural Rainfall Index (ARI) methods. Besides these two conventional methods, the use of satellite remote sensing for drought preparedness is being developed under the Agro-climatic Impact Assessment Project (AGROCIA). In India, short-term drought monitoring using NOAA-AVHRR data coupled with rainfall data is being used on an operational basis.5/ This has enabled the concerned administrators to mobilize resources towards efficiently managing the drought in their respective regions.

Flood Management

Mitigation of damage caused by recurrent floods can be achieved by using remote sensing information on terrain, surface water and identifying different risk zones in flood prone areas based on the severity index of propensity of each zone for flood damage. Remote sensing provides information on wet areas, standing water, sand cast areas, agricultural land which is completely damaged, marooned villages, canal systems and drainage patterns, thus assisting in taking appropriate measures to mitigate the sufferings of affected people, and for making reliable estimates of damage. For example, the floods in Bangladesh during July-August 1988 which were mapped using Landsat and IRS-1A data, formed the basis for international relief to Bangladesh on the order of $600 million. Flood mapping has been operational in India, China, Bangladesh, Pakistan and Latin America and management plans are drawn up for each flood risk zone. Particularly in India, microwave data from the ERS-1 SAR is operationally used along with optical data from IRS-1A/1B for flood management.

Earthquake Studies

The extensive mapping capability of geological and geomorphological features by remote sensing satellites is of immense help to study the proneness of an area towards earthquake. Even though the science of earthquake prediction is still in its infancy, the possibility of measuring even small tectonic movements using laser ranging techniques or differential GPS systems, combined with temperature measurement on the surface, for studying earthquake disasters is quite promising.

Landslide Studies

The likelihood of a landslide occurring is assessed through the identification of critical combinations of site conditions, such as soil characteristics, degree of slope, type of bedrock, vegetative cover, and rainfall and snow-melt conditions that correlate well with the past occurrence of landslides. Remote sensing satellites, with their ability to view synoptically and stereoscopically, together with aerial remote sensing, are very effective in determining the slopes, landforms, soil characteristics and vegetation cover over even smaller areas. This has greatly enhanced our capability for preparing land hazard maps in mountain regions. A number of studies have been conducted India using Landsat and IRS data along with aerial photographs to develop appropriate methodologies for terrain classification and preparing land hazard maps in the Garhwal Himalayan region, Nilgiri hills in south India and in the Sikkim forest area. This has helped in the preparation of action plans for managing landslides in these regions.

## INTEGRATING ENVIRONMENT AND DEVELOPMENT IN DECISON MAKING

The term environment is broadly interpreted to include the complex of physical, social, cultural, economic and aesthetic factors which affect individuals and communities and determine their form, character, relationship and survival. Thus, achieving a better quality of life is possible only through including environmental concerns in the developmental process. The first step, in this regard, is harmonization of sectoral development plans and the second one is to conduct Environment Impact Assessments (EIA) of development activities. While the accomplishment of the first step calls for real-time information on the mutual interdependence of various resources and their functional relationship with the quality of environment, the EIA aims at achieving judicious balance between economics and ecology through internalization of environmental quality considerations in the decision making process.

Remote sensing inputs on terrain, soil characteristics, agricultural practices, vegetation patterns, land use and overall habitats are extremely valuable for deriving certain crucial parameters which indicate the quality of natural systems and the environment before, during and after the proposed implementation of decisions to enable, if required, the adoption of alternate routes for development, process technology and project sites. There are many operational applications of remote sensing worldwide demonstrating its utility in monitoring the environment and providing extremely useful information for environmental management. For example, using remotely sensed inputs, studies have been conducted in India on environmental consequences such as deforestation, accelerated soil erosion, siltation of rivers and reservoirs, increases in the frequency of floods, landslides, shifting cultivation, urban sprawl and pollution, river pollution by domestic sewage and industrial effluents, land degradation, and of developmental activities ranging from rapid industrialization and urbanization, to the commencement of multipurpose river-valley projects and mining activities.6/ The awareness created by such types of studies in many parts of world has prompted many governments to impart environmental integrity to ongoing developmental activities. For example, in India, the National River Action plan aimed at improving water quality of the rivers is making use of this technology for setting up sewage plants for towns/mega cities located along stretches of the most polluted rivers in the country (Ganga, Yamuna, Hooghli, etc.,) Similarly, the metropolitan development authorities of metropolitan towns in the country have taken special note of this technology for their future plans of growth ensuring a clean environment and improved quality of life, especially in urban areas. Another classic example of using space remote sensing towards resolving the conflict between environment and development is unsustainable aquaculture which causes destruction of mangroves, salination of soil and drinking water supplies, and increases pollution risks and disease threats. Environmentally-friendly aquaculture can only be achieved through proper integration and analysis of diverse kinds of resources such as accurate assessments of land, water, environment, and the economic and human resources of a region. Studies have shown that remote sensing techniques coupled, with the use of GIS, could be gainfully utilized for such comprehensive analysis which otherwise is difficult through conventional techniques. While increasing awareness of integrating environment and development in decision making is being felt worldwide, space remote sensing offers valuable technological solutions in this regard.

Towards Sustainable Development of Natural Resources

The pursuit of a high quality of life for society as a whole is routed through sustainable resource management while conserving, preserving and enriching the quality of the environment. Sustainable development aims at ensuring environmental protection and economic growth with parallel compatibility. The models of development must be in harmony not only with the pressing needs of a growing population but also with the natural processes and functions of ecological systems. Any effort in this regard, calls for a holistic view of natural resources and the environment and an understanding of the mutual inter dependencies of various resources and ecosystems, while integrating the relevant environmental imperatives in the overall development process. The capability of satellite remote sensing to provide an unbiased and synoptic view of the natural resources, in a timely and cost effective manner, offers a viable technological solution to the problem of imparting environmental integrity to development processes at all levels.

The satellite remote sensing-based Integrated Mission for Sustainable Development (IMSD) is a unique Indian experience to evolve action plans taking a holistic view of available resources in the backdrop of socio-economic conditions of watersheds. The overall spectrum of IMSD includes: (i) generation of a spatial data base on natural resources using satellite data; (ii) synthesis, scientific analysis and integration of these data with collateral information such as meteorologic inputs, socio-economic, cultural and demographic information. (See Figure 10.); (iii) identification of coherent microlevel land units which are unique in terms of their resource potential and problems; (iv) evolution of locale-specific action plans for development; i.e. alternate land use practices, soil and water conservation measures, etc., consistent with terrain suitability, socio-economic and technical feasibility and cultural acceptability; (v) evaluation of these action plans by experts pooled from line departments such as agricultural, water resources soil conservation, geology, administrators, resource scientists and local progressive farmers; (vi) implementation of the action plans by the District Authorities, polling resources from various ongoing developmental scheme, and NGOs and local beneficiaries; and (vii) monitoring the overall impact by using multi-date satellite data. A comprehensive National Resources Information (NRIS) around a GIS core has been envisaged for an easy integration of spatial and non-spatial data.7/ Thus, IMSD is, end-to-end, a comprehensive action programme aimed at the optimal realization of resource potential, the harmonious development of land, water and other resources of an area on a sustainable manner, taking the holistic view of the region with the active involvement of all concerned departments.

Under the IMSD programme, the locale specific developmental plans generated for selected watersheds in different parts of the country are being implemented. Preliminary results from these watersheds where the action plans have already been implemented, show significant improvements. For example, Anantpur, a drought-prone district in the rain shadow zone in peninsular India, receives just 500 mm of average annual rainfall, which is the second lowest in the country. The climatic anomalies, along with unsustainable agricultural practices over the years, had transformed this into a drought-prone district forcing the local inhabitants in some part of the district to migrate to other areas. As a part of the action plans, developmental packages such as identification of suitable sites for water harvesting structures, i.e. check dams, percolation tanks, farm ponds and the evolution of better agricultural practices suiting the terrain characteristics were implemented. The implementation of these action plans have resulted in: (i) reduction of run-off loss by about 50 per cent, (ii) increase in the water level from 0.9 to 5 m due to the impact of check dams and percolation tanks; and (iii) improvement of agricultural productivity by 2 to 5 times. (See Figure 11.) Encouraged by the early results and convinced of the potential of remote sensing technology in achieving sustainability of land and water resources, the mission has been extended to 174 districts covering more than 45 per cent of the geographical areas of the country. It is now being realized that the integration of space-based inputs in the micro-level development processes of the country with the active involvement of all concerned organizations will be a major step towards improving the quality of life especially of those poor people who are living in degraded and vulnerable ecosystems, experiencing hunger, tremendous hardship and deprivation.

BETTER QUALITY OF LIFE THROUGH A GLOBAL ALLIANCE

While the capability of space technology towards ensuring a better quality of life is an established fact, it is unfortunate that there are many countries who are yet to fully utilize the potential of space technology in this regard. There are obvious reasons for this, which vary from resource constraints to lack of governmental support. Even otherwise, it may not be a viable option for any nation to have all satellites that could meet the varying requirements needed by different applications. For certain nations, it may not be even appropriate to have dedicated satellite missions. Thus, a global initiative and international assistance becomes absolutely essential, and bilateral and multilateral cooperative efforts need to be encouraged.

Training and development is an important area where international cooperation can yield excellent results. The establishment of the proposed United Nations Centre for Space Science and Technology Education in the Asia-Pacific Region will be a major milestone in this regard. Besides imparting specialized training in space technology development and applications, sharing of experience among various space faring nations as well as joint technology and application development programmes, will no doubt, further our efforts towards realization of goals.

While continuing our efforts towards a global alliance, it will be quite appropriate to select several areas to make a beginning. These could be environmental monitoring, education and health care and disaster management. In addition to the approximately 20 satellites that have been launched since the beginning of this decade, nearly 50 satellites have been scheduled for launch in the next 10 years which are expected to provide data related to land, ice and snow, ocean dynamics, ocean biology, atmospheric dynamics, water cycle and atmospheric chemistry, thus encompassing almost every aspect of environmental monitoring. International agencies need to work out strategies at the regional and global levels for the effective utilization of the data that will be available in varied resolutions with wide-ranging information.

Using a constellation of geosynchronous, equatorial and polar orbiting satellites, well connected by a network of ground stations, a global arrangement for education, health care and disaster management appears to be a viable option. A system concept of the proposed Global Satellite Network for Education, Telehealth and Disaster Management (GLOSNETAD) is given in Figure 12. The space segment of this system can be a constellation of communication and meteorological satellites. Existing meteorological and communication satellites could be used in the initial phase. The ground segment consists of a number of major and minor nodes along with a set of disaster warning systems situated at major disaster prone areas. The major nodes, which could be regional or national depending upon the geographical area under its coverage, are Super

Specialty Centres, with facilities to receive and analyze meteorological data, disseminate disaster warning messages and educational programmes as well as the capability to provide medical consultancy services to the practitioners at the minor or local nodes.

Figure 13 shows the disaster management component of the proposed network. A meteorological data utilization centre attached to each main node collects meteorological data and after analysis, the information about the severity of the disaster is sent to the local nodes through a communication satellite. In the case of a cyclone, the warning is sent to the receivers on the ground which are tuned to receive specific codes that are assigned to particular locations. The main node, after determining the likelihood of a cyclone hitting a place, can select the appropriate code and this signal which is relayed back to the ground receivers is sent by the satellite. Only those receivers tuned to the particular code transmitted activate a siren loud enough to be heard by the people in the neighbourhood. In the case of floods and droughts, detailed information can be sent by the main node to the concerned agencies after analyzing the data.

The education and telehealth components are shown in Figures 14 and 15. The central production units attached to each main node can produce the educational programmes which are telecast to local nodes or to the beneficiaries using a communication satellite. This component could be used for distance education, developmental communication or interactive training purposes. Similarly, the medical practitioners attached to the local nodes can interact with the experts available at the specialists hospital attached to the main node.

In the initial phases, the existing satellites can be used and main nodes can be established in each continent. Once the system is operational, a dedicated global network can be established. It is found that a constellation of 12 geosynchronous satellites, eight in the equational orbit and four in the polar orbit, can meet the requirements. Meteorological and communication payloads can be flown on these satellites, as in the case of the multipurpose INSAT satellites of India.

## CONCLUSION

Quality of life is a multi-dimensional concept that varies from individual to individual; but it is an accepted fact that the technological advances which have resulted from humanity's quest for scientific exploration and the desire to increase living standards, have greatly improved the quality of life all over the world. While improved quality of life is the result of a number of factors, a close monitoring of associated indicators and addressing the critical issues, especially those related to economic development, education, food security, health care and sanitation and environmental integrity can only improve the living conditions. Added to these are a host of other factors ranging from entertainment and human connectivity to enrichment of the human mind. Space technology lends itself as a powerful tool to address these issues. A global initiative is very much essential to ensure that the fruits of technological advances are reaching the poorest in the least developed nations, where poverty remains the central issue. It is becoming more and more clear that the challenge of poverty and the challenge of the environment are not two different challenges but two facets of the same challenge. As the former Prime Minister of India Smt. Indira Gandhi said at the United Nations Conference on the Human Environment in

Stockholm in 1972,

> "...we do not wish to impoverish the environment any further and yet we cannot for a moment forget the grim poverty of the large numbers of people. Poverty and need are the greatest pollutants. For instance, unless we are in a position to provide employment and purchasing power for the daily necessities of the tribal people, who live in and around our jungles, we cannot prevent them from combing the forests for food and livelihood, from poaching or despoiling the vegetation when they themselves feel deprived. How can we urge the preservation of animals? How can we speak to those who live in villages and slums about keeping the oceans and rivers and the air clean when their own lives are contaminated at the source? The environment cannot be improved in conditions of poverty, nor can poverty be eradicated without science and technology ".

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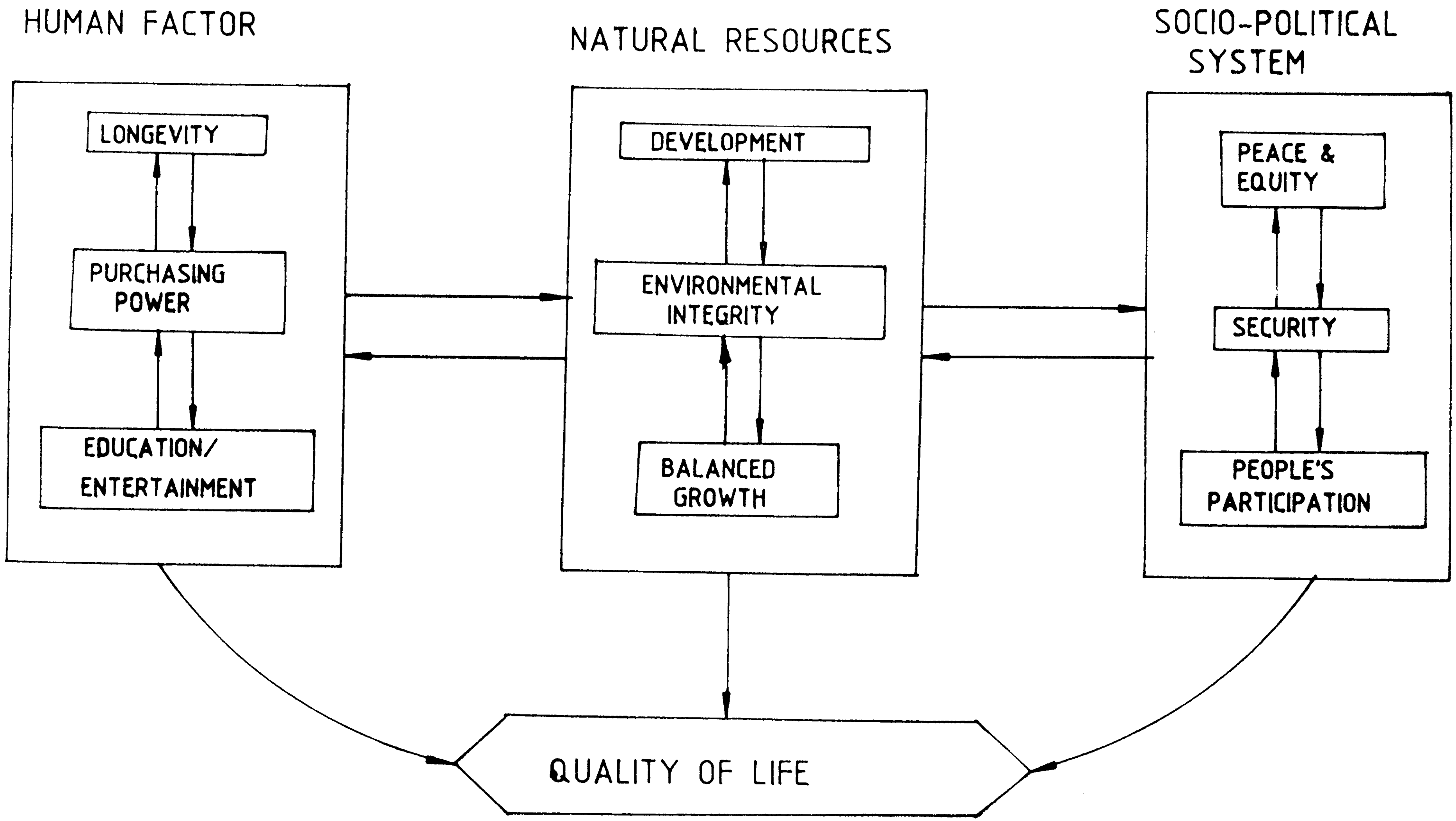


Fig. 1 : *Elements of quality of life*

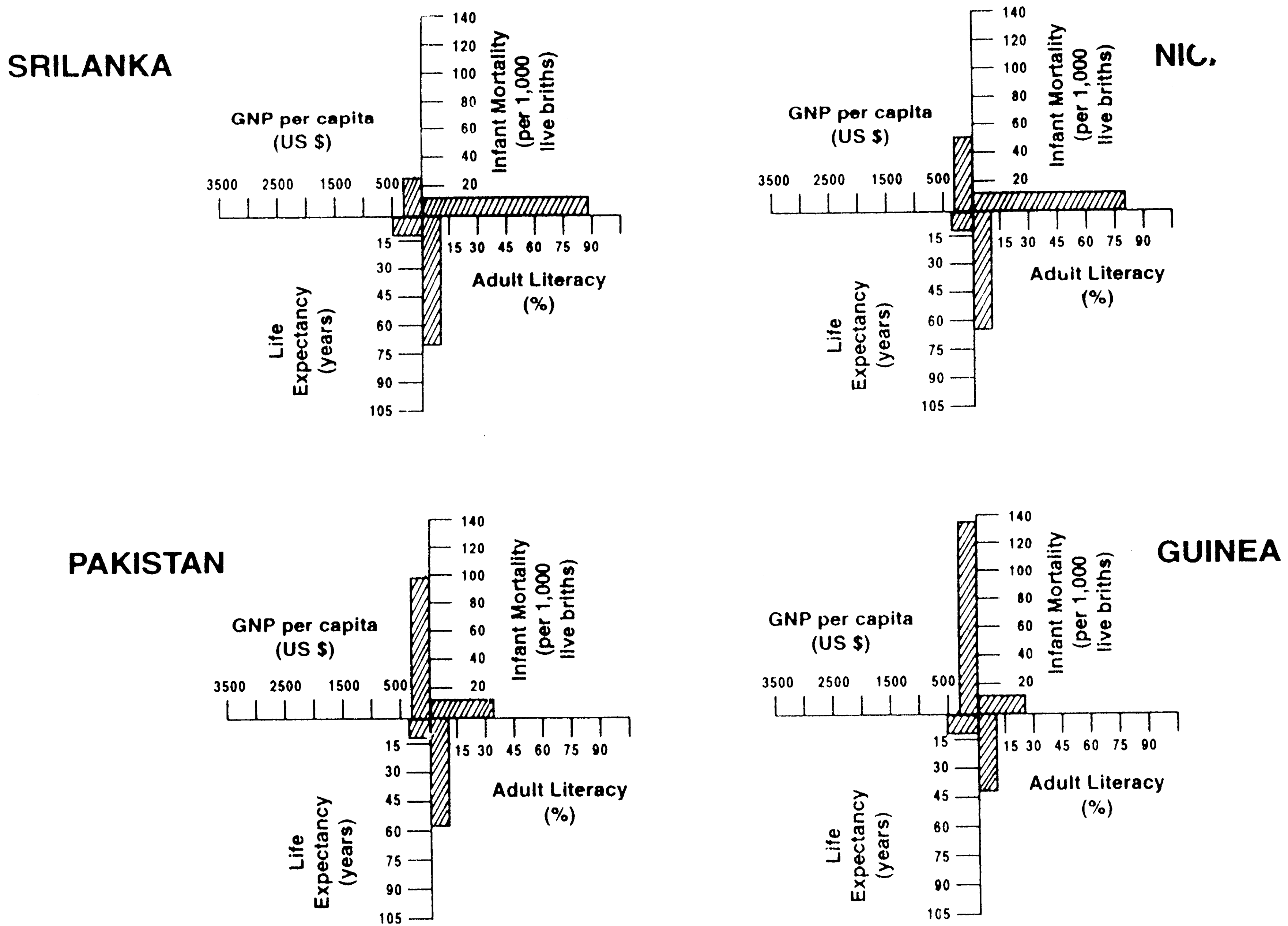


Fig. 2 : Adult literacy Vs infant mortality and life expentancy

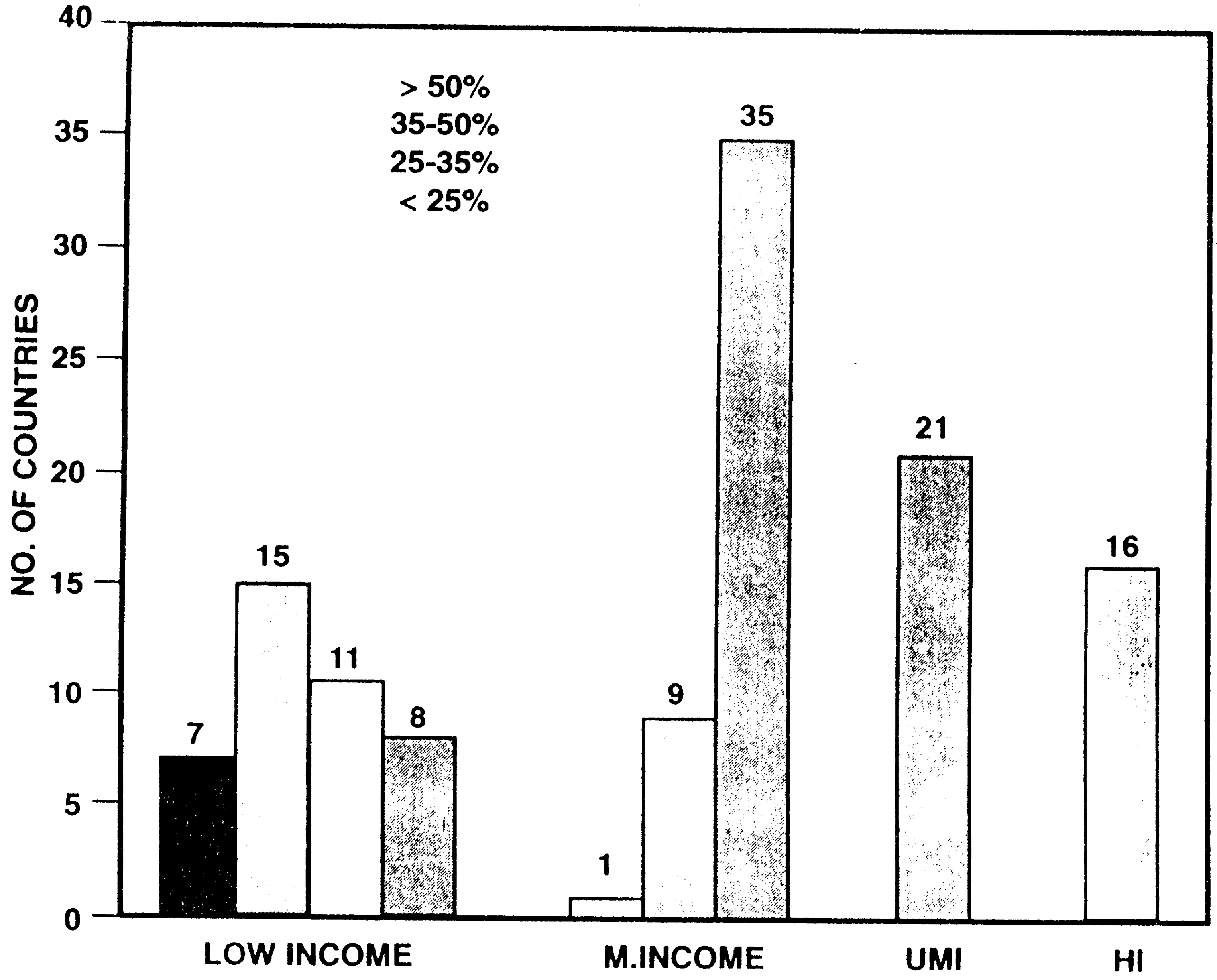


Fig. 3 : Contribution of agriculture to GDP

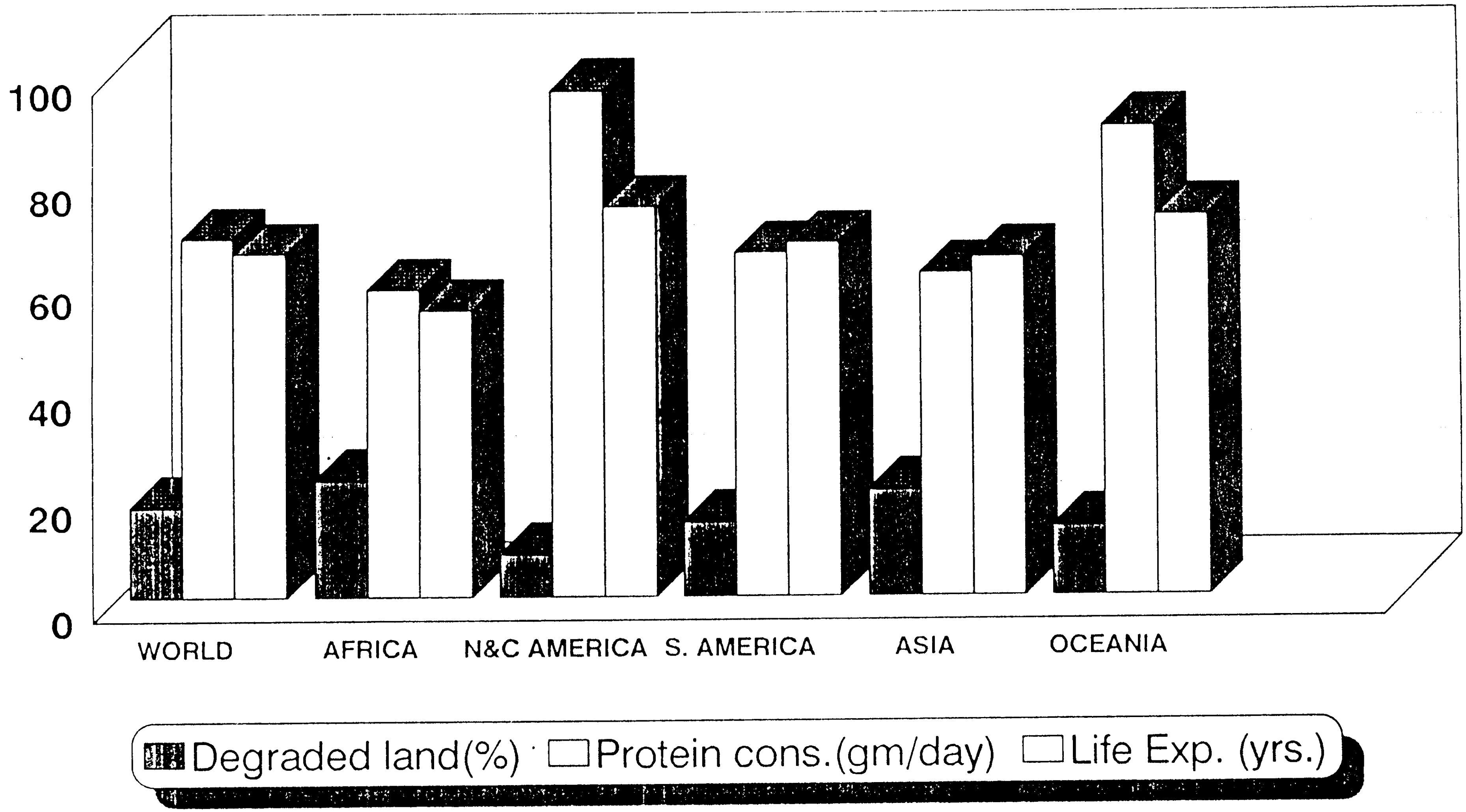


*Fig. 4 : Environment, Food and life interlinkages*

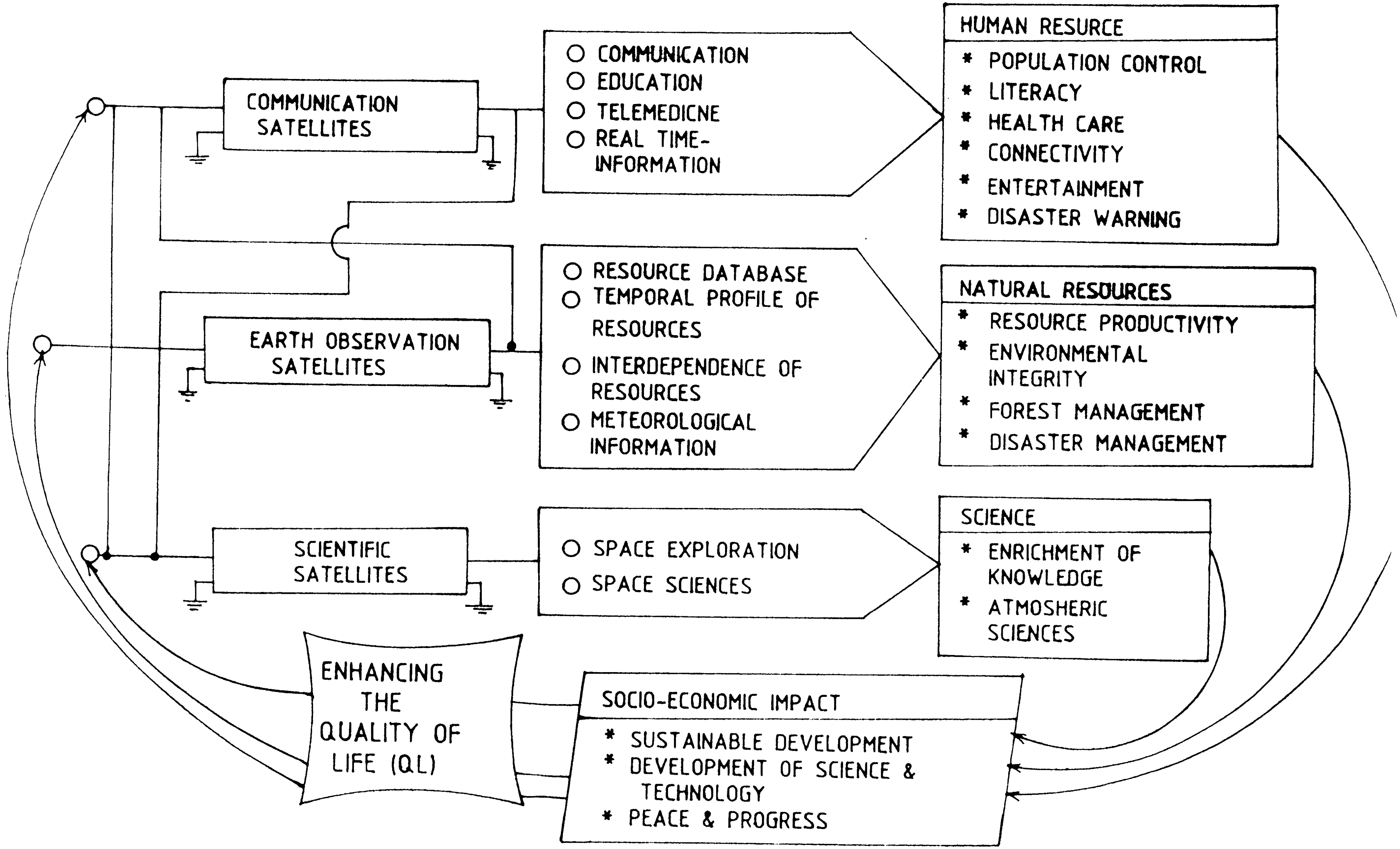


*Fig. 5 : Space technology towards enhancing the quality of life*

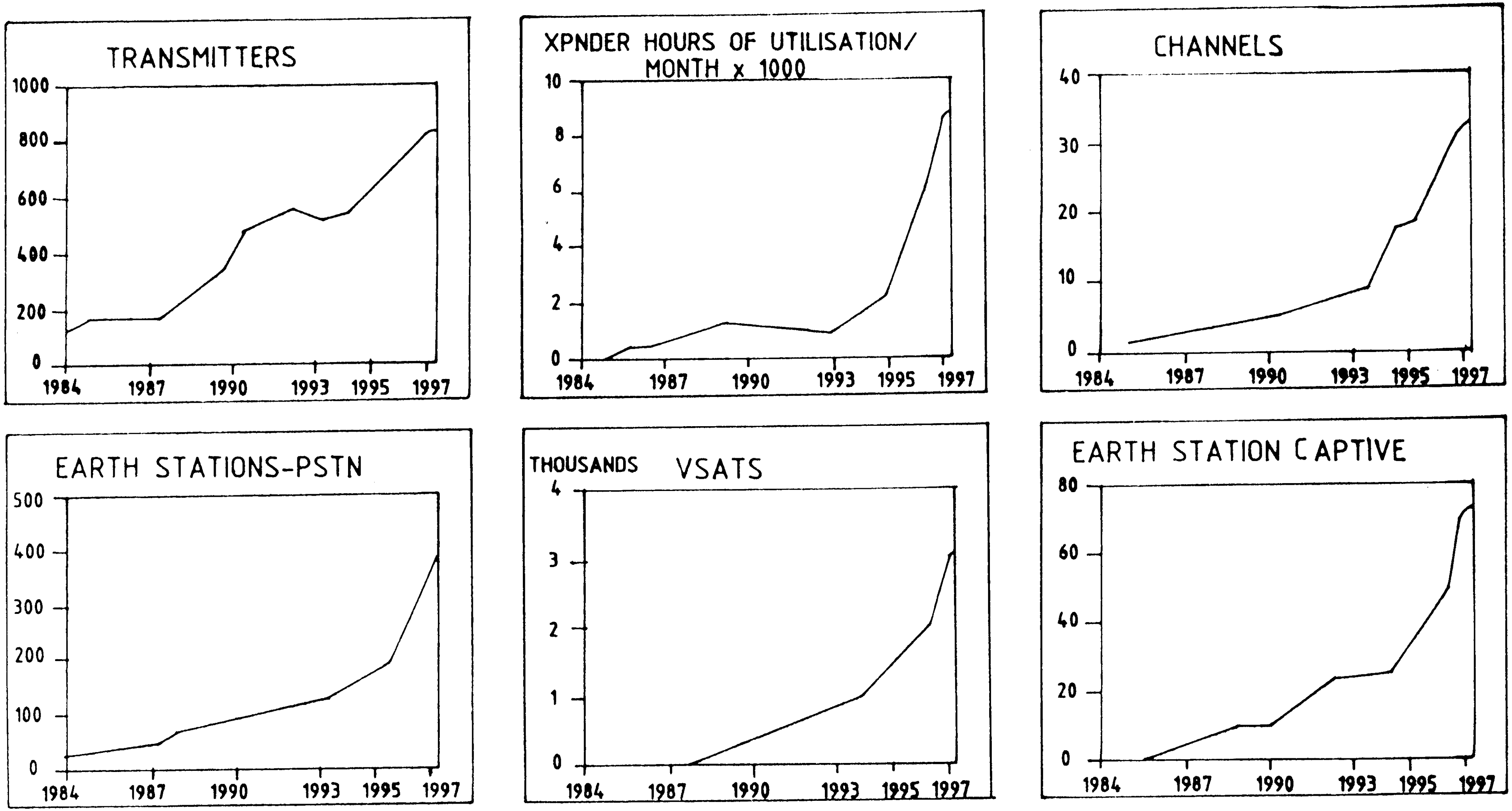


Fig. 6 : Telecom/TV growth in INSAT system

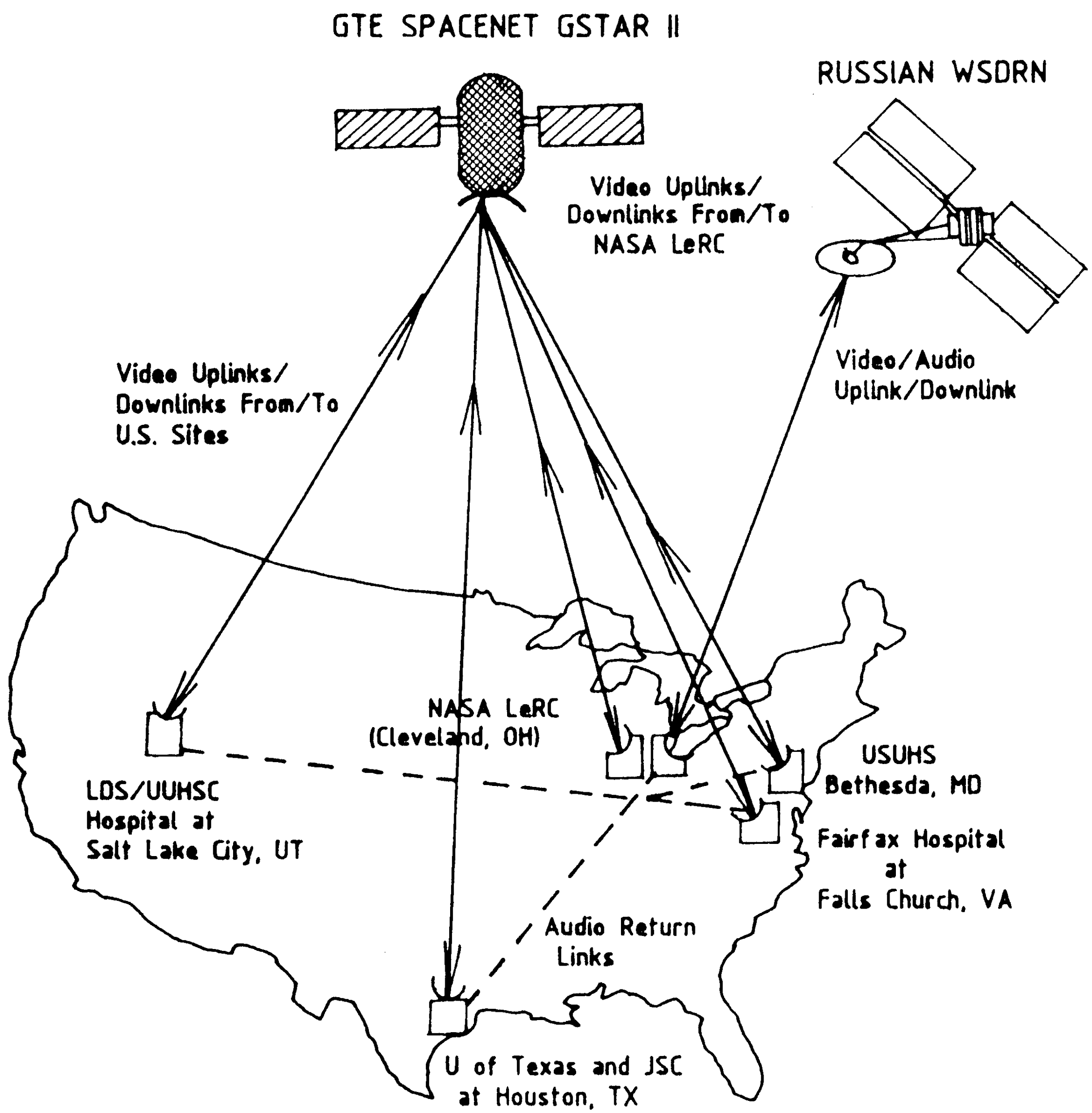


*Fig. 7 : Space bridge to Moscow*
(First International Telemedicine Program)

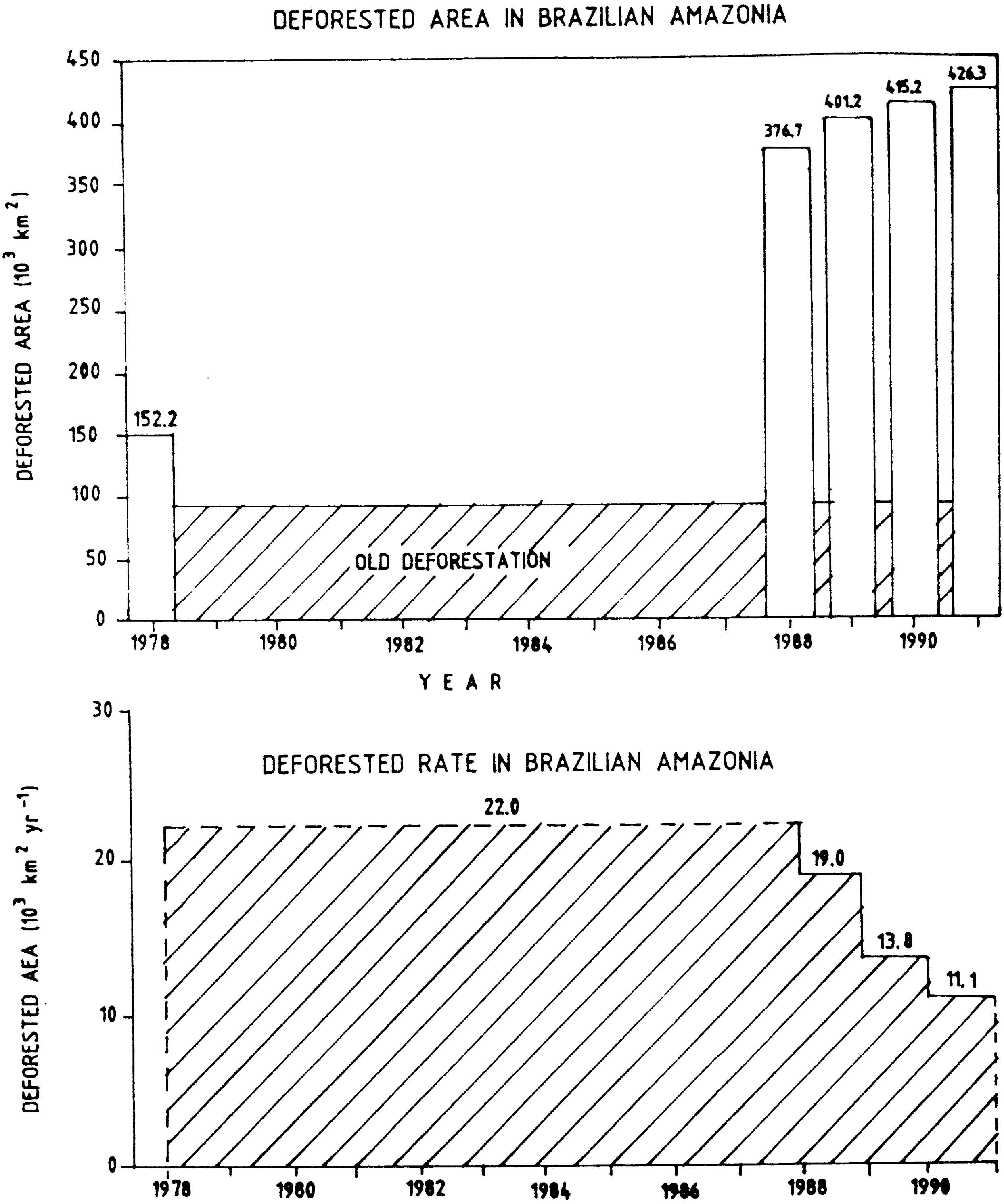


Fig. 8 : Extent and rate of deforestation in the Brazilian Legal Amazon

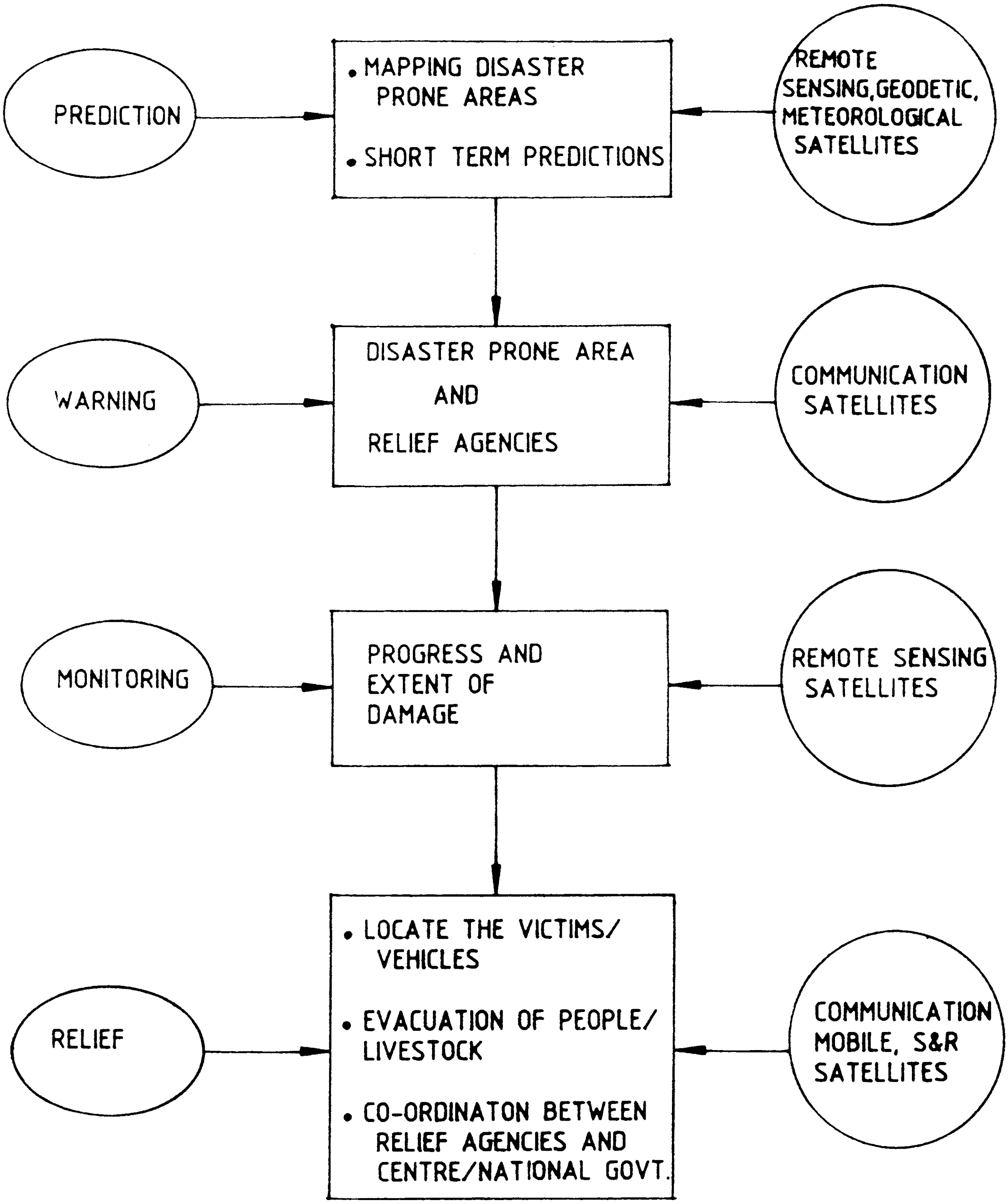


*Fig. 9 : Space and disaster management*

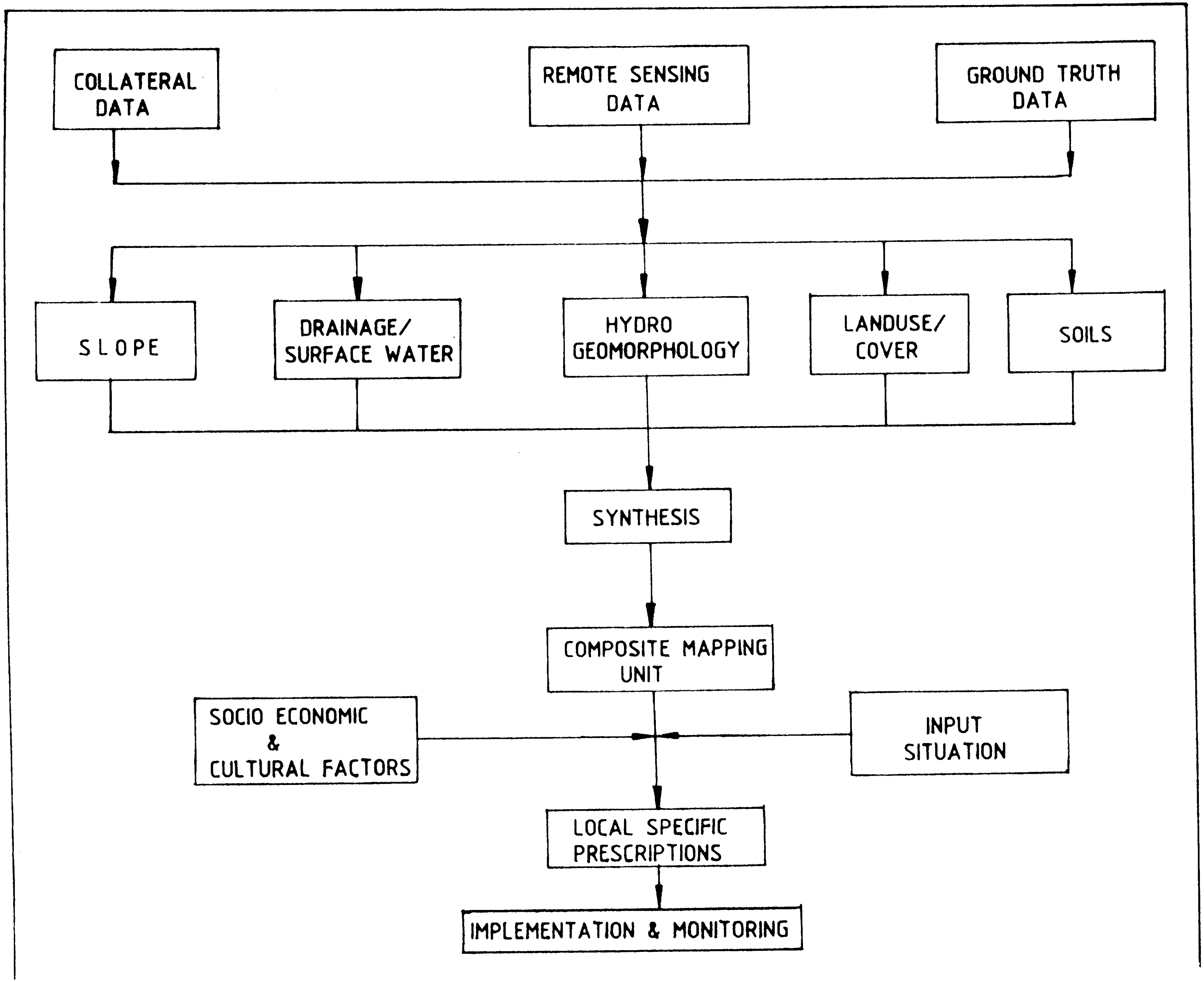


*Fig.10: IMCO SCHEMATIC*

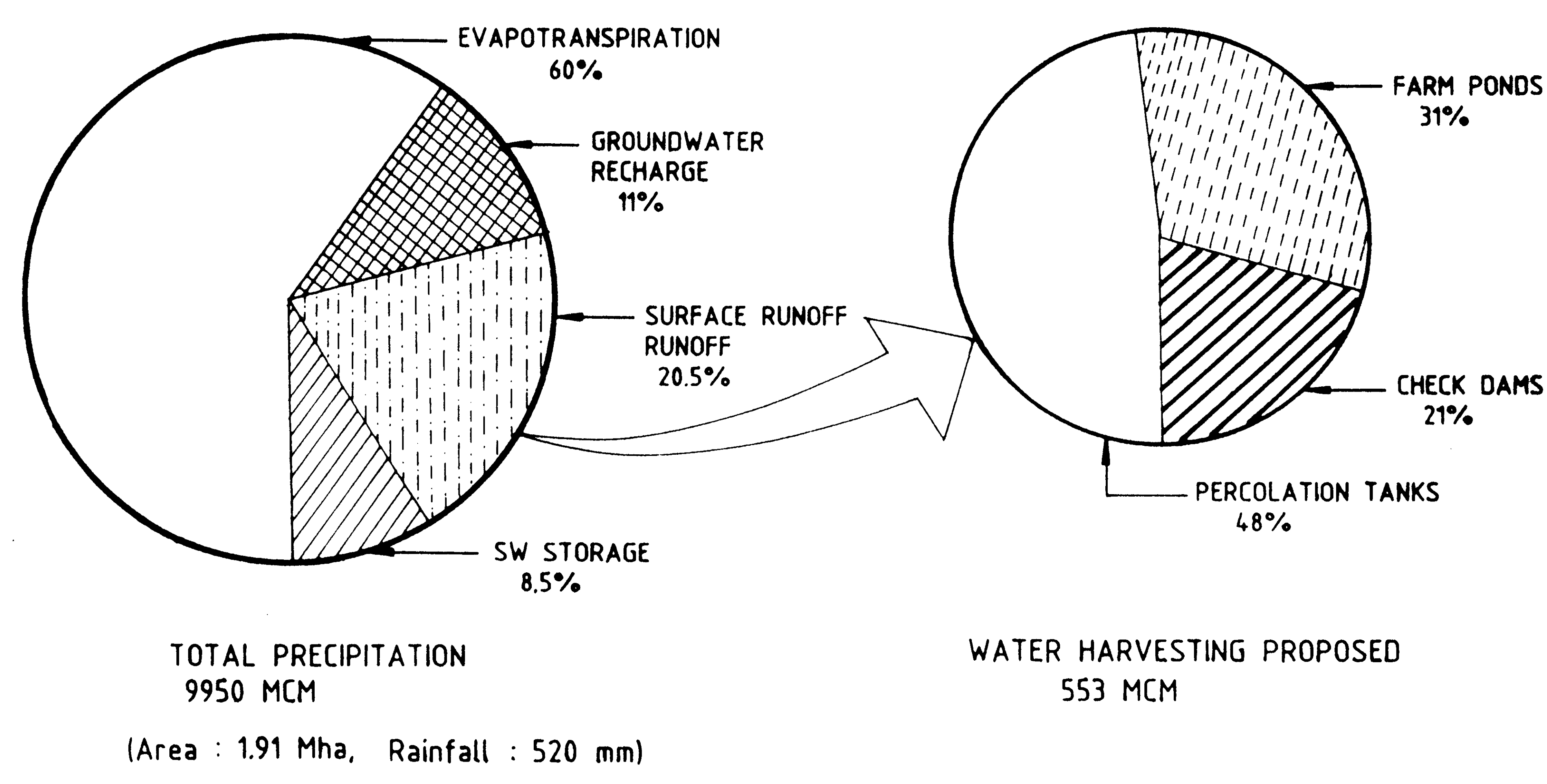


*Fig. 11 : Rainwater harvesting plans for Anantapur district*

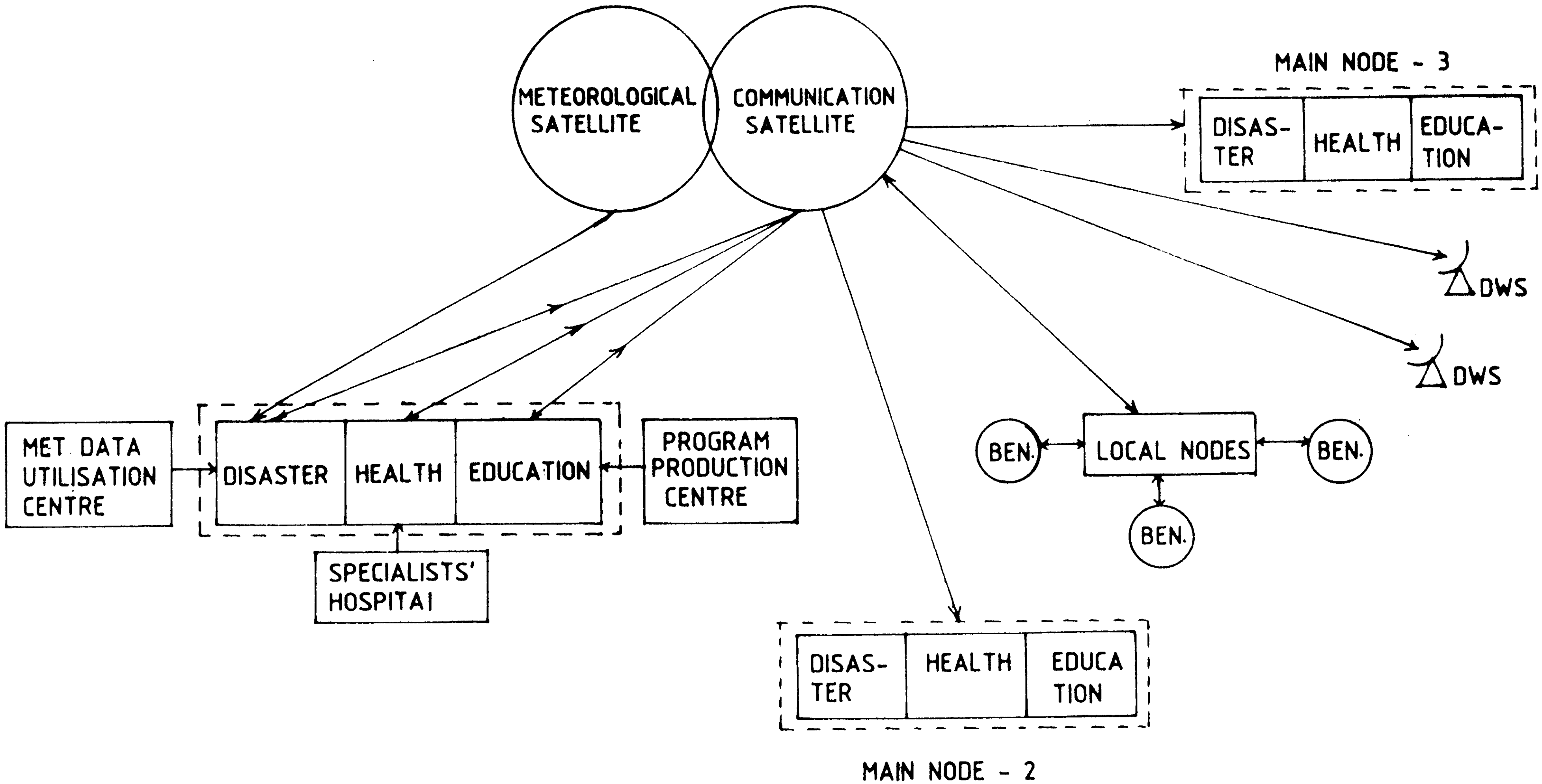


Fig. 12 : Global satellite network for Education, Telehealth and Disaster Management (GLOSNETAD)

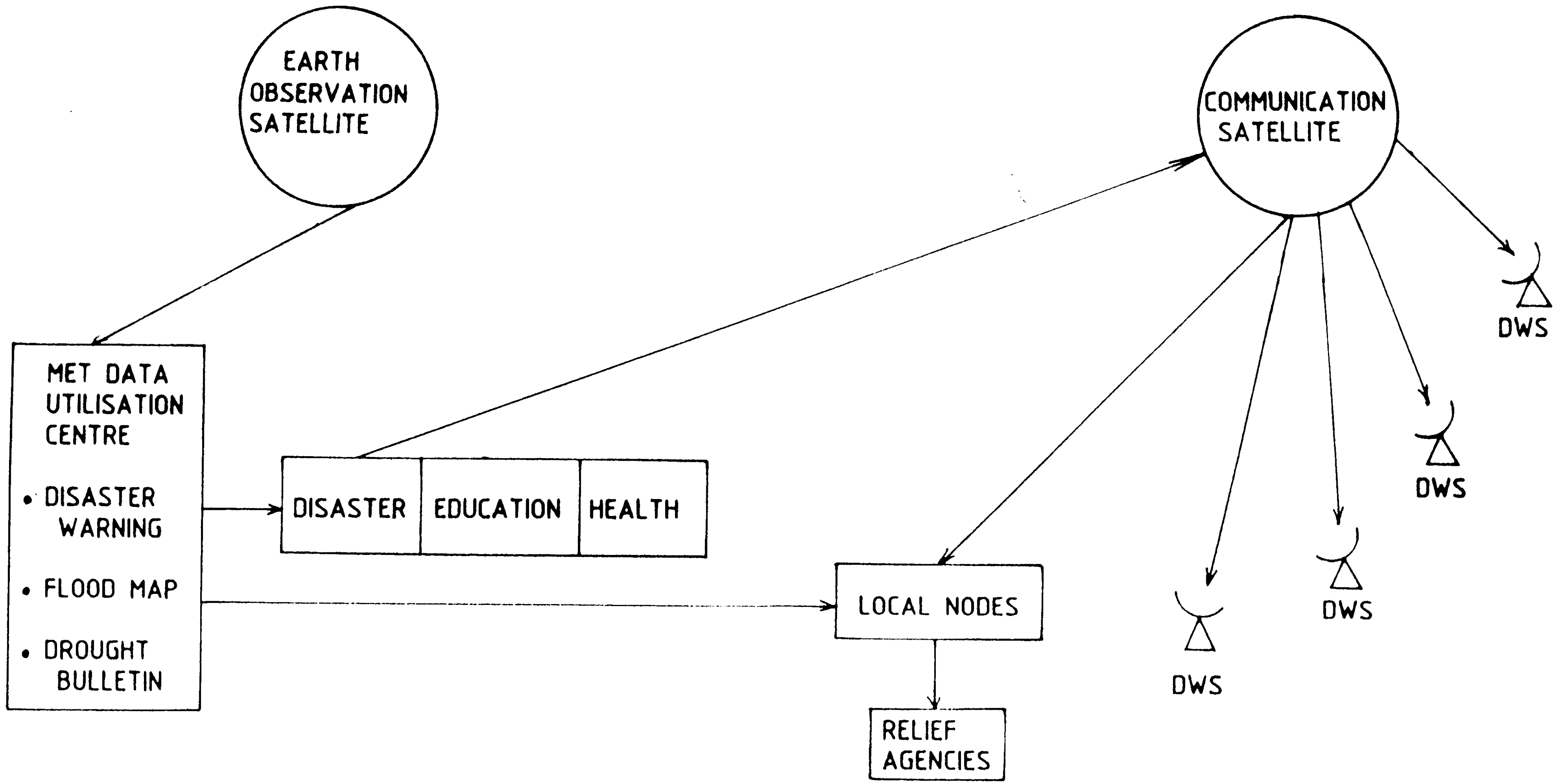


Fig. 13 : GLOSNETAD - DISASTER WARNING COMPONENT

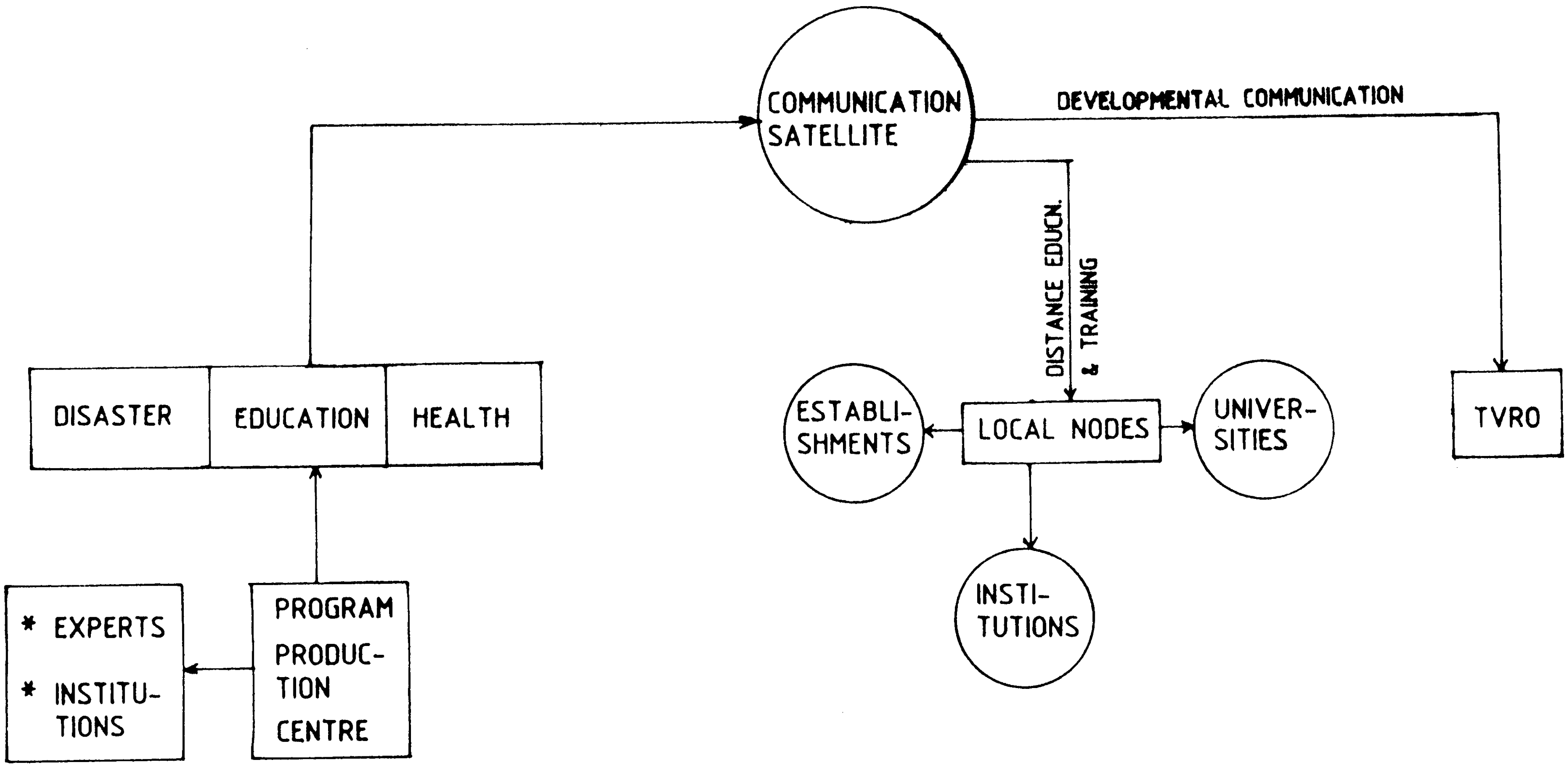


Fig. 14 : GLOSNETAD - EDUCATION COMPONENT

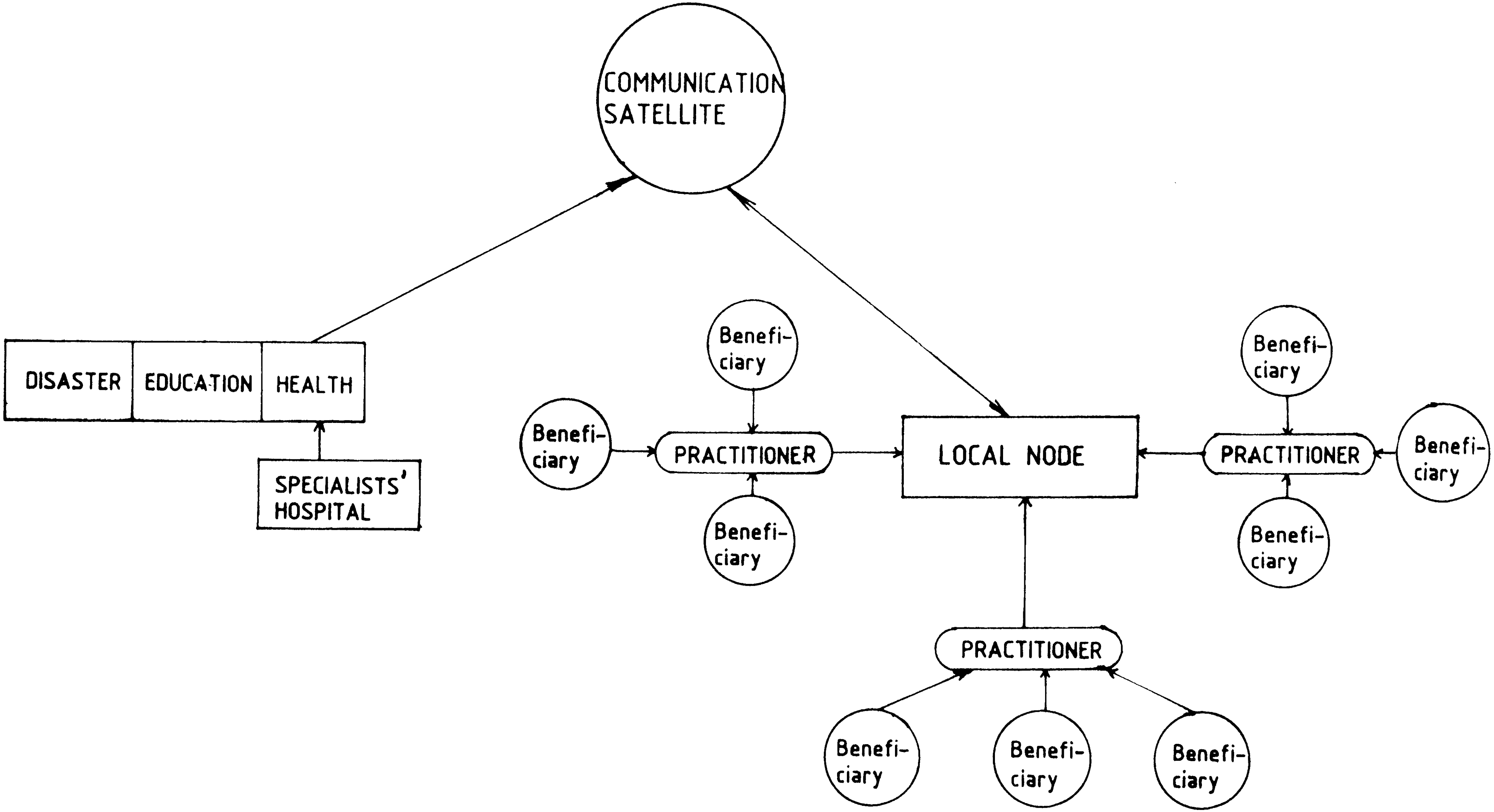


Fig. 15 : GLOSNETAD - TELE HEALTH COMPONENT

# MANAGING SMALL-SCALE SPACE PROJECTS IN DEVELOPING COUNTRIES: CHALLENGES AND PROBLEMS*

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## INTRODUCTION

Resource managers in developing countries face a number of formidable land use problems ranging from urbanization and deforestation, to sustainable development of energy, land and water resources. The urgency of major environmental issues such as desertification, soil erosion, drought and locust plagues, emphasizes the need for remote sensing and Geographic Information System (GIS) technologies in developing countries. Many of these countries have, however, recognized the potential benefits of these technologies in those fields. These tools have been developed to monitor environmental change and for the purpose of planning sustainable development. In this context, satellite data should be considered a valuable tool offering new opportunities for a number of applications within mapping, planning of rural development and management of natural resources.

Today, many decision makers lack comprehensive, up-to-date and accurate information on the resources they manage. Some areas of Africa and Latin America have never been mapped at the scales needed for sound resource management. Census statistics are usually outdated in many parts of the world and information on how important resources are changing is essentially non-existent.

## POTENTIAL APPLICATIONS OF REMOTE SENSING TECHNOLOGY

Remote sensing systems make it possible to collect and analyze information about resources and land use over large areas. Computerized GISs allow resource managers to process large volumes of geographically referenced data from multiple sources. These data can be integrated to produce maps, monitor changes in resources and model the impacts of management decisions.1/ Many resource managers in both developed and developing countries have already benefited from these technologies in fields such as watershed management, agriculture, forestry, conservation. mineral resource development and prevention and mitigation of natural disasters.

Remote sensing data can be used in a GIS to measure and map many features and phenomena of interest to resource managers as well as to inventory large areas more cost-

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* This paper, which was presented at the United Nations/ESA Symposium on "Space Technology for Improving Life on Earth," held at Graz, Austria, 11-14 September, 1995, does not necessarily reflect the views of the United Nations.

effectively than by using ground-based techniques. Remote sensing techniques have a lot of advantages over ground-based techniques. They are generally more cost-effective than ground-based techniques for mapping surface features over large areas. Depending on the size of the area, the nature of the information required and the amount of field verification needed, the cost of remote sensing inventories is usually one third of the cost of conventional ground surveys. These systems provide the most accurate information on isolated or inaccessible areas. They also provide information on dynamic processes and are an effective tool in monitoring the impact of resource management decisions.

Remote sensing can provide data on many of the Earth's features: topography, soil type, near surface geology, vegetation, surface water, shoreline, coastal resources, the oceans (surface temperature, abundance of and changes in organic material, such as algae), atmospheric temperature, cloud cover and pollution.2/

Remote sensors make it possible to update data more frequently than ground-based survey techniques and, in theory, to monitor changes occurring in features in near-real or "real enough" time. With frequently updated information, resource managers can monitor dynamic processes, such as changes in ocean productivity (i.e., changes in chlorophyll production by plankton as an indicator of likely changes in fishery locations), crop growth and vigour, erosion, deforestation, environmental pollution and urban sprawl.

Upgrading of topographic maps (at a scale of 1:50,000 and smaller) can be done based on SPOT data. Most of the important map features can be detected on high quality satellite data. While traditional updating for a whole country would take decades to complete, the use of satellite imagery could reduce this to 2-3 years.3/ In addition, it is far more cost-efficient compared to traditional mapping techniques. SPOT (or Landsat TM) data offers excellent opportunities to derive vital information concerning land use and biomass, relevant for energy planning, management of natural resources and agriculture. Using satellite data, it is possible to make time series mapping and monitor changes in land use and vegetation cover. This is a useful tool for environmental monitoring and impact assessment, especially in many African countries where areas of natural habitats, forests, agricultural land and infrastructure are now undergoing rapid changes, some of these, seriously affecting the environment and the possibility of sustainable development. In these countries, the maps available are not always updated and there is a strong demand for additional information on these subjects. SPOT XS/Landsat TM data can provide much of this additional data. Using GIS, it is possible to update these data with new recordings, make change detection analyses, statistics, maps and other geographical presentations. There is an urgent need for updated information on the status of many of the forest reserves in Africa. Multispectral satellite data with a resolution of 20-30 m is particularly well suited for forest classification.4/ Areas of encroachment and other significant changes of forest are easily detected.

Resources and environment are the main issues concerning sustainable development which balances resource exploitation, resource conservation and the protection of the environment. While in the developed world, governments, decision makers, administrators, and communities are conscious of the necessity for such a balance, notwithstanding serious problems such as industrial waste and other pollutants, their resource management models have incorporated the concept of sustainability and environmental custody. These countries also have the financial, technical and human resources, coupled with the political will, that are required to implement those models.5/ In the developing countries, and more critically in Africa, damaging changes in the domain of natural resources and land use are taking place at an incredibly rapid pace.

What is worse, is that many developing countries do not possess the necessary resources to assess and measure these changes and to understand their nature, much less to design ways to undertake and control them.

## COMMON BARRIERS FOR REMOTE SENSING AND GIS IN DEVELOPING COUNTRIES

The remote sensing technologies have been developed mainly in the developed countries. Today the developing countries seek to use these technologies for their planning and development programmes, but most of these countries are not fully prepared to utilize these technologies. Remote sensing and GIS have three important components: computer hardware, application software modules, and a proper organizational context.6/ The problems are related to the cost of data, trained manpower, software development, leadership, organization and funding.7/

## OBSTACLES RELATED TO SYSTEM INPUTS

### Data access

There is a growing realization that problems of environment and development are exceedingly complex. To understand them and to find solutions, resource managers need to have the right kind of data as well as the means to manage and interpret large volumes of data from different sources. New technologies such as remote sensing and GIS make it possible to collect, integrate and analyze data more thoroughly, accurately, quickly and cost-effectively than ever before.

Remote sensing technologies collect billions and billions of bits of data. GISs can process these data with other types of data to provide the information needed to address complex resource management problems. However, many users of these technologies do not know how to find out what data exist, where, in what form and how they can be acquired.8/ Remote sensing techniques have many advantages over ground-based techniques. They are generally more cost-effective than ground-based techniques for mapping surface features over large areas. Depending on the size of the area, the nature of the information required and the amount of field verification needed, the cost of remote sensing inventories is usually one-third of the cost of conventional ground surveys.

Resource managers around the world need access to "data about data" for their particular applications. They need to know what data are available at the regional, continental and global scales. Access to data of different kinds, primarily "ground truth" data to verify remotely sensed information and other "conventional" data, such as maps and statistics for use in a GIS, remains a major problem.9/ While reference data banks exist for space-borne sensed data, other types of data are spread out among different locations. No clearinghouse arrangement exists for cataloguing or managing all available data sets. This situation may well improve in the future, because national and international agencies that collect and manage data have begun to cooperate on the matter.

The exchange of data within and among local, state, regional, provincial or national agencies is another important, and complex, issue. Some countries feel that some types of resource information could be sensitive, and are reluctant to make them readily available. But addressing global issues such as ozone depletion, acid rain and loss of biodiversity requires data exchange across national boundaries. Sharing data at local levels is also important for solving problems such as water pollution caused by agricultural wastes.

Data Standards

The use of differing standards for data collection and archiving is a further impediment to the optimum use of remote sensing and GIS technologies. Analyzing resources over large areas with a GIS is facilitated by having reporting standards that apply over a series of scales from local to global. For example, data should be of similar types, classes, quality, precision and resolution. These requirements are difficult to meet when, as is often the case, the data have been collected using different methods. Data integration is greatly enhanced if data are stored in an electronic format. At the present time, however, most data are stored in printed, rather than machine readable form. An added benefit of electronic formatting is that it indirectly favours a move towards standards in data collection. National and international standards on data may facilitate data exchange.

There are also difficulties in obtaining relevant data due to lengthy procedures which are a result of the lack of direct access to ground receiving stations.10/ The cost of data becomes a significant barrier in the transfer process. The cost of both hard copies of imagery and computer compatible tapes (CCTs) is another problem.11/ Difficulty in determining the relative usefulness of data products available for purchase has also been identified as a problem.12/

LOW ECONOMIC STRENGTH TO PURCHASE AND MAINTAIN EQUIPMENT:

Although less expensive than traditional ground-based survey techniques for inventorying large areas, the cost of acquiring and processing satellite data is not negligible. The costs associated with the purchase of data interpretation equipment have been identified as a major barrier to the technology transfer process.13/ Most developing countries cannot afford digital processing equipment.14/ In addition, there are supplementary expenditures related to the equipment, such as costs of operation and maintenance.15/ Not only must the cost of expendables, spare parts and maintenance be considered, but also the salaries of those who run the equipment and analyze the data.16/

A data base which can be updated multi-temporally needs the application of satellite data. The handling of such data is always a high cost performing task. In most cases obtaining digital satellite data is beyond the financial capability of the small-scale organization in a developing country.

General statements about the costs associated with remote sensing and GIS are difficult to make because the costs are highly variable. Start-up costs for a GIS are roughly 10 per cent for hardware, 10 per cent for software and 80 per cent for data base construction. Maintenance and training costs also need to be anticipated.

Much of the remote sensing data available must now be purchased from commercial sources. Many users feel that the purchase price of data is, in itself, a constraint on the application of satellite remote sensing imagery to environment and development problems. Relatively few cost-benefit studies have been conducted. The newness of the technologies and the fact that benefits accrue only in the longer term make cost-benefit analysis difficult and complex. With time, however, it will be possible to better assess and quantify what remote sensing and GIS technologies have to offer.

The lack of funding for remote sensing technology transfer (RSTT) is a major concern.17/ While funding from donors to developing countries represents the major source of capital for RSTT investment, developing countries must rely, in part, on their own resources.18/ Support for this technology transfer must be on a long-term basis if it is to be successful.19/ Ultimately, RSTT must compete for funding with other investment projects.20/ It is economically difficult to implement a remote sensing and GIS laboratory in most of the developing countries without foreign aid.

These financial problems also cause a low rate of participation from the developing world at international symposia and workshops on remote sensing and GIS. In some cases, the lack of economic strength blocks the continuation and improvement of on-going research.

## HUMAN RESOURCES

### Training

Remote sensing and GIS are complex technologies that require trained personnel for their effective exploitation. Training is therefore a prerequisite, not only to begin using these technologies, but also to keep up with rapid advances in their development. Training is required at a variety of levels and in a number of forms, from one-day to one-week seminars for senior resource management personnel, to two-week to three-month training classes for more technical personnel, to university degree training at the undergraduate and graduate levels. To keep up with the technology as it evolves, overviews and in-depth introductions and up-dates on new developments, operations and maintenance should also be anticipated. Recognizing the importance of training, a number of regional and international organizations offer training programmes. Despite these efforts, however, the lack of trained personnel continues to be a critical constraint on the full exploitation of remote sensing and GIS technologies.

In order to maintain a remote sensing facility, a critical mass of trained personnel is required. Thirty individuals, representing a number of disciplines, ranging from technicians to experts in particular fields, are considered ideal for the successful operation of such a facility. Most developing countries, however, cannot reach this critical mass. The lack of experienced personnel is mentioned repeatedly as a barrier to the RSTT process.21/ The lack of trained personnel who are capable of using remote sensing imagery and CCTs is also a problem and some developing countries cannot use available CCTs due to lack of trained personnel.22/

As a result, cross-border cooperation, regional support facilities and regional centres providing all the necessary functions are often substituted for national capability.23/ This solution brings with it other problems, since national governments must cooperate to make such a regional operation viable.

The multidisciplinary aspects of remote sensing technology require experts who are well versed in both the natural and technical sciences.24/ When considering the needs of qualified personnel in the RSTT process, one must consider the overall development activities of the country to determine whether or not human resources are being diverted from activities of higher priority, leading to adverse secondary effects.25/ Due to the scarcity of technical personnel in developing countries, there is a high turnover in technical positions.

Another deficiency is related to the fact that local personnel have neither sufficient managerial training nor experience.26/ Without an indigenous capacity to perform many of these activities, countries are forced to bring in experts from donor countries.27/ This reliance on outside experts costs valuable foreign currency and discourages development of indigenous expertise.28/ Education and training represent critical elements in the transfer system. There is need for short-term training as well as long-term education which provides a broader base of understanding.29/

The lack of experts in handling and processing remote sensing and other data, computers and software, designing GIS, and related technical matters presents a great limitation. Because of this, education and training play crucial roles in the development of remote sensing and GIS technologies in developing countries.30/ The required level of training and education is dependent on the level of initial research and the individual educational environment of each country.

The lack of userfriendliness in digital image processing equipment also creates a problem for users in developing countries.31/

## WEAKNESSES OF THE DECISION MAKERS

Ground-based techniques for collecting data and manual techniques for synthesizing information are costly, cannot keep pace with constant changes in resource or land use, can be time consuming, or inaccurate, and make it difficult, or even impossible, to analyze large volumes and diverse types of information. Yet many decision makers still rely on such techniques. Some managerial level persons in developing countries stick to their own academic methodologies and are pessimistic over application of technologies. Some may prefer to use extensive ground surveys instead of low-cost black and white air photographs to make a simple map. The reverse situation is where decision makers may buy advanced technological equipment, though their institutions are not fully prepared to handle such facilities. In some cases politically appointed institutional heads who deal with resource and environmental management, may have poor general knowledge with regards to problem identification and application of new technologies.

## INSTITUTIONAL WEAKNESSES

The problems associated with the process of importing necessary equipment is often cited in many countries.32/ In addition to these problems, a common feature is the lack of physical facilities.33/ Other limitations include the limited number and geographical positions of ground receiving stations.34/ An impediment to the further use of these technologies is the lack of adequate infrastructure. Infrastructure and institutional constraints, while of concern in all countries, tend to have greater ramifications in developing nations.

Lack of cooperation among agencies is another major barrier to the RSTT process.35/ The size, structural complexity and tradition of organizations in developing countries are factors which affect both the rate of acceptance and the rate of diffusion of RSTT projects.36/ There is a need for institution building, which is necessary if technology is to be absorbed and used by local professionals.37/ In many developing countries, the lack of these managerial and organizational structures and of cooperative inputs, rather than insufficient technical manpower, is a major obstacle and bottleneck in the use of technology to accelerate development.38/

For long-term sustainability, it is essential to have a comprehensive initial training follow-up at regular intervals to deal with any problems related to an on-going project.39/ Externally funded projects are often abandoned as soon as the donor aid stops, leaving behind loads of hardware which can no longer be used.

## POOR INFORMATION FLOW

The total success of the environmental and social development programmes in any society depends on the degree of contribution of social sectors which can only be achieved through a firm circulation of information within the local society and with international societies. In most developing countries the environmental problems and related information flow among government institutions, universities, private organizations and the general public is rather weak.

## WEAKNESSES IN INTERNATIONAL COOPERATION

Developing countries have very little choice and have to accept any kind of foreign offer in hardware and training programmes. Much of foreign aid is directly connected to the governmental organizations of the developing countries without consulting the local remote sensing experts. Other organizational obstacles are related to the activities of donor organizations. For example, donor governments have been criticized for establishing certain regional centres without involving countries in those regions in the planning process.40/ Both government agencies and private sector companies have been accused of overselling.41/ Sometimes this has led to the transfer of inappropriate technology.42/

There is a lack of knowledge and communication about the costs and benefits, manpower requirements, alternatives, new applications and sources of equipment, and a lack of information about experiences using the equipment.43/ The lack of knowledge about technology related products could be due to the rapid development that the technology has been going through, or to the competitiveness and secretive attitude of the manufacturers.44/

CHALLENGES

Space technology has brought a new dimension to project management in developing countries. It is proving to be the best option so far that can effectively solve the major mapping needs of developing countries. Some of these countries have embarked on the regular use of satellite imagery for important developmental projects. However, decision makers should decide whether or not this technology can be applied successfully to high priority development programmes and whether or not the benefits of remote sensing technology outweigh its costs.

The effective application of remote sensing technology depends on a number of factors. These include the suitability of sensors, the performance of the technology transfer network which connects technology donors with recipient organizations in the host countries, particularly with the end users who will employ the technology in development projects, and inputs, e.g. funding, training and data products, which must flow through the technology transfer system, if the technology is to bear fruit.

Before acquiring remote sensing data, it is important to decide what types of data are needed and whether the data are readily available "in-house" or within other agencies, or whether they must be purchased. It must be determined which traditional data maps, site-specific literature, and statistics are needed and the type and amount of "ground truth" data that will be necessary to interpret remote sensing data. Acquisition of the right type of data, in the correct format, and with the supporting medium, as well as delivery in a timely fashion are important prerequisites for remote sensing technology to contribute effectively to development.

It is important to estimate the total cost of acquiring and processing the data and to ensure that the management decisions to be made justify these costs. It is also necessary to identify areas requiring funding. These include equipment, software, personnel, facilities, data supply, maintenance, information dissemination, and research and development.

In the technology area, when a decision to use remote sensing technology has been made, developing countries should identify and acquire appropriate equipment. In addition, there is a need to develop inter-agency data transfer protocols, and to ensure compatibility of systems. Efficient, reliable, and affordable telecommunication links are essential. There is a need for data base standardization, and for advice on data base structures. Sustainability can only be ensured if there is proper maintenance and support of the system. In order to reduce costs, optimum utilization of hardware and software is recommended.

To maintain a critical mass of technical expertise, technical education and continued in-house technical training should be maintained. Developing countries should ensure back-up support, and keep abreast with technological developments.

In view of the importance and utility of space technology, the political commitment to ensure sustainability of the system is vital. This national commitment can only be reflected in the relevant budget lines.

Remote sensing and GIS can be valuable tools for resource managers and policy makers concerned with environment and development problems. But, despite technological advances, diminishing costs and increasing "user-friendliness", the potential offered by these technologies has not been fully assessed or realized. Further research is needed to assess the costs and benefits of using the technologies for various types of applications. In addition, a number of constraints on the use of technologies -- mostly of an institutional nature -- need to be addressed. They relate to data access, data exchange, data standards, training and costs.

Data sent by one user over an electronic network can be easily read by a user at the other end of the network. Standards for "user-friendly" electronic transfer of spatial data would help facilitate electronic data exchanges, as long as the standards did not increase overhead costs or impose other burdens on users.

Other standards for data archiving also need to be considered. What data should be kept, for how long, on-line or off-line? How often should data be updated? Should data be discarded? These are some of the questions which have only recently begun to be addressed. The outcome of efforts to move towards standardization will be a critical factor in determining whether multi-source data sets in specific fields can be fully and optimally integrated. But, whatever the future holds with regard to standardization, the difficult task of integrating the large amounts of data already in hand will continue to require attention.

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# ADVANCED SATELLITE COMMUNICATION AND THE GLOBAL INFORMATION INFRASTRUCTURE?*

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## INTRODUCTION

Believe it or not, the unheralded and unrecognized key to the future of the so-called Global Information Infrastructure (GII) may not be the fibre optic cable, but actually the new and improved satellites and digital cellular systems of the 21st century. There can be no absolute proof of this statement for at least anther decade. And yet there is a convincing body of evidence that suggests that wireless telecommunications technologies and applications will be pivotal.

This is not to say that fibre optics will not be a major part of the future global information highways. They undoubtedly will be the central fabric of information super highways -- this much is largely gospel. No, the reason satellites and wireless technologies will be so very key is that they will provide the critical missing link that no other telecommunications technology can supply. To understand this proposition, we must begin by understanding more about what a 21st century GII will be like. It will, for instance, consist of many parts rather than a monolithic whole. We also need to begin to visualize what the so-called GII implies in terms of services, application, market and technology.

Fibre optic systems, coaxial cable, wire, wireless, and satellites define the key transmission technologies of our future networks. These transmission technologies, however, are like tailored clothes. Certainly neither one size nor one material fits all.

The proposed National Information Highway inside the United States and a subsequent global version of this broadband, low-cost and widely accessible information network has been extolled by President Clinton and Vice President Gore as almost a panacea. Advocates assert that the coming new electronic infrastructure will enhance the productivity of workers, assist in reducing trade deficits, aid health and education, and boost manufacturing and services. Many, however, have become jaded about the so-called "National or Global Information Hypeway" simply because so many claims have been made about its virtues. Excessive enthusiasm has made a skeptical public naturally reluctant to "plug-in" to what some tend to see as "technological overkill." The public is fearful that the coming information networks could also mean higher taxes, lost jobs, or technological intrusiveness into their lives.

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In this examination of the information future and the potential of accessing so-called cyberspace, the term Global Information Infrastructure or GII will be most commonly used rather than the Global Information Highway. This is primarily because the term "highway" can in some important ways be misleading. A highway system is a physical structure typically built by governments and, once built, is quite static and hard to change. Our 21st century information networks are more likely to look and behave more like neural networks inside the human brain.

These networks will be highly dynamic and will grow or shrink with levels of usage. In many cases involving wireless and satellite technologies they may be "more virtual than real" and also may well be built by private enterprise in a competitive environment. For these reasons and more, the "highway" analogy seems poorly suited. Instead, "reference points" such as neural networks or nervous systems seem more apt. Regardless of what we call these networks of the future there remain basic concerns about how they will impact society, both positively and negatively. Ultimately the questions are: "Is the GII a good or bad thing?" "Will it help just the developed economies or everyone?" "Will the GII be the same everywhere or will it adapt to different countries' social, economic and technical capabilities and needs?"

The skepticism factor in response to the media blitz is high not only in the United States and other countries of the Organization of Economic Cooperation and Development (OECD) but around the world. John Malone, Chairman and CEO of cable television giant TCI and a strong advocate of the new electronic technologies, has conceded the following:

> "The greatest challenge of any company deploying components of the NII [or the GII] will be staying flexible enough to respond to consumer demands as they begin to crystallize. At this early stage, consumers themselves are not sure how they will use these new capabilities..."

The biggest problem with the GII today is that would-be suppliers want a part of this lucrative information network, but they also want to sell their particular part to the exclusion of their competitor's part. There is thus no coherent whole to the GII among would be suppliers of hardware or services. Almost no one agrees when it comes to what it is, what the GII is good for, or how much it will cost. Everywhere there are advocates for various "parts" of the GII. Some have suggested that the key to the GII is simply putting the entire world on a high fibre diet. This idea of an information infrastructure that is like a highway or a railroad is an image that is both static and not at all reflective of the agility and responsiveness of modern digital telecommunications. It is in fact a 19th century or at best an early 20th century image. Others have suggested that telephone companies could extend their wire networks through digital compression techniques, while others propose that direct broadcast satellite and digital cellular systems will define information systems that are more diverse, mobile and ultimately "user attractive" than fibre or wire. Craig McCaw, founder of McCaw Cellular which was recently purchased by AT&T, expressed such an alternative view when he said:

> "Fibre broadens our telecommunications capacities, but to be truly valuable our information networks must be able to jump the tracks and reach the individual users

wherever he or she might be. Wireless technology and other service delivery options other than fibre are more like the automobile than a highway."

Several attempts have been made to interpret where we are going in our bold journey into our electronic future. Nicholas Negroponte, Director of the Media Lab at the Massachusetts Institute of Technology, has projected the evolution of the GII in what has been dubbed the "Negroponte Flip." This vision suggests that wireless systems for radio and television and satellite services will shift to cable and that wire-based telephone services will shift to wireless cellular services. In contrast, there are others who find such a dramatic headstand overly simplistic. A future that sees the evolution of many new wire and wireless systems and a merger of these systems into hybrid networks is reflected in what has now become known since 1993 as the "Pelton Merge." (See Figures 1 and 2.)

There are two basic messages in the Pelton Merge. One is that neither the NIIs in the United States, Europe or Japan, nor the ultimate GII are going to be one dimensional. The future needs of the marketplace will merge wire and wireless technologies into hybrid systems. The second message is that the networks that combine to form the GII will be both vertical and horizontal networks. On one hand, there will be hard wired hierarchical systems representing the largely one-way or top-down approach where traffic is concentrated by electronic terrestrial switches. (See Figure 3) This hierarchically concentrated model of telecommunications has also been called the bomber pilot approach to information delivery when it applies to radio and television broadcasting systems.

There will likewise be wireless and hybrid horizontal or interactive networks. (See Figure 4.) There will, in short, not be one neat formula or one single system. The multiple keys to the various NIIs, and the GII that follow, are thus based on many different service requirements, cost constraints, or need for flexibility and mobility. These hybrid wireless and wireline type networks can combine fibre, coaxial cable, twisted pair, satellite and cellular wireless systems together into a "seamless" network. This concept is shown in Figure 5. In such configurations, satellites and other types of wireless technology can make networks more flexible, more robust and more capable of providing dynamic services on demand. The advantages of having advanced satellites in a network optimized for this purpose are listed in Table 1.

No single technology nor one single system can fulfill all of the requirements related to the GII. We will need new high quality, open standards for hybrid "wire and wireless" networks to succeed. Satellites and wireless technology, however, are now clearly the weak link in the worldwide web that could allow a virtually complete "telecommunications village" to happen in the 21st century. In fact, by the 21st century we may even begin to call it the "global brain".

If this conclusion is accepted as valid, then there remains some important problem-solving to do. We must address the current deficiencies in the world of wireless and satellite telecommunications. To put the problem rather bluntly, today's wireless and satellite technology and services are lacking. They are lacking in terms of bandwidth, speed of throughput quality of service, and transmission delay. Wireless and satellite technologies simply do not measure up to the projected broad-band needs of the NII and the GII. There are major deficiencies when compared to the latest in high-quality fibre-optic technology.

Satellite technologists have pushed performance forward on the basis of a conventional path of development. This path offered more capacity at lower cost and exploited economies of scale in satellite antennas and power systems. The trouble is that this technical push did not fully consider service or customer pull. The consumer was happy with more capacity and lower cost, but very unhappy with echoes, transmission delays, lower quality, and user-unfriendly earth terminals. The time has come when satellite and wireless technology must say to the marketplace: "What do you want?" It should not longer say: "This is what you get whether you want it or not."

TABLE 1

SATELLITES AND THEIR POTENTIAL APPLICATIONS TO THE GII

A. Service Needs

- Broad band and Multi-media Based Services (Symmetrical and Asymmetrical)
- Broadcast Services (Symmetrical and Asymmetrical)
- Software Defined and Personalized Services
- High Quality, Low Bit Rate Services with Universal Accessibility

B. Economic Constraints

- Value Differentiated Services
- Cost Minimization
- Cost-Based Pricing

C. Flexibility and Mobility

- Virtual Office Access and Complete Mobility
- Network Flexibility and Reconfigurability
- Service on Demand / Bandwidth on Demand
- Instant Connection Between Public and Private Networks (Including Enterprise Networks)

Unfortunately the satellite industry is far from this highly responsive position today. Certainly contemporary satellite or wireless networks need not apply. This is because of serious limits in available bandwidth, throughput, bit error rate, and latency. This restriction to fibre optics is, however, contrary to popular belief, not a result of the limitations in the laws of physics or even technology. The reason that neither digital cellular nor satellites are currently star performers compared to fibre optic cable are simply because we have not developed and implemented the necessary technology, allocated the right bandwidth, and removed the right regulatory barriers.

Advanced satellites and innovative digital cellular technology can, in theory, do it all. As hard to believe as it may be, satellite and other wireless systems of the 21st century can provide digital rates of 100 Gigabits/second, can easily link end-users "faster" than fibre, and even provide a near-zero bit error rate. Furthermore, terrestrial wireless and satellite systems, given the right new frequency allocations, regulatory guidelines, and technological developments can do all this at competitive prices. This will not necessarily be easy. In fact, given current development programmes, sluggish regulatory reform, and frequency allocations, it is not even probable that these results can be achieved. With some new and innovative thinking and key allocation of physical and intellectual resources it nevertheless could be done.

## A SCOT ANALYSIS OF CURRENT SATELLITE SYSTEMS

The first step forward is to undertake a hard-nosed reality check of the current situation. Many very good satellite engineers wonder what the "fuss" could possibly be about. Satellite designers can be excused if they tend to be a bit neurotic and paranoid. In the last 30 years satellites have become over 1000 times more cost effective. Gains in power have been on the order of 100 times, derived frequency efficiency through re-use and compression techniques have gone up maybe 50 times and lifetime has gone up nearly 10 times. In a normal industry, such remarkable achievements would be hailed as phenomenal breakthroughs. The trouble is that fibre optics has made even more dramatic gains -- gains in throughput as well as gains in quality and in overall performance.

In a classic strategic "SCOT" analysis of strengths, weaknesses, opportunities, and threats. the satellite communications industry has a number of clear strengths and opportunities but also clear weaknesses and threats as well. In terms of strengths, satellites have the following generic advantages: dynamic service capabilities, flexibility, and cost efficiency.

### Service Strengths

Ability to deliver wide area broadcasting service. Provision of service to mobile transceivers. On-demand delivery of bandwidth and service. Multi-point to multi-point networking in Mesh-type systems.

### Flexibility

Flexibility to add service to any point at any time. Creation of flexible networks from thin to heavy streams on demand.

Cost Advantages

Cost effective coverage of rural and remote areas and distance-insensitive link connections.

Strategic Weaknesses of Current Satellite Communications

The weaknesses and threats, however, are also abundantly clear. These include the following:

- Lack of sufficient broad band frequency spectrum.
- Difficulty of operating in new millimeter wave bands due to rain fade.
- Transmission delays especially for geosynchronous satellites.
- Difficulty of maintaining consistent or sustained high quality (i.e. Low Bit Error Rates).
- Echo, rain fade, sun spot outage, scintillation.
- Maintaining cost competitiveness vis a vis fibre for high volume trunking service (i.e. bits/dollar)
- Difficulty of maintaining system security and privacy of customer messages.
- Complexity, size, and cost of ground antennas.

In short, one size does not fit all. (i.e. the customer has to consider whether this is a service that satellites can perform well and deliver at low cost or not?)

Satellites have made progress in many of these areas, but in comparison to fibre optics, simply not enough. To some customers, satellites are a nuisance which force too many consumer decisions. The appeal to many is that fibre optics can simply do it all -- except for mobile services. In short, some customers see satellites and wireless "as needed" technology only for mobile services.

Out of weaknesses and threats, however, can come important new opportunities. The potential exists for satellites to break out of their current constraints and to employ totally new technologies and architectures to revive and reinvigorate the space communications community. We do not necessarily get to where we need to go by extrapolating and extending current technology trends. There are thus two things to derive from this SCOT analysis. The first conclusion is that improving past technology is not enough to overtake fibre technology. The second conclusion is that if satellites are to play a truly key role in the future, they must be more than just a mobile service provider.

## SATELLITES VERSUS FIBER OPTIC CABLE

Table 2 shows a comparison of current fibre optic technology versus geosynchronous fixed satellite service.

The advantages of fibre optics over current geostationary satellite technology seems drawn when comparing today's geosynchronous satellite to the best of today's mono-mode systems. Even if one were to chart a course of rapid progress for satellite development in ɩually all performance areas, the issue of latency in the transmission path will always remain .or geosynchronous orbit (GEO) satellites. The GEO satellite system will be always lacking in customer performance when it comes to delays of a quarter of a second or more. Latency is a huge (but often unspeakable problem) in the world of GEOs. Another way of saying this is that satellites in Clarke orbit might continue to play a key role in a broadcast mode, but their longer term role in the Public Switched Telecommunications Network are akin to the role of the "terminally ill."

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TABLE 2

SATELLITES VERSUS FIBRE OPTICS TODAY

| PERFORMANCE MEASURE | GEO SATELLITES | FIBRE OPTICS |
|---|---|---|
| Typical Throughputs | 500 Mbs-3000 Mbs | 1000 Mbs-5600 Mbs |
| Quality of Service (BER) | $10^{-7}$ | $10^{-11}$ |
| Security of Service | Low but improving | High |
| Cost of Service (Bits/$) | $10^{8}$/$1 | $10^{9}$/$1 |
| Transmission Time | <250-500 ms | <100 ms |
| Available Bandwidth | 3000-4000 MHz | virtually unlimited |

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Furthermore, as future innovations in digital processing range upwards toward speeds of 1-10 GHz/second, the issue of transmission delays becomes more and more critical. Prototypes of optical processors that can operate at 10 GHz per second are only 10 cm across simply because calculations at these speeds must be confined to such dimensions consistent with limits imposed by the speed of light.

In short, the future demands of high data rate processing and imaging will impose key constraints on 21st century telecommunications systems (i.e. the NII and the GII). Ultimately there will be a need for truly low latency systems that are at least 50 times more rapid end-to-end than geosynchronous satellites. There are thus major longer term barriers to the use of geosynchronous satellites. Due to latency, GEO satellites will simply not be allowed to provide a full range of NII/GII services, although applications such as direct broadcast satellites will remain. Our new advanced digital satellites must then be low Earth orbit (LEO), medium Earth orbit (MEO) or High Altitude Long Endurance (HALE) systems in order to meet the latency requirement. This is then just the| starting point. Next our "designers" must solve all the other problems outlined above as well. It is a challenge, but it is possible.

## ADVANCED SATELLITE COMMUNICATIONS SYSTEMS OF THE 21ST CENTURY

Down is not out. Satellite technology has the potential to make a major comeback. In fact, in Europe and Japan major investments in research and development are being made to seek a global lead in this critical area. Satellites have the potential for overcoming current performance gaps versus fibre optic cable and to do things that fibre simply cannot do. Furthermore these gains in satellite technology can be applied to terrestrial digital wireless systems as well.

### Key New Design Objectives

Let's start with basics. How could one design such an "ultimate" satellite system? To start with, it would require an end-to-end transmission delay of under 100 milliseconds and could transmit up to 100 Gigabits/second with a near zero bit error rate and with no echo. It would need to operate with a total systems cost (ground and space systems) that is competitive with fibre optic cable. Communications should also be secure, compatible with voice, data, multi-media, video, and imaging, and readily able to interconnect with fibre optic cable or terrestrial cellular systems through open standards. Finally, we should make our ultimate satellite system capable of providing fixed, mobile or even broadcasting services as well.

Where would we start in our design project for the ultimate early 21st century communications satellite? Clearly one would look at the best of today's technology. This would mean reviewing the Teledesic design for a 840 satellite mega-LEO system as well as examining the Hughes Aircraft Company's filing for the so-called geosynchronous Spaceway system. One might wonder why the Motorola satellite system with its complex technology is not included as well. The answer is that Motorola's system relies on only 5 MHz of capacity in the 2 GHz range and this means that this system and its technology can only serve very narrow band mobile requirements and never the broad band needs of the NII and the GII. Furthermore, most of the key technologies represented by Motorola's system are incorporated in either Teledesic, Spaceway or both of these systems.

Looking further afield into experimental systems, one would review the technology represented by the best of Japanese technology. This would include the ETS-VI and ETS-VII projects, the COMETS mobile and broadcast experimental satellites and the OICETS optical intersatellite link experiment. One would also examine work of the Advanced Telecommunications Research Center in Kyoto in the areas of artificial intelligence and advanced system design. In this review of Japanese technology one would learn a great deal about optical inter- satellite links, bit-by-bit regeneration of signals on the satellite, satellite millimetre wave applications, and about AI applications to very complex beam interconnection systems. One would also look to the European Space Agency's ESTEC facility to learn about the ARTEMIS programme, as well as SILEX, and Olympus. In addition, the Italian experimental satellite project to investigate millimetre waves, known as ITALSAT, would also be of great interest. Thus, in Europe one would also learn about optical ISL's, on board processing, and the use of millimetre wave bands.

More could be learned by meeting with industrial organizations. There is much to assimilate with respect to space and ground antenna designs, power systems, monolithic technology, and use of artificial intelligence (AI) to compensate for rain fade issues. There is also much to be learned about the latest in modulation, encoding, and multiplexing systems. High on the list would be Dense Wave Division Multiplexing and new encoding systems and polarization techniques that might allow future band sharing between GEO, MEO, LEO and ground systems. One would also need to be educated about the latest in superconductivity thin film technology, breakthroughs in electronically steerable phased array antennas, and even the amazing new Unattended Autonomous Vehicles (UAVs) or Remotely Piloted Vehicles (RPVs) that will shortly make possible so-called atmospheric geosynchronous satellites.

These platforms, which are also sometimes called HALE platforms, seem to offer new solutions to the satellite latency problem at least for geographic areas some 50 to 300 miles across (or 80 to 480 km in diametre). This exotic new technology, which operates in protospace (i.e. above commercial aviation space), depends on remotely-piloted vehicle systems to maintain a platform at an altitude of 19 kms. This is incidentally enough height to provide complete coverage to Taiwan or South Korea. Initially this UAV or HALE technology would seem to be a highly cost-efficient adjunct to a LEO system like Teledesic.

## KEY INNOVATIONS FOR THE "ULTIMATE" SATELLITE DESIGN

What does it all add up to when one has swept the world's idea closet clean of ideas? The answer is plenty. There are dozens of highly intriguing possibilities. Here are only some of the most critical and provocative of the options.

### Pursue Huge New Millimetre Wave Allocation for Shared Satellite and Terrestrial Telecommunications Use

The key to this allocation doing a great deal of good would be to make it a very large band that would be perhaps 5 GHz to 10 GHz in size, somewhere between 40 and 60 GHz and make it a shared use band under special encoding techniques so that terrestrial uses and all types of satellite services in all orbits could use it. With super CDMA techniques, this band could be used hundreds of time over to derive effective use patterns that over the planet could run into the multi-terabits per second range.

Exploit the Potential of On Board Signaling, Artificial Intelligence, and Bit-by-Bit Signal Regeneration.

These techniques would allow satellites to become far more capable and to achieve prodigious levels of performance. This is absolutely critical, however, for several key reasons. These reasons are coping with the huge rain attenuation problems that exist at 40-60 GHz, the need to move toward zero bit error rates, and the need to operate smaller, more mobile and lower cost ground terminals. The up to 12 dB advantage that might be gained from these techniques will need to be reinvested to solve these problems. Artificial intelligence can particularly help in bit-by-bit processing and in assigning on board power margin stored on the satellite to rain intensive beams on an instantaneous basis.

Rationalize Bandwidth Use for Satellites and Avoid Micro-Allocations of Spectrum

Today there are hundreds of thousands of frequency allocations for many hundreds of approved services as defined by the ITU. This system is designed to give frequency to virtually every potential user, presumably on a fair and equitable basis. By dividing the spectrum into smaller and smaller segments and assigning first, second, third, and even fourth priority uses, the result is that ultimately almost everyone suffers from the inefficiency of the system. If one sought clear rationales for assignments based upon clear and coordinated sharing techniques over much broader bands, the result would likely be more effective use of the spectrum and great simplification of the allocation process at least at the higher frequency bands where there is still the potential of creating order from incipient chaos. Mobile and fixed satellite services could share with each other and terrestrial systems if bands were reasonably segmented or constrained by polarization techniques, encoding schemes, power levels, and beam structure.

Design to Universal Personal Telecommunications Standards of the Future

The future of telecommunications will for better or worse be shaped by telecommunications standards. For many years these standards, as developed by the ITU, have contained some element of conflict between wire and wireless technologies and services. The presence of the CCITT versus the CCIR tended to create tensions between fibre, coaxial cable and wire systems versus mobile wireless systems and the satellite world. The CCIR-l recommendation G.114, which states that transmission times of 400 ms or less were "acceptable" for the PSTN, was really more a matter of compromise between the terrestrial technologists who wanted less latency and the satellite engineers who argued for more. The same set of dynamics was repeated time after time in such areas as the "interference" that should be allowed within the various parts of a network in the form of hypothetical reference connections (HRX's). In this confrontation, the terrestrial advocates wanted the switching and concentration systems to receive the lion's share of the available margin and leave virtually none for the transmission link itself.

Implement Large Scale Multiple Beam or Cellular Satellites

The potential of LEO satellites is just beginning to be understood in terms of reduced path loss, opportunities for multiple frequency reuse and higher power levels due to multiple antenna beams. The designs of the Teledesic and Motorola Iridium satellite systems indicate how 50 fold re-use is possible. There have even been design studies for very advanced phased array antennas that would allow a 3,500 antenna beam network that could achieve a 500-fold or even higher frequency re-use on a satellite or a HALE platform. Admittedly the on board processor to support such a system would be an awesome device like a "super-super computer in a bread box." The limits of such a future satellite, however, are bounded as much by imagination as by technological development.

Explore Proto-Space: Hybrid LEO Satellites and HALE-Based Local Distribution Systems

HALE platforms or UAV telecommunications platforms would continuously "fly" or "hover" over one location at an altitude of about 20 km. These HALE or UAV communications systems, when coupled with LEO satellite systems, could produce the best of all possible worlds in terms of transmission delay, overcoming rain attenuation, achieving maximum possible throughput at the lowest possible cost and concentrating capacity where it is needed. It could also allow flexible and seamless provision of fixed and mobile services and reduce the cost and size of ground transceivers. The advantages of a LEO system interlinked to a network of UAV telecommunications platforms is easy to envision. The UAV platforms can cover urban areas and work with cellular beam systems to provide high throughput, mobile services and operate at frequencies where rain attenuation can be minimized or overcome with high power margins.

LEO satellites, on the other hand, can cover rural areas and interconnect HALE platforms for inter-regional traffic. In early generations the satellite might connect to a ground-based system that feeds into a HALE platform. In terms of latency or delay, the maximum pathway would typically be less than 400 km. In later stages the satellite might connect directly to the UAV as in an inter-satellite link. Since the UAV platform would operate above 95 per cent of the atmosphere, even more dramatic performance could be achieved. In advanced design concepts these UAV platforms could provide over 100,000 cellular links, hundreds of video channels or huge amounts of telephone or data capacity.

In general, the conclusion is clear. Anyone trying to design radically new designs for 21st century satellites can at least conceive of systems that do it all. They can provide mobile and fixed services, and there is enough throughput and frequency re-use so that they can handle terabits/second telecommunications links. Furthermore, there is enough power in digital encoding and processing to meet quality of service, security, and performance requirements. This is not to say that these satellites will put fibre out of business, but it is to say that fibre need not put satellites out of business either.

## TELECOMMUNICATIONS MARKETS

To state the obvious, the 21st century telecommunications markets will be huge. In round terms, telecommunications services broadly defined today are grossing $550 million per year. They could even rise to as much as $1 trillion by 2001. Data processing, computing, and information services are expected to reach about $2 trillion per year at about the same time. These projections suggest that telecommunications, information and data processing will be perhaps 8 per cent of the total global economy of some $40 trillion. It is also projected that wireless services will, if anything, grow even more rapidly. In short, wireless services are expected to grow from about $100 billion a year to over $200 billion by 2001. Satellite communications have been forecast to increase from $15 billion a year to perhaps $30 billion. The magnitude of these figures suggest that some critical decisions hang in the balance. There are several key options. Satellite communications can claim a share of the overall growth. Further, as a highly flexible and cost effective new telecommunications option, its growth could be greatest and most effective in the so-called developing world.

## NEW APPLICATIONS OF SATELLITE SERVICES

If indeed a new type of satellite is developed over the next decade, the stakes involve more than competing with fibre optic technology for market share. The key is the development of totally new services and applications to benefit humanity in developed and developing economies alike. Truly broad-band, high-quality and completely mobile services via satellite opens up a host of new possibilities. Some of the options that suddenly become both possible and cost effective are: (a) electronic tutors and tele-health units that can reach anywhere on Earth; (b) flexible telecommunications services (both mobile and fixed) to homes and businesses; (c) asymmetrical business networks; (d) tetherless offices and electronic immigrant networks; (e) interactive and mobile digital entertainment; and (f) integrated mobile and fixed telecommunications services. These are not only highly desirable and user-friendly services, but ones that fibre technology cannot easily deliver. Especially in countries with less developed telecommunications infrastructure, the satellite or wireless solution may be faster, more flexible and lower in cost. Let's briefly review these "wireless defined services".

### Global Electronic Tele-Education and Health Services: The Promise of Electronic Tutors and Remote Tele-health Units

Almost two decades ago, futurist Arthur C. Clarke in an address to the United Nations Development Programme in Paris suggested that there was a great potential within satellite and computer technology to create a new system for rural and remote education and health services. This concept which he called the "electronic tutor" was foreseen as a low-cost, interactive and user-friendly way to provide learning and health care services to the more than 1 billion people living in isolated regions of the world. As Clarke stated: "The development of the Electronic Tutor has more to do with [United States toy manufacturers] Mattel and Milton-Bradley than IBM".

The potential Clarke foresaw was in the creation of a truly mass market portable unit which could provide video, audio and text information to any location anywhere on the planet with satellite updated information on demand. As a wireless-based service, the electronic tutor could connect anywhere, even where wires and electric power are absent. These units, connected to doctors, hospitals, and para-medics, could also provide important medical and health services to rural areas as well. Parallel development of this type of wireless technology in urban and developed areas could also lead to the "electronic newspaper" available in text and images. When challenged by educators as to whether he was proposing to eliminate teaching positions, he paused and said with careful deliberation that he was not advocating the elimination of teachers, but perhaps saying that "every teacher who can be replaced by a machine, perhaps should be."

In the summer of 1994 in Barcelona, Spain, I worked with 47 graduate students from some 26 countries as part of the International Space University design project. In just several weeks these students developed a proposal for a Global Access to Tele-Health and Education System (GATES) that showed how satellite technology, coupled with various health, medical, training and education services, could transform the structure and effectiveness of global tele-services. It showed how innovative commercial partnerships and clever technology could make a difference. For much less than a few percent of our current spending on global armaments, we could begin to make a dent in global literacy and global health care.

Flexible Broad-band Services to the Home and Businesses

The impact of innovative wireless applications can be used to extend and leverage the information capabilities of the various NII concepts as well as the GII. The ability of multi-media systems to offer a wide range of new and attractive services such as videoconferencing, mosaic interface to the Internet, high speed e-mail, G-4 high speed fax, etc., is widely accepted The fact that wireless or satellite technology such as that proposed by Teledesic's mega-LEO system or Hughes Spaceway satellite system could accomplish such services is much less well known.

The cost of rewiring telephone networks to operate at high speeds or to re-engineer cable television systems to do the same is extremely expensive. Broad band advanced satellites of high power and low latency could provide instantaneous coverage of residential and business areas for fully interactive multi-media services at the T-1 rate. It could do this in New York City, Paris or Vienna or it could also do the same in Abijan, Addis Ababa, Suva, Fiji, or Agra, India. The financial advantages of the wireless systems for broad band services to the office or even private homes are impressive. They are potentially two to five times more cost effective than current wire and fibre-based systems. The current cost of transmission of a megabit of service on a modern satellite system is only about $.01, and in a decade it can be ten to even one hundred times less. Already the dominant cost for modern telecommunications and information services is not transmission, but rather the switching, the billing, the marketing, the operational services and overhead costs.

Asymmetrical Business Networks (Including Video on Demand)

The growth of enterprise networks and flexible business networks is the key to trends toward globalism, productivity increases, inventory control, service and maintenance responsiveness. As software defined or value added networks become widespread and computer-based telephony expands, the character of business communications will change. Reliance on interchange carriers and local telecommunications will decrease as software becomes more important than hardware. The ability of satellites to deliver broad band capacity where and when needed within large and complex networks is a unique feature which a static and hierarchical fibre network cannot deliver. A corporate network with 100 nodes represents a potential of 4,750 links, and a network of 1,000 nodes represents a staggering possibility of 499,500 links. If users of such a huge network need an e-mail connection at one moment and then later need a video link, the inflexibility of fibre networks to dynamically reallocate resources can be increasingly expensive to sustain.

Tetherless Offices and Electronic Immigrant Networks

The spread of electronic telecommuting has surpassed the expectations of many experts. An estimated 9 million people in the United States telecommute at least one to two days per week. The nearly 18 million cellular subscribers in the United States are a key part of this phenomena. Many professionals such as attorneys and accountants extend their work day some two hours via mobile communications. Today a growing number of workers in countries like India, Korea, Taiwan, Jamaica, Barbados are telecommuting to other countries such as the United States and Japan. The wireless office for so-called road warriors, traveling professionals, and mobile workers of all kinds seems an almost inevitable trend as the global economy shifts more and more from agricultural and industrial jobs to service based jobs dependent upon information and data rather than physical resources and a specific location.

Workers once chained to plants, offices, and fixed infrastructure are increasingly moving to interact with markets, to create global systems, and to extend services across a information-based planet. Many of the network needs in this tetherless society can only be met by wireless and satellite technology. Marketers of cellular telephones have launched a campaign saying: "You don't need a cellular phone, you need two." This suggests that the age of the so-called Universal Personal Telephone service which is now being developed as a standard within the ITU will reflect actual market demands in the next few years.

Digital Electronic Entertainment Systems

One of the trends of the 1990s that seems relentless is the move of entertainment services toward more interactivity and more mobility. The sales of portable CD players, Walkmans, portable televisions, and even television images inside of dark eyeglasses are steadily increasing. Electronic games, interactive data bases, the Internet, pay-per-view cable television, and more are all growing even though pay-per-view now only attracts about 10 per cent of cable television viewers. It seems clear that the desire for interactivity and mobility in entertainment will help to pace the growth of wireless services in the years ahead. Certainly the generation of DBS satellites will almost inevitably be interactive and support radio and television services to airplanes, trains, trucks, and cars.

A recent study conducted by TV New Zealand indicates that digitally compressed video (especially the new MPEG-2 standard) will allow a prodigious growth in satellite-based television distribution. This study estimates that over 500 satellite transponders will distribute some 7,000 television channels just in the Asia-Pacific region. The commercial success of the DirecTV DBS system in the United States and the even larger markets represented by the Japanese NSTAR system plus Astra, TV-Sat, BSB, and TDF in Europe suggests that satellite video entertainment will be an important worldwide phenomena in the 21st century that will rival the success of fibre-based cable television systems.

Integrated Fibre and Wireless Networks

The advantages of satellites and uniquely wireless applications as represented by the above applications are clear-cut, but nobody should seek to prove that either fibre, wireless or satellite transmission links are the singular answer to the exclusion of the others. Fibre is clearly best for high density trunk connections while satellites, HALE platforms, and terrestrial cellular towers are frequently best for mobile, rural and flexible network services. Fibre and satellites can and do work together to provide redundancy for network reliability. There are currently barriers to seamless hybrid networks. The most important of these barriers are "availability" of broad band radio frequency, transmission latency, compatible encoding, modulation, and multiplexing techniques, and cost-effectiveness of service. There are no valid technical reasons why focused R&D programmes can not systematically remove these barriers in less than a single decade.

## BROAD BAND SATELLITE TECHNOLOGY AND APPLICATIONS FOR TOMORROW

The thousand fold gains in satellite communications performance achieved in the last 30 years can be followed by another thousand fold gain within the next two decades. It will not necessarily be easy, but the steps to be taken are clear. The needed actions are as follows:

Major new frequency allocations: At least 5 GHz and preferably 10 GHz of new allocations are needed between 30 and 60 GHz.

New flexible frequency sharing for GEO, MEO, LEO, UAV and terrestrial systems: Some reasonable approach to bandwidth sharing for space and terrestrial systems is essential. Likewise a new approach to LEO, MEO and GEO sharing is also needed. This can be accomplished by a combination of band segmented allocations coupled with polarization and encoding techniques. One might start by specifying some new allocations for LEO, MEO and GEO systems.

Advanced on board processing together with on-board signaling, switching, error correction, and bit-by-bit signal regeneration: The key to this approach would be the intensive use of on board processing and signaling. This means that satellites could evolve to providing anywhere to anywhere connectivity via very small and user friendly earth terminals (i.e. USATs). One of the most promising aspects of this approach is the use of bit-by-bit processing to regenerate signals.

Emphasize the importance of new forms of hybrid space and terrestrial telecommunications systems: The advantages of well-planned and integrated hybrid systems involving satellites and fibre, but satellites and UAV platforms should also provide key potential benefits as well. Clearly fibre, UAV platforms, and satellites could each fill an important role in the deployment and implementation of the NII and the GII. It is a matter of assessing

CONCLUSIONS

In a market driven world, the end user is the start and the finish of all serious attempts to define a successful new service. To respond to today's market, a planner must know the range and mobility of the service requirements and map technologies to the end user's needs. If this is done for today's global market, one must conclude that the satellite industry must make some major adjustments. Key points that seem clear-cut guideposts to the future are as follows:

Recognize the inherent limitations of GEO systems for interactive broad band telecommunications systems.

For too long, satellites have been perceived as the technology of echo, high level storage and buffering, and unacceptable bit error rates. It has been branded as a high latency network inappropriate for voice and interactive data. Today satellites and UAV telecommunications platforms offer the prospect of very high quality networks that are faster end-to-end than fibre. It is now up to the best and brightest of the satellite designers to deliver on this potential and for GEO system operators to begin to plan a transition to low latency systems for all applications that are not tolerant of delays such as broadcasting or messaging systems.

Recognize that with the right satellite technology, the right frequency allocations and sharing techniques, and the right sense of adventure, satellites can play a strong and even pivotal role in the NII and the GII.

The early discussions of implementing a NII, as well as those related to the establishment of a NII, have largely been driven by the commercial interests of many of the prospective players. The cable television industry, the inter-exchange carriers, the local exchange carriers, the computer industry, the consumer electronics industries and even some of the content and software suppliers have all set forth their ideas. It is not surprising that each of these prospective players have advocated technologies with which they were familiar and in which they often had a commercial interest and a sunk investment cost.

Only recently has the wireless industry stepped up to be counted as part of the needed future telecommunications facilities. There are in essence only two basic models of the future. One model is the spider web which uses wire or cable to link everything together on a point-to-point basis with a tremendous number of switches to link various points together. The other model is the sunshine network where radio beams covers the landscape and anybody in the sunbeam can utilize the system. All users can thus link to anyone else whether they are at a fixed location, in a car or train, or in an airplane. The ultimate logic of a sunbeam network is that it provides the ultimate in connection flexibility. The sunshine network is a new paradigm that runs counter to conventional telecommunications system design and implies new methods of ownership, control and access to networks. The sunshine network is in fact compatible with spider webs nets in terms of terrestrial-wireless hybrid systems. (See Figure 7).

In fact, the only realistic projection for the next 20 years is indeed to see the organic growth of hybrid networks to respond to the diverse demands of business and consumer users.

Recognize that the so-called "ultimate satellite" design is nearly within our reach.

The design, development and deployment of the "ultimate" user friendly satellite should, in fact, be given the highest priority in the design and deployment of the NII and the GII. This is not only because it is a critical element of future networks, but because it also represents the weakest link in the chain of future user demand. Mobility and low latency transmission are simply too important of a requirement to ignore. The last half decade has represented a tempestuous time of change and innovation.

First the Motorola Iridium satellite design redefined the concept of satellite communications in terms of mobile services, connectivity, and low latency transmission. Next the Teledesic system exploded our imaginations with totally new ideas. These ideas included the concept that millimetre wave frequencies were a practical bandwidth for communication satellites. For the first time, a pathway to the future had been suggested wherein LEO satellites could be envisioned as cost effective means for providing fixed services and rural and remote services to the developing world without existing infrastructure. It also exposed the ideas that high powered, multi-beam antennas of small cellular size could achieve prodigious capacities. They took the original ideas of the Iridium systems for inter-satellite links and on board processing to another plateau of performance with two on board super computers packed into a shoe box. Building upon technology developed under the United States Strategic Defense Initiative (SDI or the so-called Star Wars programme), an awesome view of future satellite capabilities has begun to take shape.

The progress represented by satellites of the International Telecommunications Satellite Organization (Intelsat), those of the International Mobile Satellite Organization (Inmarsat), as well as Motorola's Iridium, Hughes' geosynchronous Spaceway satellite system, the LEO concepts of Teledesic and even of UAV telecommunications platforms, is awesome indeed. In less that 10 years a huge new leap in satellite technology and architecture has been achieved, at least conceptually. In another decade, with sustained innovation based on the technologies reviewed in this paper, awesome results are possible. It is reasonable to project that this sustained development could produce the so-called "ultimate satellite" by as early as 2005. Other parallel developments such as low-cost launchers, improvements in digital encoding and multiplexing, and UAV telecommunications platforms could carry these results much further. If resources are applied in a focused manner, the results could indeed be startling.

Recognize that real challenge in creating the GII is really not about developing the best satellite technology or even the best telecommunications transmission and switching systems but rather that the key is in developing the needed new applications, software and customer premise systems for health, education, training, telecommuting and innovative business and social services.

It is in this area where the United Nations and its member countries could and should strengthen their leadership role. It is often held that the United Nations is best at coordinating and negotiating international policies and not at operating international systems or programmes. In the case of international telecommunications and information systems, it may well be best to rely on industry, research institutes, and educational bodies to carry out key operational roles. Nevertheless, the United Nations and its members could be highly influential in effecting change and innovation.

It would be possible for the United Nations to request an entity such as the International Space University, now headquartered in France and with over 24 affiliate universities around the world, to develop a global data base of all satellite and fibre systems now in operation. Once created, this data base could be assessed by worldwide health and educational organizations to determine to what extent these systems could, perhaps at off-peak hours, be made available for low-cost tele-education, tele-health and tele-medicine services. One might also explore the creation of an on-line data base for finding out which video or multimedia-based materials might be obtained from centers such as the Tele-universite of Quebec, CREAD, the Open University of the United Kingdom, the Viso-Centers of France or the TeleKollegg in Germany.

These initiatives, which would begin to pool together existing national or regional data bases and encourage educational and health organizations to share their resources on a broader scale, could be started for a budget well under $1 million. Demonstration projects, testing programmes and short-term projects such as those developed a decade ago by Intelsat and the International Institute of Communications under Project Share could be re-initiated using the host of new satellite and cable facilities now available. As the Director of Project Share, I was fortunate to help start the Chinese National TV University which now has 3 million students receiving their education from some 90,000 earth stations. Those experiments and dozens like it were carried out with some 68 countries and many of them are now fully operational. With some leadership from the United Nations and support from satellite leaders, a seed could be sowed that could bear enormous educational fruit by the early 21st century if we were to but try.

We could see electronic tutors and remote hand-held health clinics deployed to a user clientele of over 1 billion people in developing countries. Such units, costing under $1,000 per copy, could begin to make a dent in global illiteracy and reduce or eliminate pandemics in the developing world. In the developed world it could also mean easy and low-cost access to mobile entertainment, car or briefcase-based "virtual offices, and much, much more. Such powerful new technology in space and on the ground could begin to create not only a global village but signal the start of a global brain. The key is to start through United Nations leadership the software and the new innovative applications that can start to change this six sextillion tonne mudball we call Planet Earth. It would be wonderful if, before another century has passed, that a serious start had been undertaken to conquer the problems of illiteracy, of health care, of meaningful jobs, and of economic disparity among the countries of the world. The satellite's role in the GII is only one of the jigsaw pieces, but if we start to fit them all together we can and will make a big difference. The sky is no longer the limit.

Now is the time for humanity to utilize satellites to move boldly to realize the central social, economic and cultural purposes that Arthur C. Clarke has always seen for his most brilliant brainchild. We at least owe it to him to try to realize the full potential of his invention within his lifetime.

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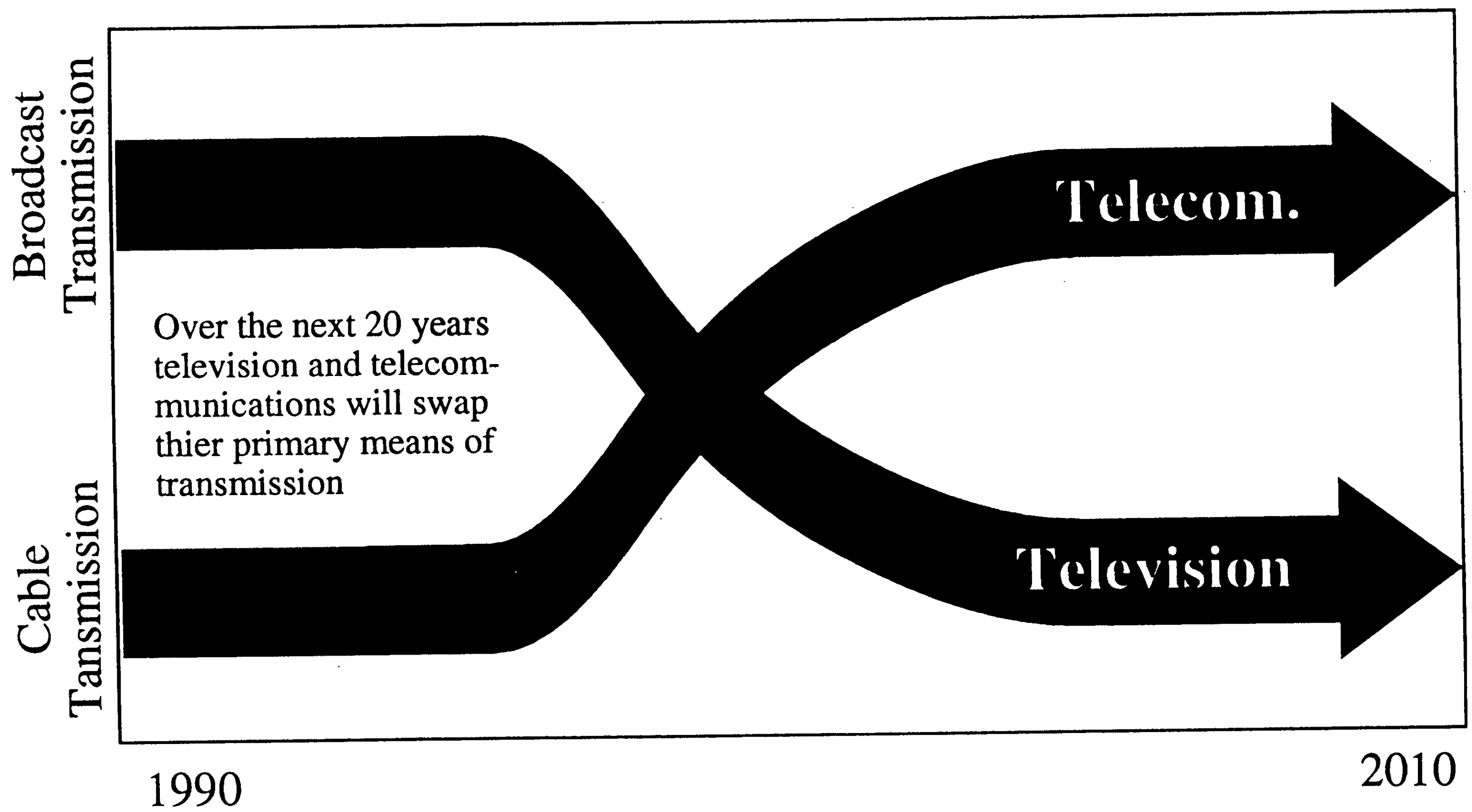
# The "Negroponte" Flip

## Trading Places



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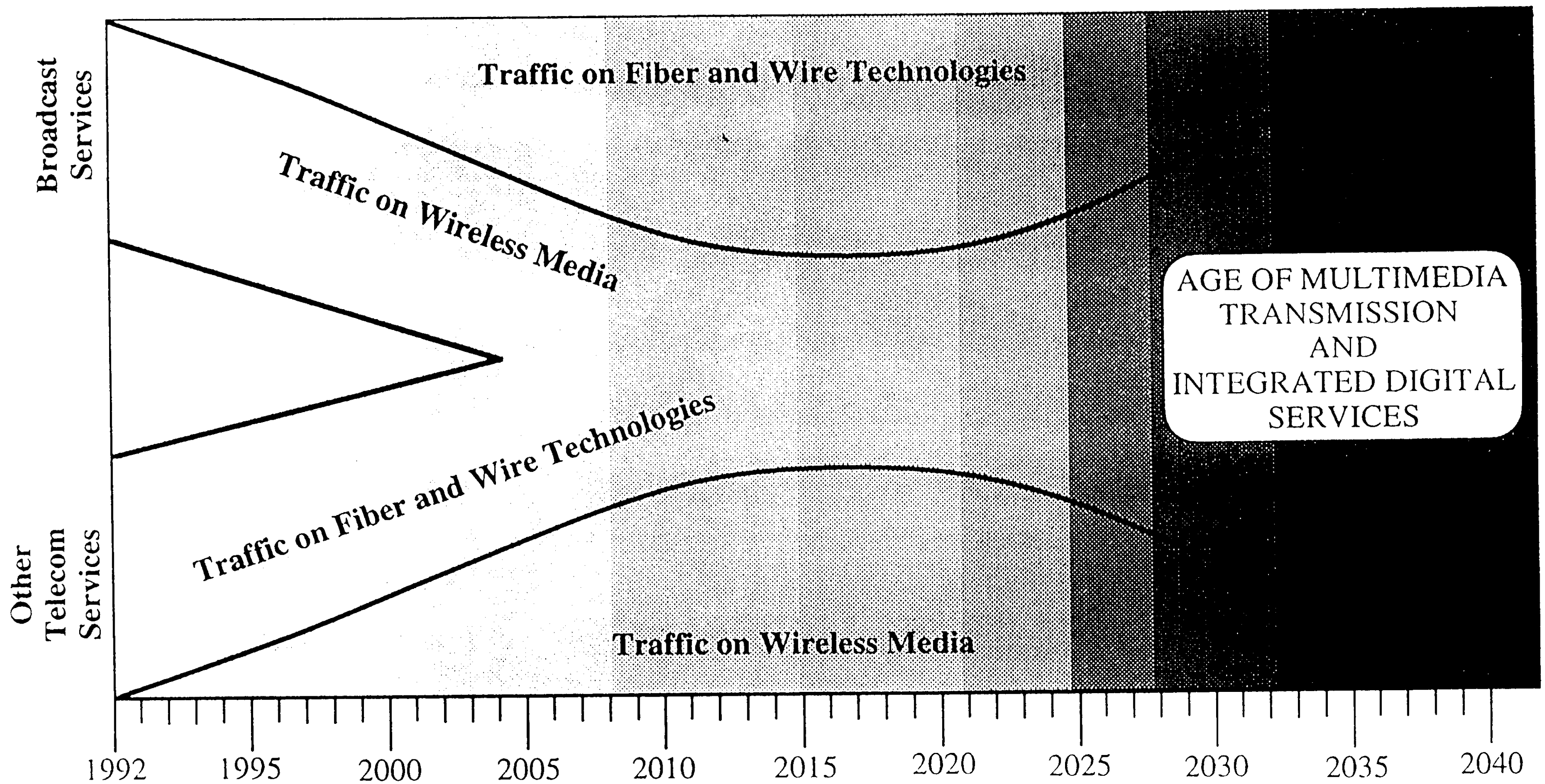

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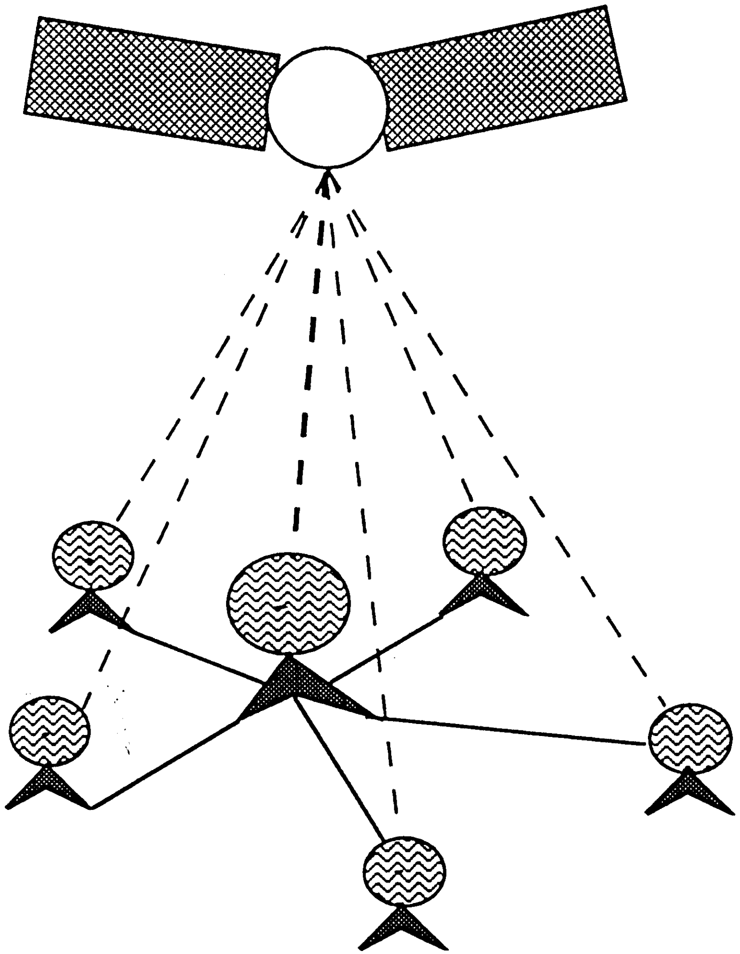

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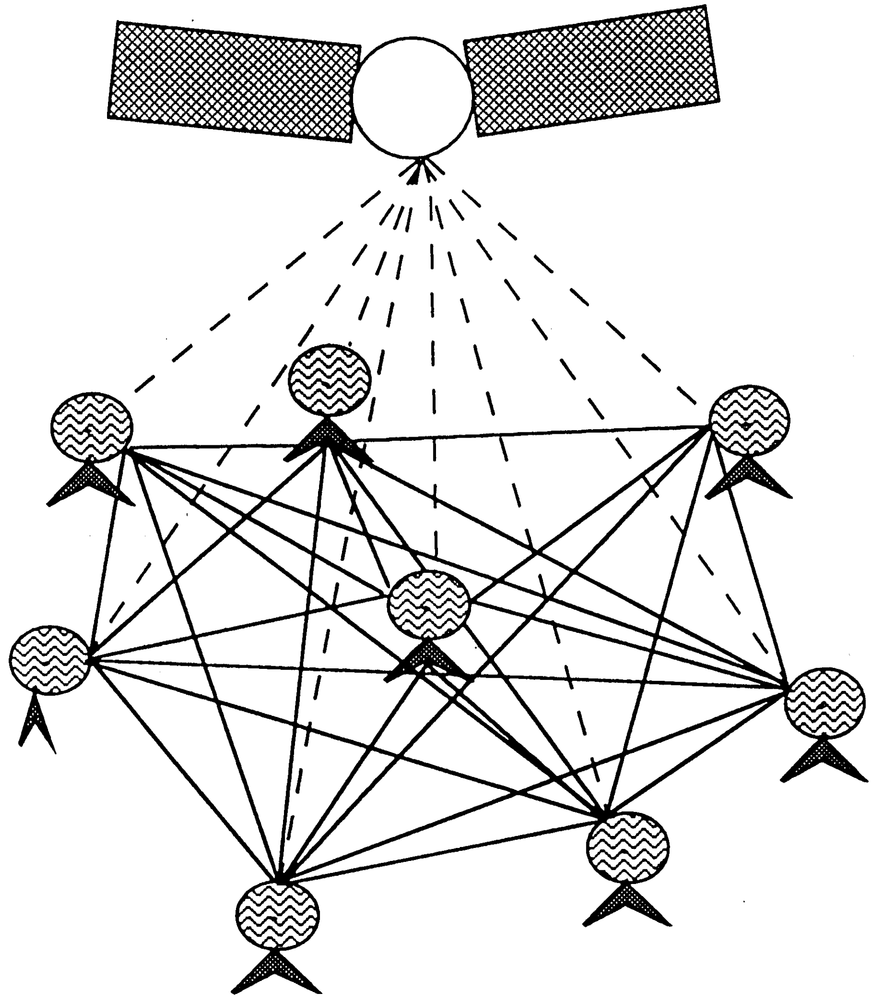

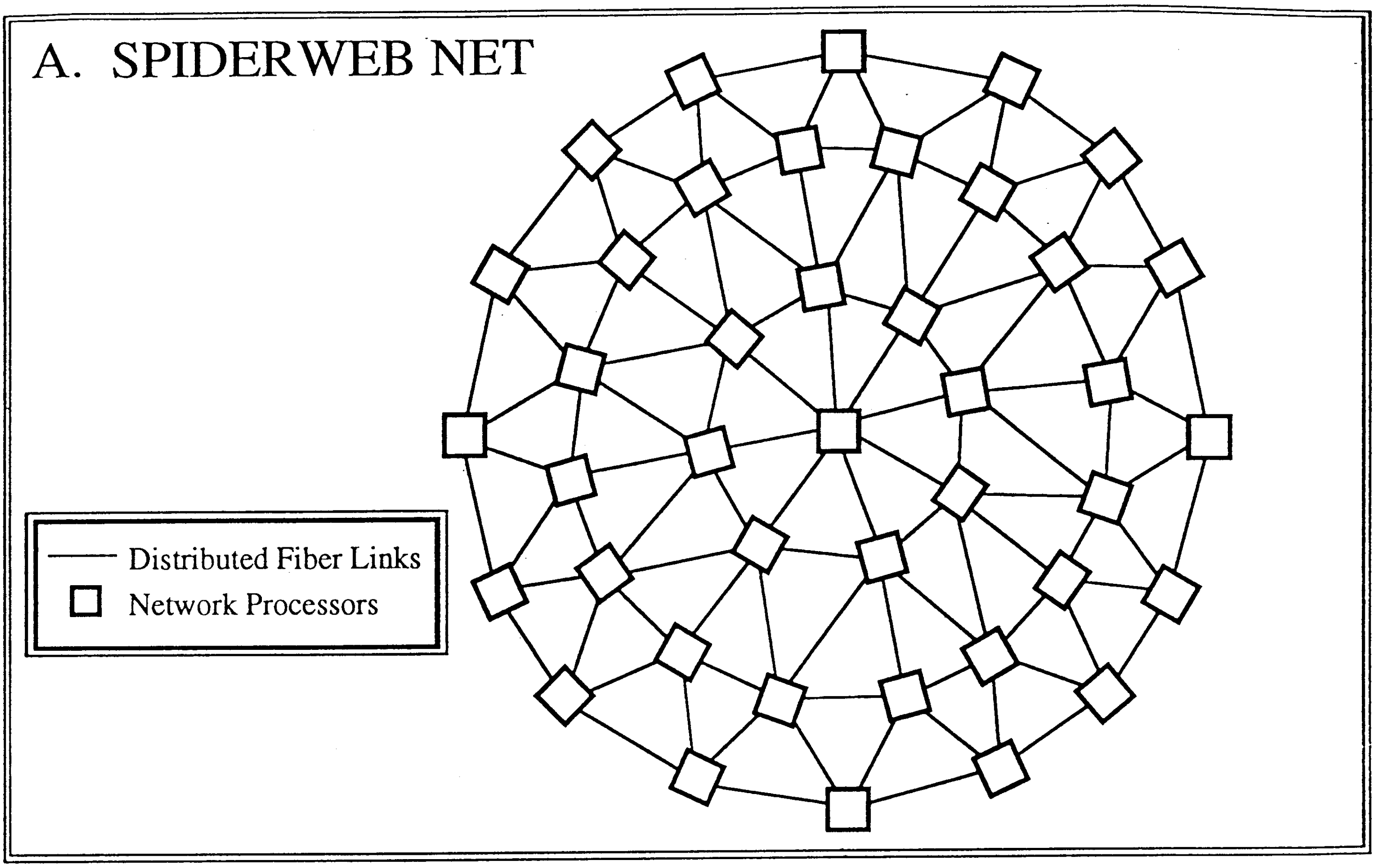
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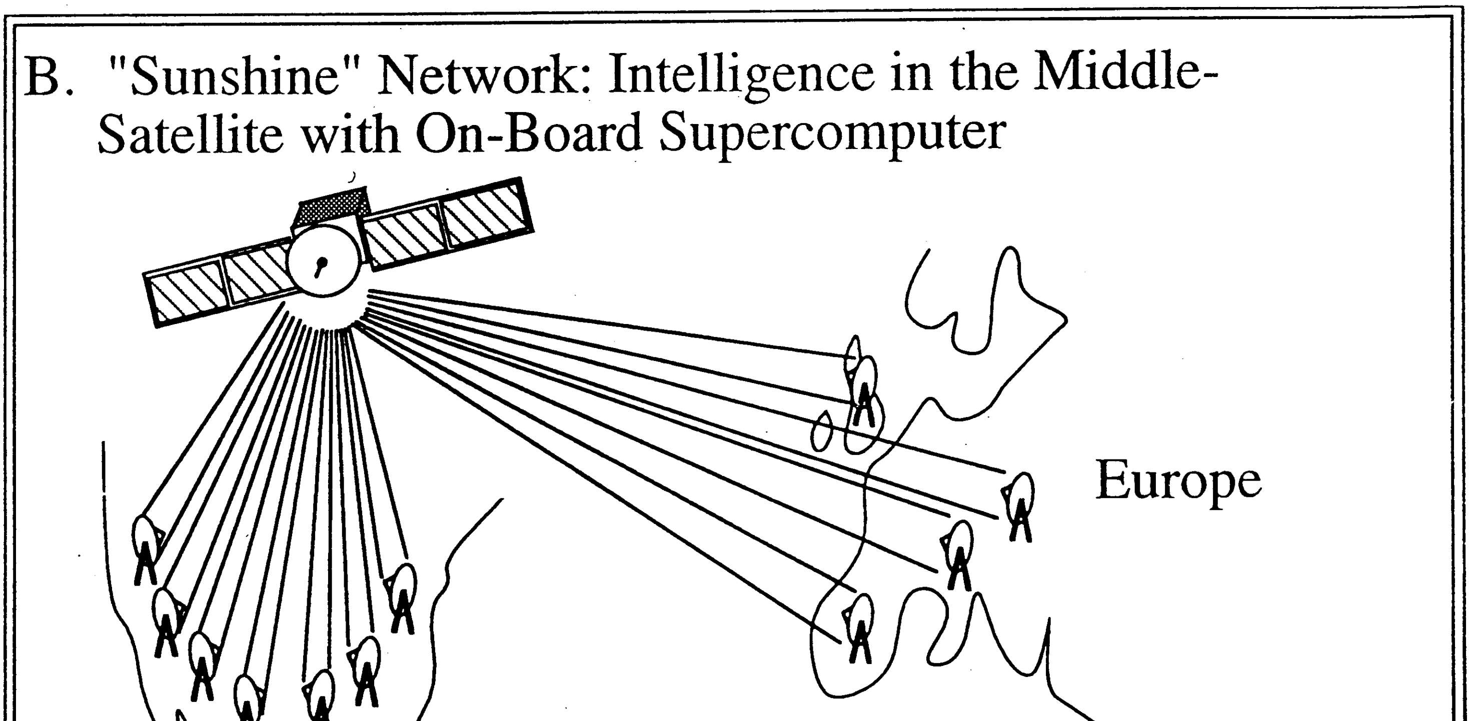
Distributed Fiber Links
Network Processors


B. "Sunshine" Network: Intelligence in the Middle-
Satellite with On-Board Supercomputer
Europe
North America
Everywhere-to-Everywhere
Connection with "Leveraged
Processing" at the Network Center

# DISASTER INFORMATION AND COMMUNICATIONS*

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## INTRODUCTION

Volunteers in Technical Assistance (VITA) and Africa have a long history of cooperation. The following is a description of VITA's Disaster Information Center and VITA's communications technologies in the context of this long relationship.

## INFORMATION SERVICES

### Inquiry Service

In 1959, when VITA was created to provide technical information and technical assistance to individuals and groups in developing countries, the first inquiries came from Africa. Inquirers in Africa still remain the principal users of VITA's Inquiry Service.1/

As questions came to VITA, volunteers met periodically and developed responses. As the number of inquiries grew, so did the list of volunteers, and so did standardized responses through more than 200 VITA publications and technical papers, and those of other organizations.2/ The number of inquiries to which VITA has responded has grown to more than 200,000. The organization now receives more than 20,000 requests for information per year.

Since 1986, VITA has broadcast a weekly show on technology over the Voice of America called "Understanding Technology." Originally broadcast in English, transcripts are made available to other language desks in VOA that translate the interviews into other languages and broadcast them later. Thus, VITA reaches many millions of people in Africa as well as in other countries through VOA.

Regardless of the type of information, it is most effective when supplemented with training. Over the years, VITA has conducted training in computerized information management in the United States, Kenya, Namibia, Zambia, and Zimbabwe for more than 300 information specialists from NGOs and government offices in 30 countries.

Two years ago VITA converted its bi-monthly magazine to an electronic-mail monthly

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called *DevelopNet News*. In addition, VITA established and monitors a conference on Internet called DEVEL-L, that provides a forum for discussion of development issues and problems.

Disaster Information Center

VITA also supplies information on natural disasters and man-made crises such as civil strife and refugee movements worldwide. In 1987, VITA received a grant from the United States Office of Foreign Disaster Assistance (OFDA) to establish and manage the Disaster Information Center.

Disaster Hotline

One of the services provided by the Disaster Information Center is a telephone "hot line." When called on by the United States government for a disaster, VITA within one day activates its telephone bank, checks its roster of volunteers, selects and trains volunteers, and begins to record offers and donations of medicine and other commodities. These offers are input to a computerized data base that is accessed directly by relief and humanitarian organizations that are already en route to the disaster site to begin to deal with casualties, and other needs of victims and survivors of the disaster.

VITA's "hotline" was activated to support disaster mitigation activities in the African countries of Somalia and Rwanda. VITA processed about 6,000 offers of assistance and commodities during these crises.

VITA's hot line has also provided information about civil strife, floods, cyclone, food shortages, earthquakes, drought and rains in Algeria, Angola, Benin, Burundi, Cameroon, Djibouti, Egypt, Ethiopia, Eritrea, Kenya, Liberia, Madagascar, Mauritius, Mozambique, Niger, Nigeria, Senegal, Southern Africa, Sudan, Tanzania, Uganda, and Zaire.

Disaster Bulletin Board

VITA has also developed its own electronic bulletin board, VITANET. VITANET is a multi-line, commercial-grade system that allows for on-line data base searching, access to training materials, computer conferences, on-line surveys, and file transfer utilities -- all of which are enormously useful during a disaster, as well as in disaster preparedness activities.

VITANET provides a stand-alone bulletin board service for private voluntary organizations and government agencies. Users are able to access up-to-the-minute information on natural disasters and emergencies including situation reports from a variety of sources including several United Nations agencies, the United States OFDA, and the International Red Cross.

The bulletin board also provides State Department Travel Advisories, a calendar of disaster related events, a worldwide key contacts data base, and a listing of commodities that are either donated or for sale for disaster relief.

The bulletin board also contains private message areas (where messages are addressed to specific individuals), and public conference areas (where messages are available to all those who have access). File areas contain topic-related reports that can be uploaded, downloaded, or read online.

VITA's mailer function allows registered bulletin board users to transfer messages and files between VITANET and similarly configured systems. The mailer can also be set up to request files from other computers. Mailers are useful for networking to another system or user community beyond the immediate bulletin board. The mailer is coordinated with the bulletin board, so that incoming and outgoing mail from either system is routed to the appropriate bulletin board users at any time.

VITANET's software interfaces will make it possible to link VITA's satellite system and packet radio networks, so that fully-automated end-to-end communications are possible. In fact, VITA is developing a "universal" station that will also interface with phone lines. The user need only input or withdraw messages, the station will automatically chose the fastest and least expensive route.

Disaster Internet Services

In September 1994, VITA installed its own direct Internet host. This enables users to search and query Internet data sources around the world, and establishes the Disaster Information Center as a gateway for partners in disaster information.

Gopher software now allows users to connect to other gopher-accessible data bases worldwide. Users can conduct key word searches and produce a listing of data sources and publications related to a particular topic. The Gopher system then allows the user to connect to these information resources around the world and view the information on screen and/or e-mail the selected documents back to their computer.

To date, the disaster ListServ now has 129 subscribers who received approximately 20,000 documents. In addition, more than 12,000 documents were picked up through the Gopher.

Field Services

In 1979, VITA began to manage agriculture, enterprise development, irrigation, renewable energy, environment, and other programmes in Africa for the United States Agency for International Development (USAID), the World Bank, the United Nations Development Programme (UNDP), and other donor agencies. In recent years, VITA has managed programmes in Burkina Paso, Kenya, Liberia, Mali, Somalia, Sudan, and Zambia. These projects have preserved resources, saved money, and led to thousands of new jobs and increased wealth for individuals in the countries in which they operated.

VITA is currently managing enterprise development projects in Benin, Chad, Central

African Republic, and Guinea. VITA also manages an environmental project in Madagascar.

COMMUNICATIONS SERVICES

VITA's work in developing countries many years ago identified that one of the major needs for development is reliable communications, and that the principal global telecommunications entities had little interest in providing service in most of the developing world. Africa still hasn't achieved the goal of 1 phone line per 100 residents. And, what phone lines there are can usually be found in the principal cities in government and corporate offices. Most of Africa's people are still more than one mile away from the closest phone.

In 1983, VITA determined to do something about the lack of communications infrastructure in developing countries by beginning to experiment with low Earth orbiting (LEO) satellites and terrestrial digital radio networks -- essentially the same technology.

VITA's communications programme is called VITACOMM and includes LEO satellites (VITASAT), terrestrial digital radio networks (VITAPAC) and electronic mail (VITANET). The following is a brief history of VITACOMM, focusing primarily on the difference phases of VITASAT's development.

VITASAT - Digital Communications Experiment

At the invitation of the University of Surrey (Guilford, England), and with the help of volunteers from the Amateur Radio Satellite Corporation (AMSAT) and VITA, VITA designed the Digital Communications Experiment (DCE). This payload was integrated into UoSat-2 that was launched in March 1984. It was used by amateur radio operators and universities in nine countries (including South Africa) to "prove the concept." This was the world's first use of a "store and forward" LEO satellite for civilian purposes.

VITAPAC - Terrestrial Packet Radio

One year later, VITA's first demonstration of terrestrial digital radio communications was requested by CARE in their response to the Ethiopian famine. VITAPAC permits real time data communications, and doesn't require the use of a satellite. As a matter of fact, when the data has moved from one computer to another, one can switch back to voice radio to discuss the message transferred.

VITA has installed packet radio networks in Chad, Madagascar, Sierra Leone, and Sudan.

VITASAT - PACSAT Communications Experiment

In 1988, VITA commissioned the University of Surrey to design a prototype payload to be integrated into the Uosat-3 satellite they were constructing. This payload, called the PACSAT Communications Experiment (PCE), was the prototype VITASAT satellite.

UoSat-3 was launched in January 1990 by Arianespace from French Guiana. Unlike the Digital Communications Experiment, the PCE could not be used by amateur radio operators; users required experimental licenses.

While VITA secured its own experimental license in the U.S. in 1988, securing experimental licenses in other countries was not an easy task for users. Since there were still no regulations anywhere in the world for licensing little LEO systems, this is somewhat understandable, and since the technology is still virtually unknown, each country of interest had its own methods for dealing with experimental license requests.

During the next several years, users secured licenses for 22 earth stations in 13 countries. In Africa, VITA installed earth stations in Djibouti, Ghana, Kenya, Sierra Leone, Somalia, and Tanzania (2).

While these stations were used to support disaster relief, child development, education, scientific, and health projects through e-mail type messages averaging 2-5 pages (some messages are longer than 50 pages), stations were also used for remote monitoring and control of mechanical systems (e.g. hybrid renewable energy power stations on two remote Indonesian islands).

Pioneer's Preference Award

Following the international allocation of spectrum for LEO satellites at the March 1992 World Administrative Radio Conference, in January 1993, the United States Federal Communications Commission (FCC) announced the allocation of 4 Mhz of VHF/UHF spectrum in the United States for little LEO systems. At the same time, it also finalized the pioneer's preference to VITA that it had first announced tentatively in January 1992. The award to VITA is the first pioneer's preference granted by the Commission.3/

Specifically, the Commission: a) allocated the 137-137.025, 137.175-137.825, and 400.15-401 Mhz bands on a primary basis for the space to Earth direction; b) allocated the 137.025-137.175 and 137.825-138 Mhz bands on a secondary basis in the space to Earth direction: c) allocated the 148-150.05 and 399.9-400.05 Mhz bands on a primary basis for the Earth to space direction; and, d) adopted specific conditions for using these bands calculated to avoid interference with existing users (government).

In granting a pioneer's preference to VITA, the Commission noted that VITA was the first to develop and demonstrate the utility of a small LEO system using VHF frequencies for civilian communications purposes. The Commission noted also that VITA, along with the Radio Amateur Satellite Corporation, designed and constructed a satellite radio package incorporating prototype technology that was launched in March 1984 aboard a scientific satellite. Thus, "the Commission believes that VITA's pioneering efforts led to this proceeding authorizing spectrum for LEOs to provide services that will provide reliable, low-cost data communications between ground stations located anywhere in the world."

Training in Digital Radio Communications

Under the auspices of the United States Telecommunications Training Institute, VITA has conducted week-long courses for the past five years. By the end of 1994, almost 100 students from nearly 30 countries, including students from 17 Africa countries had participated.4/ Students from Burundi, Zambia, and Uganda are included in the course being taught May 29 - June 2, 1995 at VITA offices.

One of VITA's goals in teaching these courses is to form a network of trained digital radio volunteers around the world, to facilitate the use of digital radio communications in remote areas of the world.

VITASAT-A/GEMstar-l

In early 1994, VITA concluded that it needed a commercial partner to pursue its mission to bring communications to developing countries. After discussions with several satellite manufacturers, VITA selected CTA Incorporated as its commercial partner.

In exchange for building the satellite, arranging for its launch, managing it in space, designing a global electronic-mail system, designing new ground stations, and writing software connecting all the above systems, VITA is permitting CTA to use its (VITA's) license for commercial purposes, thus enabling CTA to test a market several years before it could have done so on its own. This unique partnership makes it possible for VITA to continue to help improve communications infrastructure in developing countries.

The new satellite will be launched on June 7, 1995 on a Lockheed rocket from Vandenberg Air Force base. The new VITASAT satellite is also the first GEMstar satellite in CTA's proposed GEMnet system. While VITA continues its primary interest in e-mail communications, CTA plans to use the system for data acquisition, primarily for tracking cargo and/or reading utility meters in the United States.

VITASAT-A has 16 megabytes of message storage memory, and will transmit data at 9.6 kbps within the 148-150.05 Mhz band. It will receive data within the 400.15-401 Mhz band at 19.2 kbps. Data will be compressed.

The satellite orbits the Earth every 98 minutes (14 passes each day), and will pass over every spot on Earth at least four times each day. The new VITASAT system is designed to transfer data within 90 minutes through strategically located Internet Gateways.

Internet Gateways

When VITA initiated its LEO experiments in 1983, THE Internet was not publicly available, and other electronic-mail systems were only just getting off the drawing board. However, since then, the Internet has become available to the general public, and its user list increases by thousands of persons daily. Additionally, other electronic mail systems (e.g. MCImail) are also increasingly popular. Nevertheless, there is still very limited access to these Internet and other electronic mail networks in most of the developing world. The initial Gateways will be Internet gateways.

VITA is establishing Internet Gateways at specific locations that are as close to the north and south poles as possible. These sites were chosen because of current Internet connectivity, and staff experience with network operations. Initial Internet Gateways will be installed in Norway, South Africa, Australia, and Chile.

VITA's objective for the completed Gateway network is to enable the satellite to send/receive data from a Gateway every 30 minutes (approximately). In the initial Gateway network this time will be longer, more on the order of 100 minutes. Delivery to the recipient will be determined by the speed of the specific mail delivery service once the message is received from the Internet Gateway.

Another important feature of the Gateways is their ability to also perform Telemetry, Tracking and Control (TT&C) functions in support of the primary TT&C station in Blacksburg, Virginia, United States. This means that the Gateways can also control the satellite in space if required.

Additional Gateways will be installed in specific geographic areas or those with particularly high usage. For example, a Gateway will be located at Trinity College in Dublin to support TRINET, a network of universities that will facilitate research data exchange between developed and developing countries.

Messages are stored in the satellite until it passes over a Gateway. As the satellite appears over the horizon, the Gateway commands the satellite to downlink the collected messages. Next, it will uplink messages destined for remote users. When all the transactions have been completed, the Gateway then permits access to other users. Downlinked messages received at the Gateway are routed to their destinations via Internet (or other e-mail networks).

The VITASAT Internet Gateways will be located in the following countries:

- South Africa: The University of Cape Town's Electrical Engineering Department will be the site of the African Internet Gateway. This facility already provides spacecraft command facilities for other satellites, in addition to serving as the Internet hub for all the universities in South Africa.

- Norway: The Norwegian Space Center (NSC), Andoya, Norway is located above the Arctic Circle, where almost every pass of the VITASAT satellite will be accessible. The NSC also operates a large Internet facility as its contribution to the European Space Agency's satellite and rocket tracking network.

- Chile: The initial South American Gateway will be located at the Center for Space Studies at the University of Chile in Santiago. This facility has an active program of tracking NASA and ESA satellites.

- Australia: This Gateway is being proposed for the University of Tasmania in Hobart. This location is ideally suited to handle traffic for the Asia region.

Mail originating at electronic networks will go to a Network Operations Center, which will then forward the message to the Gateway station located closest to the remotely located recipient.

## DISASTER COMMUNICATIONS

It's obvious that communications are even more critical when a disaster strikes. But, what if a disaster occurs in an area where communications aren't available? Rural development organizations and relief agencies working in isolated areas are greatly handicapped because of Africa's general lack of a low-cost communications infrastructure.

During the first 72 hours, real-time communications, if they are available, are preferred because of the obvious needs to quickly identify the nature and scope of the disaster, the location and condition of victims, and to open channels to the rest of the world for help.

After preliminary needs are met, real-time communications are required only on a diminishing basis. Store and forward communications through VITASAT and Internet Gateways are usually adequate, and far less expensive. A special version of the new earth station will be available soon that also includes an antenna and a laptop computer in a suitcase sized container that makes it possible to easily set up stations at the site of disasters.

In addition to its value in disaster preparation and mitigation, VITASAT can also be used for remote sensing for drought, famine, epidemic, floods, earthquakes, storms and other disaster situations.

## NOTES

1. In the past five years, 62 per cent of the all inquiries received by VITA have come from African countries. In previous years, more than 75 per cent of inquiries came from African countries.

2. These documents will soon be available on CD-ROM. They will also be available in ASCII format so they can be e-mailed to information centres that may want to supplement their

libraries of used them to start an information centre. VITA has a working relationship with more than 50 African information centres.

3. This is the only pioneers preference awarded by the FCC to a LEO system. The applicants for licenses in the United States by the "big"(above 1 GHz) and "little" (below 1 GHz) LEO systems number eight; all but VITA are commercial companies.

4. Cameroon, Djibouti, Egypt, Ethiopia, Gambia, Ghana, Guinea, Lesotho, Mozambique, Nigeria, Senegal, Sierra Leone, Somalia, South Africa, Tanzania, Uganda and Zambia.

# SATELLITE COMMUNICATIONS STRATEGY FOR NATURAL DISASTER SITUATIONS*

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## INTRODUCTION

By their nature, disasters are difficult to tackle in a planned manner. They vary in severity, they can occur anywhere on Earth and they can last from a few minutes to several years. They are a problem to which there is no definitive solution. Nevertheless, a collection of measures can be put in place in order to prepare for such events as far as possible in advance, reduce their negative consequences in terms of property loss and human casualties and mitigate other post-disaster effects. Much progress has been made in all these areas by specialist agencies such as the United Nations Disaster Relief Organisation and the various international bodies involved with space activities whose mandate is not primarily in the area of natural disasters but who nevertheless are active in the field. As a result, there are many initiatives which at first sight appear confused and overlapping with each other, but collectively provide a powerful information gathering capability from the world community. One important theme in all of these activities is that of communications. Fast and accurate information exchange is an essential prerequisite for action.

## PRESENTLY AVAILABLE SYSTEMS

There are a wide range of systems currently available which potentially can be of immense assistance in disaster prevention, preparedness, relief and reconstruction. A few examples are given below to illustrate the range of information and assistance available.

The observation of the Earth by satellites such as the European Space Agency's (ESA) ERS satellites, provides a wide range of information which can be applied to the assessment of conditions which may lead to natural disasters or which can monitor the situation during or after such an event. This has been, and continues to be of enormous assistance in predicting and monitoring, in particular, drought conditions, locust infestation, fire damage and flooding, all of which can be observed from space. The satellites provide the basic information which, taken together with other data, enables coordination, decision and subsequent action to be undertaken.

Processing and calibrating the data forms an important part of the overall operation. This is carried out in Earth observation centres throughout the world. The end objective is to produce information which is specific to particular applications and which can be used by those concerned with disaster relief. The means to do this has become a major factor in the field of Earth

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* This paper, which was presented at the United Nations/ESA Workshop on "Application of Space Techniques to Prevent and Combat Disasters," held in Harare, Zimbabwe, 22-26 May 1995, does not necessarily reflect the views of the United Nations.

observation because the capability of the satellites to collect information consistently, tends to outstrip the effectiveness of the processing and distribution services.

Meteorological satellites such as ESA's Meteosat series, are also an important source of data which can fore-warn of natural disasters and potentially help to save lives and property. Collecting and interpreting the data is much faster and less complex than is the case for the true Earth observation satellites. Most meteorological satellites are designed to enable small and inexpensive earth stations to receive data directly from the satellite and to process it locally. The results can, therefore, be directly applied for example, in tracking the course of hurricanes. This more direct approach is possible because the data rate is relatively low. Nevertheless, because of the investment in processing equipment and the concentration of forecasting skills necessary, the interpretation of weather data still tends to be done centrally and the results distributed as products to the users.

The COSPAS-SARSAT system provides distress alert and location information to central mission control centres in many countries. It is primarily focused towards marine applications and cooperates closely with the International Maritime Organisation. Nevertheless, it is used increasingly to report ground emergencies. The system relies on two constellations of low altitude (850 km) satellites, one provided by the United States, the other by Russia which are able to relay distress messages at frequencies of 121.5 MHz and 406 MHz to the control centres. Several commercial companies market distress beacons which can be used with the system. These are commonly carried by yachtsmen, climbers, explorers and others who may be at risk. A typical distress beacon is shown in figure 1.

Similarly, the INMARSAT Global Maritime Distress and Safety System (GMDSS) is a powerful communications means to enable distress situations to be reported. Again this is primarily focused on maritime situations but can also be used on land. The distress beacons for this system are readily available from several manufacturers. The system operates at 1.6 Ghz to existing geostationary satellites and has wide coverage. Of course, as with many other organizations working in the field of disasters and rescue, INMARSAT operates the GMDSS or E-system as a marginal activity compared to their main business which is mobile satellite communications.

The GMDSS tends to overlap the COSPAR-SARSAT system in some respects. Both systems have advantages and disadvantages depending on the user's requirements and the funds available. For example, the GMDSS offers instant access but because of the use of geostationary satellites, the coverage is not completely global. On the other hand, the COSPAR-SARSAT system can lead to delays in reporting an event due to the finite time to access a low altitude satellite, but has global coverage and tends to need smaller and less expensive beacon equipment.

## THE LOCAL SITUATION

The above outline illustrates some of the information sources available, but how can this help those who are directly involved in a disaster situation? In general, a vast amount of data is available, but distributing the information needed locally still seems to be a problem.

Local people need to be made aware of the situation and local relief agencies such as fire or ambulance services need to be alerted. If help is being organised by international relief agencies, this should also be made known to the population at large. If people are required to take action such as moving from a dangerous area, these messages need to be passed on to the local inhabitants of the area affected.

There are various methods to broadcast information to the area covered. It is possible, for example, to receive information directly from a satellite or for messages to be passed via cellular networks. However, the equipment to receive such information is normally only available to relatively prosperous sections of the community and as a result the coverage would be somewhat uneven.

The most commonly available receiving equipment world wide, is the transistor radio. The United Nations has estimated that there are over two billion radios in use, with nearly half of those being in the developing countries. A system which could address a large proportion of these radios would seem to have the best chance of achieving a high penetration.

Broadcasting directly to these receivers must be done by terrestrial means. This can most conveniently and economically be achieved by use of the FM/VHF bands of frequencies (88-105 MHz), for which most transistor radios are already equipped. The use of lower frequencies would require large and expensive transmitting installations. The use of higher frequencies would preclude reception by most radios.

Distribution of the signal to the area concerned is most conveniently carried out by satellite. Existing satellite capacity is available, which can be directly leased for this purpose. Intelsat C-Band satellites, for example, provide very wide coverage. Indeed, near global coverage can be achieved by using a small amount of transponder capacity in each of the Atlantic, Indian and Pacific ocean regions. The Indian ocean coverage is illustrated in figure 2.

## TYPICAL IMPLEMENTATION

The receiving equipment for the satellite signal can be a relatively simple receive-only earth station, having an antenna diameter of 2.4 metres and capable of receiving 64 kbit/second data into which the sound transmission is encoded. Such a system is already in use for the World Meteorological Organization and can easily be extended for disaster applications.

Recent advances in the design of compact FM radio transmitters and associated antennas have opened up the possibility of designing portable transmitting stations, having sufficient range to cover a small town but requiring relatively little primary power.

By combining these two types of equipment, the receive-only satellite terminal and the portable VHF/FM transmitter, it is possible to access, via satellite, the information available in major centres and to distribute it to those who need it. The information received can be disseminated directly to the local population or directed to the local emergency services as appropriate.

Thus, small receive-only earth stations coupled with low power VHF transmitters can be an effective disaster relief tool. These receiver/transmitter combinations will be self contained standard factory produced items, thereby keeping the cost to a minimum. They can be deployed by air or by land vehicle in response to an emergency. Alternatively, local communities may decide to invest in them in advance as a precaution against possible future disaster situations. Each receive/transmitter combination has a coverage of 40 km in diameter over flat terrain. They can be used in a modular fashion in a similar way to mobile communications cells if a large area has to be covered. This requires five radio frequencies to be allocated to avoid multi path effects, giving a total spectrum requirement in the VHF frequency band of about 1 MHz. The general concept is illustrated in figure 3.

## SUMMARY OF FEATURES

Some features of the satellite/VHF system discussed are as follows:

- The RX/TX units are readily deployed to respond to a disaster situation;
- Existing satellite capacity can provide near global coverage at low cost;
- All the technology is established and no new satellite systems have to be built;
- Emergency messages can be directly broadcast;
- Coded sections of the incoming data stream can be routed to emergency services without being broadcast;
- Local information can be inserted in the broadcast;
- Large local communities can be served by bringing in additional standard transportable units to respond to a particular disaster situation;
- Having several units of similar design within a general area will provide soft fail redundancy in the case of damage due to equipment failure or disaster situations;
- The provision of such units will be at the discretion of local communities according to their needs and financial status. They need not be an externally imposed or funded solution and they will serve the whole community; and
- The transmitters can be upgraded to broadcast digital radio signals when appropriate receivers become available.

## CONCLUSION

Existing and planned satellite related disaster recognition and response systems have shown an impressive worldwide capability to assemble and interpret data from potential and actual disaster situations. One particular method of getting the results of this capability to a local area to help those who are victims or at risk has been discussed. It brings together existing technologies in a manner which is capable of providing accurate and reliable information to the affected areas. As technology in the broadcasting field advances, this system can be upgraded to take account of, e.g. digital audio broadcasting technology but only at a pace set by the user's receiving equipment. Entertainment services need high quality (wide bandwidth), daring new systems to stimulate and satisfy market demand. Basic information services require flexibility, high reliability and high penetration to properly serve the needs of the users. The approach outlined here attempts to meet these requirements.

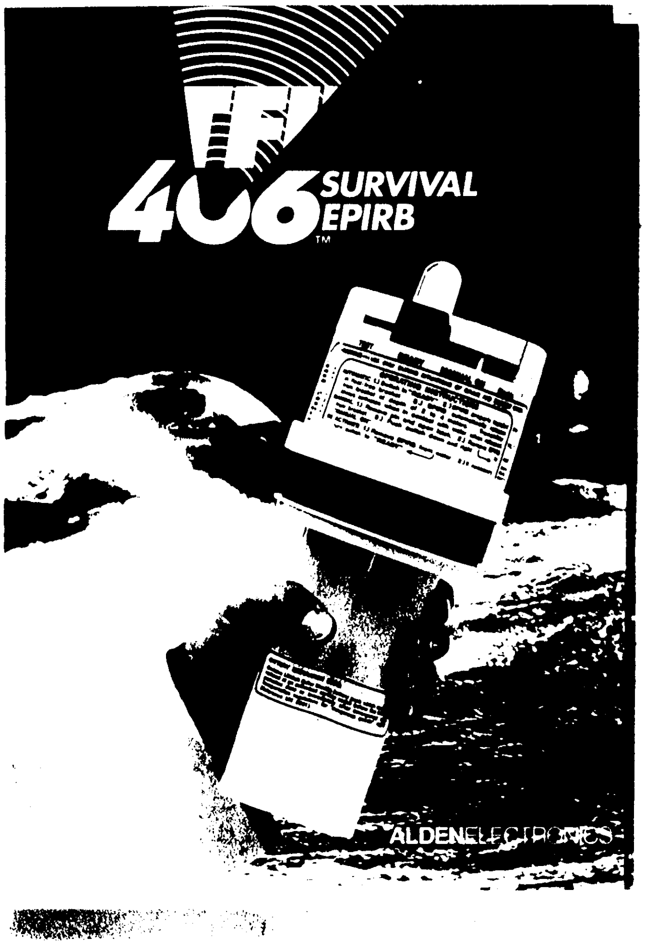


Fig. 1 : Typical Distress Beacon as used in the COSPAS-SARSAT System

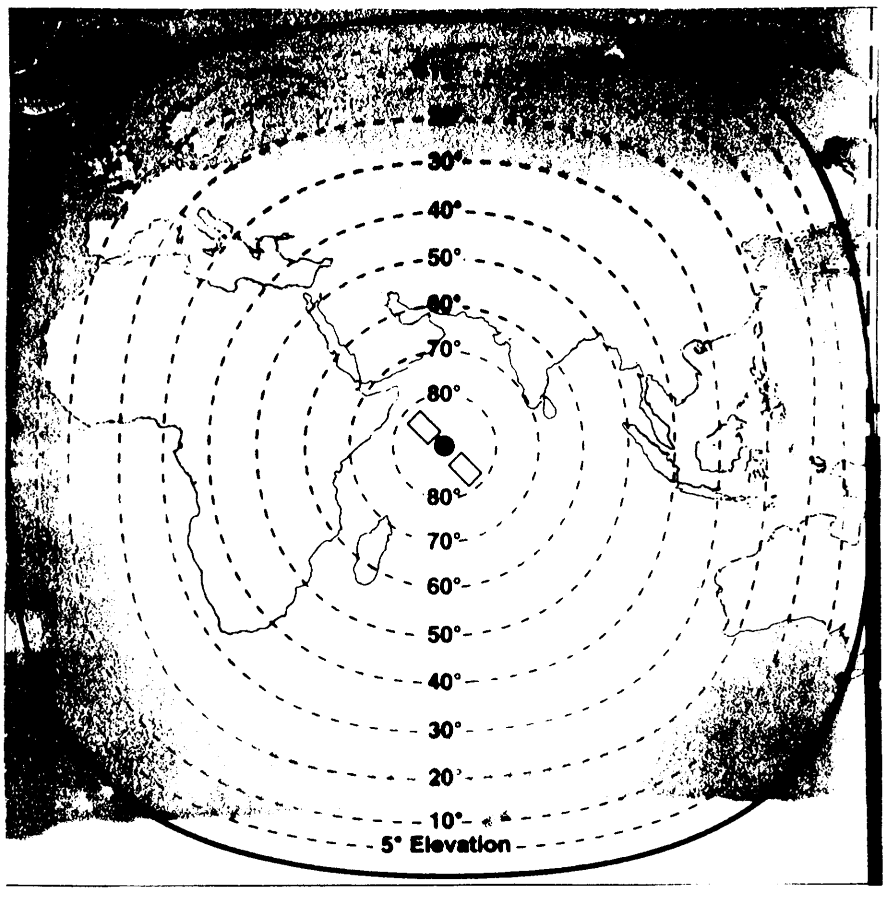


Fig. 2 : Typical coverage of an INTELSAT Indian Ocean Satellite

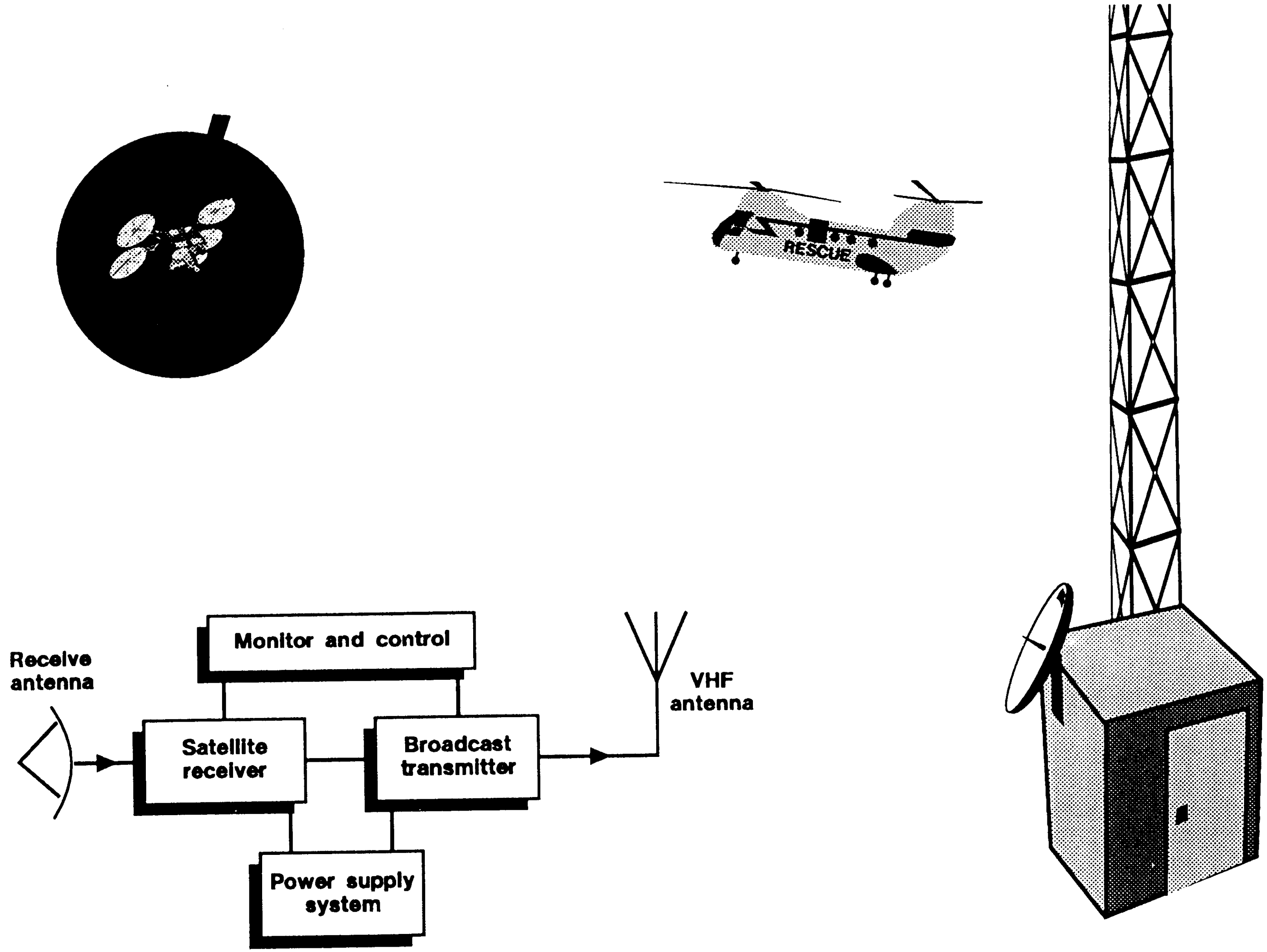


Figure 3: GENERAL CONCEPT

# SATELLITE TECHNOLOGY IN HEALTH CARE: AN UNDERDEVELOPED RESOURCE*

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Information exchange between patients and health care professionals is the base on which diagnosis and patient management rests. Face-to-face interaction is the traditional way in which communication takes place. Since the discovery of the telephone and later the wireless radio, these technologies have been used extensively in interactions between health professionals. In the past three decades, distance communication in medical care has been called telemedicine. As early as 1921, however, attempts were made to transmit medical data at a distance. A report in "Scientific American" by Winters referred to a new technology that could transmit cardiac data from ships at sea to a physician for diagnosis. Ground-based telemedicine systems were used in Nebraska in 1958 and in 1968, Bird in Boston described a successful telemedicine system which linked Boston City Hospital with Logan Airport. In 1967, the delivery of continuing medical education and medical consultation by satellite television was being tested in London, Ontario, Canada, and at Memorial University in Newfoundland, Canada.

The provision of health services to non-urban and isolated areas has always been a challenge. This is particularly true in the far north and south and in continental areas and island countries. Terrestrial-based telemedicine systems have been used to a limited extent worldwide, particularly in North America, but these networks cannot reach many needy areas. These areas can only be adequately serviced by satellite systems.

Satellite telemedicine research was a part of the overall planning for the Russian and United States space exploration programmes. The United States lunar mission was a major stimulus in that country and many telemedicine research projects followed. While these projects were successful, they were often technology driven and used expensive systems with the result that there were very few ongoing telemedicine services following the initial demonstrations. With one or two notable exceptions, there was a lull in telemedicine development during the 1980s. A brief review of the history of telemedicine will show that the slow progress internationally has not been due to the lack of technical solutions but rather to other factors. In 1983, Arthur C. Clarke told a United Nations meeting: "We have reached the stage when virtually anything we want to do in the field of telecommunications is possible. The constraints are no longer technical but economic, legal or political."

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* This paper, which was presented at the United Nations/IAF Workshop on "Space Tecnology for Health Care and Environmental Monitoring in the Developing World," held at Oslo, Norway, 28 September to 1 October 1995, does not necessarily reflect the views of the United Nations.

This statement is true today with the same factors slowing the widespread development of telemedicine systems. There are, however, some encouraging signs. With the digitization of telephone networks and the ever increasing power of computer chips, telemedicine systems are becoming more cost effective. Secondly, because of recent financial constraints in the health industry worldwide, alternative methods of delivering health care have been sought. Health information and telemedicine systems are viewed as a partial solution to health delivery problems.

Spurred by space developments and the need to evaluate distance health care systems, the United States satellites ATS-1, ATS-3 and ATS-6 were used for telemedicine research in the late 1960s and early 1970s. In 1977, the Canadian Communications Technology Satellite (CTS), called Hermes, was used for a number of important health experiments. Memorial University used Hermes to deliver distance education by one-way television and two-way voice to remote areas, and also successfully demonstrated medical data transmissions and consultations. There were a number of successful demonstration projects on Hermes and other satellites in the United States. Unfortunately, very few projects went on to a service mode. Usually this was because funding could not be found for continuing service applications.

At Memorial University, where in subsequent projects the emphasis was placed on less expensive narrow band systems, there was a continuation of research with the transfer of technology in a number of instances to the health industry after successful demonstrations. The Telemedicine Centre at Memorial has been in continuous operation for two decades.

In 1982, using Canada's Anik-B Satellite, Memorial University conducted a successful demonstration of the capacity of a telephony circuit to support health care on an oil rig, 250 km offshore on the Grand Banks. Slow scan television (SSTV) was used to transmit pictures of lacerations and other injuries and infections, and electrocardiograms and X-ray images were also transmitted.

As part of its 20th anniversary celebrations in 1985, the International Telecommunications Satellite Organization (Intelsat) established the Satellites in Health and Rural Education (SHARE) project. Under SHARE, Memorial University was given a dedicated 4-wire satellite telephony link between Canada and East Africa (Kenya and Uganda) for one year and between Canada and the West Indies for six months. Memorial's Telemedicine Centre, with the collaboration of Teleglobe Canada, Post and Telegraph of Kenya and Uganda and the support of hospitals in Eastern Canada, used the network for education, medical data transmission and administrative applications. More than 100 electroencephalograms were transmitted from Africa to the EEG Department in the Health Sciences Centre in St. John's. All participants in the project were unanimous in the opinion that this was an excellent system with which to improve health communications between the developed and the developing world. Unfortunately, the project could not secure funding after the initial 12 month experiment period. It was impossible to find approximately $100,000 for the annual line charges. There was great disappointment among our very satisfied and active participants in Africa when the project was terminated. This was further aggravated by the fact that all participants in the project were aware that there were available satellite systems with under-utilized capacity. Our experience is a lesson to any group anticipating a demonstration project with the developing world.

Our experience with the University of the West Indies, subsequent to the SHARE Project, was different in that, together, we were able to raise funds for a follow-up project and there has been a continuing relationship with Memorial.

In 1986, SatelLife, a non-profit international organization, based in Boston, Massachusetts, United States, was seeking a technical system that would provide improved health communications between the developed and the developing world. SatelLife chose to explore the use of low Earth orbit (LEO) satellite technology and established its HealthNet Project. LEO satellite technology was conceived more than two decades ago but was slow to be developed. At a workshop in Ottawa, Canada in 1981, the International Development Research Centre (IDRC) produced a seminal position paper, edited by Balson, et. al., which set out in some detail what they called "computer-based conferencing systems for developing countries." The authors concluded that: "we expect that in the next decade the use of computer-based telecommunications will become a major vehicle for domestic and international scientific and technical information exchange." They further said that, "unless the developing nations can participate in this electronic community of science and technology they will suffer from a disenfranchisement of a serious nature." The authors then went on to make a number of recommendations which in their view would, by the early 1990s, lead to what we would now describe as access in developing countries to the worldwide Internet and other networks.

It is not surprising that the IDRC was an early supporter of the work of SatelLife in developing its HealthNet Project. This also included support for Memorial University's participation in the HealthNet endeavour.

The first LEO satellite used by SatelLife for its HealthNet project was UoSat-3 which had been built by Surrey Satellite of the University of Surrey in the United Kingdom. An American non-profit agency, Volunteers in Technology Assistance, (VITA) based in Washington, D.C., contributed to the funding and for a time UoSat-2 was called VITASat. When bought by SatelLife it was renamed HealthSat-1. From 1988 to 1993, ground station licenses were obtained for 12 African countries and several other licenses for countries worldwide. The first ground station license in Canada was obtained by Memorial University.

When UoSat-3 was sold and the more powerful HealthSat-2 was purchased by SatelLife in 1993, there were fewer ground stations in use. At present, only six of the UoSat-3 terminals have been converted for use with HealthSat-2. There are functioning HealthSat-2 terminals in Ghana, Eritrea and the Sudan. During September 1995, approximately 60 users transmitted e-mail messages through the Sudan terminal and 12 through Eritrea. Users include agencies of the World Health Organization (WHO), the World Bank, the American Public Health Association, and the Alan Guttmacher Institute.

The HealthSat-2 has 12 watts power. It rotates around the Earth approximately every 100 minutes in a north-south orbit and because of the Earth's rotation and a different pass each time, every site on Earth is covered at least twice in 24 hours. There a two or three passes per day over the equatorial area and up to 12 passes over the poles. Ground stations consist of a radio, a computer modem and an antenna which may be fixed or steerable. The contact time at any point on the globe is from 2 to 18 minutes during which time e-mail may be sent to and/or received from the satellite. This type of LEO satellite costs about $3 million dollars.

Memorial University participated in two other LEO satellite demonstrations. In 1993, in a joint project with the Canadian Centre for Marine Communications (CCMC) of Memorial University, HealthSat-2 was used to provide a communications link with the Canadian Coast Guard icebreaker Louis S. St. Laurent in the Northwest passage and at the North Pole. Large amounts of data were transmitted to and from the ship by e-mail and the same system could convey information to support health care. This was the first reported use of LEO technology in the far north.

In 1995, in a collaborative effort involving the Systems Engineering Society (SES), Memorial University, SatelLife and SpaceQuest, a communications link was provided to two groups of polar explorers. In the first, the Malakhov/Weber team used the network for only a few days. In the second case, the International Polar Project, which was supported by the National Geographic Society, used a small ground station, weighing 7.5 kgs, to relay and receive e-mail to and from HealthSat-2, and through Memorial's ground station to the Internet. There were frequent communications not only with the control offices in Minnesota but there was also access to hundreds of school children worldwide through the Internet. Satellite transmissions continued over several weeks until the end of the trip.

Of particular importance was the successful transmission of pictures taken by a digital camera. On 3 April, the first digitized picture, using compression techniques, was transmitted from the North Pole to a ground station in the south.

Apart from SatelLife and VITA there are a number of other organizations using similar technology and amateur radio operators have, of course, been using similar systems for some years. There are also several commercial organizations now planning or beginning to use LEO satellites for commercial services. ORBCom/Teleglobe, and Motorola (Iridium) are examples of these.

While a few non-profit organizations have been leading the way, the continuing use of LEO satellites by these organizations for research and demonstration, while very desirable, may soon be caught up in licensing and regulatory issues. Despite this, the future of LEOs seems assured and they remain a major potential vehicle to bridge the communications gap between the developed and the developing world.

There are many other satellite systems (including satellites placed into the geostationary orbit) that are available commercially or can be used for telemedicine activities. The International Mobile Satellite Communications Organization (Inmarsat) provides a worldwide, effective, albeit costly, telephone service to ships at sea and other remote areas. A number of other mobile satellite services are being offered, including the North American MSat service.

Geostationary satellites provide worldwide services and have been used in the United States/Russian Federation demonstration during the Armenian earthquake disaster and the Space bridge demonstration in 1993.

The American armed forces have developed telemedicine systems which were used in Somalia and Croatia. These systems are relatively inexpensive as compared to the extremely expensive United States/Russian Federation projects. The Somalia project used an Inmarsat terminal.

In addition to communications satellites, remote sensing satellites can provide very valuable information about drought areas, weather systems, floods and other geographical data which could have a profound effect on the health of populations.

A number of satellite models for worldwide health and education applications have been reported. One of these models is the Global Access Tele-health and Education Systems (GATES) developed at the International Space University's 1994 summer session in Barcelona by a group of over 24 young space scientists who took as their project telemedicine and distance education. While the system suggested may seem somewhat unwieldy, expensive and economically of questionable feasibility, there are components of the plan which are worthy of serious consideration and continuing study.

Telemedicine development in the 1980s was much slower than predicted due to a number of factors, including resistance to change on the part of health providers, the high cost of effective systems, the absence of a system of remuneration for service providers and a lack of leadership on the part of governments. In the past three or four years there has been a worldwide surge in interest in telemedicine. The Arthur D. Little consultancy has predicted that the use of currently available telemedicine video systems would alone result in annual savings of $50 billion in health spending in the United States.

On the international front, the G7 countries, as one of their global health care initiatives, have taken as one theme international telemedicine with emphasis on maritime needs and disaster response. Any telemedicine system developed for these services will be largely dependent on satellite systems.

The provision of a wide range of social and government services to island countries and territories throughout the world is of interest in the United Nations and other international organizations and again space technology will provide the core of health and education communication systems for these regions.

The serious environmental and educational needs, let alone health needs, of northern and circum-polar areas will demand effective, available and economically viable satellite systems. Some countries, such as Indonesia and Brazil, have chosen satellite technology for their main communications systems. Satellites are also essential for reaching isolated areas in Africa, continental Europe and China.

There is a need for continuing research and development in the application of satellite telemedicine and distance education systems to meet the needs of the developing countries and remote regions of developed countries such as Canada. Rapid developments in information technology in the developed world, including the use of electronic communication and publication, may in fact worsen the knowledge gap between the have and have not areas of the world unless e-mail can be sent and received by terrestrial or satellite networks.

The United Nations and other international organizations could influence policies which would see the development of telemedicine and distance education systems and networks where they are needed. These systems should be cost effective and established only where needs have been assessed and there is a commitment for participation by those to be served. Attention should be given not only to capital costs but also to ongoing operational requirements.

There are currently satellite systems emerging or already available that can do much to rectify the gross knowledge imbalance that exists in many parts of the world. Regulatory, legal and political issues should be addressed and resolved if support services for health care and education are to be met. Without good health for individuals and an educated and trained population, there will be no sustained economic development. It is in the interest of all of us to work towards goals that we have already set out. There is a great need for continuing research and development in the telemedicine and distance education needs of the developing countries and remote regions of developed countries. Regulatory and political issues should not be permitted to inhibit the development of adequate worldwide satellite services which are now essential and feasible.

# HEALTHNET: SOLVING COMMUNICATIONS PROBLEMS FOR HEALTH CARE WORKERS*

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## INTRODUCTION

In the developed world, it's an everyday experience to make a voice call, fax transmission, or even to join a videoconference -- often across many time zones, even to the other side of our planet. When SatelLife was founded, these commonplace communication experiences were impossible for health workers in many developing countries -- sometimes because of poor local and international technical facilities, and sometimes because of exorbitant tariffs. Even with today's improved telecommunications networks, communications in remote and rural areas is still difficult or impossible, and always extremely expensive. SatelLife was created to help these people overcome these problems.

## SATELLIFE AND HEALTHNET

### SateLife

SatelLife was an initiative of the 1985 Nobel Peace Laureate, the International Physicians for the Prevention of Nuclear War (IPPNW), as a programme to demonstrate that when physicians around the world join together, problems such as the crisis of health care in the developing world can be solved, just as IPPNW demonstrated that physicians from opposite sides of the Cold War could join to call for a ban on nuclear weapons.

SatelLife developed the HealthNet concept of cooperatively shared communications and information services to support public health and medical research in the developing world, and is the administrative centre for HealthNet projects in the developing world. It commenced operations in 1989 and established the first HealthNet in Zambia in 1992. HealthNets now operate in 15 African countries and in four Asian countries.

Satellife is registered as a not-for-profit organization in the Commonwealth of

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* This paper, which was presented at the United Nations/IAF Workshop on "Space Technology for Health Care and Environmental Monitoring in the Developing World," held at Oslo, Norway, 28 September to 1 October 1995, does not necessarily reflect the views of the United Nations.

Massachusetts and as a public charity in the United Kingdom. SatelLife is governed by an international Board of Directors, chaired by its founder Dr. Bernard Lown.

HealthNet

In 1985, Dr. Lown proposed a "Strategic Health Initiative", a low-cost space telecommunications system to support medical education in developing countries. Years of economic decline had resulted in obsolescence and scarcity of medical references and textbooks in African medical schools, and a lack of subscriptions to the medical journals where all the latest medical knowledge is found. Although modern communications might have helped to remedy this information gap, conventional telecommunications in Africa and much of the developing world was both poor quality and extremely expensive, especially for underfunded public health programmes. The HealthNet concept came into being as a means to bring together medical schools, institutions, and medical users of telecommunications in each country, to obtain better quality, more affordable international telecommunications services, using communications and computer technology with costs that are within the reach of developing countries and organizations.

Because the Healthnet concept was intended to provide access to information becoming available in digital form, and because electronic message systems are the most efficient use of scarce, unreliable, and expensive communications, Healthnet was designed as a computer-based message system that gives health care workers around the world access to the global Internet, and provides them with access to appropriate sources of information through the Internet.

HEALTHNET TODAY

HealthNet now serves health workers in the developing world, especially Africa, in medicine, public health, and the environment, including academic medical centers, research institutes, medical libraries, health ministries, hospitals and clinics, non-governmental organizations (NGOs), grassroots associations, and other organizations concerned with the improvement of health.

HealthNet is made up of member national HealthNet sub-networks. Each is under local control of a Users (or Licensing) Council, which functions as a Board of Directors, and a Steering Committee or smaller planning group, that can look after day-to-day issues much like an Executive Committee. In 1993, these HealthNets began to change from informal university-based research projects to legally registered NGOs, operating on a cost recovery basis as not-for-profit businesses. HealthNets would often continue on the same premises, but independent of the universities.

INFORMATION SERVICES

The information services offered by SatelLife to health workers in the developing world are based on two facts: an acute shortage of current health information; and the isolation of the health worker from colleagues.

Libraries, hospitals and other organizations often lack adequate funds or foreign currency to subscribe to medical journals or to maintain on-going subscriptions. Health workers are also hindered from sharing information with each other about issues because of the high cost of telephone calls, fax services and travel.

The goal of HealthNet's information services is to connect the health worker with a range of information options in a cost-effective manner with the most affordable and appropriate technology. South-South, North-South and South-North information sharing and distribution is supported by HealthNet. These services continually evolve in response to the needs and resources of HealthNet users.

UNIQUE SERVICES

Many of these services are not available in any other electronic form through other sources in the countries served by HealthNet, including: electronic publications, bibliographic search of the National Library of Medicine (NLM) in Washington, D.C., United States, and library partnerships.

HealthNet News, other electronic publications

These publications, compiled by SatelLife or produced by collaborating organizations, cover topics that are of interest and relevance to those who work in health in the developing world.

*HealthNet News* features current clinical medical information. Summaries, abstracts, short reports, and some full text articles from many journals are included with permission from publishers. Distribution is limited to HealthNet users in developing countries.

*African Medical Librarians Bulletin (AMLB)* is made possible by contributions by African medical librarians. It contains selected tables of contents as well as abstracts from local and regional medical publications.

*WHO Library Digest for Africa* is edited by the staff of the World Health Organization (WHO) Library in Geneva. This publication includes WHO material of interest to librarians and health workers in the developing world.

*WHO/AFRO Infodigest* is compiled by the Documentation Centre in Brazzaville, Congo, and highlights tropical diseases and other health issues.

*AIDS Bulletin*, compiled by SatelLife, includes clinical information on HIV/AIDS including STD's. Distribution is limited to HealthNet users in developing countries.

*Mothers and Children* contains information concerning the health and nutrition of women and children. It is the electronic form of the same publication produced by the American Public Health Association.

*Population Issues* features information on population, family planning and reproductive health.

Batch Internet NLM Information System (BITNIS)

SatelLife is collaborating with the NLM and the Pan-American Health Organization (PAHO) to test, demonstrate, and train users in BITNIS in medical libraries and research centres in HealthNet countries in Africa. HealthNet users are provided BITNIS access at reduced rates comparable to those charged students in the United States.

BITNIS is a data base search tool which allows users to do automated searches of 21 abstract data bases at the NLM. Searches are prepared on Grateful Med, a software package developed by the NLM. The search strategy is saved, then sent via an e-mail network, such as HealthNet, to the BITNIS gateway at the NLM. The actual search is performed by a computer and the results are returned to the user. Abstracts and bibliographic references are available in the data bases; full text articles cannot be obtained.

The average cost for a search is approximately $1.00-$3.00, and many times may even be considerably less. The searches are performed very quickly by a high-speed computer. The time taken to perform the search depends on how well the search has been defined.

Library partnerships

SatelLife initiated the Library Partnership Program which now facilitates access to medical literature for libraries in the developing world. This programme is largely a volunteer effort and depends on the creation of "partner library" relationships between institutions and medical librarians. Users request searches for abstracts and/or full text articles through their national librarian which are fulfilled regionally or by the international partner librarian.

ADDED VALUE FOR MEDICINE

Other services, while not unique, provide added value by gathering a developing-world medical community through networking: developing-world access; "listservs" or conferencing; referral to experts, data bases, and Internet resources; and distance learning support.

Developing-world access

HealthNet users can send electronic mail to their colleagues nationally, regionally and internationally. For example, using his or her computer, a health care worker in a rural hospital can send a message to a colleague in a neighboring district, in the region, or to an institution located in another part of the world. Conversely, electronic mail allows easy access from physicians and researchers in developed countries to colleagues in developing countries.

Several internationally-funded projects use HealthNet to provide access to their colleagues in developing countries; for example, WHO's Special Programme for Research and Training in Tropical Diseases (TDR) has supported expansion of HealthNet into Asia. The first phase implementation in Asia includes TDR-related institutions in the Philippines, Sri Lanka, and China.

Conferences: medical-content listservs

Among many "listservs", or e-mail distribution services, operated by HealthNet, the following are examples of important medical information services provided in this way. These electronic conferences allow HealthNet users around the world to form discussion groups on issues pertinent to their immediate needs and/or their professional interests. Conferences provide an interactive format allowing users to either follow or participate in "conversations" irrespective of time and place. Examples include: a) ProMED: Program for Monitoring Emerging Diseases; b) HIV/STD; and c) E-Drug: Essential Drugs

## PROMED: PROGRAM FOR MONITORING EMERGING DISEASES

Numerous recent episodes of emerging and re-emerging infections, including the continuing spread of dengue viruses, the now frequent appearance of hitherto unrecognized diseases such as the hemorrhagic fevers, and the resurgence of old scourges like tuberculosis and cholera in new, more severe forms, attest to our continuing vulnerability to infectious diseases throughout the world.

Many experts, both within and outside government, have warned of the need to improve capabilities for dealing with emerging infectious diseases. The development of an effective global infectious disease surveillance system has been the primary recommendation of expert analyses.

ProMED was set up specifically to plan and promote a global system of early detection and timely response to disease outbreaks. Proposed by the Federation of American Scientists, a public policy research organization, ProMED was inaugurated in September 1993 at a Geneva conference co-sponsored by 60 prominent experts in human, animal and plant health. The conference called for a coordinated global programme and charged the ProMED Steering Committee with the task of designing it. Members of the ProMED Steering Committee come from all over the world and include representatives of the WHO, the United States Centers for Disease Control and Prevention, the United States National Institutes of Health, and International Epizootic Organization, as well as other organizations and academic institutions.

In cooperation with SatelLife and HealthNet, ProMED has inaugurated an e-mail conference system on the Internet to encourage timely information sharing and discussion on emerging disease problems worldwide. Through HealthNet, this low-cost system reaches participants in developing countries and remote areas. Subscription to the ProMED e-mail conference is free of charge.

HIV/STD ELECTRONIC CONFERENCE

The overall goal of this project is to reduce the burden that isolation imposes on health care workers in the developing world who struggle with limited resources to treat a flood of patients with HIV/AIDS or related sexually transmitted diseases (STDs). SatelLife, through HealthNet, will create and administer a global network for HIV and STDs by means of electronic conferencing, so that physicians, health care workers, and policy makers from the developing world can be linked with colleagues in the industrialized world and in their own regions. This project will provide the first electronic mail conferencing for clinicians and researchers in HIV/STDs throughout the world with particular emphasis on engaging those from the developing world. In the struggle against HIV/AIDS, information and communication can save scarce resources, offer a wider range of treatment possibilities, and influence prevention efforts.

E-DRUG: ESSENTIAL DRUGS MAILING LIST

The objective of "E-DRUG" is to support the concept of essential drugs by improving and speeding up communications between all health professionals working in the field of essential drugs. Colleagues in developing countries often cannot afford telephone and fax lines. Normal postal services are too slow and unreliable. Many have already discovered the usefulness of e-mail as an affordable tool for communication. E-DRUG is a free service of SatelLife, and will only cost the normal costs of sending/receiving ordinary e-mail messages.

The list "Who is where on e-mail in essential drugs?" has been maintained by Wilbert Bannenberg for over a one year and contains more than 266 names people and organizations associated with essential drug information. E-DRUG has been specially designed for colleagues in countries without access to interactive Internet tools such as WWW, gopher, USENET and FTP.

E-DRUG is used in the following ways: a) to send a question to all members (e.g., requesting suggestions as how to lobby Parliament or the Medical Association etc.); b) to request a list of available files from E-DRUG (e.g. "Who is where on e-mail in essential drugs"); c) to inform all members about a new reports: *Essential Drug List*, *National Drug Policy*, *Standard Treatment Guideline*, etc.; d) to allow subscribers to receive a regular bulletin highlighting new developments and recently available files; e) to receive publicly available information sources (e.g., WHO/DAP publications, the Model WHO Essential Drug List, the UNIPAC Essential Drug price list, articles from the Essential Drug Monitor or INRUD News).

The primary language of E-DRUG is English, but similar systems could be opened in Spanish (MEDICAM-E) or French (E-MED) if there is enough interest.

## OTHER SERVICES

### Access to Data Bases and Experts

HealthNet users cannot usually afford, nor do their local telecommunications environments permit, direct or on-line access to international data bases. SatelLife has secured permission from the NLM to make many of its data bases such as Medline, Toxnet, Cancerlit, and others accessible via e-mail search vehicles such as BITNIS. Access to some data bases are fee related.

### Distance Learning

HealthNet's technology lends itself to distance learning applications through e-mail, distribution of health information, and electronic conferencing.

### Internet Resources

HealthNet offers pointers to useful health mailing lists, World Wide Web homepages, Gopher and FTP sites on the Internet. Sites will be screened so that offerings will be appropriate for users with or without direct Internet access.

## COMMUNICATION TECHNOLOGY SERVICES

HealthNet is intended to function reliably and inexpensively, especially in areas where there are poor or non-existent telecommunications infrastructures, using technology available in these locations. Much of the inspiration and technology for HealthNet was taken from amateur-radio communications, which has developed a wide variety of low-cost technologies, many involving personal computer systems. These experimental data communications systems are used only for personal hobby communications in the United States and Europe, but are often the only communications systems available to medical workers in developing countries.

### LEO microsatellites HS-1, HS-2

The HealthNet satellite system offers Internet message services to any remote area or areas where the local telecommunication infrastructure is poor or inefficient. SatelLife began in 1989 with the concept of delivering a communications alternative for medical information, that used a LEO amateur packet radio technology satellite to link medical education centers in Africa with medical libraries and other centers in the United States, Canada, and Europe. At that time, the poor telecommunications infrastructures made it impossible to establish electronic mail linkages directly between most African countries. A "store and forward" microsatellite was thought to be the best solution to address both the issues of cost of telecommunications and the problems with poor infrastructure. The alternative solution envisioned use of the LEO satellite as a relay between each ground station in the South, serving as a national hub for e-mail and other data communications, and major medical research and education centres in the North. Satellite acquired Healthsat-1 (HS-1) to begin experimenting with this service on amateur frequencies.

In the Fall of 1991, SatelLife began its initial demonstration project with the installation of five experimental ground stations in eastern Africa -- Kenya, Mozambique, Tanzania, Uganda and Zambia -- and the establishment of its Internet gateway at Memorial University, St. John's, Newfoundland, Canada. It was expanded to an additional 10 countries by the International Development Research Centre in Canada and funded as research in health communication. Problems of physical installation and operation, and automation of software, were solved to create a system providing e-mail: every ground station acts as a post office node, which can be accessed on the ground via telephone and modems for delivery and pick-up of messages. Prior to each satellite pass, messages are bundled by ground station destination and prepared for satellite uplink. Any mail destined for addressees on other systems was gatewayed into the global Internet at the Canadian station and vice versa.

Small networks were envisioned in each country, which would link key health related institutions such as the Faculty of Medicine, medical library, ministries of health, NGOs, offices of the WHO and the United Nations Children's Fund (UNICEF), etc. The computer centres at the initial five universities were identified as key collaborators, where hub stations or nodes were licensed by the PTTs. The users of this network were expected to number in the dozens, and message traffic among the ground stations was expected to be well within the capabilities of the satellite network.

Despite problems with equipment and software, HS-1 usage grew very rapidly; users soon numbered in the hundreds in some networks and message traffic grew to nearly 1 megabyte per day. Growth would clearly have continued. However, the limited capacity of the satellite was insufficient to meet the demand. It was decided that the first satellite would be replaced by a second more powerful satellite, Healthsat-2 (HS-2), with similar technology, operating on frequencies allocated for commercial operation. United States licensing for use of these frequencies is a long process, and in the interim, experimental licensing at the Memorial University Center for Telemedicine, St Johns, Newfoundland, Canada, was used to continue experimentation. In the interim, international dialed telephone data communications was provided to support the demonstrated need and demand.

The current HealthNet satellite (HS-2) is a LEO satellite capable of store and forward full-duplex communication at 9,600 bps. The satellite was launched in a polar orbit which means that the satellite will have passes (crossings of the sky) in any location around the globe. Locations close to equator will have four passes per day, with each pass lasting for about 13 minutes. Due to the sun-synchronous orbit, the satellite passes will occur around the same time every day -- two passes around 10 AM and two passes around 10 PM. The satellite has one downlink and two uplink communication channels. There can be several users requesting messages from the satellite, but only two users can send messages to the satellite at one time.

The ground equipment needed to contact the satellite consists of an IBM-PC compatible computer, a Terminal Node Controller (TNC), a satellite radio and antennas. At this stage, SatelLife is testing a new radio design that merges the satellite radio and the TNC into a single portable box. The new system was tested in the field at the North Pole in the spring of 1995, by the International Arctic Expedition led by Will Steger which was sponsored by the National Geographic Society. The experiment showed that small portable equipment for LEO-based store-and-forward message services have a unique role in communications to remote regions.

For the user, the HealthNet software is similar to any e-mail offline reader/writer software. The system permits messages addressed to Internet destinations, to any other satellite station or to any other HealthNet user. Binary files may be attached to messages or transferred by separate file request. All routing and delivering is transparent to the user.

Low-cost amateur PC message networks (FIDO)

The LEO satellite was initially expected to be an essential tool for the solution of the communications problems in developing countries because phone circuits, when they existed, were not good enough to allow reliable transmission of data. Since then, modern telephone switching equipment has been installed in many cities in Africa, providing good international connections, and sophisticated error correcting modems make data transfer possible even in places where the phones do not work well. Because of these rapidly evolving technologies, dialed telephone circuits and error correcting modems are often a more economical and efficient solution for international transfer of electronic data in developing countries than our microsatellite. FIDO message networks, which developed in an amateur experimenter community similar to that of amateur radio, during the growth of the Internet, provide an economical alternative to Internet e-mail systems, with equal or better services. FIDO networks were in widespread use in Africa in the 1980's and SatelLife joined the many NGOs supporting their use. The organization is committed to supporting this low-cost access system with advanced Internet services, brought as close as possible to the end-user.

The evolution of Healthnet has produced a large network of FIDO message network nodes, some using a packet radio satellite for transport of message files, with central routing of messages to and from FIDO networks and the Internet at a Sun UNIX computer located in Cambridge, Massachusetts, United States. The network is still growing rapidly, although much of its growth is in the "points" connected to network nodes rather than in the nodes themselves. The service is affordable for organizations in the developing world because phone calls placed at the Cambridge hub are billed at United States rates rather than rates set by PTTs. The cost of international calls are presently subsidized by private and corporate donations and foundation grants. The organization is beginning to move these telecommunications expenses and other costs of operation to a cost-recovery basis, in order to eventually make HealthNet self-sustaining.

HEALTHNET-II

Where communications facilities are intermittent, of poor quality, or expensive, the most efficient way of using them is by data communications transmission of digitally encoded messages rather than direct "real-time" voice or fax connections. SatelLife therefore has put much of its efforts into providing and improving access to "store-and-forward" message communications: electronic mail, or "e-mail". During the years of SatelLife's development of HealthNet, e-mail systems have developed from an academic curiosity into the global Internet, and our work on message services to the developing world has kept pace, developing worldwide Internet access for HealthNet members using technology that matches the needs and resources of each member network: a) Conventional FIDO and Internet technology including modems, routers, permanent leased circuits, and both PC and UNIX workstation computer systems; b) LEO store-and-forward amateur-packet-radio satellite Internet message service for remote areas, via UNIX gateway hubs; and c) Surface amateur-packet-radio Internet message network for regional access via UNIX gateways and routers .

These new directions in HealthNet technology led to the development of "HealthNet-II" with special communications services for remote areas, improved Internet integration, and advanced information services.

ADVANCED INFORMATION SERVICES

This redesign of HealthNet is not driven by technology opportunities alone; the principal benefits of HealthNet-II will be in access to advanced information services to HealthNet users. In each case, advanced services have higher telecommunication costs, which must be covered by project funding or cost recovery programs. Implementation of these services will therefore also be determined on a case-by-case basis by HealthNet User Councils.

UNIQUE SERVICES, EXPANDED

Currently, electronic publications are distributed by e-mail or by e-mail-based "netnews" or "echomail" conference systems. This poses several technical problems of accurate delivery of their contents. First and foremost is the absence of graphic materials, which are often too large in digital form to distribute with text; second is graphic-related text features such as non-English character sets, especially accented characters and, of course, Asian languages. "File server" distribution of such materials in their full form from UNIX server systems at HealthNet library locations would minimize communication costs and improve the quality of information distributed.

Electronic interlibrary loans for selected partnerships also becomes possible, using similar Internet software tools already in widespread use in the United States and Europe.

Local archiving and indexing, and full-text retrieval, of electronic publications is also possible at UNIX servers, especially CD-ROM-based publications as available. Within copyright restrictions, it may also be possible to provide e-mail-server access to such search tools.

BITNIS access to the United States NLM is a useful tool, but requires a great deal of experience to formulate accurate and efficient searches. This experience is best obtained by interactive use of the NLM databases directly through Grateful Med. This is a software tool running on Internet host computers at the NLM, accessible only through full Internet connections via "telnet". SatelLife is investigating the use of scheduled dialup Internet connections (originated in the United States to minimize costs) to support classroom use of a shared Internet connection, for BITNIS/Grateful Med training in Africa.

Distance education support is one of the most intriguing applications of advanced Internet services. Hypertext Markup Language (HTML), a formatting tool for documents used in the World Wide Web (WWW) graphic display interfaces now familiar to many researchers in developed countries, is designed for linkage of related brief documents in a way that is ideal for presentation of a structure of related pages for interactive self-education. Although most of the use of Web tools is for presentation of graphic images, some software exists that can present the HTML text components of a Web page on a text-only screen, or with limited graphics, on a DOS PC screen. In addition, local dialup modem access to a serial line on a UNIX system can function as a BBS for self-education and DOS PC Web software can be packaged with educational material prepared for it on a diskette, for stand alone use.

SatelLife is investigating a specific application of this HTML-based technology to interactive presentation of diagnostic flowcharts, as an element of a future project for the Global Initiative on Asthma (GINA).

Added value for medicine

Many Internet users in developed countries have asked how they can affiliate themselves with HealthNet to support its work, or to have access to SatelLife's electronic publications. SatelLife is developing an electronic directory service to provide electronic mailbox "aliases" for existing electronic mail addresses on other networks, which can be made available to such users as individual affiliate subscribers.

One aspect of this directory service that can lead to more flexible e-mail use among HealthNet users is its ability to record other identifying attributes, e.g. professional specialization fields, along with personal and e-mail routing attributes. These could be used to support e-mail list distribution with much greater flexibility than that of our present listserv.

The Internet now is closely identified with WWW Web page interactive access. The costs of interactive international Internet WWW access are prohibitive for anything but a large campus or national network connection to the global Internet, even with a subsidy, and are out of reach for many public health users. Local Web page "mirroring" of selected Web pages in developed countries may make it possible to provide access to important sources of information otherwise unavailable, especially to users on networks in medical schools and teaching hospitals.

SatelLife is investigating ways to provide Internet interactive services on schedule or on demand via international dialed modem link, at affordable costs. Added costs of international communications require accounting and cost recovery, so the problems involved are not entirely technical.

SatelLife continues to explore ways of making advanced services accessible through store-and-forward services, "plain old e-mail", by servers at UNIX machines for such advanced Internet services as FTP and gopher. As indicated above, bibliographic searching applications of e-mail servers are also under consideration.

User support services

SatelLife has always attempted to provide good documentation to support HealthNet users, who often are just beginning to explore serious uses of their computers. It will provide multi-lingual printed and embedded documentation, and online documentation in conference or newsgroup form.

An e-mail support desk service has always been available at SatelLife, but in an informal fashion. We plan to improve problem tracking, resolution, and response to originators of problem reports. With Internet services available at field locations, many of these support activities can be handled effectively by staff and volunteers in the developing world. We also plan improved response to voice and fax calls to SatelLife, with an off-hours support policy.

User directory servers

With UNIX systems in field as well as central locations, it may become possible to provide User Councils with flexible HealthNet user group directory services, including central United States or European billing for NGOs with operations in many locations, aliased "healthnet.org" addresses for existing e-mail addresses, and flexible e-mail lists using affiliation by directory attributes including project or sponsor concern, professional concern, regional/local/national concern, or an ad hoc group concern.

Conferences/newsgroups

SatelLife plans to provide access to selected Internet "newsgroups" and other sources of similar material from collaborating organizations, as available for open distribution. Limited distributions similar to our electronic publications may also be available to specific destinations; e.g. HealthNet-only newsfeed, or distribution to medical campus networks.

IMPROVED INTERNET INTEGRATION

As a provider of Internet electronic mail addresses, each HealthNet is an Internet service. However, there are distinct "levels" of Internet capability, and e-mail only services have the fewest capabilities. We plan to offer HealthNet User Councils the opportunity to upgrade their networks to improve services without requiring users to dismantle their existing software and buy new computer hardware.

Conventional Internet technology

Since 1993, SatelLife has operated the Internet domain "healthnet.org", to support access by its member networks. The Sun Microsystems UNIX computers that support this domain are located at the Department of Telemedicine, Memorial University, St Johns, Newfoundland, and at the organization's headquarters in Cambridge, Massachusetts. Internet backbone service via New England Academic and Research Network (NEARNet) has been provided by Bolt, Beranek, and Newman Inc. (now BBN Planet Inc.), which in 1995 graciously donated 56KB leased line service to us in recognition and support of SatelLife's work.

The success of the global Internet, in capturing the imagination of the development community, has led to a strong demand for high-speed Internet Protocol (IP) services between developing countries and the United States and Europe. While the cost barriers of providing international permanent leased lines are still prohibitive for most public health and medical education programmes in developing countries, there are now several cases in which IP access is a realistic alternative to store-and-forward networks, and SatelLife is investigating ways to help our member networks take advantage of these circumstances as they arise.

Personal computers are now affordable and available worldwide, but PC software poses many problems for Internet service operations, which are typically based on the more complex UNIX engineering software system. In the past two years, public domain software for UNIX on PCs has become a stable and respected (and very low-cost) alternative to commercial UNIX system software. SatelLife is working to bring together TCP/IP networking, AX.25 packet satellite ground station, and FIDO components into an automated system that we can help nonspecialists support. Our own engineering task will be to provide software to simplify control and monitoring of this package, so that the amount of UNIX-specific experience and training required is kept to a minimum. To accomplish this task, SatelLife is exploring partnerships with technical universities in Europe, Canada, and the United States.

This new network node technology should not affect current users of our FIDO network, but will offer each HealthNet Users Council many new options in Internet services to campus networks where they exist, including local and international UUCP and TCP/IP connections as available, and will make each HealthNet more useful and attractive to users of standard Internet mail systems. The change from FIDO to a UNIX node will be the User Council's decision, and thus the global HealthNet will gradually evolve into a new "HealthNet-II" in which Internet technology provides a wide range of advanced interactive information services to meet developing countries' medical information needs.

FIDO network technology

FIDO message networks, which developed in an amateur experimenter community similar to that of amateur radio, during the growth of the Internet, provide an economical alternative to Internet e-mail systems, with equal or better services. FIDO networks were in widespread use in Africa in the 1980s and SatelLife joined the many NGOs supporting their use there. There are now thousands of Africans using FIDO network systems daily for routine business and personal communications, and many services providing access to the Internet through FIDO networks.

It is recognized that this installed base of e-mail users is not likely to change to non-FIDO systems -- in large part because they cannot afford to upgrade the older computer systems that can run the FIDO mail software -- and SatelLife is committed to supporting this low-cost access system with advanced Internet services, brought as close as possible to the end-user. SatelLife is investigating the use of existing software tools which are used for FIDO-Internet gateway systems, for a viable solution that can be installed in a UNIX system in the field to support a local HealthNet's FIDO access needs. At the same time, SatelLife is investigating support of user access by similar UNIX-based software systems using "UUCP", and dialup Internet Protocol (IP), and with such systems the local HealthNet node can support access with any of these, depending on the quality and cost of local phone service.

HealthSat-II network for remote access

HealthSat-II (HS-2) is an amateur radio technology satellite using the same basic communications components, both on the satellite and in the ground station, as with HS-I, but as a mature example of this type of system it is sufficiently more powerful in several respects that its capabilities are significantly improved. At the time of its launch, the manufacturer, Surrey Satellite Technology Ltd. of the United Kingdom, described HS-2 as a "state-of-the-art" microsatellite and the "culmination" of its work in store-and-forward communications; this description seems appropriate. A comparison is contained in Table 1.

HS-2 presents an opportunity for the development of a communications system in support of health care and development for remote, rural, and mobile locations, providing national and regional e-mail message services, with a gateway to the global Internet in the national capital or regional center. There are two, fundamentally different types of HS-2 ground stations: a) a "terminal" ground station, low-power, integrated with control software in a general-purpose PC computer for greatly improved ease of use; and b) a "hub" ground station, high-power, attached to a multiprogrammed dedicated communications computer (also a PC, but larger and more powerful, using UNIX system software) serving as an access system for other computers but not primarily as a user message terminal.

In HealthNet-II, the hub serves as a gateway for e-mail and other Internet services using a variety of communication technologies. In general, the HS-2 link does not serve as the only access to the rest of the network and the following options are also available: a) HS-2 satellite message transport to HS-2 national/regional terminal ground stations (and backup international message transport); b) international direct dial modem: UUCP and PPP (TCP/IP) access; c) local direct dial modem: UUCP, FIDO, PPP access; d) AX.25 VHF packet radio; and e) HF radio data link.

Table 1

| **HealthSat-I (HS-1)** | **HealthSat-II (HS-2)** |
|---|---|
| One uplink receiver, one downlink transmitter | Three uplink receivers, two downlink transmitters |
| 4W nominal output power; 3W typical | Output transmitter power selectable from 1W to 12W under software control. (+6dB improvement over HS1) |
| Single 8MHz 80C186 communications processor | Dual redundant 8MHz 80C186 communications processor |
| 1802 COSMAC control processor (36KB program memory addressable) | 10MHz 80C188 control processor (1MB program memory addressable) |
| 4MB CMOS RAM with ERCC memory error protection | 48MB (3 x 16MB) SRAM with EDAC memory error protection |
| Experimental (amateur secondary) frequencies | General mobile-satellite frequencies (as of 1992 WARC) |
| Switchable 1200/9600 bps link speed | 1200/9600 bps uplink, 9.6Kbps/38.4Kbps downlink |
| Open-access AX.25 PACSAT protocol system | Open-access AX.25 PACSAT protocol system; revised "New Uplink Protocol (NUP)" was deliverable December 1993. AX.25 and NUP operation will both be available concurrently in service. |
| Age: 5.5 years, past 3 years without failure | Age: 2 years, no major failures |
| Estimated lifetime: 10+ years based on 11.5 years of UoSAT-2 | Estimated lifetime: 10+ years |

HS-2, with the NUP protocol upgrade, is expected to make it possible for multiple transactions between the hub and a number of terminals within a single pass, so that delays in message delivery within the nation or region, and in forwarding to the global Internet, are minimized.

SatelLife is currently developing this hub communications system by testing the Linux public-domain operating system and public-domain communications software (some of it from the same amateur-radio community that developed AX.25 and the PACSAT protocols). Windows-based software for terminal ground stations from the same community, will make it possible for SatelLife to develop the terminal ground station with confidence in its flexibility, reliability, and ease of use. HS-2 can then provide a viable "last-mile" Internet communications solution as originally intended.

Surface amateur-packet-radio message network for regional access

To improve upon its ability to provide developing countries with low-cost, effective telecommunications, SatelLife is investigating digital store-and-forward communications via High Frequency (HF) and Very High Frequency (VHF) packet radio, as a practical tool to provide Internet message service to HealthNet users in remote regions.

Like LEO satellite technology, HF allows for linking remote locations served by poor or non-existent telephone service. Unlike LEO satellites, HF radio links can provide telecommunications for longer periods of time than a typical 15-minute satellite pass. HF radio propagation is highly variable, depending upon the time of day, time of the year, sunspot activity, and other naturally occurring phenomena, but paths of up to 1,000 km can be maintained over long periods of time, using modest power levels with good antenna systems.

Incorporating HF as a networking solution is a great challenge because HF reception is noisy and erratic, and as a result it is considered by many to be an outdated, obsolete method of communication. However, HF is enjoying a resurgence of popularity due in part to recent advancements in digital technology and linking methods. Research and development is no longer restricted to government-sponsored programmes. Many commercial manufacturers in Europe and the United States now offer a variety of PC-compatible data modems to address this technology. The rapid commercial development is being fueled in part by interest among the world's radio amateurs.

SatelLife's HF network may employ automatic linking technology based on Automatic Link Establishment (ALE) standards. ALE operates on one of a group of radio frequencies, with on-going measurement of channel quality by comparing the signal-to-noise ratio and the bit error rate. If either the signal-to-noise or bit error rates rises to unacceptable levels ALE will direct the linked stations to a different frequency in the group that is more favourable to present propagation conditions.

To complement ALE, SatelLife is studying two forms of data modem technology: CLOVER, which allows for various bandwidth-efficient combinations of discrete amplitudes and phases; and PACTOR: an improved version of AMTOR which responds well to changing channel conditions. A network of one or more HealthNet HF stations can link to a central "hub" or gateway, typically located in a capital city, linked to the global Internet via campus network high-speed links or dialed modem connection.

In addition to HF radio, SatelLife is also exploring VHF radio networking solutions. Unlike HF, VHF radio is short-range (up to 100 km) in nature. It is typically used in "line-of-sight" applications. VHF is limited in applications where natural obstructions, such as mountains, lie in the signal path. However, VHF does not suffer from erratic propagation phenomena like HF. Thus, paths are more reliable and noise-free, and higher data rates can be sustained. In some instances links can be maintained 24 hours per day. This permits the use of TCP/IP Internet protocol systems over VHF links, with speeds approaching that of leased lines. SatelLife is investigating use of amateur packet radio networking software in "Linux" UNIX software for PCs to provide regional access to hospital and campus LANs as well as to the global Internet.

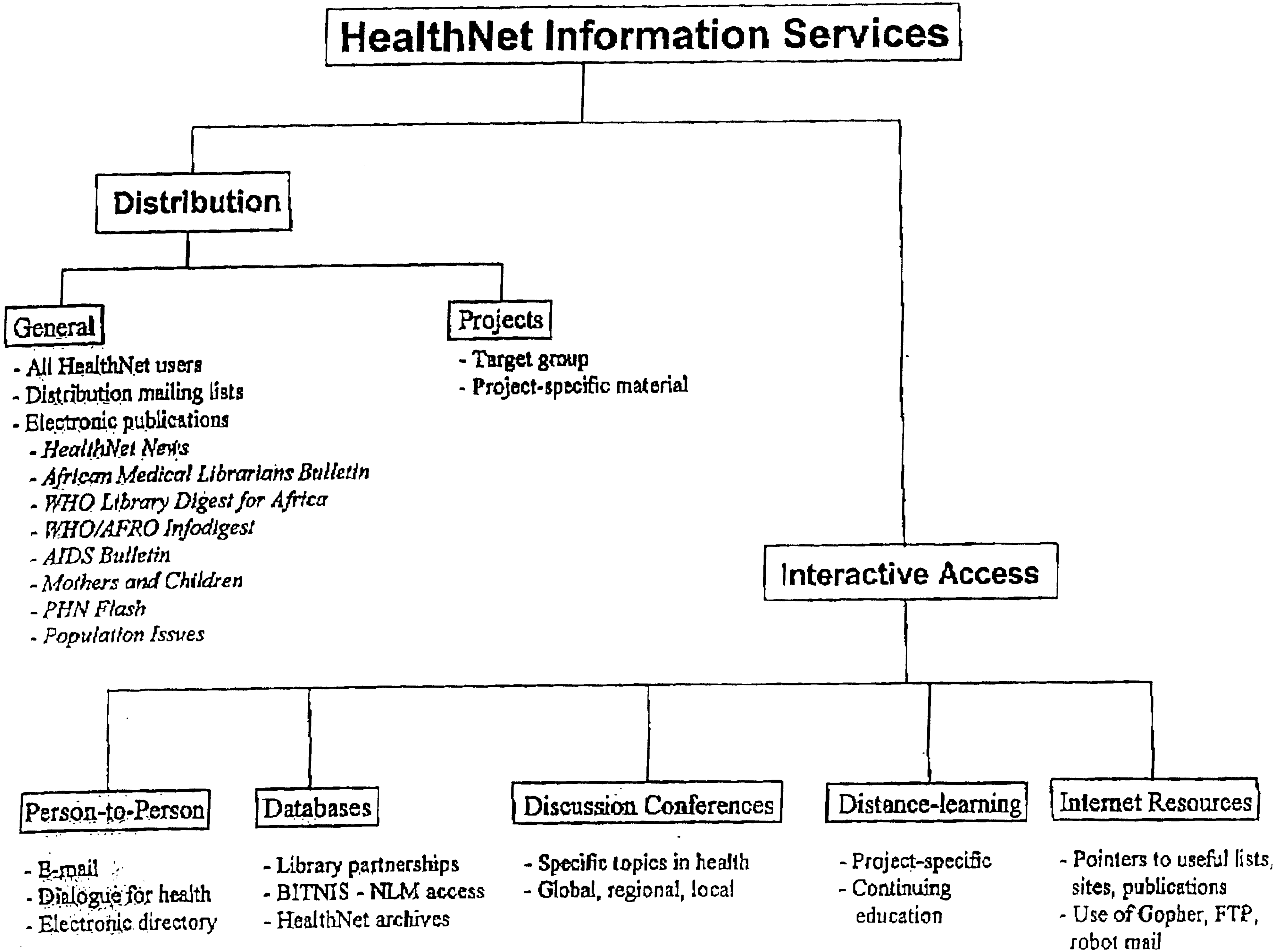
To complement in-house packet radio work by its engineering staff, SatelLife has established a working relationship with individual engineers at the Mitre Corporation, Bedford Massachusetts, who are following the organization's progress with interest.

SUMMARY: NEW DIRECTIONS IN HEALTHNET TECHNOLOGY AND INFORMATION SERVICES

This successful network is more than a demonstration. It has become an essential service to many of its users. SatelLife plans to add to its software and hardware to add services, control and reduce costs, and improve reliability. However, this is only an intermediate step in the development of this network, because health care needs and technology opportunities make it necessary to constantly reevaluate its operation. SatelLife is currently at an important point in this development, because changes in satellite technology, and opportunities in radio technology, and the approach of Internet connectivity to African universities, mean that this network for routing messages will become increasingly diverse and technologically complex.

The only practical approach to handling this complexity with software that can automate enough of the message service operations to make it feasible to operate with non-specialist staff, is to base the system on a powerful multi-programming engineering software environment such as UNIX which has become the standard tool for solving these types of problems. UNIX is likely to become an increasingly central part of our software repertoire, although hopefully not increasingly visible to message service users. The change from FIDO to a UNIX node will be the User Council's decision, and thus the global HealthNet will gradually evolve into the new HealthNet-II.

One of the biggest problems in this evolution is training network managers in the new technology. SatelLife will provide training and support upon installation, and will plan for interim direct operations support from Cambridge. In collaboration with university programmes in the United States, Europe, and Canada, SatelLife will encourage development of university curriculum in developing countries, in engineering, computer science, and telecommunications, and other technical training programmes, in directions that will familiarize students (including our network managers) with the problems and new solutions we are dealing with. We believe the availability of public domain UNIX for PCs is an extremely important tool for this educational revolution in Africa and other less-developed regions. Although our resources are limited, we will support network managers that can use such software in such a programme, to familiarize themselves and others with UNIX and Internet technology.


HealthNet Information Services
Distribution
General
- All HealthNet users
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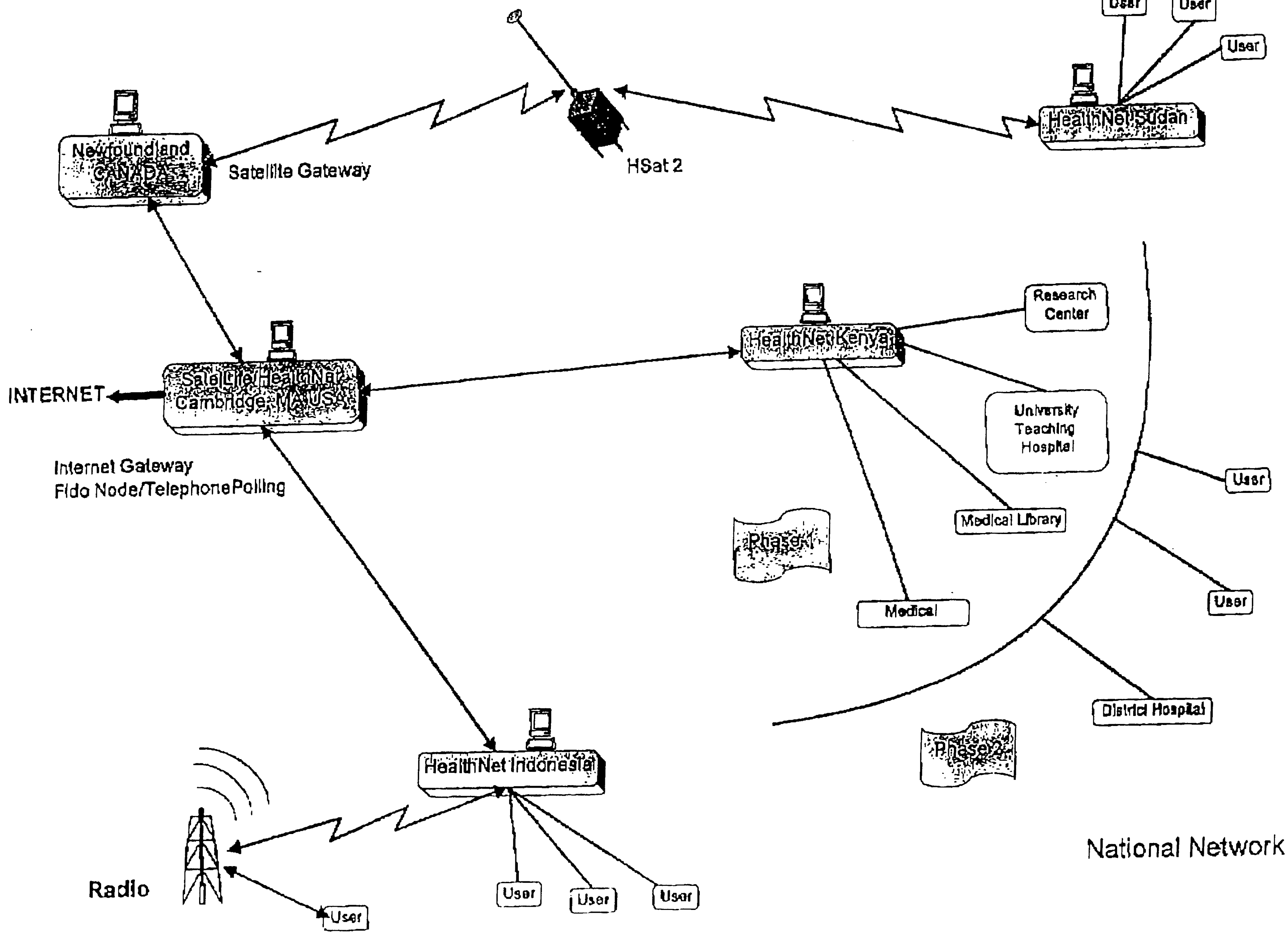
- Electronic publications
- HealthNet News
- African Medical Librarians Bulletin
- WHO Library Digest for Africa
- WHO/AFRO Infodigest
- AIDS Bulletin
- Mothers and Children
- PHN Flash
- Population Issues
Projects
- Target group
- Project-specific material
Interactive Access
Person-to-Person
- E-mail
- Dialogue for health
- Electronic directory
Databases
- Library partnerships
- BITNIS - NLM access
- HealthNet archives
Discussion Conferences
- Specific topics in health
- Global, regional, local
Distance-learning
- Project-specific
- Continuing education
Internet Resources
- Pointers to useful lists, sites, publications
- Use of Gopher, FTP, robot mail

# HEALTHNET



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Phase 2
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District Hospital
National Network
HealthNet Indonesia
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# THE USE OF REMOTE SENSING TECHNOLOGY IN COMBATTING FOREST FIRES*

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## INTRODUCTION

Fire hazards, whether natural or human-induced, occurring again and again, have swept the vegetation of various areas except in the very wet rain forest. As a result of deliberately set or accidental fires, there have been disastrous effects on the ecology and economy of the concerned areas. In developing countries such as Tanzania, however, deliberate burning of vegetation continues to aid farming and hunting of game in forested areas. The impact of fire on forest land can be detected by using remote sensing techniques and Geographical Information Systems (GIS).

Remote sensing refers to the science of detecting and interpreting objects from a distance. To do this calls for some kind of sensor, positioned on a platform which detects and records data from one or more bands within the electromagnetic spectrum. While remote sensing technology is used in the data capture, GIS technology may be employed in the digital entry, storage, transformation, analysis and display of spatial data and information on fire hazards. In GIS, spatial data are described by their location (geo-referencing) and by attribute data (what it is).1/ The application of remote sensing systems, especially thermal infrared for fire sensing and location, is reported to have been in development and use in forest fire management in the United States for about three decades.2/

The objective of this paper is to review the capability of remote sensing techniques in combating forest fires. It is suggested that remotely sensed data, in combination with a GIS, provides the most promising tool for assessment of forest resources damage caused by forest fires. The information so obtained is a key to informed decision-making in forest management.

Knowing as we do that disasters impede development inertia by disrupting it, especially in developing countries such as Tanzania, the usefulness of new planning technologies such as remote sensing and GIS need to be explored as they are adopted. In other words, we cannot afford to wait for concrete test results where there is some evidence of success.

In view of the capability of remote sensing and GIS technologies to record and maintain information about land in electronic media and to produce various kinds of graphical displays including maps, so that information may be utilized for a wide variety of needs, we are

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* This paper, which was presented at the United Nations/ESA Workshop on "Space Techniques to Combat Natural Disasters," held at Harare, Zimbabwe, 22-26 May 1995, does not necessarily reflect the views of the United Nations.

approaching an era in which the map is no longer the data base but merely one product of an electronic data base.3/

It is hypothesized that remote sensing and GIS, which are capable of generating alternative outcomes to be projected on map and table formats and as data bases, form important tools for forest fire management for sustainable development.

The issue at stake with any type of disaster is the fact that concern may take place several years before the event or shortly before or even shortly after it occurs.4/ The first instance is referred to as disaster preparedness and seeks to establish the causes and to set in motion the mechanisms which reduce disaster vulnerability. The second situation, better known as disaster prediction/forecasting, is more or less the same as the first one save for a short time span between availability of hazard information and the striking of the disaster. The third instance is referred to as damage assessment of the disaster which is conducted after the event. In the following section we will review the applications of remote sensing and GIS technologies in the detection and assessment of the degree of damage for decision-making with special reference to forest fires.

## APPLICATIONS OF REMOTE SENSING AND GIS TECHNOLOGIES IN COMBATING FOREST FIRES

### Fire Detection

Remote sensing techniques have already been employed in forest fire detection. According to Warren, three types of fire sensing systems have been categorized on the bases of areal extent. These are first, stationary, second, small area and third, large area.5/

Stationary fire sensing and location systems have been in use for time immemorial, taking advantage of selected vantage points such as hills and towers. Such points have facilitated the sensing and locating of fires from visual observation of the fire or resulting smoke. More recently, automatic fire sensing and location systems have been developed and are in use in Europe. The basic method uses a thermal infrared (IR) system sometimes coupled with a visual band system. The IR system detects hot spots and the visual detects smoke. The systems are mounted on a tower or at a vantage point in a remote location. They can scan 360 degrees or selected sectors and may include elevation steps on subsequent locations to increase coverage. When an abnormal fire or smoke is detected, an aural or visual alarm is given at a fire control centre. The video display of IR or TV can be selected and viewed by people at a dispatch or other centres. It may be technically possible to transmit the information by satellite.

Stationary systems for fire sensing should preferably be located on relatively flat terrain or across the front side of mountain ranges where the potential for fire starts exists without other means of early detection.

The instrument called the Advanced Very High Resolution Radiometer (AVHRR) carried on the geostationary satellites of the United States National Oceanographic and Atmospheric

Administration has a resolution of about 1 km which means the acquired imagery provides an overview of a very large area.6/ It is capable of showing an impressive number of forest fires.

Small areas are arbitrarily defined as 1,200 acres or less. The small area fire sensing and location systems utilize Forward Looking Infrared Radar (FLIR) or pyroelectric videocons (PEV) as the thermal sensing unit. The outputs are in the standard video format used in the United States and are displayed on a black and white or colour video monitor. As a helicopter flies around a fire perimeter, its location is stored every second or two. Hot spots inside or outside the fire perimeter or any other point of interest can be entered. Notebook-size PCs are used to store the navigation receiver location data. These are then connected to a drafting plotter on the ground, scaling points are entered and the fire perimeter and hot spots plotted, to scale, on a map or overlay. This provides a direct means for mapping a fire.

A large area is arbitrarily defined as over 1,200 acres. In the United States, fire sensing and location for large areas have used airborne thermal IR line scanning systems which process the IR information onto film strips developed on the aircraft. The film strips are physically delivered at the nearest landing strip, then driven into the Incident Command Post (ICP). There a trained IR interpreter manually transposes the fire/hot spot location information from the film onto a map.7/

Fire Mapping

Conventional fire mapping techniques employing aerial photography using a 35mm camera externally mounted to a small plane coupled with field observations have been used in forest fires. By interpreting slide images and analyzing data from field observations a map of the fire perimeter for the Everglades National Park, for example, was produced.8/

By employing a Global Positioning System (GPS), both aerial and ground, fire mapping has been undertaken with limited success especially for the former. The aerial GPS fire mapping was such a success that the actual fire line in the park was limited to the maneuverability of the helicopter.

Imagery from the Landsat Thematic Mapper (TM), with resolution of 30 metres, is capable of providing views of forest fires as demonstrated in the Yellowstone area.9/

Imagery from the French SPOT remote sensing satellite, has a resolution of 10 metres. Like the Landsat, SPOT images are capable of showing areas damaged by forest fires.10/

## TOWARDS A FOREST FIRE PREVENTION PLAN

In the final analysis, remote sensing should make the mismanagement of resources more difficult, because of the ability of modern systems to alert the resource planner to many kinds of environmental stress or damage.

Imagery from an Infrared Thermal Scanner, capable of showing the location and extent of hot spots within a fire perimeter, provides important information for tactical planning and suppression activities.11/

After the GPS vector data are imported in the computer data base by using a GIS (IDRIS), it can be overlaid with other historic fire data or other map layers such as soils, vegetation or Landsat imagery.12/ Vector data can be combined to show chronological burn patterns that assist in planning prescribed burns, suppressing wild fires and fire ecology analysis modeling.

## CONCLUSIONS AND RECOMMENDATIONS

New as the remote sensing and GIS technologies are elsewhere in the world, progress in their utilization in developing countries, however, is already under way. Recently, the United Nations Institute for Training and Research (UNITAR) opened a new window of opportunity by offering an intensive basic training in GIS and remote sensing to two Tanzanians and seed equipment (hardware, software and other peripherals) so as to establish a national node, at the National Environment Management Council (NEMC).13/ This centre will be linked with other nodes through the Global Resource Information Data base (GRID).

With respect to technology management, the latest GIS programme, known as IDRISI, and its companion TOSCA, has already been introduced in Tanzania through UNITAR.14/ There is a need for an evaluation of the technological needs in disaster management. In other words, the technology should prove to be a function of demand. Let us not put the cart before the horse! Further, this should go hand in hand with corresponding commitment by the relevant institutions to meet the continuing capital, data, personnel and organizational needs of the project if the programme is to be sustained.

It may be concluded that remote sensing images are a useful data base source when used in conjunction with sufficient ground truth in combating forest fires. As for developing countries, however, remote sensing images are severely constrained by delays in data processing and in transmitting the needed information to the consumers.

While a GIS analysis may employ data from sources of varying temporal dimension, there is a need to rate each data source on the basis of the temporal relevance at the time of study.

Equally important, there is a need to start considering the overall relevance rating of the data sources used in the GIS technology to solving a particular disaster problem at hand.

There is an urgent need, therefore, to enhance coordination nationally, regionally and internationally in order to explore the wider applications of remote sensing and GIS technologies in disaster mitigation for sustainable development.

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# SATELLITE IMAGE DATA IN SUPPORT OF MONITORING FOREST DEGRADATION*

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## INTRODUCTION AND BACKGROUND

Much of the world's forest resources are under intense pressure, especially in the inter-tropical belt. All projections indicate a further decrease of wooded areas in these regions because of the needs of a growing world population, intensified farming and greater use of wood for energy. There are major weaknesses in the policies, methods and mechanisms adopted to support the multiple ecological, economic, social and cultural roles of trees, forests and forest lands.1/ Deforestation, particularly in the developing countries, has a dramatic impact on fuelwood and fodder supplies, soil fertility and water resources.

Uncontrolled deforestation changes the water balance, leading to climatic changes via decreased evapotranspiration, reductions in rainfall, further loss of moisture in tropical forests and downstream flooding along densely populated river corridors. While originally the pollution of the environment was seen as a problem of the developed countries only, arising as a detrimental consequence from industrial growth, today it has become clear that "sustainable development" in both the North and South can only be achieved on the basis of a global partnership that addresses both the problems of environment and economic development in an integrated manner. 2/.

The loss of tropical forests is currently one of the most serious environmental threats. Despite the significant importance of forests to people, a large amount of the worldwide's tropical forests have been lost since the beginning of the twentieth century and an incalculable number of trees have been lost because of forest degradation, over exploitation of timber and fuelwood, overgrazing of livestock, and other non-suitable land use practices. There is a considerable lack of reliable up-to-date information on forest resources in most developing countries. Even the total area of forest is often in dispute and, under such conditions it is not surprising that the rate of tropical forest depletion is much higher than earlier estimates.3/

Forests represent a large portion of the Earth's renewable resources. While the forests in developing countries are disappearing at the rate of thousands of square kilometres per annum, gradual forest decline due to anthropogenic factors such as air pollution is also a major problem

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* This paper, which was presented at the United Nations/ESA Symposium on "Space Technology for Improving Life on Earth," held at Graz, Austria, 11-14 September 1995, does not necessarily reflect the views of the United Nations.

in the industrialized worldwide. In the European Union, for example, almost 30 per cent of the land surface is covered by forest and there is a widespread concern within the scientific, industrial and public sectors of European society that a continuation of recent trends in forest decline may lead to a plethora of undesirable consequences.4/ Forest damage or decline is described as any type of intensity of an effect, on one or more trees, that temporarily or permanently reduces their financial value, or impairs or removes the biological ability of growth and reproduction. While decision making processes rely heavily on adequate information, it is satellite imagery that can provide adequate and rapid assessment for different stages of stress due to pollution, lack of water, insect damage, fire damage and other causes.

In this context, the European Commission (EC) initiated through its Institute for Remote Sensing Applications (IRSA) the development of techniques for deriving through satellite observations relevant, timely and accurate information on the state and evolution of Earth surface characteristics. These activities can be seen in the framework of supporting the sectorial policies of the European Union in areas such as agriculture, forestry, environment, development and regional aid and support of the European scientific and applications communities in the utilization of Earth observation data. Forest monitoring in both the tropics and temperate zone are specifically addressed in IRSA's research programme.

COST ORIENTED MONITORING OF FORESTS

Financial constraints often limit developing countries in the exploitation of space technology for needed socio-economic development programmes. Significant costs include the initial investment for technology acquisition, the purchase of data on a regular basis and research to develop methodologies for the specific needs of individual countries. One of the primary measures that should be implemented to improve forest management and possibly stop or reverse the indicated trends is the development of techniques that provide rapid, accurate and inexpensive information about forest conditions. Thus, in the assessment of forests for their productivity and sustainability, low cost satellite data should play a key role in measuring relevant parameters at recurring intervals and on appropriate scales.

In many cases, traditional sources of information, such as field and aerial surveys are too time consuming and expensive. It has become apparent that the synoptic coverage provided by Earth observation satellites is the only tool to monitor and quantify forest resources when whole countries or continents are involved.5/ Phenomena and resources that transcend boundaries can easily be observed by using remote sensing with much less logistical or administrative difficulty than is the case with ground surveys. Moreover, remote sensing can provide up-to-date and accurate information which is essential for appropriate policy formulation and effective decision making.6/ With several series of satellites in orbit, an applications specialist or forester can select imagery from among a wide range of spatial, spectral and temporal resolutions.

For regional studies, a forest manager might use data obtained by sensors carried on meteorological satellites. The current satellites of the United States National Oceanographic and Atmospheric Administration (NOAA) carry a variety of sensors to observe the Earth and its atmosphere and provide effective worldwide coverage every day. These data can be complemented by high resolution data of the currently available active and passive sensor systems, by existing statistical and ground information and then incorporated in a system capable of efficient data storage and expedient data processing such as a Geographical Information System (GIS). The stored data can then be used to produce maps showing general species distribution, volume estimation or general forest condition and changes in the distribution of forests can be delineated.

## THE ROLE OF THE NOAA SATELLITES

Advanced Very High Resolution Radiometer (AVHRR) data are presently derived from the NOAA-9, -11 and -14 satellites in the afternoon, and NOAA 12-in the morning. These are well suited for global and continental scale applications due to their moderate spatial and high temporal resolution and their spectral bands that are suitable for the detection of important terrestrial attributes.7/ The NOAA satellite has a sun-synchronous polar orbit with an altitude of 870 km and an inclination of 99 degrees towards the equator.

The AVHRR detector itself is an electromechanical device that forms the image by a side-to-side scanning movement as the satellite travels along its path. It has a spatial resolution, as measured by the Instantaneous Field of View (IFOV) at a nadir of approximately 1.1 km x 1.1 km and with its wide swath width can sense almost the whole Earth on a daily basis.8/ The AVHRR senses with five channels the electromagnetic reflectance of a red (0,58 - 0,68 m), a near infrared (0,72-1,10 m) and a thermal infrared (3,55-3,93 m, 10,50-11,30 m and 11,50-12,50 m) portion of the electromagnetic spectrum. While the AVHRR sensor was designed originally for meteorological, hydrologic and oceanographic studies, the utility of using its Large Area Coverage (LAC) and Global Area Coverage (GAC) data for terrestrial applications was soon recognized.9/

The potential of AVHRR data for vegetation mapping was first reported at the beginning of the 1980s and GAC data have since then been effectively used to compute Global Vegetation Indices (GVI). These data are produced by spatial and temporal sampling of geographically registered GAC images over weekly periods to reduce the effects of cloud cover and have a potential for monitoring global vegetation resources.10/

There is also a growing demand for consistent and comprehensive information regarding the characteristics and spatial distribution of the Earth's land cover.11/ This has led to the initialization of a number of projects using AVHRR data such as the International Geosphere Biosphere Programme's (IGBP) global 1 km land cover project, with the goal of collecting, archiving and processing daily AVHRR data for all terrestrial surfaces and then deriving land cover data sets from this archive.12/

## FOREST AND LAND COVER MAPPING AND MONITORING IN EUROPE

The extraction of information on land cover from remotely sensed data is a fundamental activity, necessary for a variety of applications including land use mapping and monitoring, ecological monitoring of vegetation communities, agricultural and forest monitoring, the calculation of land capability and the estimation of interactions between the land surface and the atmosphere.13/ The Environmental Mapping and Modelling Unit (EMAP) of IRSA has initialized a project on using NOAA-AVHRR data for establishing European forest and land cover data sets at a 1:1 million scale. These data will be made available to planning and policy making offices of the EC, to the international scientific community, and to regional forest and land use managers. A major advantage of these data sets over conventional maps will be the possibility to update them on a regular basis and therefore to monitor and detect changes in the status of European forests and land cover.

The NOAA-AVHRR data set covers Europe from the Portuguese coast to central Crete and from northern Algeria to southern Sweden. In total, 68 relatively cloud-free mosaics have been selected from March to October 1993 and been reprocessed into eight monthly Maximum Value Composites (MVC)14/ by independently compositing daily Normalized Difference Vegetation Index (NDVI) and Surface Temperature (Ts).15/ The rationale for compositing NDVI and Ts is supported by recent findings indicating that multitemporal series of the ratio between Ts and NDVI have the greatest potential to discriminate between land cover classes.16/ Further evidence for this is provided by Running who showed that the addition of Ts can discriminate regional land cover classes more efficiently than NDVI alone.17/

The eight MVC's will be input into an unsupervised classification scheme. Clustering will be performed in a spatially stratified manner in an attempt to reduce the biophysical variations in NDVI and Ts associated with climatic, soil and topographic effects. Subsequent class labelling assignments will be performed interactively using existing products, including the Digital Chart of the Worldwide Database, the 53-Monitoring Agriculture by Remote Sensing (MARS) agricultural test sites, the European Space Agency forest map and the land cover statistics of the Statistical Office of the European Commission (EUROSTAT). A GIS will be used in this procedure because of the diverse nature of the data sets (raster, vector and summary statistics), because of their large data volume and to produce the final product. End users may then utilize the data for extracting information on regional or administrative levels and combine it with other socio-economic relevant data.

## FOREST MONITORING IN THE TROPICS

IRSA's thematic project Tropical Ecosystem and Environment observations by Satellite (TREES) is dedicated to the mapping and monitoring of forest resources in the tropics. As alluded to in the introduction, tropical deforestation is not only a pressing issue, but is also highly controversial. Assessments vary, methods of analysis and observation vary and so too does the resulting information. The TREES project, recognizing the value of AVHRR as a data source from experience gained in the 1980s, has used these data to produce the first ever wall-to-wall map of tropical forest/non-forest areas at a resolution of 1 km.18/ Moreover, in the recent TREES-ERS1-94 study, 477 synthetic aperture radar (SAR) images acquired within a one month period were mosaicked and combined to a coherent 100 m resolution map of the central African basin.

The assembly of an appropriate wall-to-wall data set was in itself a major achievement of the project, and highlights the difficulties of gaining regular access to satellite imagery, even those data which are nominally "low cost", such as the AVHRR. The TREES project, by establishing a series of agreements with ground receiving stations, was finally able to assemble an appropriate data set. After eliminating excessively cloudy scenes, or those with missing or corrupted lines, the remaining data were analyzed using spectral discriminators (contrasts), temporal discriminators (seasonality), spatial-textural features (patterns) and indicators of deforestation (e.g., fires and roads).19/ A validation exercise was also designed to confirm class assignment and to calibrate the AVHRR area measurements. This was based on a sample of more than 60 Landsat TM images across the tropical belt and used, through regression analysis, to "correct" the AVHRR results.

To move from data collection, through information generation to forest monitoring, the TREES project created a GIS-based Tropical Forest Information System (TFIS). TFIS has been designed to: store the worldwide results of the AVHRR analysis; integrate auxiliary data sets (images, maps, photographs etc.); provide an analytical tool for the study of forest dynamics; and handle data sets from various sources in various formats and map projections.

The TREES Project has demonstrated that the AVHRR data can provide the information for carrying a base line assessment of tropical forest cover.20/ The lessons learned from this first TREES project have led IRSA to propose a second phase called TREES II (1995-1998). This project will be geared to the development of a prototype operational tropical forest monitoring system.

## CONCLUSION

Satellite remote sensing technology and applications techniques using AVHRR multi-spectral data are well developed. Despite this, there is a great potential for increased applications of remote sensing in developing countries. Among the obstacles that need to be overcome in particular are the lack of persons trained in image interpretation and image processing and the high cost of data, particularly for extensive repetitive coverage. Initiatives, such as the use of portable, local satellite receiving systems and the collection of global AVHRR data under the auspices of the IGBP-DIS can help in part to mitigate such problems.21/ There is no doubt that remote sensing and GIS will play a key factor in collecting information on the status of forests on a worldwide basis and that this information is a pre-requisite for an efficient implementation of their sustainable development.

## ACKNOWLEDGEMENTS

The authors would like to thank J. Megier, J.P. Malingreau and F. Achard for their comments and contribution.

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# DESERTIFICATION CONTROL AND REMOTE SENSING IN GHANA*

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## INTRODUCTION

Concern about desertification as a form of land degradation has been expressed in West Africa since the early decades of the present century. In 1935 it was estimated that the Sahara Desert had advanced 250 km southward over the 400 years since 1500.1/ The concern was expressed in Ghana in the late 1970s and early 1980s following the first World Conference on desertification in 1977.2/

The United Nation General Assembly, in its resolution 39/168 B of 17 December 1984, added Ghana to the list of countries eligible to receive assistance through UNSO in combating desertification.3/ The inclusion of Ghana in the desertification control mandate of UNSO is based on the fact that parts of the country, especially the upper eastern and northern regions are characterized by an arid climate and are especially vulnerable to the harmattan, a hot desiccating, dust-laden wind that blows from the northeast across the Sahara. Agricultural and other socio-economic activities in the fragile ecosystem of these northern parts of the country have led to deforestation, rangeland deterioration, soil erosion, vegetation degradation and other manifestations of desertification, resulting in drastic declines in agricultural productivity, cattle losses and extensive hardship for the people of the region.

Elsewhere, pockets of moderate to severe land degradation have also occurred, especially around urbanized areas, the transition zones and the coastal plains.

Early attempts at solution consisted principally of forestry management and improvements in agricultural land use for most of the 20th century. The land use approach culminated in what was designated as land planning during the period 1950-1960. The 1960's and the 1970's were a period of increasing agricultural activity without corresponding measures to combat the threat of land degradation and desertification. Efforts to combat the threats of desertification have been most sustained over the past 15 years. The role of space applications to combat the threat of desertification is envisaged in the use of satellite remote sensing data for the analysis of the spatial and the temporal dimensions of the problem to provide for inventory development, planning and long term monitoring of the environment and natural resources.

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* This paper, which was presented at the United Nations/ESA Workshop on "Application of Space Techniques to Prevent and Combat Natural Disasters," held at Harare, Zimbabwe, 22-26 May 1995, does not necessarily reflect the views of the United Nations.

THE PROBLEM

Ghana is located north of the equator and south of the Sahara Desert in West Africa. It encompasses two of the major east-west ecological zones: the high forest in the south and the guinea savannas in the north. The northeast corner of the country has the characteristics of the Sudan savanna to the north bordering the Sahel. Ghana shares a coastal savanna and thicket zone with Togo and Benin.

Early observations of the problem of degradation in the form of loss of vegetal cover and soil erosion in Ghana were made by forestry and agricultural officers, particularly in the northern savanna areas of the country, during the 1930s.4/. Lynn, commenting on the problem in the northeast said "here is a land planning problem that will admit of no delay, the human population is increasing with improvement in health facilities, livestock population is also increasing." 5/ Though measures relating to forestry and agricultural land use have intermittently been attempted since then, these have not solved the problems of land degradation.

Adu observed serious soil erosion in the Upper Eastern Region in Ghana.6/ But the problems of land degradation and the threat of desertification became most apparent during 1982-1983 when raging bush fires affected both forest and savanna at the height of an intermittent but increasingly severe drought.7/ It became necessary then to obtain some idea as to the spatial extent and the magnitude of the threat of desertification. It was estimated that about 30 per cent of the area of Ghana suffers from some degree of hazard of desertification (See Figure 1).

DESERTIFICATION CONTROL

Early approaches to combating the processes of desertification were in the areas of forestry and agricultural land use.

Forestry

The Ghana Forestry Department was established in 1909.8/ An ordinance in 1927 empowered the Department to protect forests on government lands and on school and private lands at the request of the land owners through the establishment and maintenance of forest reserves. Preservation would also be undertaken on lands in respect of which the Governor-in-Council was, on the advice of the Chief Conservator of forests, satisfied that the forest thereon ought, in the public interest, to be protected from injury or destruction, as the case may be, or that forest growth should be established thereon, in order to safeguard the water supply, to ensure the well-being of agricultural crops in the vicinity and to supply forest produce.9/

By 1939, when the World War II began, the target of 20 per cent reservation in the high forest areas had almost been achieved. Reservation was extended to the northern savannas where the objective was to provide an extensive system of reserves supplemented by plantations and woodlots for the supply of fuelwood and poles for construction. A few reserves and plantations were established in the coastal savannas programmes. Reforestation and afforestation programmes were conducted between 1970 and 1980 in response to the urgent need to rehabilitate degraded forest and savanna lands. Forest reservation and management was least developed in the savanna areas which are the most vulnerable areas (See Figure 2). Table 1 shows that unreserved forest is nearly all converted into farmland, mostly under bushfallow cultivation.

Current efforts are being directed at the introduction and development of community forestry and agroforestry, particularly woodlot planting supported by the Forestry Department and a large number of nongovernmental organizations.

*Table 1: Forest and savanna cover and utilization as of 1987.*

| | FOREST ZONE | | SAVANNA ZONE | |
|---|---|---|---|---|
| | $km^2$ | % | $km^2$ | % |
| Reserved | 16,788 | 20.41 | 8,806 | 5.69 |
| Unreserved | 396 | 0.48 | 72,008 | 46.08 |
| Farm and Others | 65,075 | 79.48 | 75,467 | 48.29 |
| Total | 82,259 | 100.00 | 156,281 | 100.00 |

AGRICULTURAL LAND USE

The Department of Agriculture was established in the 1920s. There was a general lack of knowledge as to the approach to the problems of tropical agriculture. Permanent cropping was considered desirable because it would reduce pressure on available lands. There was need for experimentation. The approach which was formalized in the critically affected areas in the northern savannas after World War II was known as land planning.10/ It consisted of defining land planning areas on the basis of the extent of loss of vegetal cover, soil erosion, reduced productivity and population pressure. Plans were made by the district officers of the departments of agriculture, forestry and animal husbandry, together with representatives of the local people. Planning provided for reforestation of denuded areas, improvements of community grazing lands, the use of animal traction, small dams to provide water for watering livestock and for irrigation, soil erosion control measure such as contour plowing, strip cropping, and improved cropping practices such as crop rotation and manuring. During the period 1950-1960, the approach was well developed and appeared effective.11/ Seven areas were planned in this manner (See Figure 3). The Soil Erosion and Land Planning Ordinance, 1953, (amended in 1957) provided the legal framework for land planning in all the ecological zones of the country. No land planning areas had been delimited in the forest and coastal savanna zones when planning came to an abrupt end soon after independence in 1960.12/

Even though forestry management in the form of afforestation and reforestation programmes have continued through this century, the discontinuation of the land planning initiatives prevented the opportunity to work directly with the people to improve agricultural land use and to reduce the pressure on forests and savannas. 13/ Degradation and the desertification hazard has seldom been controlled. Several programmes and projects have been initiated since the late 1970s. These include the regional projects, the Upper Regional Agricultural Development Project (URADEP), The Northern Regional Rural Integrated Development Project (NORRIP) and the Small Holder Rehabilitation Programme funded by IFAD and commonly referred to as IFAD. These programmes and projects have the objective of improving the socio-economic infrastructure in areas such as health, education, water supply, transportation and markets with the expectation that the improved social and economic conditions of the people will enhance their ability to protect the land resources and the environment. The UNESCO Collaborative Integrated Project on the Savanna Ecosystems of Ghana (UNESCO-CIPSEG) within the Man and Biosphere (MAB) programme is currently developing an approach that is based on the traditional concept of the sacred grove, an area of original vegetation protected from normal use through local taboos and norms. These will be managed along with the community lands on the model of the Biosphere Reserve system building on the experiences and the traditional values of the people.14/ The Land Management component of the Ghana Environmental Resource Management Project is also developing a pilot phase of a community land planning approach that is similar to the land planning approach of the 1950s. It is within this general developmental context that the Ghana Environmental Protection Agency has established a Desertification Control Unit which seeks to coordinate and support the educational and awareness programmes to control desertification.

USE OF HIGH RESOLUTION SATELLITE IMAGES

The limited success in the control of land degradation and desertification may be attributed to a number of factors which include the lack of data relating to the spatial and the temporal dimensions of the problem.

The use of spatial data for the analysis of the threat of desertification is acknowledged.15/ High resolution satellite remote sensing data is suitable for the collection of spatial data for broad planning and monitoring. The possibilities of assessing the spatial and the temporal dimensions of the problem of desertification are particularly enhanced.

The first application of high resolution satellite data in Ghana was in 1979 when Tippets-Abbett-McCarthy-Stratton (TAMS) and the Earth Satellite Corporation interpreted Landsat multi-spectral images to produce land use and land cover maps in a Landsat related study for the regional planning of the onchocerciasis-free areas of northern Ghana and the adjoining areas of Burkina Faso (See Figure 4).16/ The maps were produced at the scale of 1:250,000. Ancillary information from ground survey and aerial photograph sources on soils and topography were also used. The maps provide valuable base information for monitoring cover and land use changes. SRT-XS data was used by the Department of Geography and Resource Department in 1993 to assess land use and cover conditions in a part of area covered by the Landsat study. It was observed that the spatial distribution of land use and cover in the area of the present Upper East Region have not changed except the development of a medium scale dam for the cultivation of irrigated crops (See Figure 5). Cover conditions may have deteriorated and surface processes of sheet and gully erosion intensified in many localities. Detailed analysis of two 10 x 10 km sites in the Bongo and Zebilla areas suggested that the proportion of land surface without vegetal cover at the beginning of the dry season in November was rather high in local areas, approximately 12-25 per cent The proportions will be expected to be much higher at the end of the dry season when the rains start with adverse implications for the soils stability.

## CURRENT APPLICATIONS

The most extensive use of high resolution satellite data in Ghana is currently taking place within the Remote Sensing Applications Unit (RSAU) of the Department of Geography, University of Ghana, to map current land use and cover for the country. The Project is using satellite image data to map land use at the scale of 1:250,000 as part of the Environmental Information Systems Development component of the Ghana Environmental Resources Management Project (GERMP). The GERMP is part of the implementation of the Environmental Action Plan prepared by the Ghana Environmental Protection Agency during the period 1986 to 1990 and adopted by the government in 1991. The other sets of data to be produced include topography, meteorology, soil suitability and land ownership. These data sets are expected to be available by 1997 and will be organized into an environmental database that will be developed and shared in an environmental information systems network.

## STATUS OF MAPPING

### Materials and Methodology development

A country cover of Landsat TM images of Ghana covering the period 1990-1992 have been acquired for the planned mapping. These have been geometrically corrected and two sets of 24 one degree image maps have been prepared from a seamed coverage of the country. The band combinations used for the four composites were 4,5,3 (RGB). This was considered the most useful combination for the time of the images when widespread haze was present. Vegetation conditions are well indicated. The original TM scenes, radiometric and geometric images on exabytes and film negatives are also available.

It is generally believed that digital mapping for land use under tropical conditions is unreliable due to the practice of bush fallowing, mixed cropping and the small size of the average farm plot. The methodology proposed for the present mapping is on screen digitization of class boundaries using the ERDAS imaging software. The boundaries file will be converted into a vector file using the Arc Info software to obtain a compatible format with the digital topographic base maps that are being prepared by the Ghana Survey Department.

We have found it necessary to undertake field interpretation of the images prior to mapping. The methodology developed for the field interpretation involves:

a) The visual identification of the surface cover types on selected image sheets using tonal and textural variations in the spectral responses in the selected bands 4,5,3 (RGB) and using the light table;

b) Reconnaissance field visits to interpret the tonal classes for cover and land use;
c) Assignment of land use and cover class and code according to the proposed classification scheme;
d) Class boundary mapping in the laboratory;
e) Field characterization using walking transects and field observations including:
   i) vegetation
   ii) land use
   iii) surface conditions
f) Digitization of the boundaries on screen.

The methodology is being used for the mapping of three sheets in the present phase of work, which will take place between March and June 1995, and which is regarded as a training phase. Full-scale mapping is expected to begin in July 1995 with three teams after the proposed classification and the methodology have been discussed in a workshop. Mapping is expected to be completed in 1997.

Classification

A four-level hierarchical classification has been proposed.17/ It takes into consideration a classification scheme developed in the 1950s.18/ The proposed scheme has gone through a number of revisions since September 1994. It is likely to be further improved as work progresses.

One of the factors which was taken into consideration in drawing the scheme was the fact that there are three major ecological zones in the country with differences in agricultural and other land use conditions: the coastal savannas, the high forest and the northern savannas. The four levels of classification envisaged are as follows:

Level I: Principal landscape cover comprising agricultural crop lands, forest lands, savanna lands, built up areas, paved surfaces, bare surfaces, water bodies and wetlands.

Level II: Cropping, or the subtype of main cover eg natural forest, plantation savanna woodland.

Level III: Ecological zone character of main use or subtype of main cover i.e. high forest, interior savanna, coastal savanna.

Level IV: Utilization type or product eg. oil palm cultivation, cassava, timber production.

Present mapping is to be done mainly at level II.

Outputs and Relevance

The expected outputs of the mapping will be:

a) a set of current land use maps of Ghana at the scale of 1 :250 000;
b) current land use statistics for national, regional and subregional areas; and
c) accompanying bulletins for each of the 24 map sheets indicating the environment and land use conditions of the sheet areas.

These will form an important part of data sets required for the development of an Environmental Information System for the planning and monitoring of the environment and resources. The Desertification Control Unit within the EPA will be expected to use the maps to assess the medium and longer term effects of the many environmental and land use improvement programmes and projects currently being undertaken in all the ecological zones of the country but particularly in the northern savannas.

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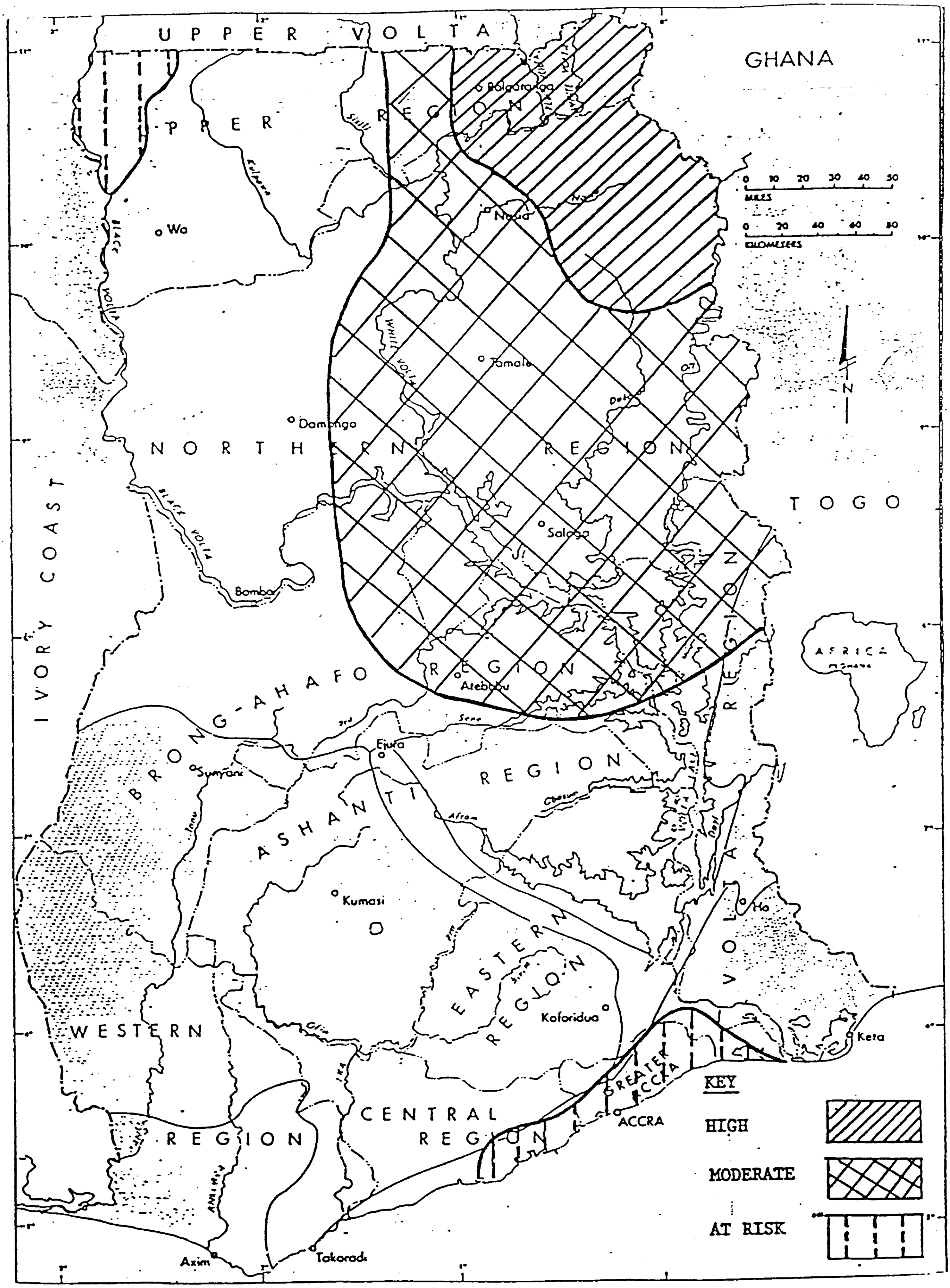



Fig 1: A generalised map of desertification hazard in Ghana.

Source: UNSO, 1986.

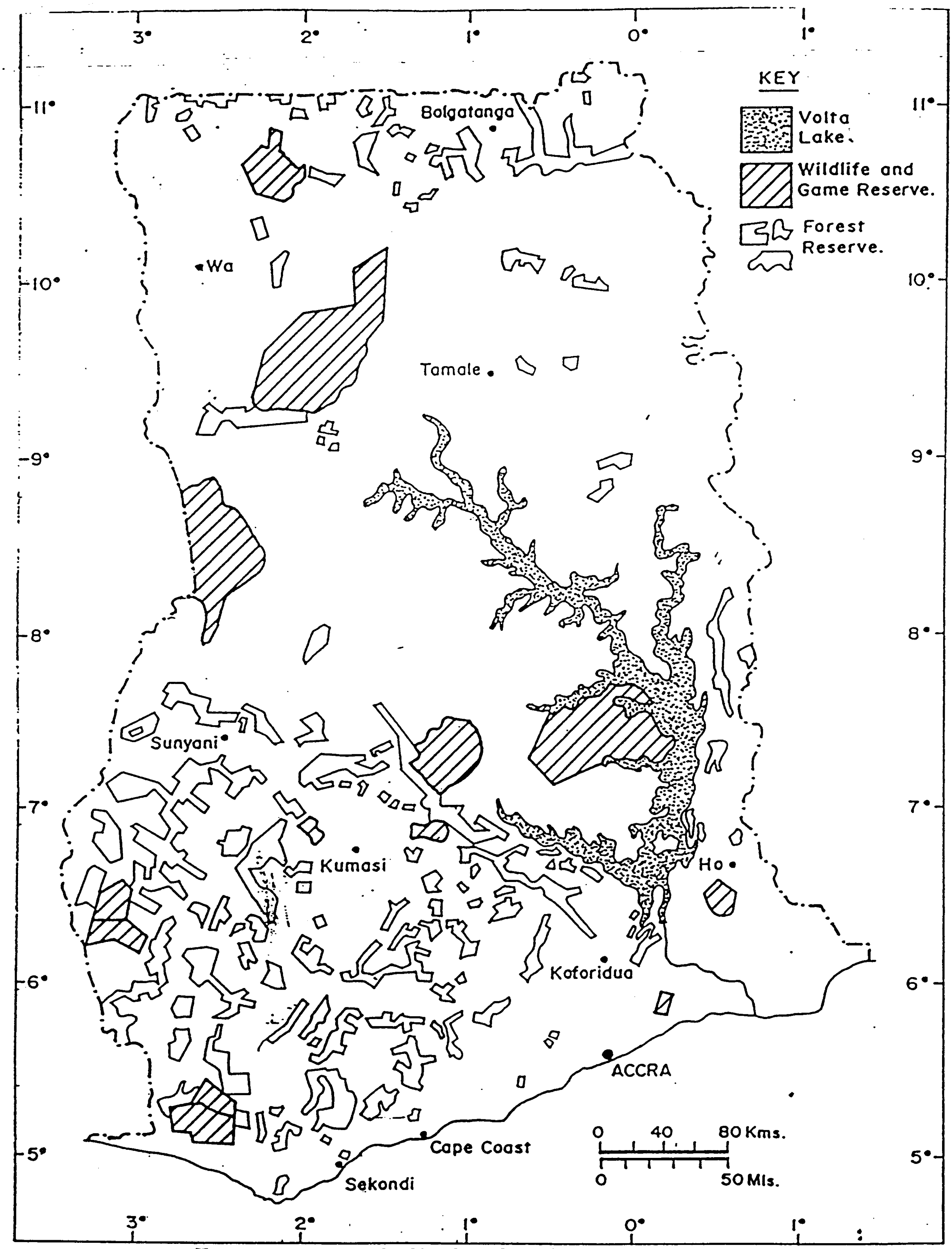



Fig 2: Forest, wildlife and game reserves.

Source: Benneh and Agyepong 1990

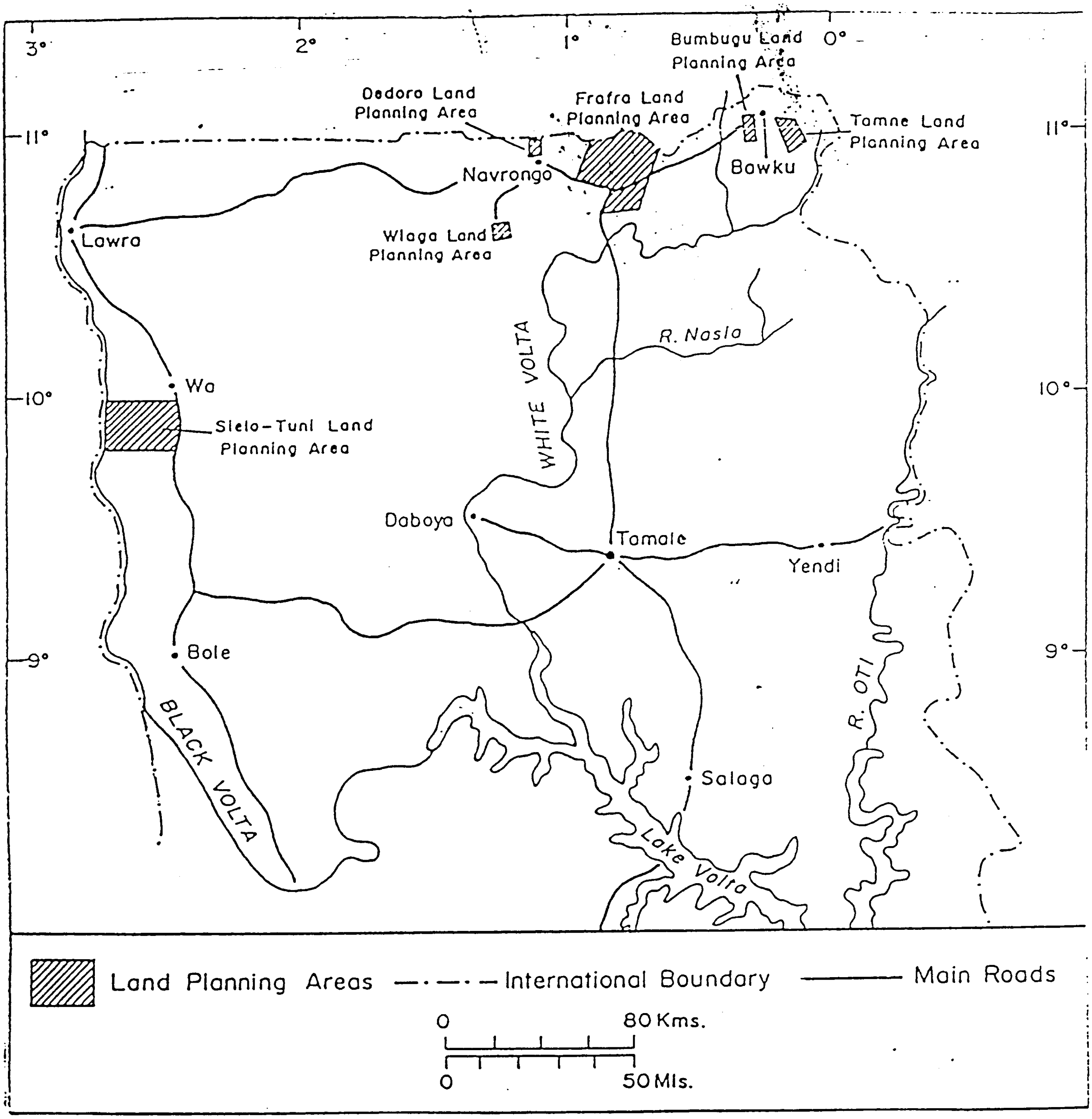
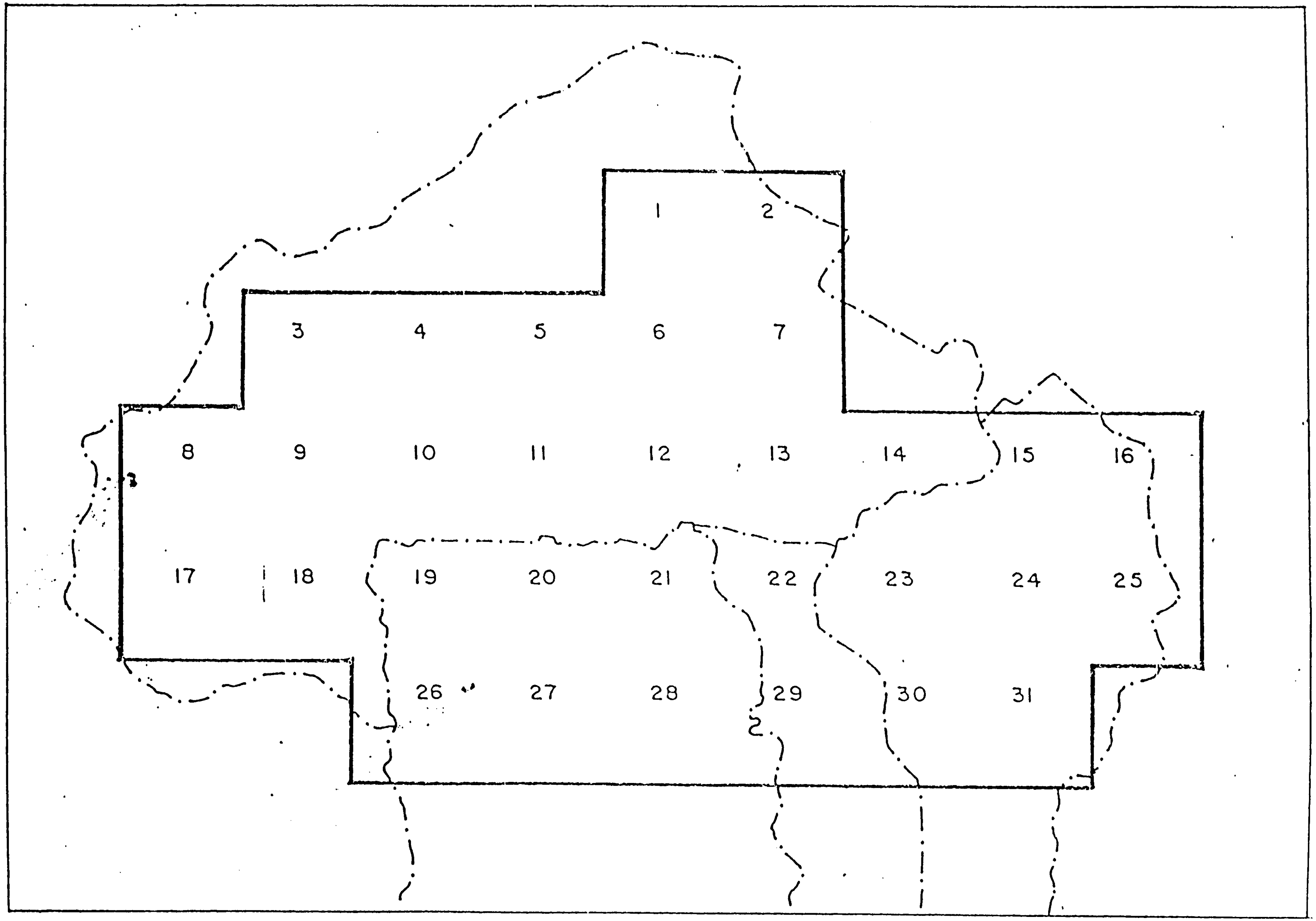


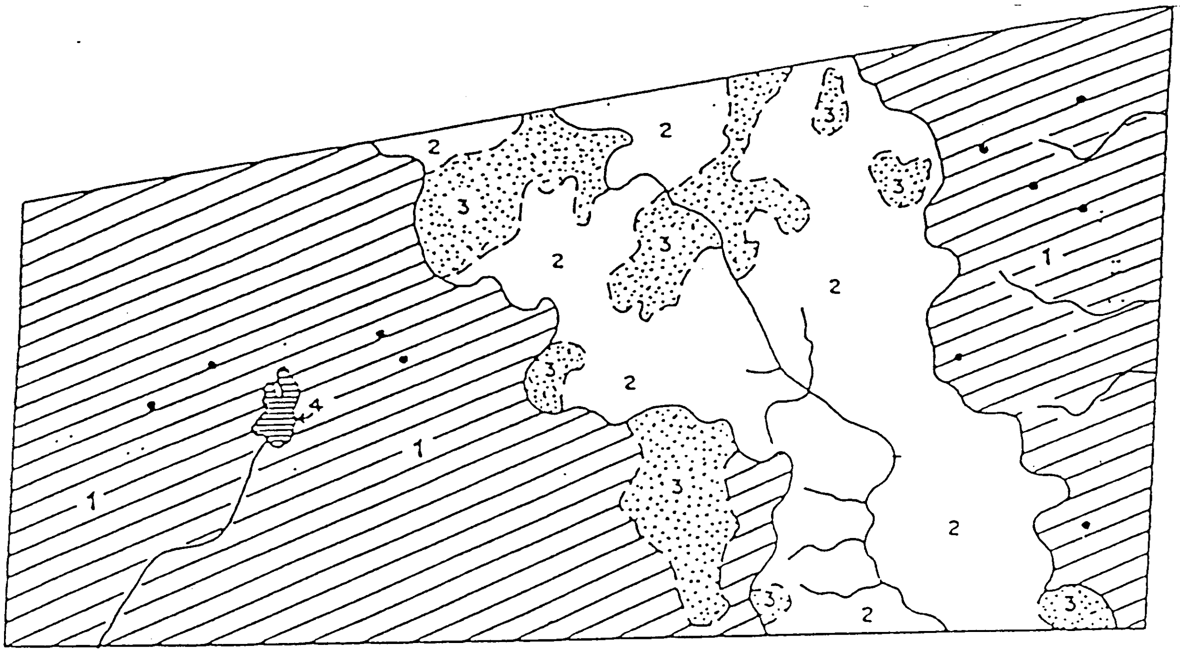

Fig 3: Land planning areas in northern Ghana (1957)

Source: Hilton, 1959.

Fig. 4. THE ONCHOCERCIASIS-FREE STUDY AREA USING SATELLITE IMAGE DATA




Source: USAID/ADB 1979



1:400000

LEGEND

1. Farm land with little woody cover up to 35% bare soil and rocky surface.

2. Heavily degraded forest reserved (Red Volta) with irregular mainly undefined boundary.

3. Burn scars confined to forest reserved and its margins (Nov).

4. Vea dam and reservoir

Rivers and streams.

• Small dam and dug-out sites

Fig 5: Land use and cover interprretation of the Upper East Region, using satellite images SPOT XS FCC.

Source: DGDR, 1993.

# REFUGEE MONITORING WITH HIGH-RESOLUTION SATELLITE SENSORS*

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## INTRODUCTION

Over the past decade the world has experienced several large catastrophes where thousands of people have died, such as in Somalia and Rwanda. As the population in developing countries is rapidly increasing, often amplifying well established cultural, economical and political disagreements, the chance of such horrifying disasters to happen again is unfortunately still present. The situation seen in Rwanda might be a vision of the highly complex disasters likely to occur in the future, e.g. French soldiers moved into Rwanda to establish a safe zone for 800,000 fleeing people. They unloaded 11,000 tonnes of humanitarian aid, performed 75,000 first aid treatments and 700 operations.1/

Because of the increasing scale and frequency of such emergencies, a continuous search for more effective methods to respond is necessary. This project intends to investigate one such method, i.e. the possibilities for use of high-resolution (< 4 m) images for refugee monitoring. The project will use existing technology and communication lines, as well as already initiated satellite programmes as a base for logistic support.

In order to provide objective and accurate information in the planning phase of relief operations, high-resolution satellite imagery (HRSI) can be a very valuable tool. The images can be used to monitor refugee movements and where camps are being established, thus rapidly providing information on the magnitude of the emergency, e.g. the number of people involved, which is especially valuable in the early phases of an operation. Experience shows that estimates on the number of fleeing people involved during the first phase of a catastrophe tend to vary considerably among national and international agencies. Remotely sensed images, combined with experiences from previous operations, can provide a better overview of what is needed in terms of medical and logistical support. Once the camps are established, continuous monitoring will help estimate the number of people there, their location and the areal extent of the camps. From this, relief organizations can get updates on important parameters in order to handle the situation as effectively as possible. Day-to-day observations will give important information on the growth rate of the camps and thus help in the further planning and implementation of the relief work.

## OBJECTIVES AND BENEFITS

The main objective of this research project is to use HRSI to obtain estimates of refugee

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* This paper, which was presented at the United Nations/ESA Workshop on "Application of Space Techniques to Prevent and Combat Natural Disasters," held at Harare, Zimbabwe, 22-26 May 1995, does not necessarily reflect the views of the United Nations.

camp: population (P); area (A); and growth rates, $dP/dt$ and $dA/dt$.

This information, as well as detailed road maps from the HRSI should be linked to Geographical Information Systems (GIS) in order to further clarify the expected complexities of future catastrophes.

The benefits of succeeding with the above objectives would he improved efficiency in all phases of relief work, especially in the important early stages of an operation. A more subtle way of using this information is the possible deterrent effect it would have on people who plan mass-killings of refugees within the camps. If these people know they are being monitored from space, they may reconsider their plans, since such monitoring can improve the chances of providing evidence against hose responsible for such crimes. If mass-killings should occur, HRSI could help determine the extent of the tragedy in an objective way. A deterrent effect will also be valuable for the protection of relief personnel working in the camps.

STATE-OF-THE-ART

The high resolution satellite sensor with the best resolution available on a commercial basis today is the KVR-1000 with its 2 m panchromatic (black and white) ground resolution. This instrument is flown on Russia's Kosmos satellite series. The sensor was originally developed for intelligence purposes, but the images available on the open market have been degraded to 2 m ground resolution. In other words, "spy" satellites can obtain images with a much finer resolution. Archived data are available back to 1984, providing the possibility of case studies from previous disasters. At present, Russia is the only supplier of such high resolution images. Unfortunately there have been incoherences related to Russia's sale of these images because of conflicts between intelligence and commerce.2/

Since the United States government in 1988 removed its restrictions on the spatial resolution from United States commercial satellites, several companies have obtained licenses and made detailed plans on building and launching high resolution satellite sensors.

WorldView Imaging Corporation was the first company to get such a license. The WorldView sensor is scheduled for launch in late 1995 and will provide panchromatic images with 3 m ground resolution. Its revisit period will be 4.75 days at equatorial latitudes. In 1994, the Clinton administration announced a new policy, designed to encourage development and employment of high-resolution satellites and the sale of the acquired data. Since then, two more licenses have been granted. Eyeglass International and Space Imaging both plan to deploy advanced high-resolution satellites. The Eyeglass satellite, a spin-off of the United States remote sensing intelligence community, will deliver 1 m resolution panchromatic images. Its revisit period at equatorial latitudes is two days. This satellite will deliver data from mid-1997. The Space Imaging Satellite (SIS) is scheduled for launch in early 1997 and will deliver panchromatic images of 1 m resolution and multi-spectral images (visible and near infrared channels) at 4 m resolution. The revisit period is also two days.

Greensat is a South African project originally designed for military surveillance purposes, but due to the political changes in South Africa and the former Soviet Union, the project had its government support cut and was converted to a commercial programme. Two different satellite types are planned within this project. GS-01 will fly on the first Greensat, scheduled for lift-off in late 1995. Its high-resolution camera will acquire panchromatic images with 1.8 m ground resolution with a revisit period of two days. Greensense, a constellation of Greensats, has a high-resolution camera with 2.5 m resolution, but this might be modified to provide ground resolution less than 1.5 m. Its revisit period is also two days. The first Greensense is planned for launch in late 1997. It should also be mentioned that France has entered the race with the Helios-1 satellite, providing images at approximately 1 m ground resolution. However, this satellite is primarily for intelligence purposes and the possibilities of acquiring images commercially are highly uncertain. Table 1 lists the mentioned parameters and the timetable for launch of the satellites.

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Table 1: Sensor Characteristics/Timetable for availability of HRSI

| Parameter | KVR-1000 | WorldView | Eyeglass | SIS | GS-101 | Greensense |
|---|---|---|---|---|---|---|
| Ground Resolution | 2m | 3 m | 1 m | 1 m | 1.8 m | ≤2.5 m |
| Revisit Period | -- | 4.75 days | 2 days | 2 days | 2 days | 2 days |
| Planned Launch | 1992 | 1995 | 1997 | 1997 | 1995 | 1997 |
| Operational Until | 2000 | 2000 | 2000 | 2000 | 2000 | ? |

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## DATA ACQUISITION AND DISTRIBUTION

In order to effectively use HRSI on an operational basis, the data distribution system must be fast.3/ Images should be analyzed and distributed to involved relief organizations within 24 hours after the satellite has passed in order to provide updated information.

Unfortunately this is not the situation at present. The KVR-1000 data have a 30-day delivery schedule. However, it should in general be possible to reduce such lags considerably by pre-ordering images for operational use over areas at risk.4/ Another factor is the uncertainties related to the conflict between the Russian intelligence community and the image distributors, Sovinformsputnik, on which images to release. Because of the fact that the sensor was originally planned for intelligence purposes, its data acquisition techniques are not known in detail. On the positive side, a large data bank of images acquired with the KVR-1000 already exists (1984 until the present), thus providing diverse images for case studies. The following figures are examples of images acquired with the KVR-1000. Figure-2 is a detail from Bangkok. The image clearly demonstrates the wide variety of features that can be observed with HRSI. Cars and buses are clearly visible on parking lots and bridges, as are the boat and ship wakes. Trees and streets can also easily be detected.

Figure-3 is a detail from the countryside in Oregon, United States. The enlarged image is a subset of the lower left area seen in the main frame. From the 2 m ground resolution of individual pixels, one can estimate the small road in the zoomed section to be 2-3 m wide. A house or storage building is also clearly seen in the enlarged area.

The image of a part of Princeton, New Jersey, United States in Figure-4, exposes a large amount of detail. A baseball ground and football stadium can be seen in the upper right of the image, and several parking lots with automobiles are also evident. The inset image is a close-up of the area just above the inset frame. Here one can see tennis courts with dark shadows in the middle. This can be the signature of a shadow from a net, or possibly from people on the courts. If e.g. a dark object on a light, uniform surface, as in this case, is less than 2x2 $m^2$, it can still be detected. The pixel in which the object is "within" will have lower intensity compared to the surrounding pixels, thereby distinguishing the signature from that individual pixel.

With such resolutions, it is possible to clearly identify tents and groups of people. The resolution is still too coarse to identify individuals. With knowledge on e.g. how many people are normally related to each tent, a rough estimate of the population can be made. Advanced image processing, e.g. edge enhancement, might also be used to determine the number of people in a crowd. The areal extent of the camps can be directly determined from investigating the HRSI. By continuous monitoring one can establish estimates on how fast the camp population and area is growing. It is important that thorough case studies be carried out in order to establish a data base on this kind of information.

The data distribution systems of the new commercial satellites, such as Greensat, WorldView, Eyeglass and SIS are expected to be significantly faster and much more reliable for commercial purposes, than that of KVR-1000. The system architectures will differ between these satellites, e.g. Greensense will rely on a large network of regional ground stations as it has no on board data storage. This limits the use of images to areas where the satellite is within view of the ground station. The WorldView system uses the on board data storage to save images acquired elsewhere and download these once within view of a compatible ground station.

An unfortunate trend is seen in the data distribution plan for Eyeglass, as the customer is being offered exclusive rights to images on a first-come first-serve basis. Two types of agreements are being offered: Gold and Platinum. With the Platinum agreement, a country can secure the right to monitor its neighbours, while its neighbours are denied access of images of the country possessing the Platinum agreement. The Gold agreement secures a country the right to image itself, while denying its neighbours these images. If such agreements become normal, several countries might find themselves paying off satellite companies in order to deny neighbours the chance of imaging them. It could be difficult to get access to HRSI for relief work if this policy become common. It is therefore important that the United Nations, e.g. the Office for Outer Space Affairs (OOSA), plays an active role in forming such policies.

## IMPLEMENTATION

When case studies of HRSI related to refugee relief operations have been carried out, and if this information proves valuable for relief agencies, the operational work should be strongly linked to the United Nations. The United Nations has well established communication lines to relief agencies and long experience in administrating relief operations. An operational monitoring group could e.g. be linked to the Military and Civil Defence Assets (MCDA) in disaster relief. This is a project within the United Nations Department of Humanitarian Affairs emergency response system. The aim of the project is to increase both the volume and the efficiency of the international community's contribution to humanitarian operations and to further develop and disseminate facilitation procedures designed to avoid time-consuming delays in getting appropriate relief to the scene of the emergency throughout the world.5/

The MCDA project is also developing a data bank in which HRSI information related to relief operations could be stored. According to MCDA's Plan of Action, major annual field exercises will take place in the coming years.6/ Kenya might host such an exercise in 1995. These exercises could be very valuable for HRSI verification operations.

Information based on HRSI could also through e.g. the UNHCR be provided to the International Refugee Electronic Network (IRENE) and the Global Early Warning System (GEWS) for Displaced Persons.7/

The formation of a policy for HRSI refugee monitoring should be done in close cooperation with the United Nations OOSA and the remote sensing obligation principles it has developed. Special care should be taken as to the legal status of the "sensed" country's right to access images taken over its own territory. If imaged states should be allowed access to HRSI acquired by others for e.g. refugee monitoring, these data could be used to limit the effectiveness of, and further complicate, relief operations.

## CONCLUSIONS

Important information related to refugee monitoring, such as camp population, area and growth, can be extracted from HRSI. Case studies will clarify how accurate this information can be determined and how valuable it will be in relief-operations. Today's highest resolution sensor, the KVR-1000, can directly detect objects of 2x2 $m^2$. In the near future, sensors with resolution down to 1 m will be available on a commercial basis. The data distribution systems of these satellites will be vastly improved compared to that of the KVR-1000. If the use of HRSI proves valuable in relief work, the operation of such a monitoring system should be administered by the United Nations.

NOTES

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5. United Nations Department of Humanitarian Affairs, "MCDA project: An innovative tool in DHA's emergency response system," Military and Civil Defence Assets in Disaster Relief, DPR 213/3 MCDA, Geneva, 1994.

6. ibid.

7. Onishi, A. "Global model simulation: A new frontier of economics and systems science," Technical Report, Soka University, Institute for Systems Science, 1994.

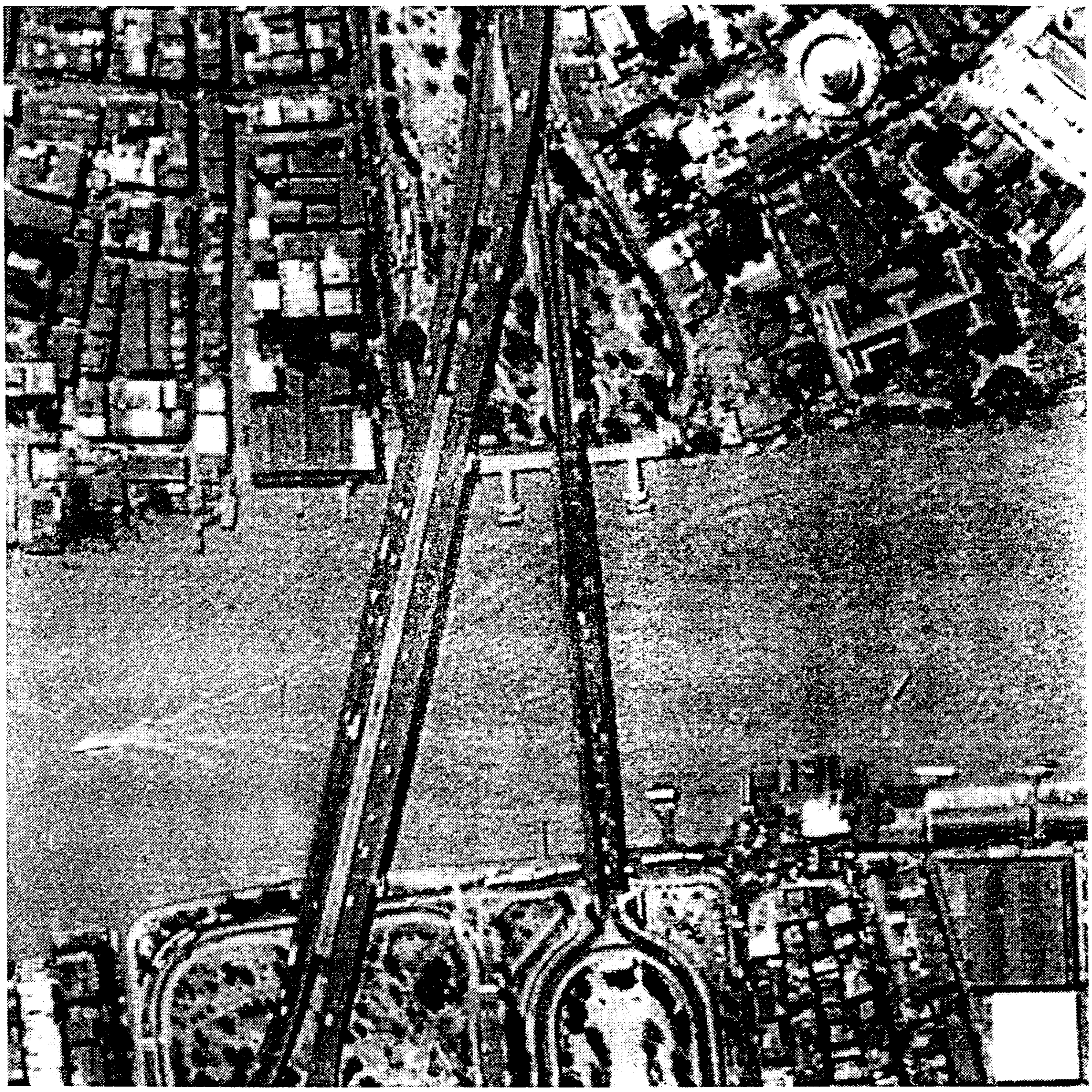

Figure 2: Detail from Bangkok. KVR-1000 sensor, 2 m ground resolution. Image courtesy by C.E.N. Digital Satellite Images.


Figure 3: Oregon countryside. KVR-1000 sensor. 2 m ground resolution. Image courtesy by C.E.N. Digital Satellite Images.


Figure 4: Detail from Princton. KVR-1000 sensor, 2 m ground resolution. Image courtesy by C.E.N. Digital Satellite Images.

# PRODUCTION OF SATELLITE IMAGES BASED ON SPOT DATA*

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## INTRODUCTION

The participation by Sweden in the SPOT programme resulted in the establishment of Satimage. Being one of the two main receiving stations for SPOT data, the Kiruna site now receives and archives more than 100,000 scenes a year. Satimage is the distributor of standard products for Scandinavia, while derived products are offered to the world market.

The importance of geocoding was realized early in the development process and the installation of a system for precise correction of both SPOT and Landsat images was finalized in 1987. Two other factors, the development of a digital method for stereo image compilation by the Swedish Space Corporation, and the establishment of a cartographic development unit in Kiruna by the Natural Land Survey of Sweden, led to the decision to develop full topographic mapping capabilities in Kiruna. The separate units of this system are now operational. After an integration phase, production is expected to start during the first half of 1998. The maps will be marketed under the name TOPSAT.

This paper briefly describes the production process and methodology used.

## PLANNING AND DATA ACQUISITION

In the planning of a mapping project, specifications for coverage, recording period, and viewing angle limitations must be established.

In a project involving the production of digital elevation models (DEM), stereo coverage has to be planned with viewing angles large enough to obtain the specified accuracy in elevation.

For planimetric mapping using mono-images, viewing angles should be kept low to avoid terrain displacement errors.

However, for map revisions where a DEM is already available, full flexibility is allowed for viewing angles, resulting in a shorter timeframe for covering the mapping area with good images.

The data received is preprocessed to computer compatible tapes in the CRIS system at Satimage or CNES. Normally, completely raw data are used for further processing, but level 1A data may also be used.

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* This paper, which was presented at the Fifth United Nations/Sweden International Training Course on "Remote Sensing for Educators," held at Stockholm from 1 May to 9 June 1995, does not necessarily reflect the views of the United Nations.

## RADIOMETRIC CORRECTION

The raw SPOT data is transferred to computer diskette for further processing in the Satimage precision correction system. The radiometric correction comprises both a gain/bias replacement and, optionally, convolution filtering.

The gains and biases applied are the same as those applied on standard level 1A data. The intermediate, radiometrically corrected scenes can then be stored with 16-bit resolution, thus avoiding any loss of accuracy due to truncation before resampling.

Filtering is presently used to decrease striping noise, taking advantage of the regularity of the noise in the still geometrically raw data. If the use of a deconvolution kernel is introduced in the standard level 1A data to correct for blurring caused by the instrument transfer function, it can also be applied at this stage.

## GEODETIC ADJUSTMENT

The geometric relation between the pixels in the SPOT scene and the ground coordinate system is determined by the use of ground control points. Well defined points in the SPOT scene are marked to sub-pixel accuracy on a TV monitor, and their corresponding XYZ-coordinates are digitized from maps, or acquired by ground measurements (e.g. GPS). The measurements thus made are used to calculate updated satellite ephemeris and attitude parameters. The location of the raw pixels can then be calculated in any desired output projection.

Chip correlation can be used as an alternative to ground control point marking as described above. Chips are small image sections, 32 x 32 pixels large, covering distinctive features in an image. The chips have been assigned ground coordinates from maps, or from the coordinate system of a previously corrected image. The manual marking can thus be replaced by an automatic correlation process.

## RESAMPLING

The production of the image in the selected output map projection is done in the resampling process.

The mapping parameters determined in the geodetic adjustment, together with framing information, are used to calculate the resampling coefficients. Cubic convolution resampling kernels are normally used for interpolation, but when producing an output pixel size larger than that of the input, a special integration kernel is used.

If a DEM is available, it may be introduced in the resampling process to eliminate terrain displacements due to oblique viewing angle. The DEM is first resampled to the output space, and a terrain displacement vector is calculated for each output space pixel. When not using a DEM, the image is projected down to the ellipsoid. The terrain displacements are then still present, allowing for parallax measurements in stereo imagery.

## DEM EXTRACTION AND ORTHO-IMAGE PRODUCTION

The DEM extraction uses precision corrected stereo imagery, projected down to the ellipsoid. The parallax measurement process is digital, and fully automated. It is based on least squares matching at the nodes of bi-linear finite elements. High reliability is achieved by imposing constraints on elevation smoothness, and through gross error rejection by data snooping.1/ A DEM grid selected spacing is calculated over the overlap area. This is used to produce an elevation image and elevation contours.

Ortho-images are produced in the DEM extraction process. The extracted DEM may also be used to produce ortho-images from other scenes during their resampling.

## MISTAKING AND MAP SHEET SECTIONING

When the mapping area has been covered by ortho-images, they need to be mosaicked together before they can be sectioned into the final map sheet layout.

Mistaking starts with radiometric matching of the different images. This can be done interactively by an operator, using look-up table modifying routines, or by an automatic procedure for matching image histograms to a reference image histogram in overlap areas.

A polygon is then drawn to define what part of a new image that is to be merged into the mosaic. This polygon may become quite irregular, in the attempt to avoid clouds and uniform areas. The mistaking operation is not done by a sharp cut, but by allowing for a blended region of selected width. The new image is thus gradually blended into the mosaic, making the seam practically invisible.

## INTERPRETATION AND PRODUCTION OF CARTOGRAPHIC OVERLAYS.

The interpretation is done by photo interpreters on full scale photographic enlargements. These are produced from the digital ortho-images by using a precision film recorder.

The interpretation results in thematic overlays on films. These are then transferred to a Scitex system by the use of a scanning device. The Scitex production system has software for cartographic applications, handling both vector and raster data. Cartographic processing is performed and this involves creating patterns and symbols for different finds of land cover, roads, etc. The processed overlays can finally by reproduced on film by a raster plotter.

## FINAL MAP PRODUCTION

The final map can be produced either by offset printing, or as photographic copies. For printing, the ortho-image is transferred to the Scitex system where it is composed with the cartographic overlays and elevation contours, finally to be turned out as ready printing originals.

For photo copying, the ortho-image is reproduced on a precision film recorder. Cartographic overlays and elevation contours are reproduced on separate films, and finally copied into the ortho-image.

## ACCURACY ACHIEVED

The planimetric accuracy achieved by the precision correction of SPOT panchromatic imagery is difficult to measure, because it will often be of the same magnitude as that of the maps to which it is evaluated, making it difficult to distinguish between map and image errors.

Using Swedish 1:10,000 scale maps for control points, rms residuals of 4-7 m are normally achieved. When comparing the final resampled image with the map, its rms error is about the same as the adjustment residual rms, if a DEM of good enough accuracy was used in the resampling. When not using a DEM, terrain displacement errors are added, with a magnitude depending on viewing angle and topography.

Image-to-image registration using chip correlation was tested using two panchromatic SPOT scenes. They were acquired on different days, but from the same viewing angle to minimize influence from terrain displacement errors. After adjustment and resampling, the images were compared by correlating 26 well distributed check-point chips. The overall rms difference was found to be 2.1 m.

The accuracy in elevation, achieved by the stereo image matching process, is dependent on such factors as viewing angle (base to height ratio), time between registrations and type of land cover. Normally, it will range between 5 and 15 m.

## CONCLUSION

The accuracies achieved in the correction of SPOT imagery clearly demonstrates its potential for topographic mapping at the scale 1:50,000 and smaller. The development of fast systems for satellite image processing, coupled with easy access to imagery from all over the world by the SPOT system, make map production from satellite imagery very competitive when compared to conventional mapping techniques. As much of the world still remains to be mapped at these scales, the next few years will most certainly see a rapid increase in topographical mapping from SPOT imagery.

## NOTES

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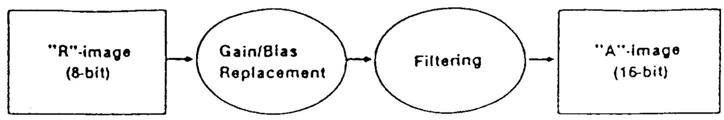


Fig. 1. Radiometric correction process.

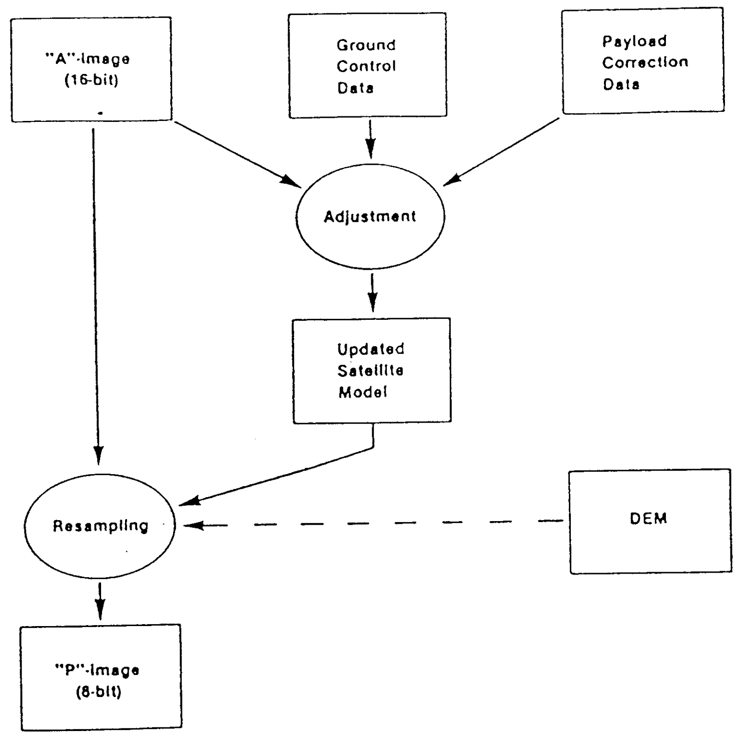


Fig. 2. Geometric correction process.

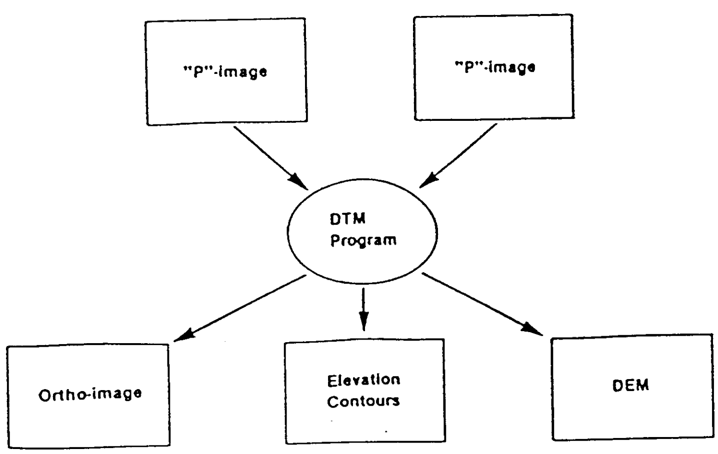


Fig. 3. Stereo-compilation process.

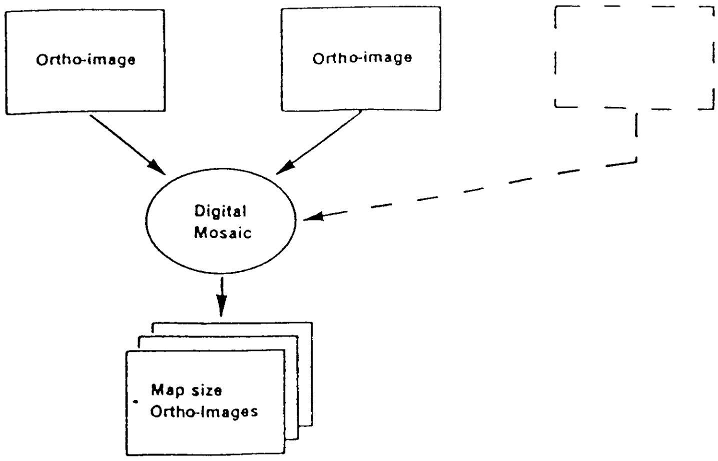


Fig. 4. Mosaicing.

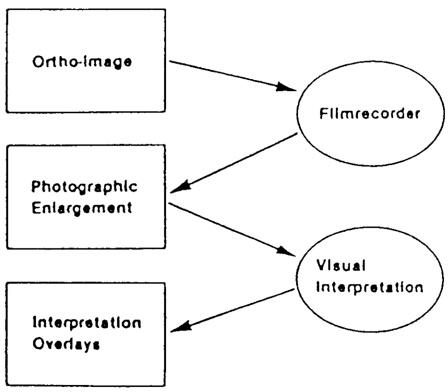


Fig. 5. Interpretatión process.

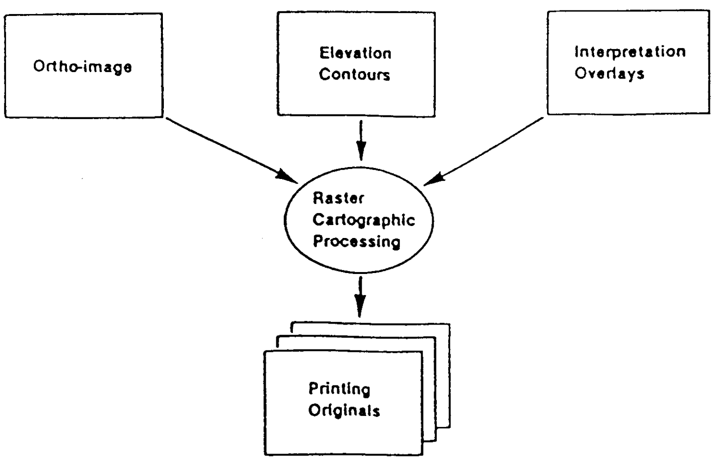


Fig. 6. Map compilation process

# PLANNING AND MANAGING REMOTE SENSING BASED PROJECTS AT THE VILLAGE LEVEL - A CASE STUDY OF ANANTAPUR DISTRICT, ANDHRA PRADESH, INDIA*

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## INTRODUCTION

Anantapur district, which is in the southwestern corner of Andhra Pradesh State, covers an area of 19,135 sq. km and has population of 31,83,814. The population density is 166 persons per square kilometre compared to an average of 242 persons/sq. km in other Indian states. The district has 964 villages falling under 63 mandals (administrative divisions). Out of the total population, 76.5 per cent are in rural areas and 15.4 per cent are cultivators, 17 per cent are agricultural labourers and 54 per cent are non-workers. Out of the cultivators, 41 per cent are small farmers, 49 per cent are marginal farmers and only 10 per cent are large farmers. The district has 42 per cent literacy rate and the decennial population growth rate is 24.95 per cent.

The State forms part of the northern extremity of the Bangalore plateau and slopes from south to north. The district lying off the coast does not enjoy the full benefit of the north-east monsoon and, rain from the south-west monsoon is also limited because the region is cut off by the high Western Ghat mountains. The region is thus subjected to recurring drought. The average precipitation in the district is 516 mm per annum spread over four seasons. Rainfall decreases from east to west with about 700 mm to about 250 mm. The rainfall is not only minimal, but erratic in nature. There were severe droughts in 1896-97, 1900, 1901, 1924, 1925, 1934-35 and 1941-42. The analysis of rainfall data for the last 100 years reveals that out of the last 10 decades, seven have been drought affected decades and in the last 10 years, six were rainfall deficient resulting in severe drought conditions. The district is devoid of significant perennial surface water resources and hence only 7.89 per cent of the geographical area is irrigated. Nearly 55 per cent of the irrigated area is under wells. The district is predominantly occupied by hard rocks, hence ground water potential is also limited. The terrain is undulating, resulting in a high run-off and contributing to active erosion of the top layer of soil. Evapotranspiration is also high due to the region's semi-arid climate, high temperature and high wind velocity.

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* This paper, which was presented at the United Nations/ESA Symposium on "Space Technology for Improving Life on Earth," held at Graz, Austria, 11-14 September 1995, does not necessarily reflect the views of the United Nations.

Because the bulk of the population is dependent on agriculture, the net sown area is about 69 per cent of the State's geographical area despite the incessant drought conditions. The major crop is groundnut, which is cultivated under rainfed conditions. The average yield of the crop is 689 kg./hectare compared to the State average of 867 kg./hectare. After the crop is harvested, the land is left fallow and that results in the absence of work for many of the landless poor and agriculture labourers.

The perpetual occurrence of drought has left the district with vast stretches of barren rocky areas or degraded soils with very poor crop yields. Soil erosion has become a major problem which in turn has caused many irrigation tanks to silt up. Thus, the meager surface water storage available is also decreasing. Sustaining the rainfed agriculture is also becoming a herculean task. The decreasing availability of surface water has kept the pressure on ground water and over exploitation of the limited resource has become a common practice. This has resulted in the decline of water levels and most of the dug wells which tap weathered and fractured parts of the hard rock to an average maximum depth of 20-25 m have now gone dry. The forested areas which supported elephants at the beginning of the century are now devoid of any major vegetation cover.

INTEGRATED MISSION FOR SUSTAINABLE DEVELOPMENT (IMSD)

The Indian Government Department of Space has sponsored the Integrated Mission for Sustainable Development (IMSD) project. The project is co-sponsored by the Government of Andhra Pradesh (A.P.) State. The A.P. State Remote Sensing Applications Centre (APSRAC) has carried out the study in order to find a scientific and lasting solution to mitigate recurring droughts at the micro (village) level.

The goal of the IMSD project is to generate natural resource information and prepare action plans for development of the terrain on a sustainable basis, thereby ensuring its productivity and maintaining the quality of the environment. A detailed data base on natural resource, terrain conditions, socio-economic status and demography is a prerequisite for preparing such action plans. Keeping in view the concept of sustainability, it is particularly important that the data bases are presented in the form of maps to facilitate spatial analysis.

The methodology of the study involves generation of thematic maps showing current land use/land cover, types of wastelands, forest cover/types, surface water resources, drainage pattern, potential ground water zones, landforms (geomorphology), geology (rock types, structural features, mineral occurrence), soil types, etc., using data from Indian Remote Sensing (IRS) satellites. The map showing slope/aspect is prepared using topographic contour information and meteorological data (rainfall intensity, distribution, etc.) are collected from existing data bases. By integrating the above thematic layers using GIS techniques, derivative maps called Basic Integrated Land and Water Resource Units (BILWRU) showing resource availability of individual land parcels, land characteristics, status of soil erosion, priority watersheds needing immediate treatment, etc., are prepared. These maps are validated through adequate field checks and by using authentic existing information on various aspects. Socio-cultural, socio-economic and demographic information are gathered from existing data bases and through selective field surveys. Specific developmental plans for these units are arrived at in consultation and close coordination between space scientists, experts from various Central/State developmental departments, agricultural universities/research institutions, district level officials and local farmers and villagers, so as to ensure the technical feasibility and cultural acceptability of such action plans.

Based on the BILWRUs and keeping in view the present day cropping patterns and the needs of the people, Recommended Optimal Land Use and Farming Systems (ROLUFS) were developed in consultation with various scientists of Indian agricultural institutions.

Keeping in view the severe drought situation and paucity of water resources, site specific drought proofing works such as optimal *in situ* soil and moisture conservation measures such as rain water harvesting structures, soil and moisture conservation measures, fodder, fuel wood and permanent tree cover development zones, etc., were recommended.

## THE NATURAL RESOURCES OF ANANTAPUR DISTRICT

Detailed natural resources mapping on a 1:50,000 scale has been taken up using satellite remote sensing data of the IRS-1A satellite (Plate-1A). Information such as rainfall, socio-economic data, etc., which can not be collected via remote sensing, is collected through conventional techniques.

### Rainfall

The rainfall of the district has been analyzed for the last 100 years and the average rainfall is observed to be higher than the current average annual rainfall as it is taking into account very good rainfall periods from earlier in the century. Hence, the rainfall pattern of the last 30 years has been analyzed and it has been observed that there has been a steady decline in rainfall (See Figure 1). It is very clear from Figure 1 that out of the last 34 years, 17 years have had below normal levels of rain. There are years such as 1984, 1985, and 1986, where there was no monsoon. However, it has also been observed that there have only been several years in which the district received very good rainfall (near the 800 mm level). In 1989, the district experienced unprecedented rainfall and runoff which resulted in flash floods that breached 37 irrigation tanks. Taking the clue of availability of good rainfall, the IMSD programme has been designed to harvest the rainfall of the good rainfall years and store it below the ground so that the water can be used during the periods of drought.

The weekly rainfall analysis of 1994 (See Figure 2) shows that during a substantial part of the rainy season, the district was receiving much lower than normal weekly rainfall, in some cases as low as 10 mm. There were severe dry spells, such as in 13th, 14th, 15th and 16th weeks of 1994, which is a crucial period for crop production. The district's annual average rainfall works out to 516 mm, which means a total precipitation of about 9,950 MCM.

Surface Water

There are three major rivers that flow through the district: the Penner, Hagari and Chitravati. They are mostly dry except for seasonal run-off. There are about 3,000 irrigation tanks which are able to hold only about 8 per cent of the precipitation, or 840 MCM.

Geology

The geological formations in the district are a group of metamorphic rocks belonging to the Archaean age and which consist of schists, gneisses, migmatites and younger granites, pegmatites, quartz veins and basic dikes. The Archaean rocks suffered a considerable degree of tectonic disturbances, as a result of which the rocks have been metamorphosed and recrystallized. Alluvium can be seen along sections of the following rivers: Penner, Hagari, Chinna Hagari, and Chitravati.

Hydrogeomorphology

The major portion of the district form a pediplain carved, out of Archaean gneisses, schists and granites with hill ranges and scattered hillocks of relatively small relief. Based on geomorphic expression, geology, relief, soil cover, structure and ground water prospects, the district has been divided into different hydrogeomorphic units. Valley fills, flood plains, moderately weathered pediplains along the fractures have been determined to be ground water potential zones. The well inventory, as well as data collected during finalization of drogeo-morphological maps, has provided a better appreciation of the relation between ground water potential and geomorphic units. Ground water in the predominantly hard rock area of the district occurs in the weathered and fractured rocks under the water table and is semi-confined to confined conditions. With the introduction of fracturing and also due to weathering, they have developed secondary porosity which has improved the chances of tapping better yields and have given rise to potential aquifers at depths. The degree of weathering varies from less than 1 m near the outcrops and hill slopes to more than 20 m in the valley bottoms and topographic lows. This weathered zone has been tapped extensively by dug-wells, dug-cum-borewells and borewells which invariably tap the fractures occurring below the weathered zone. The yields vary from less than 20 $m^3$ per day to 90 $m^3$ per day.

Status of ground water development

Ground water resource potential estimation at the village level for the entire district has been carried out. The inflow components considered are recharge from rainfall, recharge from applied irrigation and tank seepage. The outflow components taken into consideration are irrigation draft, and domestic draft. Finally, the ground water balance and the status of development were arrived at for each of the villages covering the entire district. Thus the villages with over draft conditions are identified.

Artificial ground water recharge

Rainfall is the major source of ground water recharge. An assessment of water resources in the Anantapur district revealed that out of the total rainfall received, only 11 per cent is going down into the ground water and about 8 per cent is stored as surface water, while about 60 per cent is lost in the form of evapotranspiration and about 20 per cent goes out as surface water runoff. To ensure that at least 20-30 per cent of the rain water is used for recharging the ground water, rainwater harvesting and artificial ground water recharge structures need to be constructed in the entire district. These water harvesting structures help in storing the rainwater and allow it to percolate down to the ground water, thus raising ground water level.

Based on the status of ground water development and predominant ground water irrigated areas, artificial recharge structures such as check dams, percolation tanks and farm ponds and sub-surface dikes were recommended to recharge the wells in the downstream areas to augment the ground water supply during drought spells.

Rural drinking water supplies and fluorosis problem

Ground water is a major source of drinking water in the rural villages of Anantapur district. The fluoride level of more than 1.5 ppm has been determined to be injurious to human health. There are about 210 villages in Anantapur district affected with dental and skeletal fluorosis. The problem has been endemic with the community having no answers to it. Remote sensing-based selection of sites for drilling borewells in about 87 villages to locate low fluoride ground water sources was recommended and has been implemented with an 80 per cent success rate.

The occurrence of high fluoride bearing ground water in the district is quite well known because of its association with the rock types such as younger granites occurring in the district which have high fluoride bearing apatite and fluorapatite minerals. The areas with prominent high fluoride bearing waters of more than 1.5 mg/l occur mostly in the Kadiri, Penukonda, Dharmavaram, Anantapur, Gorantla, Gooty, Rayadurg, Kalyanadurg, Ramgiri, Tadpatri, Narpala and Singanamala areas. Village ground water samples were analyzed for fluoride measurements. The analysis showed that the fluoride rich ground water is getting diluted by the low fluoride surface waters downstream of surface water bodies as a result of augmented infiltration. In view of these observations, it was recommended that rainwater harvesting structures such as check dams and percolation tanks be constructed upstream of the low fluoride zone so that the impounded water would not only recharge ground water, but also would help in diluting fluoride rich ground water. Such structures would thus serve the dual purpose of improving both quality and quantity. Thus, the 200 check dams have been built to dilute the drinking water sources.

A major drinking water supply scheme was taken up by the Sri Satya Sai Trust for providing drinking water to 790 villages at a cost of 170,000 million rupees in the record time of eight months. The project was started on 1 February 1995 and is scheduled to be completed by 23 November 1995. Remote sensing based hydrogeomorphological maps followed up by ground hydrogeological and geophysical surveys were used to select drilling sites for 190 villages. In a record time of two months, the entire site selection and drilling process was completed by 31 March 1995 with a success rate of more than 90 per cent.

Soils

The soil series in the district have been mapped using remote sensing and field information and 96 series have been identified. The classification of soils according to soil taxonomy places these soils into the orders of Entisols, Inceptisols, Vertisols and Alfisols. These have been further divided into sub-groups in each of the orders, which have a number of soil series under them. The soils are mostly moderately deep to deep, light brown to yellowish red, gravelly sandy clay loam, very deep, very dark grey to black, clayey, highly calcareous, shallow to moderately deep, dark brown, clay loam and slightly calcareous. Soil salinity and alkalinity development and sheet erosion is also predominant. In general, the soils are poor in nutrient status.

Land use/land cover

The district has various land use/land cover classes which are derived from multi-date satellite data. The district is predominantly occupied by kharif unirrigated areas, irrigated areas using surface water and ground water resources can be seen along the valley portions. The other land use/land cover classes include built-up lands, kharif irrigated, rabi irrigated, double crops, fallows, degraded and under-utilized forest, barren rocky stone areas, salt-affected lands, land with or without scrub, sheet rock areas, etc. The net sown area is about 69 per cent of the geographical area.

Forest covers about 10 per cent of the district, while barren and uncultivable lands such as hills, etc., cover 8.74 per cent. The area put to non-agricultural use such as for buildings, roads, and waterways, covers about 6.3 per cent. The only persistent drawback in the vast extent of barren and uncultivable land. About 20 per cent of the area is arable, but fallow. A single dry crop is raised under rainfed conditions both in black and red soils. In the black cotton soils late kharif or early rabi crop is taken to facilitate tilling in black soils.

Slope

Slope and altitude are very important from a land utilization point of view. The maps showing slope aspect are prepared using Survey of India topographic maps on a 1:50,000 scale.

Socio-economic status

The primary activity in the district is agriculture. Industrial development is comparatively insignificant in this district. With regard to the social situation, the need for social justice and equality are the two important aspects to be considered. With regard to inequalities in the social sector, land holdings are particularly uneven in their distribution, except in a few pockets which are primarily dry areas. Based on the socio-economic data supplied by the District

Administration, using conventional surveys, maps showing demographic details, the size of farming community, the number of farmers living below poverty line, fodder and fuelwood demand and availability, biogas plants, and drinking water needs were prepared. The infrastructure status has also been analyzed based on standard score method and mandals with different infrastructure facilities are evaluated.

INTEGRATION AND RECOMMENDATIONS

The data obtained by using remote sensing techniques as well as conventional methods have been integrated using the GIS approach to prepare BILWRU derivative maps. Recommendations were made by APSRAC, for each of the BILWRUs based on the water, soil, slope, land use and socio-economic aspects such as Recommended Optimal Land use and Farming Systems (See Plate-1D). The recommendations included:

a) Intensive agriculture with drip irrigation, in areas with good ground water potential, good soils, and gentle slopes;

b) Irrigated dry crops are recommended in areas with moderate ground water prospects and gentle to medium slopes on good soils, horticulture in moderately good ground water zones with good soils; and

c) Dry farming is recommended in areas with poor ground water potential and moderately good soils with soil and moisture conservation measures.

The various crops suitable in each of the BILWRU were identified and recommended.

RECOMMENDED DROUGHT PROOFING WORKS

Various types of drought proofing works were recommended to reduce the impact of drought (See Plate-1C). The mandal-level details of recommended drought proofing works are given in Table 1. They include:

a) Rain water harvesting structures such as percolation tanks, check dams, form ponds, diversion drains, and sub-surface dikes were recommended at specific sites.

b) *In situ* soil and moisture conservation measures including vegetative barriers, contour bunding with stone checks, etc.; soil erosion control measures including planting of soil binding species, gully control works etc., broad bed and furrow method of cultivation and conservation ditches, and irrigation water management and horticultural species planting on field bunds.

c) Fodder, fuel wood and forest development measures including fodder development in tank foreshores and marginal agricultural lands, reclamation of salt affected lands and planting of salt tolerant/resistant fodder species, fuel wood plantation, reclamation of salt affected lands and planting of salt tolerant/resistant fuel wood species, Social Forestry and Silvipasture, Casuarina and soil binding species, afforestation/Silvipasture, afforestation with contour trenches, quarrying with environmental protection measures and avenue plantation along all roads and railway tracks.

RAINWATER HARVESTING STRUCTURES

Based on geology, geomorphology, soils, drainage, etc., rainwater harvesting structures such as checkdams, mini-percolation tanks and farm ponds, are recommended upstream of the ground water irrigated areas to immediately replenish the aquifer immediately. The areas of dikes, reefs, outcrops, lithologic contacts, black soil areas, saline soils, tank command etc., are avoided for recommending these rainwater harvesting structures.

Checkdams are recommended upstream of ground water irrigated areas on lower order streams whereas mini-percolation tanks are recommended on second or third order streams. The catchment area of the checkdams is usually less than the catchment area of mini-percolation tanks and the capacity of each structure is less than 1 Mcft. In all, construction of 2,400 rain water harvesting structures, mostly percolation tanks and checkdams, was recommended. Out of this number, the District Administration has already constructed 1,600. Most of the structures have received 6-8 fillings during the monsoon of 1993 and 1994.

Farm ponds are recommended for capturing run off from the agricultural fields and can provide one life saving irrigation for the dryland agriculture. They need not be located on the streams but they can be located on the sites wherein 15-20 ha of catchment can be tapped. They are recommended more in black soil areas than in red soil areas as better assured runoff can be obtained. Surface water resources in this area be exclusively allocated for artificial recharge through a network of recharge structures after duly desilting existing surface water bodies. This will result in greater irrigation potential while solving the rural water supply problems, compared to the conventional practice where surface water resources are directly used for irrigation. This can be achieved due to the judicious irrigation water management under wells that benefit from artificial recharge, thus minimizing the losses due to evaporation and unproductive seepage.

IMPLEMENTATION

The various scientific recommendations given are validated in the field through participatory rural appraisal (PRA) exercises. The rural population of a village is assembled for a day long discussion and field visits along with the District Officials from various sectors. The inputs from the space technology are presented to the people and their reaction to the suggestions are discussed at length. A model of their village is drawn by the people with coloured chalk powder locally known as "Rangoli." Standing around this coloured model, the scientists and the people debate on various pros and cons of individual recommendations given vis-a-vis the traditional practices and traditional wisdom. Thus, an operational, implementable and acceptable programme is finalized.

The District Collector, who is the Chairman of the District Rural Development Agency, dovetails the developmental funds available under various programmes such as the Drought Prone Area Programme, Employment Assurance Scheme, Integrated Wasteland Development Programme, Special Component Plan, Tribal Sub-plan, Afforestation programmes of the Forest Department., minor irrigation programme, National Watershed Development Programme, soil conservation programmes, animal husbandry department programmes, etc. The programme is implemented through a watershed development committee comprising of the beneficiaries themselves with the assistance of Non-Governmental Organizations (NGOs). The watershed development committee consists of a President, Secretary, and beneficiary members with powers to operate a joint bank account wherein the watershed development funds are deposited in installments. The beneficiary groups of Development of Women and Children in Rural Area (DWCRA) programme and their family members form the nucleus of these watershed development committees, thus the self help groups already mobilized in a village are drawn to participate in the watershed development programme. The women who are active in the DWCRA programme influence their husbands or male members of their family to take up the various drought proofing works under watershed development. This leads to massive participation by rural farmers, agricultural labourers, and people below the poverty line. The NGOs and voluntary organizations who are active in the district are also encouraged to mobilize the people's participation and to form beneficiary groups. Large scale participation of NGOs in a campaign mode has led to a massive people's movement for watershed development. The watershed development teams thus participate in actual implementation of the total programmes of the watershed development physically and also contribute either labour or logistics or if the benefit goes to the entire village, funds available from the village Panchayats such as Jawahar Rojgar Yojana, Intensive Jawahar Rojgar Yojana, etc. A district level committee was formed with participation from NGOs, experts, and direct beneficiaries.

Financial resources from various programmes such as the Prime Minister's Employment Assurance Scheme (EAS), Drought Prone Area Programme (DPAP), Jawahar Rojgar Yojana (JRY), Intensive Jawahar Rojgar Yojana (IJRY), Schedule Caste Action Programme (SCAP), etc., were also utilized.

Water conservation with the help of checkdams, has been an important feature of the implementation work. Check dams are low priced cement structures, recommended along a stream course in medium slope areas, upstream of ground water irrigated areas to recharge ground water and act as water points for cattle. Accordingly, the District Administration has taken up the construction of rainwater harvesting structures and a total of about 3,000 check dams/percolation tanks have been completed. The ground water levels and the extent of area under irrigation before and after the rainwater harvesting structures were monitored.

RESULTS OF IMPLEMENTATION IN VANJUVANKA WATERSHED

The ecological problem common to the entire district is more pronounced in this watershed. The area receives just about 300 mm of rainfall, with the lowest being about 250 mm and the highest about 400 mm. In the last 10-15 years, before the implementation of the IMSD project, there has been consistent droughts and just about 25-40 per cent of the crop is successful. Due to delayed and erratic monsoons, people were often unable to sow on time nor reap the groundnut crop. The satellite imagery of Vanjuvanka watershed (See Plate-1B) shows the minimum vegetation cover available during post monsoon (Rabi) season.

As per IMSD recommendations, groundnut is intercropped with redgram, which is a deep rooted crop. This not only helps in soil regeneration, but also gives additional yields to the farmer. Along with the intercropping pattern, another recommended practice of ploughing along the slope and contour bunds with a trench inside has been implemented. This helped in arresting the water velocity, reduced soil erosion and facilitated moisture retention. Construction of rainwater harvesting structures was undertaken at recommended sites. About 57 check dams and mini-percolation tanks have been built along with diversion drains and farm ponds.

Rockfill dams are being interspersed with the check dams to prevent soil erosion and siltation. These rockfill dams help to reduce the flow of water. Desilting of tanks is being taken up in conjunction with the application of silt on the fields to improve soil fertility and moisture holding capacity.

Vegetative barriers and contour bunding with stone checks have been built to prevent soil erosion and siltation of water harnessing structures. Apart from this, stone checks have been made to treat the gullies that have formed over years.

To provide fodder and fuelwood and to restore natural forest cover, alternate land use systems are being implemented in the marginal lands, tank foreshores, saline lands and degraded forest lands. Areas with gentle slopes in forest areas have been brought under silvi pasture. Contour trenches and contour bunding with afforestation is carried out on steep sloping forest areas. Plantation of soil binding species like the casuarina have been taken up for arresting migrating river sands. Human and cattle trespassing in these areas has been checked by cordon walls around the afforested hills. Local utilitarian species of trees such as Neem, Tamarind, Pongamia, Babul, etc., have been planted in different nurseries. Avenue plantations have been undertaken along all roads and railway tracks. Such activities have helped restore the natural forest cover which is urgently required.

A detailed analysis of Normalized Differential Vegetation Index (NDVI) of the watershed before and after implementation has shown an increase by about 48.3 per cent in the Vanjuvanka watershed. Slowly but surely the valley is giving nature a wide berth to thrive upon.

There is no doubt that things have changed for the better in Anantapur district. More than anything else, the difference has been made possible, due to the support and participation of the people at the grassroots level. Unlike most projects where the beneficiaries form a mute audience, the farmers participating in this project are quite vociferous.

Rich mulberry plantation for sericulture, and other cash crops like sunflowers, are grown in the watershed. The catchment areas of checkdams, the tank foreshore, the farm bunds, the contour trenches, the saline lands, and the hills tops all support vegetation. Horticulture in the form of banana plantations, papaya plantations, sethaphal plantations, coconut trees, etc. can also be seen. In the 3-4 years that the programme has been operating, the impact has been seen in terms of soil and water conservation, ground water recharge and irrigation possibilities being developed in the watershed.

An impact analysis was also carried out to see the effect of the RWHS. The analysis clearly indicated the rise in water table and increase in the command area under wells located on the downstream of RWHS indicating augmented recharge from the percolation tanks/checkdams (See Table-2) which ultimately resulted in sustainable development of the watershed. Ground water levels were monitored at 37 wells. The effect of fillings in these structures was significant within 3-4 days of rainfall and in about 15 days the ground water levels stabilized. The effect of these structures is also visibly brought out by the satellite data (See Plate-1E).

Afforestation, additional plantation for sericulture and horticulture and changed cropping patterns have transformed the entire landscape from brown to green.

Resource limitations, both human and financial, plague most of our well intended and well planned projects. This limitation has been taken care of in the IMSD approach. There are various NGOs who are committed to working in the area of sustainable development and have already made progress in the field.

Apart from the NGO activities, the integration of various other government programmes such as the DWCRA programme for women and children or the TRYSEM programme for self-employment among youth, provided a ready-made network leading to a cross section of people in rural areas. Ultimately, the operationalization is achieved through a campaign in the village involving youth, the DWCRA group members, the voluntary organizations, the gram saksharta samiti, etc.

The women involved in the economic activities under the DWCRA, in a carpet weaving centre, are also sensitized to other issues related to health care and nutrition, family planning, environmental protection, etc., and therefore such places are much more than money earning centres.

## CONCLUSION

Every effort for sustainable development in the district is channeled towards IMSD activities and the achievements so far indicate that work on other micro watersheds along the same lines is likely to be met with the same success. As is the case with any successful experiment, the Anantapur approach also presents a number of dimensions and perspectives for viewing the process of comprehensive and sustainable development.

During these years attempts have been made to regenerate its natural resources and bring a semblance of normalcy to its disturbed ecosystem. A lot of barren lands today carry lush vegetation. At a lot of places the depletion of the ground water table has been reversed. Soil which can support healthy vegetation has been provided due protection. And, along with all this, there are people, sensitized to the environmental problems and aware of the need to lend their help in getting Anantapur back on its feet with the help of space technology at the village level.

Now, in these watersheds rain water harvesting through check dams, percolation tanks, farm ponds, contour bunding across the slopes, vegetative barriers, horticulture, avenue plantation, afforestation with silvi pasture, fodder in foreshore areas of tanks, fuel wood plantations, etc., have become a common site. The extinguishing of forest fires by the people themselves has become a common practice. The integrated development of a watershed programme has led to substantial water availability which in turn has generated a reasonable extent of additional irrigated crops and general vegetation cover over the area.

Based on the encouraging results of the pilot studies carried out in various districts of the country, locale-specific action plans have been developed by integrating thematic information on land and water resources, derived from remotely sensed data with meteorological data and socio-economic information, and a nationwide project entitled Integrated Mission for Sustainable Development (IMSD) has been launched in 172 problem districts of the country. These districts, covering nearly 45 per cent of India's geographical area, are those perennially affected by drought, flood and coming under hilly and tribal areas are under active study and implementation in India.

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Fig.1

# RAINFALL - ANANTAPUR

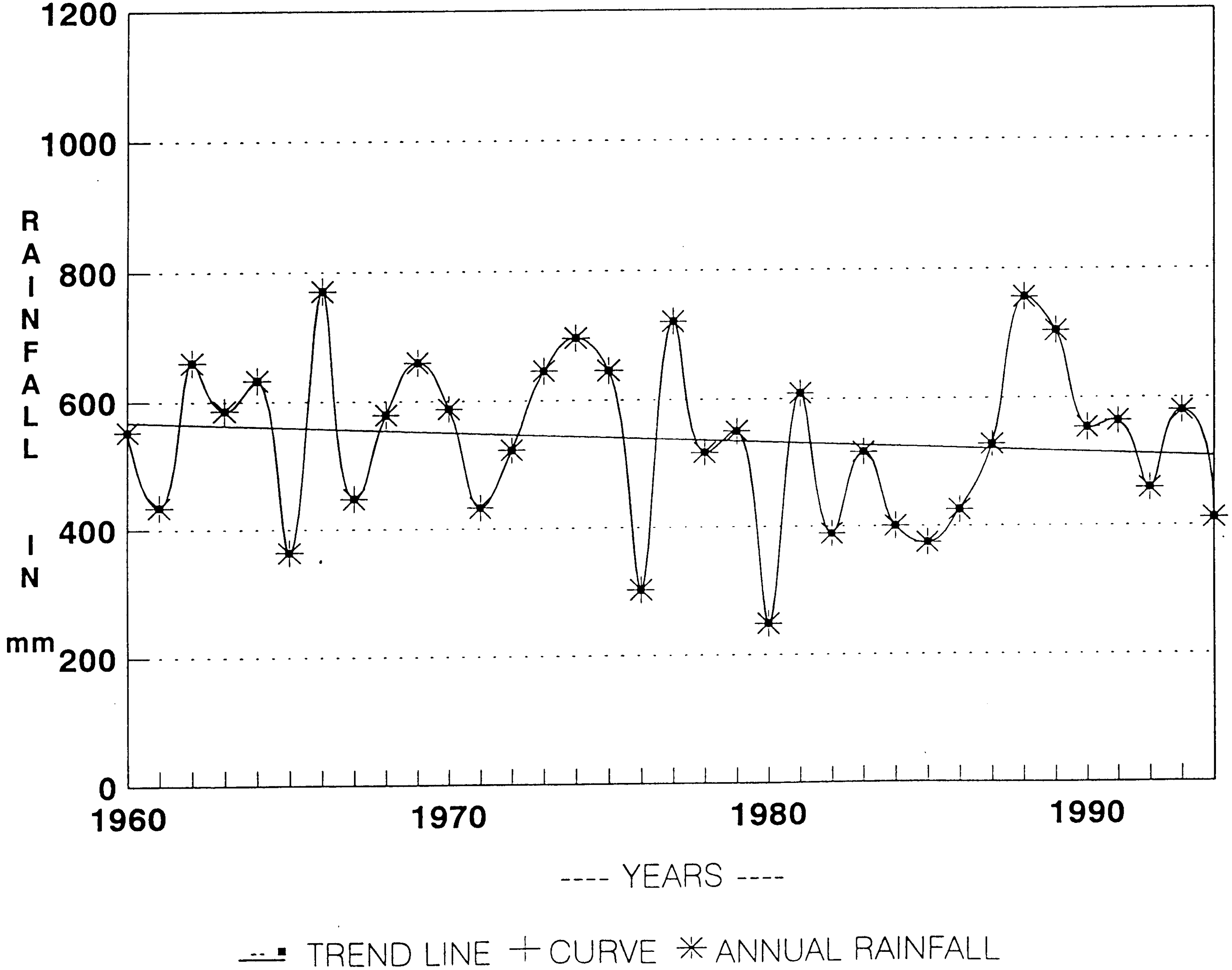
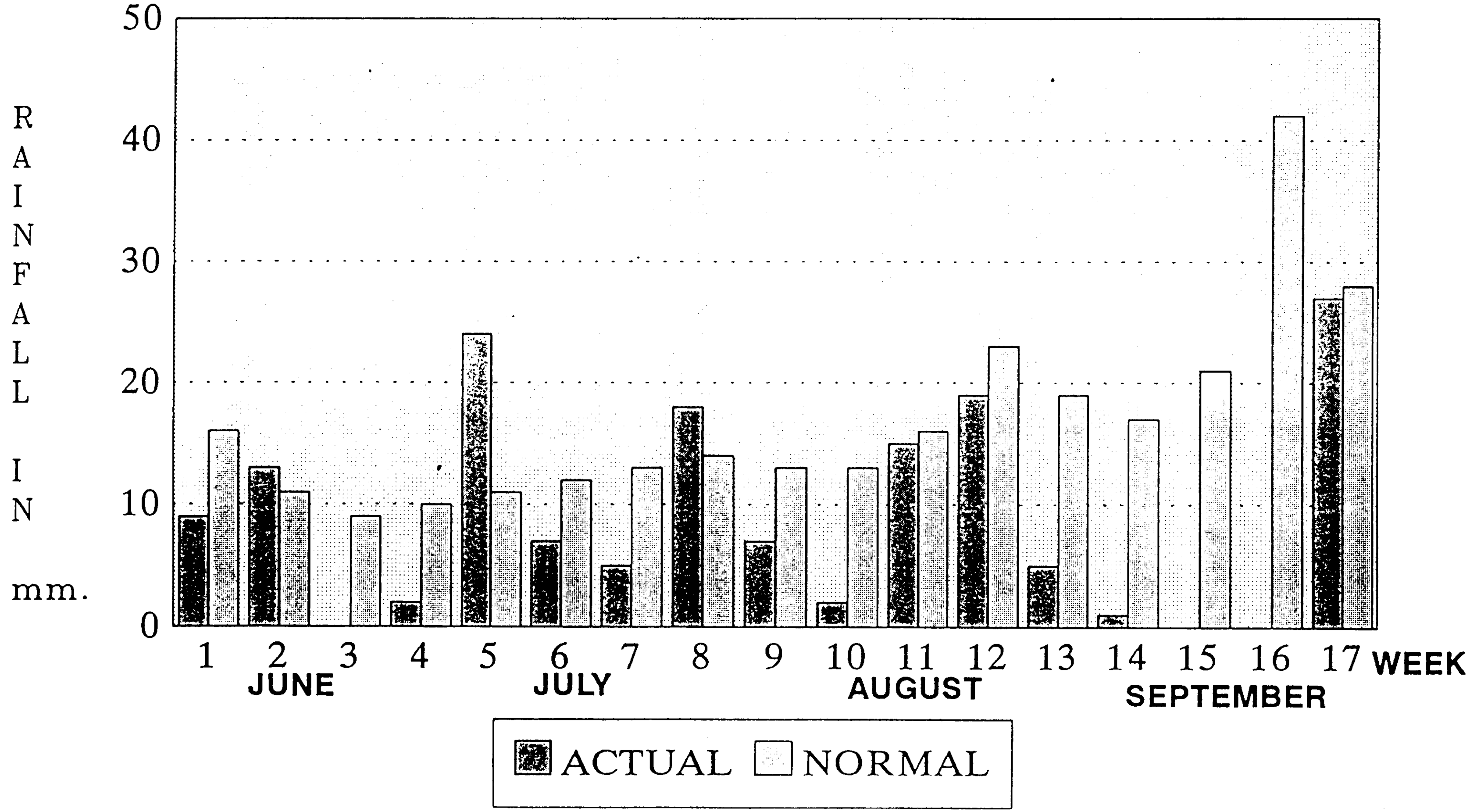
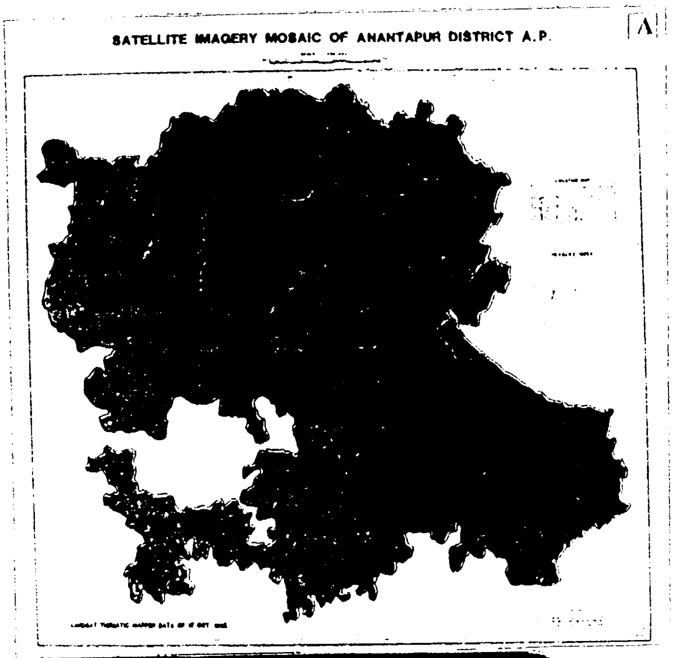
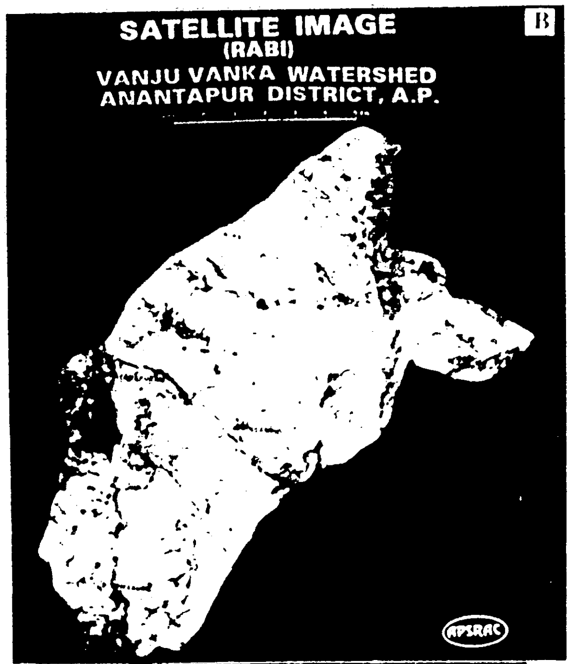


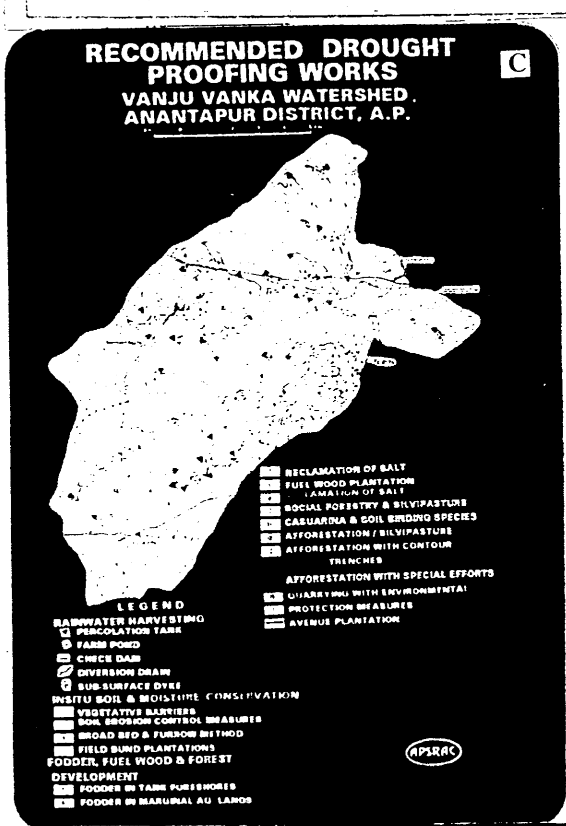
Fig.2

WEEKLY RAINFALL - ANANTAPUR
JUNE - SEPTEMBER,1994

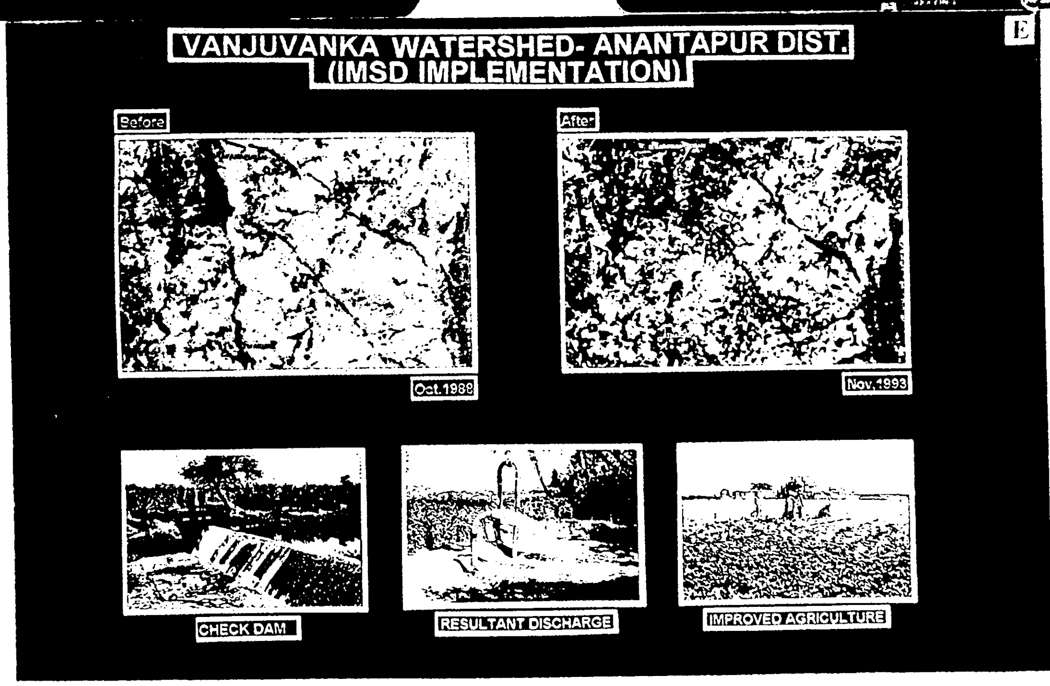



A
SATELLITE IMAGERY MOSAIC OF ANANTAPUR DISTRICT A.P.


B
SATELLITE IMAGE
(RABI)
VANJU VANKA WATERSHED
ANANTAPUR DISTRICT, A.P.
APSRAC


C
RECOMMENDED DROUGHT PROOFING WORKS
VANJU VANKA WATERSHED,
ANANTAPUR DISTRICT, A.P.
LEGEND
RAINWATER HARVESTING
PERCOLATION TANK
FARM POND
CHECK DAM
DIVERSION DRAIN
SUB-SURFACE DYKE
INSITU SOIL & MOISTURE CONSERVATION
VEGETATIVE BARRIERS
SOIL EROSION CONTROL MEASURES
BROAD BED & FURROW METHOD
FIELD BUND PLANTATIONS
FODDER, FUEL WOOD & FOREST DEVELOPMENT
FODDER IN TANK FORESHORES
FODDER IN MARGINAL AU LANDS
RECLAMATION OF SALT
FUEL WOOD PLANTATION
SOCIAL FORESTRY & SILVIPASTURE
CASUARINA & SOIL BINDING SPECIES
AFFORESTATION / SILVIPASTURE
AFFORESTATION WITH CONTOUR TRENCHES
AFFORESTATION WITH SPECIAL EFFORTS
QUARRYING WITH ENVIRONMENTAL PROTECTION MEASURES
AVENUE PLANTATION
APSRAC


D
BASIC INTEGRATED LAND AND WATER RESOURCE UNITS (BILWRU)
RECOMMENDED OPTIMAL LAND USE AND FARMING SYSTEMS (ROLUFS)
VANJU VANKA WATERSHED,
ANANTAPUR DISTRICT, A.P.
LEGEND
BASIC INTEGRATED LAND AND WATER RESOURCE UNITS (BILWRU)
INTENSIVE AGRICULTURE
PADDY
IRRIGATED DRY
VEGETABLES
GROUNDNUT
SALT RESISTANT FODDER SPECIES
SALT RESISTANT CROP
BAJRA
RAGI
MULBERRY
VEGETABLES/GROUNDNUT
DRY FARMING
KORRA
GROUNDNUT PERENNIAL PIGEONPEA INTERCROP
GROUNDNUT-JOWAR INTERCROP
SUNFLOWER
SUNFLOWER/VEGETABLES
HORTICULTURE
CITRUS SPECIES
BER
POMEGRANATE
FUEL WOOD PLANTATION
SILVIPASTURE IN FOREST AREAS
FOREST PLANTATION
APSRAC


E
VANJUVANKA WATERSHED- ANANTAPUR DIST.
(IMSD IMPLEMENTATION)
Before
After
Oct.1988
Nov.1993
CHECK DAM
RESULTANT DISCHARGE
IMPROVED AGRICULTURE

MANDAL WISE DETAILS FOR RECOMMENDED DROUGHT PROOFING WORKS ANANTAPUR DISTRICT

| MANDAL | No. of Rainwater Harvesting Structures | | | | Area in Ha. for In Situ Soil and Moisture Conservation | | | | Area in Hectares for Fodder, Fuelwood and Forest Development | | | | | | | | | | Road length in Km for Avenue Plantation |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 |
| ANANTAPUR | 670 | 28 | 13 | -- | 15573 | 33 | 1765 | 4146 | -- | 945 | 1084 | 721 | 68 | 362 | -- | -- | 730 | 55 | 273 |
| RAPTADU | 616 | 10 | 5 | -- | 12233 | 463 | 170 | 5651 | 88 | -- | -- | 382 | 447 | 805 | -- | -- | -- | 70 | 243 |
| GARLADINNE | 340 | 27 | 14 | -- | 11206 | 56 | 4358 | 4541 | -- | 802 | 230 | 1226 | 126 | -- | -- | 579 | 1575 | 5 | 250 |
| ATMAKUR | 531 | 34 | 66 | -- | 14071 | 33 | 83 | 5077 | 160 | -- | 680 | 631 | 20 | -- | -- | 442 | 2727 | 315 | 248 |
| KUDERU | 900 | 82 | 55 | -- | 20207 | 894 | 60 | 4693 | 40 | 2427 | 572 | 268 | -- | -- | -- | 1380 | 1063 | 748 | 327 |
| SINGANAMALA | 220 | -- | 12 | 1000 | 9195 | 150 | 1145 | 8591 | -- | 3212 | 522 | 1167 | -- | -- | -- | 496 | 5374 | -- | 258 |
| B.SAMUDRAM | 323 | 13 | 8 | -- | 8732 | 195 | 1960 | 9430 | 2 | 1095 | 398 | 1044 | -- | -- | -- | 180 | -- | 8 | 233 |
| NARPALA | 418 | 30 | 39 | -- | 7128 | 15 | 220 | 7485 | 38 | 3490 | 112 | 1573 | -- | -- | -- | 1876 | 1073 | 13 | 263 |
| TADIPATRI | 674 | 11 | 7 | -- | 9970 | -- | 14171 | 4173 | -- | 4587 | 165 | -- | -- | -- | 175 | 38 | 135 | -- | 440 |
| YADIKI | 455 | 1 | -- | -- | 1821 | -- | 7506 | 2996 | -- | 2302 | -- | 188 | 142 | 4165 | -- | 138 | 4796 | -- | 316 |
| PEDDAPAPPUR | 422 | 10 | 3 | -- | 219 | -- | 4911 | 3172 | -- | 1002 | 359 | 1190 | -- | -- | -- | 1731 | -- | -- | 305 |
| PUTLUR | 668 | 9 | 1 | -- | 145 | -- | 9812 | 427 | -- | 3807 | 10 | -- | -- | -- | -- | 2251 | 2666 | -- | 336 |
| YELLANUR | 374 | 20 | 4 | -- | 1795 | 40 | 5693 | 1740 | 77 | 2275 | -- | 1126 | -- | -- | -- | 1670 | 5890 | 5 | 301 |
| GUNTAKAL | 647 | 9 | 35 | 2250 | 15924 | 190 | 3621 | 4554 | 10 | 2415 | 505 | 45 | -- | -- | -- | 448 | 3686 | 399 | 355 |
| GOOTY | 204 | 4 | 3 | -- | 5258 | -- | 45 | 4825 | -- | 2550 | 1487 | 404 | -- | -- | -- | -- | 1232 | -- | 312 |
| PAMIDI | 256 | 3 | 1 | -- | 7068 | 23 | 150 | 7166 | 53 | 430 | 661 | 615 | -- | -- | -- | 1430 | 2076 | -- | 183 |
| PEDDAVADUGUR | 388 | 15 | -- | -- | 5324 | -- | 485 | 3234 | -- | 1317 | 940 | 1009 | -- | -- | -- | 240 | 2498 | -- | 356 |
| URAVAKONDA | 902 | 21 | 21 | -- | 14028 | 799 | 3835 | 3547 | -- | -- | -- | 1047 | 125 | -- | -- | -- | -- | 198 | 393 |
| VAJRAKARUR | 1104 | 49 | 4 | 1500 | 10853 | 35 | 19071 | 2092 | -- | -- | 106 | 1955 | -- | -- | -- | 1633 | 618 | 208 | 504 |
| VIDUPANAKAL | 927 | 1 | -- | -- | 2617 | 2969 | 24187 | -- | -- | 75 | 93 | 148 | -- | 680 | -- | 20 | -- | -- | 425 |
| DHARMAVARAM | 411 | 30 | 8 | 1750 | 18778 | 610 | 124 | 6492 | 103 | -- | 297 | 2220 | 986 | -- | -- | 173 | 2783 | 185 | 413 |
| TADIMARRI | 573 | 36 | 13 | 3000 | 2753 | -- | -- | 5495 | 41 | 1319 | 774 | 1102 | -- | -- | -- | 15 | 35 | 165 | 232 |
| BATTALAPALLI | 383 | 4 | 4 | 1500 | 12946 | -- | -- | 6315 | 20 | 172 | 233 | 592 | 172 | -- | -- | 8 | 305 | 30 | 282 |
| C.K.PALLI | 408 | 68 | 44 | 8000 | 15635 | 658 | 71 | 5253 | 170 | 4978 | 960 | 936 | -- | -- | -- | 113 | 2810 | 91 | 362 |

| MANDAL | No. of Rainwater Harvesting Structures | | | | Area in Ha. for In Situ Soil and Moisture Conservation | | | | Area in Hectares for Fodder, Fuelwood and Forest Development | | | | | | | | | | Road length in Km for Avenue Plantation |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 |
| KANAGANAPALLI | 631 | 48 | 23 | 1000 | 24798 | 188 | 385 | 4848 | 139 | 9 | 227 | 725 | 512 | 3274 | -- | 1420 | 1849 | 25 | 444 |
| RAMAGIRI | 533 | 17 | 13 | 4000 | 15197 | 398 | 783 | 2897 | 88 | 1420 | 103 | 233 | 404 | 3949 | -- | 865 | 873 | 45 | 281 |
| KALYANDURG | 483 | 33 | 17 | -- | 33162 | 68 | -- | 11685 | 65 | 792 | 140 | 229 | -- | -- | -- | 360 | 1422 | 115 | 522 |
| BELUGUPPA | 179 | 15 | 9 | -- | 11963 | 10 | -- | 6963 | 137 | 509 | 107 | 94 | -- | -- | 105 | 180 | 460 | 28 | 400 |
| KAMBADUR | 679 | 32 | 18 | -- | 22491 | 713 | -- | 8354 | 146 | 471 | 477 | 803 | -- | -- | -- | 290 | 88 | 169 | 323 |
| KUNDURPI | 329 | 30 | 35 | -- | 15907 | 1174 | -- | 8893 | 18 | 1064 | 836 | 486 | -- | -- | -- | 328 | 1783 | 5 | 292 |
| BRAHMASAMUDRAM | 198 | 13 | 7 | -- | 18531 | 50 | -- | 5669 | 78 | 110 | 660 | 610 | -- | -- | -- | 230 | 413 | 78 | 386 |
| SETTUR | 388 | 11 | 2 | -- | 20469 | 213 | -- | 5465 | 85 | 1053 | 1106 | 585 | -- | -- | -- | 320 | 240 | -- | 327 |
| RAYADURG | 283 | 44 | 10 | 2500 | 18669 | 115 | -- | 1346 | 50 | 120 | 173 | 1961 | -- | -- | -- | 280 | 2740 | 63 | 367 |
| D.HIREHAL | 360 | 18 | 6 | -- | 12582 | -- | -- | 4461 | -- | 772 | 320 | 34 | -- | 739 | -- | 600 | 2753 | 15 | 416 |
| GUMMAGATTA | 292 | 3 | 3 | -- | 16278 | 188 | -- | 5257 | -- | -- | 35 | 363 | -- | 274 | -- | 223 | 688 | 90 | 267 |
| KANEKAL | 503 | -- | -- | -- | 6642 | -- | -- | 4447 | -- | 813 | 81 | 139 | -- | -- | 295 | -- | -- | -- | 459 |
| BOMMANHAL | 214 | -- | -- | -- | 5607 | -- | -- | 2957 | -- | -- | 301 | 323 | 70 | 1129 | 113 | 50 | 363 | -- | 336 |
| PENUKONDA | 332 | 33 | 21 | 500 | 8554 | 903 | -- | 4549 | 139 | 6665 | 584 | 1192 | -- | -- | -- | 464 | 6463 | 77 | 242 |
| SOMANDEPALLI | 380 | 26 | 16 | 500 | 8517 | 560 | -- | 4934 | 163 | 1530 | 80 | 813 | 333 | 1581 | -- | 133 | 888 | 24 | 206 |
| RODDAM | 655 | -- | 3 | -- | 17523 | 379 | 1513 | 7665 | 586 | 2634 | 905 | 994 | -- | -- | -- | -- | 45 | 36 | 302 |
| PUTTAPARTI | 139 | 13 | 10 | -- | 8766 | 80 | -- | 2631 | -- | 3624 | 32 | 1268 | -- | -- | -- | 2240 | 4677 | 137 | 158 |
| KOTHACHERUVU | 170 | 8 | 4 | 750 | 8454 | 179 | -- | 10394 | 104 | -- | -- | 1075 | 240 | -- | -- | 22 | 2802 | 86 | 218 |
| BUKKAPATNAM | 167 | 5 | -- | 1250 | 7496 | 38 | -- | 2450 | -- | 1621 | 50 | 1738 | -- | -- | -- | 64 | 1007 | 92 | 185 |
| MADAKASIRA | 656 | 43 | 12 | 1000 | 20863 | 10 | -- | 4980 | 210 | -- | -- | 1410 | 655 | -- | -- | 595 | 2048 | -- | 349 |
| AMARAPURAM | 421 | 7 | 15 | -- | 12308 | -- | -- | 7518 | 547 | -- | 210 | 663 | 257 | -- | -- | -- | -- | 253 | 250 |
| GUDIBANDA | 318 | 43 | 22 | 500 | 13437 | -- | -- | 4692 | 331 | -- | 408 | 723 | -- | -- | -- | 633 | 1000 | 28 | 229 |
| ROLLA | 217 | 22 | 32 | -- | 8787 | 73 | -- | 3070 | 50 | 344 | 32 | 817 | -- | -- | -- | 1008 | 547 | 70 | 134 |
| AGALI | 111 | -- | 2 | -- | 7036 | -- | -- | 2367 | 214 | 823 | 78 | 884 | 36 | -- | -- | -- | -- | 50 | 136 |
| HINDUPUR | 203 | 2 | -- | -- | 8283 | 30 | 13 | 6473 | 71 | -- | -- | 1168 | 325 | -- | -- | 167 | 650 | -- | 236 |
| PARIGI | 210 | 7 | 5 | -- | 4756 | 48 | -- | 7130 | -- | -- | -- | 72 | 68 | -- | -- | -- | -- | -- | 172 |
| LEPAKSHI | 242 | 15 | 11 | 2250 | 6994 | 20 | 8 | 2839 | 43 | 207 | 192 | 434 | -- | -- | -- | 181 | 312 | -- | 178 |
| CHILAMATUR | 486 | 14 | 6 | -- | 11780 | 258 | -- | 4973 | 15 | 1008 | 79 | 1094 | -- | -- | -- | 409 | 691 | 278 | 216 |

| MANDAL | No. of Rainwater Harvesting Structures | | | | Area in Ha. for In Situ Soil and Moisture Conservation | | | | Area in Hectares for Fodder, Fuelwood and Forest Development | | | | | | | | | | Road length in Km for Avenue Plantation |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 |
| GORANTLA | 627 | 53 | 6 | -- | 16875 | 347 | -- | 5941 | 77 | 1430 | 291 | 1580 | -- | -- | -- | 384 | 2336 | 114 | 234 |
| KADIRI | 319 | 14 | 11 | 1500 | 10817 | 233 | -- | 3020 | -- | -- | -- | 958 | 20 | -- | -- | 110 | 1048 | 14 | 199 |
| MUDIGUBBA | 849 | 6 | -- | 6250 | 30544 | 319 | -- | 5680 | 81 | 2969 | 177 | 1543 | -- | -- | -- | 85 | 5131 | 304 | 412 |
| NALLAMADA | 340 | 13 | 44 | 4250 | 12499 | 127 | -- | 5680 | -- | -- | -- | 1065 | 30 | -- | -- | 243 | 1120 | 164 | 241 |
| N.PULIKUNTA | 877 | 20 | -- | -- | 11220 | 256 | -- | 1771 | -- | 5622 | -- | 1013 | -- | -- | -- | 811 | 5157 | 60 | 306 |
| TALUPULA | 562 | 21 | 20 | 275 | 16134 | 861 | -- | 3693 | -- | 3070 | 23 | 1398 | -- | -- | -- | 102 | 12 | 43 | 246 |
| NALLACHERUVU | 315 | 10 | 8 | 2000 | 9623 | 98 | -- | 2600 | -- | 251 | -- | 1220 | 12 | -- | -- | 50 | -- | 62 | 96 |
| O.D.CHERUVU | 507 | 36 | 28 | 1000 | 13231 | -- | -- | 4363 | -- | 1236 | 70 | 1772 | -- | -- | -- | 230 | 1425 | 64 | 228 |
| TANAKAL | 766 | 21 | 19 | -- | 9639 | 663 | -- | 4785 | -- | 3909 | 39 | 1336 | 208 | -- | -- | 28 | 939 | 43 | 202 |
| AMADAGUR | 463 | 23 | 2 | 500 | 10197 | 279 | -- | 3005 | -- | 1176 | -- | 1071 | -- | -- | -- | 517 | 4946 | 191 | 111 |
| GANDLAPENTA | 440 | 37 | 8 | 750 | 8845 | 53 | -- | 1795 | -- | 1214 | -- | 1010 | 18 | -- | -- | 997 | 15473 | 31 | 189 |
| Totals : | 28658 | 1271 | 808 | 49775 | 748953 | 16094 | 106145 | 303335 | 4239 | 85666 | 18004 | 54485 | 5274 | 16958 | 688 | 29480 | 114461 | 5349 | 18105 |

1. Farm Ponds
2. Check Dams
3. Percolation Tanks
4. Diversion Drains
5. Vegetative Barriers, Contour Bunding with stone checks etc.
6. Soil erosion control measures including planting of soil binding species, gully control works etc.
7. Broad Bed and Furrow method of cultivation & Conservation ditches.
8. Irrigation water management and horticultural species planting on field bunds.
9. Fodder / plantation development in tank foreshores.
10. Fodder develoment in marginal agricultural lands.
11. Reclamation of salt affected lands and planting salt tolerant / resistant fodder species.
12. Fuelwood plantation in marginal lands
13. Reclamation of salt affected lands and planting salt tolerant / resistant fuelwood species.
14. Social forestry and silvipasture.
15. Casuarina and soil binding species.
16. Afforestation / silvipasture
17. Afforestation with contour trenches
18. Quarrying with environmental protection measures
19. Avenue plantation along all the major roads.

Table - 2

**EFFECT OF CHECK DAMS ON THE GROUND WATER LEVEL IN VANJUVANKA WATERSHED, ANANTAPUR DISTRICT, A.P.**

| NAME OF THE VILLAGE | NO. OF WELLS BENEFITED | GROUND WATER EXTRACTION STRUCTURE | TOTAL DEPTH in m. | WATER LEVEL(bgl) BEFORE / AFTER in m. | RAISE IN WATER LEVEL in m. |
|---|---|---|---|---|---|
| KARUTLAPALLI | 4 | DW | 7.0 | DRY/3.9 | > 3.1 |
| | | DW | 11.4 | DRY/7.5 | > 3.9 |
| | | DW | 15.0 | DRY/10.0 | > 5.0 |
| | | DW | 11.0 | DRY/8.1 | > 2.9 |
| KARUTLAPALLI | 2 | DW | 13.0 | DRY/12.1 | > 0.9 |
| | | DW | 14.0 | DRY/10.6 | > 3.4 |
| KARUTLAPALLI | 2 | DW | 12.6 | 10.6/7.5 | 3.1 |
| | | DW | -- | 9.0/7.8 | 2.8 |
| KADADARAKUNTA | 3 | DW | 9.6 | DRY/9.0 | > 0.6 |
| | | DW | 10.8 | DRY/10.3 | > 0.5 |
| | | DW | 10.8 | DRY/10.3 | > 0.5 |
| P.YALERU | 1 | BW | -- | 28.7/18.0 | 10.7 |

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