THE POLITICS OF REMOTE SENSING WITH PARTICULAR REFERENCE TO DEVELOPING COUNTRIES

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SUMMARY

This thesis can be divided roughly into two sections. The first section, Chapters One to Four inclusive, present a brief history of satellite remote sensing, followed by an attempt to assess the political and socio-economic facets of the technology, and their consequent implications for Third World countries. This section includes an in-depth discussion of the legal and commercial issues associated with remote sensing, and a general discussion of various other factors, such as overwhelming financial difficulties, that have prevented or restricted the employment of the technology in Less Developed Countries.

The second section, Chapters Five to Eight inclusive, details various benefits to be gained from the use of satellite remote sensing and attempts to present the means by which it could successfully be adopted and utilised in the Third World. India is used as an example of a Third World state that has successfully employed remote sensing for national development. The way in which India established its remote sensing programme is carefully analysed and discussed, using it as an example that other Third World countries could possibly follow and adopt.

The research concludes that, politically, remote sensing has proven an extremely controversial subject, especially in the Third World. The ability of satellite remote sensing to aid development within Less Developed countries is recognised, but it is also accepted that most of these countries are obstructed by many problems if they wish to attempt to adopt this technology.

KEY WORDS: Politics, Third World, Developing countries, remote sensing

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CHAPTER ONE

INTRODUCTION

Remote sensing has been described as:-

> "the acquisition of information about an object without physical contact" (Colwell, 1983)

In this context the human eye is an example of a remote sensing device, however, the term 'remote sensing' usually refers to the observation, study and monitoring of Earth resources from a distance.

Surprise is often expressed that politics can actually be associated with remote sensing. However, given the unique capability of remote sensing to collect data over large areas, often without regard for national boundaries, and the recent information revolution, making information an increasingly valuable commodity, one can begin to comprehend why the political and legal implications of the technology have become a focus for international attention. As O'Brien (1983) explains

> "to the extent that information is a basis of power, the ability to collect, store, access, process and work with it can give countries (as well as groups and institutions within them) political, economic and social advantages over other countries (and their groups and institutions)." (O'Brien, 1983)

It seems evident that various countries, and in particular Less Developed Countries (LDCs), feel that remote sensing technology has helped to widen the gap between the rich North and the poorer South, by allowing the former to use the information to exploit the latter. One example often cited is that affluent Northern multinational companies can use remote sensing information to their advantage in crop yield forecasting and mineral discovery. Also, the recent commercialisation of remote sensing has made a significant impact upon remote sensing activities, for example, by raising data product prices and introducing the concept of 'copyright'. This thesis addresses these problems, particularly in reference to LDCs, and discusses the reasons why some Third World countries have experienced difficulties in adopting remote sensing. Suggestions are made on the ways in which LDCs might more easily utilise the technology.

This research works on the assumption that LDCs are

> "... those countries characterized by low levels of economic development; that is, the poor nations of the world. These nations comprise a distinct bloc of nations with economic and social characteristics quite different from those of the rich nations" (Hodgson et al., 1983).

Chapter Four discusses the economic disparity between LDCs and developed countries which highlights the North-South dichotomy.

Before addressing the complexities of remote sensing, it seems necessary to view the evolution of remote sensing via a brief historical outline. Satellite remote sensing, the main concern of this work, has developed as a sophisticated technology within and alongside aerial photography. As such the history of satellite remote sensing is preceded by a brief summary of the development of aerial photography.

1.1 History of remote sensing

Remote sensing has always been driven by man's desire to discover more about the Earth. Aristotle (384-322 B.C.) experimented with light and described the principle of the 'camera obscura'; light passed through a small opening into a box can be used to form pictures (the literal translation of "photograph" is "to write with light"). Aristotle's experimentation with photography was continued by various scholars and scientists, and by the end of the Nineteenth Century, the basic principles of modern photography were established.

It was only a matter of time before photographers began to take photographs above ground level. The first known photograph taken from a balloon was obtained in 1859 by Gaspard Felix Tournachon of Petit Bicetre, near Paris. In 1860, Samuel King and James Black took photographs of Boston, Massachusetts from a balloon 1,200 feet above the ground. During the American Civil War photographs of Confederate positions were reportedly taken by photographers in balloons for the Union forces (Colwell, 1983).

Photographs were first taken from aeroplanes in April 1909 by Wilbur Wright, over Centocelli, Italy. Aeroplanes provided more reliable and flexible platforms for cameras taking aerial photographs than balloons. It is not surprising that the First World War led to great developments in aerial photography and photo-interpretation. Most developments in remote sensing have been 'spurred' on by military needs - this is a recurring theme, shown by the fact that most civilian remote sensing programmes are spin-offs of military remote sensing programmes. At the beginning of the First World War, there was semi-official use of aerial cameras. A Lieutenant Laws, R.F.C., took the first aerial photographs of German territory. The photographs were of such obvious intelligence value that military use of aerial photography received official support (Colwell, 1960).

Photo-interpreters could predict enemy movements by observing such factors as the variation in amounts of rolling stock at important railheads and of ammunition at dumps. In 1918, photointerpreters of the American First Army, identified 90% of the German military installations opposite the First Army's part of the front line (Colwell, 1960).

During the inter-war years, especially in Canada and the United States, aerial photography was used for civilian uses, such as archaeology, geology, agriculture and forestry. This led to greater improvements in photography. By the early 1940's, both Britain and Germany had excellent photo-reconnaissance and photo-interpretation capabilities. This was extremely important because as General Werner von Fritsch, Chief of the German General Staff predicted,in 1938:

> "The nation with the best photo-reconnaissance will win the next war" (Colwell, 1960).

In the summer of 1940 British photo-interpreters detected German invasion vessels concentrated across the English Channel. The R.A.F. acted upon this information and effectively prevented the imminent invasion of Britain. Photo-interpretation was also used to detect German warships in ports and at sea, leading to raids which very much restricted the movement of German warships.

World War II was important to remote sensing in several ways: large numbers of people were trained in the art of photo-interpretation; and other aerial reconnaissance devices such as thermal infrared and radar systems were developed. The first successful airborne imaging radar, the 'Plan Position Indicator', was developed in Britain as an aid to night-time bombing. New potential was recognised for civil and commercial uses of photo-reconnaissance methodologies, for example in the fields of geology, soil, civil engineering, plant sciences and wildlife management.

The 1950's witnessed greater employment of remote sensing for reconnaissance purposes. It was a time when the Western world was worried about the expansionist aims of the Soviet Union and the American government realised that it was imperative to know exactly what advances the Soviets were making in missile and nuclear weapon development. At the Geneva Summit of 1955, President Eisenhower suggested to Soviet Premier Bulganin that

> "the superpowers should open their skies to each other's reconnaissance aircraft to ease the fears of war in the anxious hearts of people everywhere". (Brookes, 1975).

The CIA, described as the 'world's policeman against communism' (Brookes, 1975) were the leading advocates of monitoring Soviet military developments. They extended their means of gathering information with long-range, high-altitude aircraft. The U.2 which could cruise at 80,000 feet was developed by Lockheed. On 1 May, 1960, Gary Powers, the pilot of a U.2 on a reconnaissance mission (Pakistan-Norway), was shot down over Soviet territory. 'The Powers Incident'

> "taught the air forces of the US and the Soviet Union that the future of strategic photo-reconnaissance lay not so much in higher-flying aircraft, which were both politically provocative and very dependent on the physical endurance of the men who flew them, as in spying satellites. (Brookes, 1975)

The American Department of Defense initiated the development of photo-reconnaissance satellites in the late 1950's. Discoverer satellites, first launched in 1960, carried high-resolution cameras that took photographs of predesignated targets. Once the film was exposed it was parachuted back to Earth in a capsule. At the same time, SAMOS (the Satellite and Meteorological System) was developed. This was a low-resolution photo-reconnaissance satellite designed to take pictures of broad areas, so as to detect new weapon developments and deployments within the Soviet Union (Majetic, 1984). Within seven days of the launch of SAMOS II in January 1961, Secretary of Defense, McNamara was able to tell reporters that on examination of SAMOS prints there was no missile gap between the US and the Soviet Union. During the 1960's SAMOS satellites provided coverage of all of China and nearly all of the Soviet Union. The Soviet Union joined 'the optics race' in April 1962 with the launch of Cosmos 4.

Brookes (1975) stated that both the US and the Soviet Union kept reconnaissance satellites on standby for use in times of acute political tension. Apparently, American reconnaissance platforms were especially active during the Arab-Israeli war of 1967. In June, 1971, Big Bird was launched. It was the first of a new range of American reconnaissance satellites and it carried the instruments for both area surveillance and close-look activities. Big Bird was capable of a ground resolution of 6 inches from 100 miles above Earth. It carried infrared cameras and sideways-looking radars, and could cover every part of the globe in 12 hours.

Photo-reconnaissance from space has advanced to such a degree that it has become virtually impossible for any nation to hide its main military or industrial activities from the superpowers. For example, in the USA the KH(Keyhole)-8 satellite, launched in August 1966 was reported to have a resolution of 16cm, able to detect objects as small as a standard paperback from 233km in space. The KH-11 satellite, launched in 1976, combined both close-look and area surveillance and also introduced digital imagery technology, whereby images were collected electronically and transmitted directly to Earth via a communications relay satellite. This was done in near real time so that images were provided virtually as they occurred. The new KH-12 satellite, due for launch in 1988 will apparently have a resolution of less than 10cm and will use thermal infrared sensors (Brown, 1987). It has been suggested that sensors currently under development will collect simultaneous images in as many as 200 or more contiguous spectral bands. Obviously this will be a very important development towards the identification of Earth objects, as cover types may be more rigorously classified into narrower spectral categories.

There can be no doubt that aerial photography and satellite imagery have eliminated the fear of the unknown. One classic example is the Cuba Crisis of 1962, when the US discovered, using aerial photography, that Soviet-built Intermediate-Range Ballistic Missiles (IRBMs) were being erected in Cuba. Aerial photography was used throughout the crisis to analyse the situation. John McCone, the Director of the CIA at that time, stated that war over Cuba

> "was avoided because every weapons system was correctly identified in time to give the President and his policy advisors time to think, to make a rational estimate of the situation and to devise means of dealing with it with a maximum chance of success and a minimum risk of global war" (Brookes, 1975).

Aerial photography and satellite imagery are obviously essential tools of modern diplomacy, supplying political leaders with the necessary information to play an important role in the international arena and eliminating unnecessary fear and panic. In the same way satellite imagery from commercial systems has been used to provide details of crisis areas and violation of arms control agreements. For example, a detailed image of the damaged Chernobyl nuclear plant was provided by the Landsat 5 Thematic Mapper. In addition, a widely publicised image of the Krasnoyarsk phased-array radar being built in the USSR and possibly violating the ABM treaty, was supplied by SPOT-1.

1.2 Civilian remote sensing systems

The first use of remote sensing by satellite for civilian purposes was by the meteorological satellite Television Infrared Observation Satellite (TIROS-1), launched by NASA in April, 1960. J.A. McDivitt and E.H. White performed the first geological photographic experiment on the Gemini-Titan mission in June 1965. The result was thirty-nine usable overlapping photographs of south-west America and North Mexico. The Gemini Mission, by producing photographs of geological and agricultural significance, gave NASA an impetus to develop a land remote sensing system. So too did the Apollo Program, the American effort to land men on the moon. This involved a project called Lunar Orbiter, in which five observation satellites monitored the lunar surface (1966-67) to determine whether the manned lunar vehicle could land safely. The resulting photographs were so good, and of such value to geologic and mineral studies, that NASA was further inspired to develop an earth-oriented satellite observation system.

1.3 LANDSAT

NASA established an experimental earth resources survey programme, assisted by researchers in universities and elsewhere. On 23 July, 1972, the Earth Resources Technology Satellite (ERTS-1) was launched. It was equipped with a 4-channel

Multispectral Scanner (MSS) and a 3-camera Return Beam Vidicon (RBV), a data collection system, and two video tape recorders. Both the MSS and RBV viewed a ground area of 185km x 185km with a ground resolution of approximately 80m for MSS and 40m for RBV. The MSS had a mirror that oscillated in a plane perpendicular to the path of the satellite, therefore continuously sweeping across the 185km-wide ground track. The mirror focussed the image of a small segment of the earth on a set of photoelectric sensors with different spectral responses. For the first MSS, there were four bands, two in the visible region and two in the infrared (Committee on Practical Applications of Remote Sensing from Space, 1985). Each of the three cameras of the RBV had a different filter that determined the three spectral bands of the instrument: blue-green, yellow-red and near infrared. However, after a few weeks, the RBV failed and the MSS, which continued for five and a half years, became the primary source of Landsat data.

Landsat 2 was launched in January 1975 when the name of the series was changed from ERTS to Landsat (ERTS-1 being renamed Landsat 1). Landsat 2 did not cease operation until February 1982. Landsat 3 was launched in March 1978. A fifth band in the thermal infrared was added to the MSS, but unfortunately this band did not function properly. The RBV on Landsat 3 produced a resolution of approximately 40m by using two identical cameras that were aligned to simultaneously view adjacent 84km square ground segments. For all Landsats, data was transmitted directly to a ground station when the satellite was in range. When the satellite was out of range, data was temporarily stored on magnetic tape and later transmitted to a ground receiving station.

In July, 1982, Landsat 4 was launched. The RBV was abandoned and a new instrument, the Thematic Mapper (TM) was employed. The TM is effectively a much improved MSS, operating in 7 spectral bands, rather than four. The TM scans and obtains data in two directions, resulting in greater resolution - 30m for six of the TM's seven spectral bands instead of the usual 80m of the MSS. For the TM's thermal infrared band, the resolution was 120m. Landsat 4 was dogged with technical difficulties, which led to the early launch of Landsat 5 in March 1984.

At the time of writing, plans are being made for the launch of Landsat 6 in early 1989. The satellite will employ an Enhanced Thematic Mapper (ETM) which includes the current TM bands and an additional 15m panchromatic channel in the 0.5 - 0.9mm wavelength range. Landsat 6 will also feature an Emulated Multispectral Scanner (EMSS) which will have the same bands of Landsats 1, 2, 4 and 5 at 60m resolution (Hyatt, 1988). Hyatt (1988) describes a further stage that will take Landsat into the next century and its fourth generation:

> "it is proposed that the Landsat-H satellite will carry a payload that includes Multispectral Linear Array (MLA) 'Smart Sensors', a 5m High Resolution Pointable Imager (HRPI), L, C and X Band synthetic aperture radar and an active optical sensor for night imaging and atmospheric calibration".

Between 1979 and 1982, responsibility for the Landsat programme was shifted to National Oceanic and Atmospheric Administration (NOAA) in the US Department of Commerce. In 1979 NOAA initiated studies to determine whether the private sector could operate a land remote sensing system in the future. President Carter was in favour of the commercialisation of the Landsat system, but committed the US to continue providing data at least through the 1980's. Under the Reagan administration it was decided that the process of transferring Landsat to the private sector should be accelerated. In the Fiscal Year 1982 budget, request plans to build Landsats 6 and 7 were dropped, such was the hope that the private sector would be able to launch remote sensing satellites by the late 1980's. In March 1983, President Reagan announced the decision to transfer the Landsat system, the civil weather satellite system, and future ocean-observing systems to the private sector as soon as possible (Committee on Practical Applications of Remote Sensing from Space, 1985). The Administration's proposal for the transfer of the weather satellite system was dropped in November 1983.

The acceleration of transfer, as desired by the Reagan administration, was undermined by the premature failure of Landsat 4 and the subsequent early launch of Landsat 5 in 1984. It was obvious that a follow-on satellite was needed sooner than expected. In May, 1983, the Department of Commerce established a Source Evaluation Board (SEB). It was the task of the SEB to invite and assess proposals from parties interested in taking over and operating the Landsat and weather satellites. Eventually, the Earth Observation Satellite Company (EOSAT, a conglomerate of R.C.A., Hughes Aircraft Co., and several other companies) was selected (Committee on Practical Applications of Remote Sensing from Space, 1985).

1.4 Systéme Probatoire d'Observation de la Terre (SPOT) 1, 2, 3 and 4

On 22 February, 1986, SPOT I was successfully launched by the Ariane-1 launcher into a 832km high orbit. It was designed by the French Centre National d'Etudes Spatiales (CNES) and built by French, Belgian and Swedish partners. The payload of SPOT-1 includes two identical High Resolution Visible (HRV) imaging instruments. These sensors can operate in the panchromatic (black and white) or multispectral (colour) modes and in the visible and near infrared ranges of the spectrum. Resolution capabilities are 10m and 20m respectively in the panchromatic and multispectral modes. The satellite allows nadir (vertical) and off-nadir (oblique) viewing, the latter is important for recording stereoscopic pairs of images of a given scene, that is images acquired at different viewing angles during successive satellite passes. Although the revisit frequency for any given point would be 26 days, off-nadir viewing during satellite passes near the area of interest increases revisit possibilities (National Remote Sensing Centre, 1986).

Plans for the present SPOT programme extend into the 1990's. SPOT-2 will be essentially the same as SPOT-1 apart from some technical differences. SPOT-1 and SPOT-2 have an expected life of two years, SPOT-3, with an expected life of four years will replace SPOT-2 towards the end of 1990. It is proposed that SPOT-4 will be available in 1991, serving as a back-up to SPOT-3. The sensors carried on these latter satellites will be modified and improved versions of their ancestors (Hyatt, 1988).

The French government funded the initial research and development, and the construction and launch of the first SPOT satellite, together with the basic service infrastructure, at a cost of about 2.5 billion French francs. Planned as a commercial operation system from the outset, it was then the responsibility of SPOT Image, the company set up to market SPOT products, to generate enough income to finance follow-on satellites. At the time of writing, SPOT Image apparently has yet to make a profit and is dependent upon subsidies from the government and the private sector (MacKenzie, 1988).

1.5 Metric Camera and Large Format Camera (LFC)

Hyatt (1988) explains that

> ... the Metric Camera and Large Format Camera missions were flown on the Space Shuttle (*in 1983 and 1984, respectively*) to test the potential of high-resolution spaceborne photography using modified high-altitude aerial cameras."

The objective of the Metric Camera experiment was to assess the mapping capability of high resolution space photography for compiling topographic and thematic maps, at scales of 1:50,000 - 1:100,000, especially in unpopulated or less developed areas of the world, and for updating and revising maps. The LFC was also designed for mapping purposes. Both experiments were successful and provided a large amount of cloud-free imagery.

1.6 Modular Opto-electronic Multispectral Scanner (MOMS)

The German developed MOMS was designed for regional and global optical remote sensing applications onboard aircraft or space platforms, and flown on the Shuttle in 1983 and 1984. The MOMS has a spatial resolution of 10-20m and stereo capability. The modular assembly of the system also allows collection of target specific data in various bandwidths.

1.7 Seasat and Shuttle Imaging Radar (SIR) A and B

Seasat was designed for oceanographic observation and comprised five sensors, including an L-band Synthetic Aperture Radar (SAR) capable of observation even in unfavourable weather conditions. Seasat was launched in June 1978, but failure occurred in October 1978. The SIR-A and -B missions, flown in 1981 and 1984 respectively, followed on from the Seasat Mission. The missions successfully demonstrated the penetrative capability of radar and fulfilled the objective of providing information necessary for the design of future radar systems (National Remote Sensing Centre, 1986; Hyatt, 1988)

1.8 Heat Capacity Mapping Mission (HCMM)

The HCMM was designed to assess the feasibility of using thermal infrared imagery for various environmental applications. Data was collected in the visible and near-infrared channel at 500m resolution and in the thermal channel at 600m resolution. The HCMM operated in a sun-synchronous orbit, allowing imagery to be collected at times of maximum temperature variation.
The

> "... day/night temperature difference can be used to determine the thermal inertia of the ground surface scanned." (National Remote Sensing Centre, 1986)

1.9 Coastal Zone Color Scanner (CZCS)

The CZCS was the main sensor onboard Nimbus-7, launched in 1978 and operational until 1984. The CZCS was the first sensor specifically aimed at oceanographic and coastal zone water monitoring. Water colour was measured in five spectral bands, whilst one band was dedicated to the measurement of water temperature.

1.10 IRS-1A

Launched in March 1988, the Indian remote sensing satellite IRS-1A has three Linear Imaging Self-Scanning (LISS) cameras using charge-coupled device imagers. LISS-1 has a resolution of 73m, whilst LISS-1A and 1-B both have a 36.5m resolution.

1.11 Meteorological Satellites (Metsats)

Metsats are specifically designed for the observation and collection of meteorological imagery. Thus, orbits and sensors are chosen according to weather variations and the areas being covered.
include:

- the TIROS-N series
- Meteor series
- Geostationary Operational Environmental Satellites (GOES)
- Geostationary Meteorological Satellite (GMS)

- Geostationary Operational Meteorological Satellite (GOMS)
- Meteosats

1.12 Future remote sensing systems

Proposals for future remote sensing satellites include the following:-

International Space Station - this is a cooperative project between the USA, the European Space Agency, the National Space Development Agency of Japan, and Canada. Included in the manned station will be two polar platforms that will carry a variety of remote sensing packages, such as the Ocean Remote Sensing Assembly, Land Ocean Remote Sensing Assembly, and the Atmospheric and Meteorological Ocean Remote Sensing Assembly. It is planned that construction should begin in 1992, with completion aimed at 1994.

Radarsat - it is proposed that this Canadian developed platform will carry a 25 - 30m resolution synthetic aperture radar and an optical scanner. The satellite will be used for observation of oceanographic and coastal areas and of weather phenomena. Launch of the satellite is planned for the early 1990's.

Tropical Earth Resources Satellite (TERS) - this is a joint project between Indonesia and the Netherlands Agency for Aerospace Programmes. The aim is to develop a remote sensing system that will be relevant to the needs of tropical countries, and particularly to Indonesia. The satellite will have a resolution capability of 10m in the panchromatic mode and 20m in the colour mode. The satellite will be tailored to sensing equatorial vegetation and atmospheric conditions. The projected launch date is late 1980's/early 1990's.

CHAPTER TWO

LEGAL IMPLICATIONS OF SATELLITE REMOTE SENSING

2.1 Introduction

Legal opposition to remote sensing seemed to stem from differing interpretations of the 1967 Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies. The Treaty was designed that space exploration might improve conditions on Earth. Remote sensing satellites

> "were planned from the very beginning of the space age for a variety of purposes, each intended to apply analyzed data, wherever applicable, to earthly problems." (Matte et al., 1976).

Remote sensing did not become an international 'bone of contention' until the 1960's when it was becoming increasingly widespread. When the major space powers met in the newly formed United Nations Committee on the Peaceful Uses of Outer Space (UNCOPUOS) they initiated negotiations on the formulation of the legal principles regarding the use of outer space.

All the space treaties have been based on the idea that all outer space is an 'international common', a realm that remains outside the jurisdiction of any country. The other 'international commons' consist of a number of major river systems, some lakes and inland seas, most of the oceans, Antarctica, the atmosphere beyond the airspace immediately above the land, and the Earth's weather and climate. All of these realms are *res nullius*, meaning they are the property of no one (Brown et al., 1977).

One of the most crucial points in the legal regulation of remote sensing from space has been the conflict between the freedom of outer space for every state, and the idea of complete sovereignty of all states over their territories, as specified by international law. It is believed that the concept of state sovereignty dates back to approximately 3 000 B.C. Initially, only land areas and adjoining coastal areas were involved, but later natural resources such as mineral deposits were included (Benkö et al., 1985). Because remote sensing can provide detailed imagery of countries and their natural resources, some nations have opposed the freedom of outer space. For this reason it has taken the UNCOPUOS more than a decade to formulate a reasonably acceptable document dealing with remote sensing. The 'Principles relating to remote sensing of the Earth from space' (hereafter referred to as 'the Principles') were accepted by the General Assembly of the UN on 3 December 1986 (documented in Appendix I).

2.2 Attempts to establish a legal order for satellite remote sensing

Before negotiations on the formulation of the legal principles regarding the use of outer space, there were three legal instruments that applied to Outer Space:

1. Declaration of Legal Principles Governing Activities of States in the Exploration and Use of Outer Space (UN Resolution 1962 (XVIII), 13 December 1963).
2. International Co-operation in the Peaceful Uses of Outer Space (UN Resolution 1963 (XVIII), December 1963).
3. Question of General and Complete Disarmament (UN Resolution 1884 (XVIII), 17 October, 1963).

These three legal documents together with five others that were formulated in the UNCOPUOS (Rescue Agreement, 1968; Liability Convention, 1972; Registration Convention 1976; Moon Agreement, 1979; Principles on Direct Broadcasting Satellites, 1982), all repeated the idea that

> "outer space, including the moon and other celestial bodies, is not subject to national appropriation by claim of sovereignty, by means of use or occupation, or by any other means" (Article II, Outer Space Treaty, 1967 quoted in Benkö et al., 1985).

This text is accepted as indicating that no claims of national sovereignty can be extended to activities in outer space (Benkö et al., 1985).

The UNCOPUOS has been the major forum of discussion concerning the legal regulation of remote sensing. In 1969, the Scientific and Technical Subcommittee drew attention to the possibility of using remote sensing for the exploitation and monitoring of global resources. In June 1970 Argentina put forward the first formal proposal for the regulation of remote sensing. This led to the formation in 1971 of an interdisciplinary 'Working Group on Remote Sensing of the Earth by Satellites', a body within the Scientific and Technical Subcommittee. Until December 1986 this Working Group tackled the task of formulating a set of principles on remote sensing by satellites. Many drafts were tabled, especially by developing nations, but most proved to be unacceptable to all members of the UNCOPUOS.

In 1975 the Working Group found five common principles in the drafts that had been received from France (1969); Argentina (1970); the USSR (1973); Brazil (1974); France/USSR (1974); Argentina/Brazil (1974); and the USA (1975). By 1979, the number of common principles had increased to seventeen. However, many of these principles were without consensus and were subject to alternate formulations. This lack of agreement seemed to be based on differences in attitude to the major issues of the right to sense and to disseminate remotely sensed data.

Behind these differences were a number of basic national interests. Some countries believed that national security was threatened by the 'openness' of remote sensing. The legality of remote sensing was questioned in terms of the right to sense, to acquire and disseminate primary data and to disseminate analyzed information. Understandably, developing countries have been concerned with how remote sensing will affect their control over indigenous development and exploitation of natural resources. Many Less Developed Countries' (LDC) view of this has been coloured by the struggle for a New International Economic Order (N.I.E.O.), which will be discussed later in this section. There was also the question of a structure

> "...in which many states can participate either on an experimental or operational basis so that distributable benefits can be placed in the hands of those who would derive the largest advantages from programs for sharing". (Christol, 1982)

2.2.1 The right to sense versus sovereignty

The 'right to sense' seems to have been the most controversial issue throughout the UNCOPUOS discussions about remote sensing. Positions of various nations have ranged from the unrestricted right to sense, to one of prohibition without the prior consent of the sensed state. Between these poles were two middle groups. There were those that accepted the necessity of remote sensing activities, but required at least prior notification, if not the right to refuse such sensing in the absence of their prior approval. There were also those that accepted the legality and necessity of remote sensing, but were concerned about third parties acquiring sensed data concerning their natural resources.

Those nations arguing for a system of prior consent have

> "... based their arguments on territorial sovereignty, sovereignty over natural resources and wealth, and the security and economic considerations therein involved." (Magdelénat, 1981).

These states further argue that although remote sensing is a space based activity and thus protected by international law, it is essentially earth-oriented. Therefore, it follows that by collecting imagery of foreign territory without acquiring permission, the sensing body is violating the sensed state's sovereignty. This contention was voiced in Article V of the joint Argentina/Brazil Draft Treaty of 1974, which said that

> "states shall refrain from undertaking activities of remote sensing of natural resources belonging to another State without the consent of that state." (Magdelénat, 1981).

It is argued that those countries opposing remote sensing from space, or wishing to impose restrictions upon the activity, are mainly located in the Third World (Myers, 1985). One exception in the developed world was the USSR (1977), which proposed the classification of remotely sensed imagery according to spatial resolution into 'global', 'regional' and 'local' information. Global information would have a spatial resolution ranging from several hundred metres to several kilometres; regional from 50-100 to 300-500 metres; local from 30-50 metres. The USSR argued that local information should not be distributed without the consent of the sensed state. This proposal was rejected by the Legal Sub-Committee of the UNCOPUOS (Christol, 1980). Most developed countries, on the other hand, advocate complete freedom to sense. The American view was outlined in a Presidential Directive of 20 June 1978, which stated that the United States rejects any claims to the sovereignty over outer space or over celestial bodies, or any portion thereof, and rejects any limitations on the fundamental right to acquire data from space (Magdelénat, 1981). This view supported the Outer Space Treaty (1967) which stipulated that space is free for exploration and use by all nations.

2.2.2 Dissemination of data

The issue of dissemination of remotely sensed data has been very complicated and at times quite explosive. Indeed, the 1979 Legal Subcommittee did not even discuss the issue so as to avoid pointless and protracted deliberations! The problem has been complicated by several factors. Remotely sensed imagery can be classified as either primary, processed or analyzed data. Primary data is the raw unprocessed material obtained by a remote sensing satellite. In the new Principles (1987), primary data are distinguished as

"... the raw data that are acquired by remote sensors borne by a space object and that are transmitted or delivered to the ground from space by telemetry in the form of electromagnetic signals....";
processed data as "... the products resulting from the processing of the primary data, needed to make such data usable";
and analyzed data as "... the information resulting from the interpretation of processed data, inputs of data and knowledge from other sources." (United Nations, 1987)

Throughout the negotiations participant states have taken different positions on the dissemination of the different types of data. These positions usually reflect their views on the right to sense. On one hand, countries such as the United States favour universal dissemination of all classes of remotely sensed imagery. On the other hand other nations have argued that sensed states should at least have first access to primary data. Those countries that have argued for a system of 'prior consent' usually also believe that sensed states should have the exclusive right to receive the products of the sensing process, including processed and analyzed data.

As with the issue of the legality of remote sensing, arguments concerning dissemination are centred around national outlooks. Various developed countries that advocate an unrestricted data dissemination system quote the 1967 Outer Space Treaty, in particular Article XI which reads,

"In order to promote international cooperation in the peaceful exploration and the use of outer space, states ... conducting activities in outer space .... *agree to inform the Secretary-General of the United Nations* as well as the *public* and the *international scientific community, to the greatest extent feasible and practicable,* of the nature, conduct, locations and results of such activities. On reviewing the said *information*, the Secretary-General of the United Nations should be prepared to *disseminate* it immediately and effectively. (emphasis added)." (Myers, 1985).

Some of these countries also argue that sensed states should not have free access to processed and analyzed data which are different from primary data because they require a certain amount of input from the sensing body. By contrast, most LDCs argue for first and free access for sensed states. These countries argue that important data, for example data concerning mineral resources and crop information, might be withheld from them.

Benkö et al.. (1985) claim that in

"... 1984 NASA's Defense Department Liaison Office released only part of the more than 1000 Earth pictures obtained with the STS 2 camera after having screened those pictures to gain information important from a military point of view. The images of importance from the military point of view are not released."

Developing countries have been concerned that the same activity and constraints might apply to non-military data.

The idea that a restrictive system of remote sensing would be damaging to international progress has been the subject of considerable debate. A constrained dissemination system could result in data being available only to those few countries which operate satellites. Such a situation would be undesirable and potentially dangerous. For instance, if a multi-national corporation was to obtain exclusive information concerning a newly discovered source of oil in a developing country, it could develop and exploit to its own advantage that resource which could have been economically beneficial to the sensed state.

2.3 Third World concerns about the legal implications of satellite remote sensing

It is believed that

> "the struggle for the formulation of a set of principles regarding remote sensing of the Earth by satellites and data gathered with these satellites essentially centres around the interpretation of the term 'sovereignty" (Benkö et al., 1985).

Because remote sensing is a space-based activity, where no sovereign rights are applicable, it has been suggested that

> "...information collected in outer space about another State's territory cannot be the exclusive property of the sensing State." (Benkö et al., 1985)

On the basis of this theory, some LDCs believe that if other states are collecting data of their territory, they should at least be asked for prior consent to do so.

Myers (1985) believes that sovereignty cannot be defined in legal terms, although countries refer to it as such,

> "...especially when they seek to justify actions or political stances which may be of questionable legality".

Instead, sovereignty can be understood as

> "a permanent rule organized on the basis of legal principles and exercised over a specific territory, characterized outwardly by a certain degree of effective independence and inwardly by effective rule" (Myers, 1985).

Myers (1985) further believes that the strength of a state's sovereignty is dependent upon its ability

> "... to withstand pressures from other states which claim similar rights and independence. When interests of states overlap, the sovereignty of one or more must be compromised. Sovereignty, therefore, is never absolute."

Sovereignty can be viewed as a relative concept because although it is based on legal theory, it must be backed by political power -

> "sovereignty based upon theoretical right weakens in the face of sovereignty based upon power to control" (Myers, 1985).

Given this fact, it is not difficult to comprehend why LDCs feel at a disadvantage in situations where they feel their sovereignty is compromised.

2.4 The Third World and the New International Economic Order

To understand the stance taken by Third World countries on the issue of remote sensing requires an understanding of the Third World's feelings about the present international economic order. The fight for a more equitable system of remote sensing can be seen to go hand-in-hand with the fight for a New International Economic Order (N.I.E.O.). Throughout the negotiations in the UNCOPUOS, the Third World countries seemed to be largely influenced by their status as LDCs and allied feelings of nationalism. Myers (1985) states that

> "nationalistic concerns include effective control of natural resources."

It has been felt by many developing countries that remote sensing can undermine their control over natural resources.

Under the current international economic order, the South: that is the developing countries of Africa, Asia and Latin America, is largely dependent upon the Northern developed economies for its survival. The forms of dependence are several: most developing countries have small internal markets and thus rely upon Northern states to purchase their produce. In the area of investment, a large percentage is owned by Northern investors, usually in the most important and profitable areas of production such as raw materials and export industries. Another more subtle form of dependence is aid. It has been suggested that foreign economic aid to the South is often concentrated on one Northern source, which accords the latter political leverage, which might take the form of manipulation or decision-making. (Spero, 1982).

The call for a N.I.E.O. was initially voiced by the so-called Group of 77. This coalition of developing countries, pressing for economic concessions from developed countries, was formed in 1964 at the U.N. Conference on Trade and Development. From the middle of the 1970's when the Bretton Woods economic system collapsed and Southern states discovered the power of oil as a negotiating tool, the Third World initiated a concerted effort to establish a N.I.E.O. The aim was to change

> "...the present system in which a few wealthy, industrial and powerful states make most of the important decisions that affect all others." (Myers, 1985)

Third World countries have been motivated by the belief that all states should, without outside interference, be responsible for their own political and economic management and development.

The N.I.E.O. was documented in the Charter of Economic Rights and Duties of States. This Charter proposed far-reaching changes including trade and monetary reforms, substantial increases in aid, control of multinational corporations and the assertion of permanent sovereignty over natural resources. The issue of remote sensing is directly linked with the latter proposal. Many Third World countries have been concerned that developed states will use remote sensing imagery to exploit sensed states in much the same way as they exploited nations in times of colonialism. This view was expressed by the Indian delegation at the UNISPACE '82 Conference which stated that

> "...two states with a good remote sensing capability between them can be in league against a third which possesses little or no such capability and hence cannot take countermeasures." (United Nations, 1982)

This is the reason why developing states have so fervently opposed an open system of remote sensing, in terms of activities and dissemination.

A specific concern of Third World states is that uncontrolled remote sensing of natural resources could hamper their economic progress and well-being. They argue that this is credible because they are economically dependent upon the exploitation of their natural resources. The worry exists that information gathered from remote sensing data could adversely affect a state by influencing international market conditions. For instance, if an LDC was economically dependent upon its coffee crop, global knowledge of a glut of coffee could have an unfavourable impact on prices. There is also concern that sensing states and multinational corporations in particular might use remote sensing data to discover new sources of minerals, for example oil, and exploit that resource to the detriment of the sensed and other states. Overall, developing countries have believed that remote sensing is contributory to the continuation of unequal economic and political relationships between the developed and developing world. It has been claimed that the Third World regard remote sensing activities

> "...as a means to minimize their efforts to control and manage their own destinies without excessive foreign influence." (Myers, 1985).

2.5 Principles relating to remote sensing of the Earth from space

The Principles relating to remote sensing of the Earth from space (Document A/RES/41/65 - Appendix I) were adopted by the General Assembly on 3 December 1986, after more than 10 years of deliberations. Although the General Assembly adopted these principles by a general consensus, it was not put to a vote and some member states of the UNCOPUOS expressed their reservations about them. Some delegations believed that

> "...while the agreed principles on remote sensing were an acceptable compromise, they were accepting them on the understanding that the Committee would continue to work on that question in order that the concerns of developing countries would be more adequately met." (United Nations, 1986) .

Before the Principles were accepted, Christol suggested that if they were adopted through consensus, they might be put forward in such general terms that

> "... the question may arise as to their exact application to real situations. It will also be seen that in many respects (the Principles) do not create new rights and duties" (Christol, 1980).

Although this seems correct, the principles were not designed as

> "...a legally binding document, but reflect a mutual understanding among Member states on the question of remote sensing and its implications." (Kopal, 1987).

The General Assembly believe that the Principles

> "...will contribute to the strengthening of international co-operation in this field...." (United Nations, 1987).

This belief is evident throughout the text of the Principles, and takes into account the needs of developing countries. Principle II stipulates that

> "remote sensing activities shall be carried out for the benefit and in the interests of all countries, irrespective of their degree of economic, social or scientific and technological development, and taking into particular consideration the needs of the developing countries." (United Nations, 1987).

Principle V calls upon those involved in remote sensing activities to promote international co-operation in these activities.

> "To this end, they shall make available to other States opportunities for participation therein."(United Nations, 1987).

Furthermore, Principle XIII requires that

> "...a State carrying out remote sensing of the Earth from space shall, upon request, enter into consultations with a State whose territory is sensed in order to make available opportunities for participation and enhance the mutual benefits derived therefrom." (United Nations, 1987).

The present open system of remote sensing, in terms of activities and dissemination of data is reaffirmed by Principle IV, which asserts that

> "remote sensing activities shall be conducted in accordance with the principles contained in Article I of the Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and other Celestial Bodies, which, in particular provides that the exploration and use of outer space shall be carried out for the benefit and in the interests of all countries, irrespective of their degree of economic or scientific development, and stipulates the principle of freedom of exploration and use of outer space on the basis of equality." (United Nations, 1987).

Further promoting this open system is Principle IX which requires that

> "...a State carrying out a programme of remote sensing shall inform the Secretary-General of the U.N." (United Nations, 1987).

This would seem to suggest that ideally, there would be no surreptitious remote sensing activities, though obviously this happens in the military field.

It is debatable whether the Principles are adequately structured to cope with developments in the international remote sensing arena, especially in the area of commercialization, or whether various changes are in keeping with the spirit and aims of the document. For example, the US Congressional Office of Technology Assessment voiced its concern that the media's use of high-resolution images from remote sensing satellites might precipitate an international crisis (US Congressional Office of Technology Assessment, 1987). From 10 August 1987, according to the US Commerce Department's final rule on private remote sensing licensing, the Secretaries of State and Defense were invested with the power to veto license applications or suspend operations of US commercial satellite remote sensing organizations on the grounds of national security or international obligations. One could question whether such an action respects the Principles which support

> "... the freedom of exploration and use of outer space...." (United Nations, 1987)

The Principles do seem rather vague, but this seems necessary when one takes into account the multi-faceted nature of remote sensing, and the variety of national opinions on the subject. To make such a document too specific would probably be a retrograde step, possibly alienating countries and erasing some of the benefits hard-won through years of international negotiations. In order that the Principles should be as relevant as possible as the various changes occur, Voûte suggests that

> "perhaps ... it would be in the interest of the international community to elaborate and update at intervals the principles and rules developed by the UN Committee on the Peaceful Uses of Outer Space, and agreed upon in 1986. (Voûte, 1987)

Despite some of their weaknesses, the Principles are admirable in their design which attempts to promote international co-operation and fairness in remote sensing. Although some states do hold some reservations about the document, the adoption of the Principles would seem to be a very significant advancement.

CHAPTER THREE

COMMERCIALIZATION OF REMOTE SENSING ACTIVITIES

The commercialization of remote sensing satellites is a recent economic development, beginning with Landsat in the late 1970's. It is a situation that has affected, in both beneficial and detrimental ways, all users of remote sensing data. It seems fair to say that commercialization has effectively changed remote sensing on an international scale, and because it is an on-going process the consequences are not altogether certain.

3.1 LANDSAT

In the late 1970's President James Carter of the USA stated that his administration aimed to commercialise Landsat. Up to this time the land remote sensing programme had been

> "... an experimental program intended to demonstrate that certain technical systems were feasible" (Committee on Practical Applications of Remote Sensing from Space, 1985).

Considered in these terms, the US land remote sensing program had been a success, and the Carter Administration felt that Landsat should no longer be the responsibility of the National Aeronautics and Space Administration (NASA). Commercialization was to be a gradual process and as such the US was committed to maintaining the continuity of data from the Landsat system through the 1980's. Upon succeeding the Carter government, the Reagan administration decided that commercialization should be accelerated. As a result of this, the Fiscal Year 1982 budget dropped funds to build Landsat's 6 and 7, since it was hoped that the private sector would be able to build and operate Landsat satellites by the late 1980's. In July 1981, the Cabinet Council on Commerce and Trade was assigned the duty of finding the best way of transferring the Landsat system to the private sector as quickly as possible, and of deciding whether the government's civil weather satellites should be transferred to the private domain at the same time. In fact, the proposal to transfer the weather satellites was dropped in November 1983.

A Source Evaluation Board was established by the Department of Commerce in May 1983 to attract and assess proposals from parties interested in operating the Landsat and weather satellites. A draft request for proposals was issued, at first relating to both Landsat and weather satellites, but following the withdrawal of the latter, only to the Landsat system. Seven bids were made, two of which were considered by the Secretary of Commerce for further talks. One of these two dropped out, leaving the Earth Observation Satellite Company (EOSAT - a partnership of RCA, Hughes Aircraft Company, with Computer Sciences Company as a major subcontractor) as sole contender. During these negotiations, the necessity of a policy decision was made all the more urgent by the premature failure of Landsat 4, which led to the early launch of Landsat 5 in 1984.

Legislation in the form of the Land Remote Sensing Commercialization Act of 1984 (Public Law 98-365), authorised the transfer of land remote sensing capabilities from the Federal Government to the private sector. Three of the primary purposes of the Act were to:

1. guide the Federal Government in achieving proper involvement of the private sector by providing a framework for phased commercialization of land remote sensing;
2. maintain the United States' worldwide leadership in civil remote sensing, preserve its national security, and fulfil its international obligations;
3. minimize the duration and amount of further Federal investment necessary to assure data continuity while achieving commercialization of civil remote sensing. (Committee on Practical Applications of Remote Sensing from Space, 1985).

In September 1985, EOSAT took control of the Landsat system, assuming responsibility for the orbiting Landsats 4 and 5, marketing of all Landsat data, the construction of Landsats 6 and 7, and of new ground stations for these satellites. The US Government agreed to support this by providing a subsidy of more than $250 million over ten years. The hope was that over ten years, EOSAT would make Landsat a viable commercial operation, thus eliminating the need for Government support or subsidies. However, the process has been hampered by various financial and political problems.

EOSAT faced a severe financial crisis when the Office of Management and Budget (OMB) refused to allocate $69.5 million in Fiscal Year 1987 to allow continuation of Landsat operations. OMB policy at that time advocated greater private sector financing of Landsat, stressing that the Federal Government should not fund both follow-on satellites (Landsat's

6 and 7), even though this was agreed with EOSAT. OMB Deputy Director, Joseph R. Wright stated that

> "if Congress were to decide not to continue Landsat, I question whether the impact on the users would be significant." (Foley, 1987).

This was in consideration of the well-stocked Landsat archive and the fact that additional data could still be obtained from US Allies' satellites. Wright also cited the fact that the Defense Department had not been willing to financially support Landsat, and other Landsat users had not been vocal enough in their support, as extra reasons to discontinue Landsat. The threat of the Landsat programme ending at the time was so serious that President Reagan was called upon by Congress to discuss and remedy the problems. In fact, later in the year, in the Fiscal 1987 Supplemental Bill, Congress provided EOSAT with $62.5 million to build follow-on satellites (Foley, 1987). Apparently, this money was not to be released until Congress and the Reagan Administration settled their differences over the programme. In July 1987, the Administration supported the construction of one follow-on satellite, with research into a second one. However, Congress was adamant that the follow-on program should provide two satellites. Obviously, with such political tangles, EOSAT is presently unsure of where it actually stands, a situation which is not conducive to either medium or long-term planning.

On top of the funding problems, Landsat 5 is not expected to function beyond December 1988, with the earliest possible launch date for Landsat 6 estimated to be mid-1989. During the data gap, it has been stated that EOSAT will obtain SPOT data to supplement their data archive (Meyer,1987). SPOT Image hopes that this will prove a good opportunity to convert Landsat users into SPOT users. This might be the case, as present and potential Landsat users are understandably concerned about the future of EOSAT. It is estimated that EOSAT customers number more than 8,000 in more than 100 countries. Obviously, having invested in ground stations and tools for the analysis of Landsat data, these customers need guaranteed continuity of data. EOSAT's present position, which does not seem to inspire confidence, needs strengthening if it is to stand up to increasing foreign competition. Apart from SPOT, other bodies will be offering remotely sensed data during the 1990's. These include Japan with its JERS-1 satellite for earth resources sensing, Canada with RADARSAT to monitor coastal areas and ice formations, the European Space Agency with ERS-1, and the Indian satellite IRS-1.

3.2 Systéme Probatoire d'Observation de la Terre (SPOT)

Until 1986, Landsat had effectively monopolised the remote sensing commercial market. However, on 22 February 1986, from the Guiana Space Center in French Guiana, SPOT I was launched by the Ariane-1 launcher into a 832km Earth orbit. The SPOT programme had been planned from its conception in the 1970's as an operational commercial system. A Preliminary Exploration Programme was initiated in 1984, which provided price-reduced imagery to some 130 experimenters from an international range of research institutes. The aim of the programme was to investigate and promote the potential of the SPOT system. (Jaques et al., 1986) The institutional structure of SPOT operations was set up with the Centre National d'Etudes Spatiales (C.N.E.S.), the French space agency with the participation of the Institut Géographique National, a number of French, Belgian and Swedish industrial companies and SPOT Image, a commercial corporation. The CNES and its partners are in charge of spacecraft procurement, launch and operation, and SPOT Image controls data distribution and all commercial relations with data users.

3.2.1 SPOT commercial data distribution

With the SPOT programme, the French government agreed to fund the initial research and development and the construction and launch of the first satellite, together with the basic service infrastructure, at a cost of approximately 2.5 billion French francs. Responsibility, to meet all its operating costs and to generate sufficient surplus to pay for follow-on satellites, was then passed to SPOT Image, (Jaques et al., 1986). Since 1982, SPOT Image has gradually formulated its commercial data distribution policy and has set up a global network of SPOT data distributors. The data distribution policy is established upon two basic principles:

- non-discriminatory data dissemination
- copyright protection of intellectual property on the data.

As a consequence of these principles, it is stated that:

1. SPOT data are sold to end users under the condition that they cannot be reproduced for transmission to a third party
2. Official SPOT data distributors receive a licence for such reproduction (including royalty fees for duplicated data) and are committed to non-discriminatory distribution within their commercialization zone.

3. Value added companies require a licence for 'derived works and products', allowing them to elaborate and commercially distribute value-added data derived from SPOT images. (Brachet, 1986)

Distribution contracts have been signed with companies and government agencies in over 40 countries including most of Western Europe, parts of North and South America, several countries in Asia, Australia and some countries in Africa.

Although EOSAT and SPOT Image currently monopolise commercial remote sensing activities, it would seem likely that other competitors will become an important force in the 1990's. These will include the European Space Agency, Japan, Canada and India. The impact that these competitors will have upon global remote sensing activities is not altogether clear. It has been stated that SPOT and EOSAT representatives believe the more bodies involved in remote sensing, the better for business. It is hoped that an increase in the remote sensing activities will make more potential customers aware of the benefits of remote sensing.

One future cause for concern may be the distribution policies of future competitors. For example, at the end of 1987, British Petroleum p.l.c. voiced concern about

> "... the Japanese failure so far to commit themselves to an open skies policy for their resource satellite JERS-1...." (House of Lords Select Committee, 1987)

JERS-1 is due for launch in 1991. Such a policy would seem to challenge 'the Principles Relating to Remote Sensing of the Earth from Space', which stipulates that

> "remote sensing activities shall be carried out for the benefit and in the interests of all countries, irrespective of their degree of economic, social or scientific and technological development...." (United Nations, 1987).

Certainly, a discriminatory policy will leave various countries and companies feeling commercially disadvantaged, and will refuel international arguments about the legality of remote sensing. As the Geosat Committee Incorporated testified,

> "if, for whatever reason, the principal satellite producing countries should turn away from the 'open skies' policy, then the world risks an expensive, proliferating 'intelligence arms race' to develop nationalistic remote sensing satellite systems to further compete for world resources." (US Congress, 1983)

3.3 Implications of commercialization for developing countries

3.3.1 Prices

Because the Landsat and SPOT programmes are essentially commercially-oriented, data prices have increased considerably in comparison to those before commercialization. It would seem that high data prices are considered necessary if SPOT-Image is to meet all its operating costs and pay for follow-on satellites, and if EOSAT is to gain the required revenue stipulated in the Landsat Commercialization Contract.

Between 1972-82 the annual charge for a Landsat ground station was (US)$200,000. In 1983 the charge was increased to (US)$600,000. As a result of the US governments's reluctance to further subsidise Landsat operations, data prices rose rapidly in the early 1980's, as shown in Table 3.1.

Table 3.1 Landsat data prices, 1977-1985 (US Dollars)

	1 Jan 1977 to 30 Sept 1981	1 Oct 1981 to	1 Oct 1983 to 30 Sept 1982	Price increases effective Jan 1985 Feb 1985
	$	$	$	$
Photographic frames:				
Multispectral	8-50	8-70	26-175	30-195
Thematic Mapper			33-235	75-290
Computer Compatible tapes:				
Multispectral	200	300-600	650-1300	730
Thematic Mapper			2 800	4 400

(United Nations Centre on Transnational Corporations , 1984)

One can understand the Landsat price increases when one takes into account the 'Required

Revenue' clause of the Landsat Commercialization Act (1984).

Table 3.2 Landsat Revenue Projections

PERIOD	REQUIRED REVENUE DOLLARS
	$
9/85 to 09/85	442,826
9/85 to 12/85	3,431,897
9/85 to 03/86	7,491,147
9/85 to 06/86	11,550,397
9/85 to 09/86	15,609,647
9/85 to 12/86	19,668,897
9/85 to 03/87	22,723,897
9/85 to 06/87	25,778,897
9/85 to 09/87	28,833,897
9/85 to 12/87	31,888,897
9/85 to 03/88	34,033,897
9/85 to 06/88	36,178,897
9/85 to 09/88	38,323,897
9/85 to 12/88	40,468,897

Table 3.2 (Washington Remote Sensing Letter, 1985) gives the required revenue projections up to the end of 1988, for unenhanced data sales, ground station fees, and royalty income. They do not include any revenues from value added services and products. According to the Landsat Commercialization Act

> "the Contractor shall have the right to terminate ... this contract if the actual cumulative revenue realised is less than the Required Revenue" (Op cit.).

Table 3.3 SPOT data prices (£ sterling)

Digital Products

Product	Product Fee	Royalty Fee	Price (Exc. VAT)
	£	£	£
Full Scene panchromatic or multispectral 6250 bpi	395.00	306.00	701.00
Full Scene panchromatic or multispectral 1600 bpi	425.00	306.00	731.00

Photographic Products

Product	Product Fee	Royalty Fee	Price (Exc. VAT)
	£	£	£
Black and white print	20-61.00	30-81.60	50.10-142.00
Black and white film negative/positive	170.00	56.10-163.20	226.10-333.20
Colour film negative	250.00	163.20	413.20
Colour film positive	94.50	163.20	257.70

(National Remote Sensing Centre, 1986)

Developing countries often identify financial barriers to their use of remote sensing technology, and it would seem that the higher prices introduced since the commercialization of Landsat will certainly inhibit the use of remotely sensed data in the Third World, especially amongst users that are still in the process of evaluating the usefulness of remotely sensed data and those in the early stages of adopting remote sensing technology. Pakistan recognised that before commercialization

> "... one reason why remote sensing technology was being widely and enthusiastically applied all over the world, was the reasonable, affordable price at which Landsat [data] could be procured." (Pakistan National Report, 1986)

Remote sensing companies can understand the dilemma of Third World countries, but cannot afford to be give-away businesses. Jean-Claude Rivereau, SPOT Image marketing

Manager, acknowledged that many potential Third World Countries would find SPOT Image's prices too expensive at one-tenth of the cost (Jaques et al., 1986). It is quite likely that as prices increase, developing countries will increasingly depend upon overseas aid agencies to finance and support remote sensing programmes, which will presumably increase Third World reliance upon the Western World. This increased dependence would be anathema to those developing countries that wish to control their own political and economic management without Western interference. For them, it might be a good idea to look for sources within the Third World. One possible future supplier might be India, which plans to share data from its new IRS-1A remote sensing satellite with other countries, in particular those in the Third World. The satellite has comparable performance capabilities to the current Landsat generation. It carries three Linear Imaging Self-Scanning (LISS) cameras using charge-coupled-device imagers. Two of the cameras (LISS-1A and -1B) have a resolution of 36.5m, while LISS-1 has a 73m resolution. The price of data from IRS-1 is expected to be very reasonable, since IRS is a non-commercial venture, and the government wishes to recover material costs only. A computer-compatible tape from the LISS-1 camera is expected to cost approximately $200. (Mama, 1987).

From discussions with university staff and professionals involved in remote sensing it is quite clear that price increases have had a constraining effects upon research and development in the field. At the Office of Technology Assessment Workshop on Remote Sensing (US Congress, 1983), one university professor reported that:

> "ordering just four prints of a TM image would exhaust my entire teaching budget for all of my courses for an entire year! As of February 1985, a single frame of TM data in CCT format would cost me more than is contained in my total teaching budgets for 4 years! It is quite clear that these prices will (and already have) caused me and many other teachers to modify the course content, decrease the availability of 'hands-on' laboratory materials for the students to use, and virtually eliminate future orders for Landsat products to use in the classroom." (US Congress, 1983).

Obviously, the restriction of the research and development community will have serious consequences. It could lead to a 'vicious-circle' situation, because if research and development is restricted, future developments in remote sensing technology could also be seriously restricted and the number of skilled personnel will dwindle, which would have a negative effect upon the international remote sensing scenario. EOSAT is attempting to stimulate the research community, recognising it as essential to the future of the remote sensing industry. However, EOSAT is prohibited by law from providing cut-price data and, as such, has testified before congressional hearings in support of research data grants. (Meyer, 1987)

3.3.2 Availability and continuity of data

It has been suggested that a price increase does not necessarily mean the end of the use of satellite data in developing countries. If data is provided promptly and continuously, developing countries might still use remotely sensed data to replace other, more expensive methods of obtaining information about natural resources (US Congress, 1983). However, it would seem that Third World users of remote sensing technology are particularly concerned about the availability and continuity of data from present and future satellite systems.

The future of Landsat is far from assured, making it almost impossible for Third World countries thinking of investing large sums of money for using remote sensing technology,

> "... to develop the capacity successfully to incorporate remote sensing data into national development planning." (US Congress,1983).

This is also particularly serious for countries involved in medium- and long-term projects that require Landsat data on a continuous and timely basis, for example in a crop monitoring exercise. In addition, the situation will be of considerable concern to those countries that have invested in expensive equipment to receive and utilise Landsat data.

Apart from the present policy wrangles over EOSAT, there are other factors that affect the availability and continuity of data from both EOSAT and SPOT Image. There appears to be some difficulty in receiving Landsat data promptly after a satellite pass has been made. One Landsat customer believed that

> "... it is only possible to collect data once every 16 days and then there has to be minimal cloud cover for it to be usable." (Meyer, 1987).

and that delivery time is very variable,

> "...if you order before the pass, data are delivered 2-3 weeks afterward. If you order after the data are collected, it can take from six weeks to two months." (Meyer, 1987).

SPOT Image also seems to have problems in delivering data promptly. Images that are received at the Toulouse or Kiruna receiving stations can take up to two weeks to deliver. Obviously, this hampers the development of markets such as agricultural forecasting (MacKenzie, 1988).

It appears that the introduction of the 'sensing-upon-request' operations by EOSAT for Landsat-4 and -5 and by SPOT Image for SPOT-1 has made a considerable impact upon the availability of data (Voûte, 1987). Despite this there has not been such a drastic change to the past policy of Landsat. There was limited space on the satellite's recorder, which meant that it was only switched on intermittently to collect data when out of reach of a ground station. Currently, the satellite only collects specific data on the order of a customer if the required data is not stored in the archives. Thus, the difference between past and present Landsat practice is that data is no longer collected when the satellite is within reach of a ground station, unless there is a customer request for data of that area. The problem with this practice is that there will be less or no usable data for those areas where no order has been placed. This effectively limits

> "... the opportunities to refer to archival material for specific purposes or in cases of urgently emerging needs." (Voûte, 1987)

It is believed that the availability of data from SPOT-1 can be affected by the technical specifications of the satellite. The payload of SPOT-1 comprises two identical High Resolution Visible (HRV) sensors and a package consisting of two magnetic tape data recorders and a telemetry transmitter. It is possible to point the mirrors of the HRV sensors from nadir (i.e vertical) to up to 27° either side of vertical. The nadir position is used to obtain stereopairs of images, and the off-nadir position is employed to acquire oblique views to cover an area of interest which is off-track.

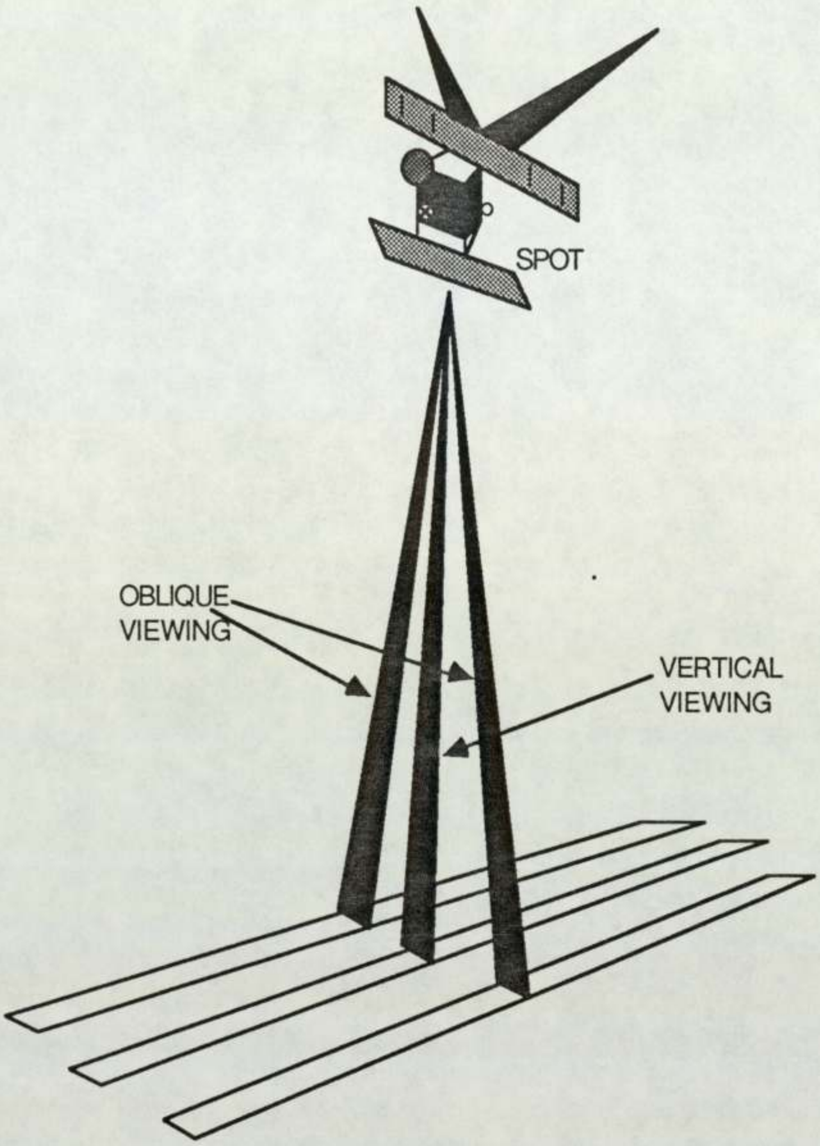


Figure 3.1 Viewing Characteristics of SPOT

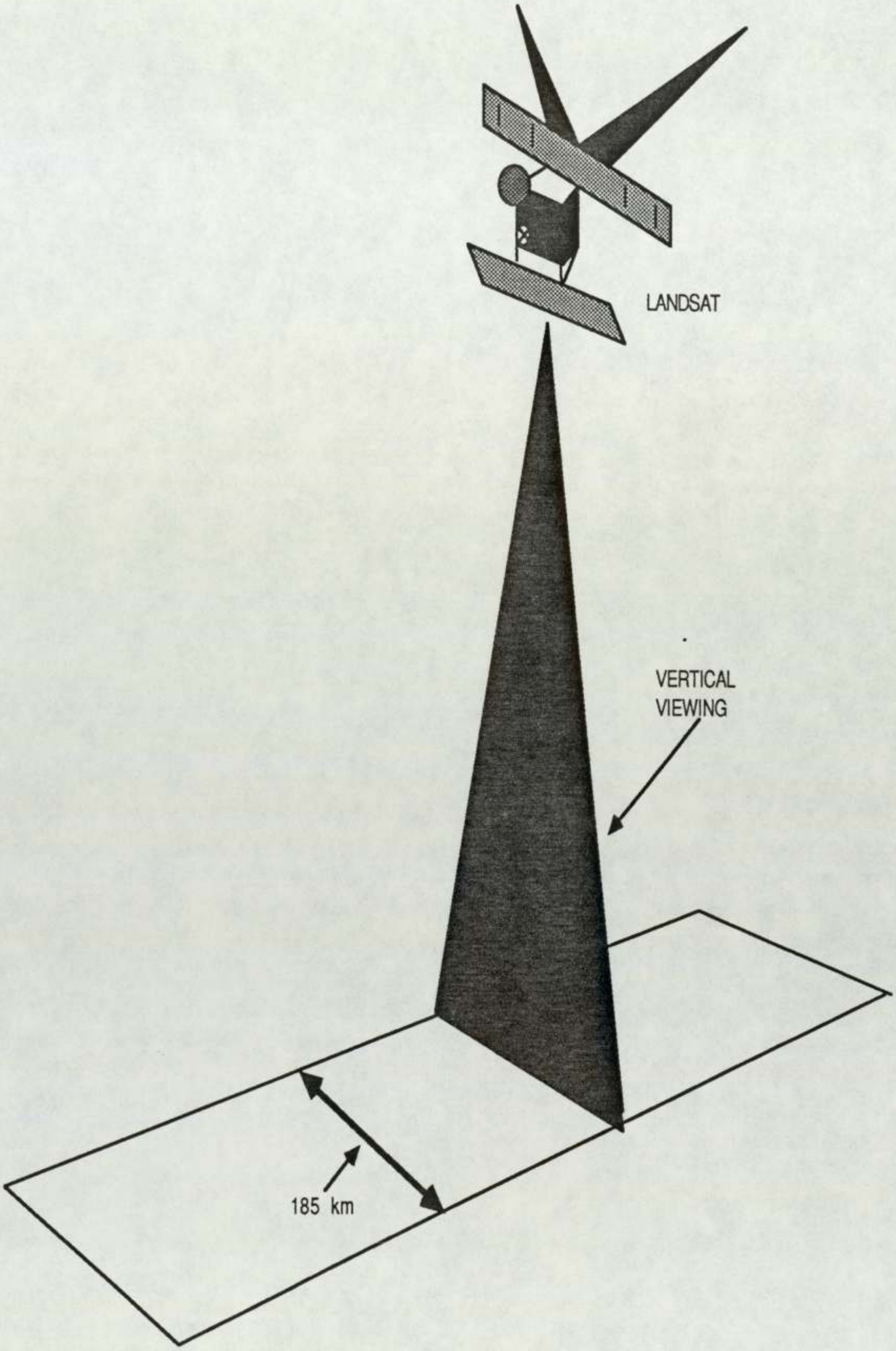


Figure 3.2 Viewing Characteristics of Landsat

The programme of planned viewing is controlled by the satellites onboard computer. If SPOT's sensors are programmed only for nadir viewing, the revisit frequency for any given point would be 26 days. This would be unacceptable for the monitoring of phenomena within a timescale of several days to a few weeks, especially if cloud cover could prevent the acquisition of usable data. (National Remote Sensing Centre, 1986). According to Voûte, SPOT-1's specifications

> "... leads to a situation where, depending upon the customer requests received and paid for, the data coverage of the various regions is uneven and depends upon demand." (Voûte, 1987).

It appears that between February 1986 and May 1987, much imagery was produced for areas of France, for which there were many customer orders. Areas of France for which there were no customer orders, were left blank. Thus, a situation might arise that vertical imagery of an area is urgently required, but will not be obtained because a contract has already been placed for the acquisition of oblique imagery of that area. Indeed, it could be said that

> "... this practice could even be used on purpose for preventing data acquisition over sensitive areas by a well-calculated ordering of the largest amount of data possible from other areas, assuming that the contracting receiving/processing facilities are willing to pay the price." (Voûte, 1987).

Obviously, the problem of limited availability of data is a global issue, and especially serious for developing countries and research and development institutes. For developing countries about to adopt remote sensing technology, the limited acquisition of data might lead them to look to other more dependable, but possibly less efficient methods of observing natural resources; for those developing countries already employing SPOT and Landsat imagery, they might be seriously hindered in their efforts. Some developing countries viewed the transfer of the Landsat programme as a hostile act, fearing that commercialization would reduce their opportunities of using Landsat data for national development, which might be sold preferentially to political or economic adversaries. It is quite possible that the remote sensing research and development community, already set back by the substantial price increases, will also suffer as a result of the reduction in the amount of data collected over certain areas.

3.3.3 Copyright restrictions

For the commercialization of remote sensing systems to be viable, in terms of gaining the greatest return and making remote sensing products more desirable, it was necessary to introduce strict copyright regulations and contracts between systems operators and distributors, and between users and operators or distributors. These regulations contrast sharply to the free-flow of data associated with Landsat before commercialization.

It was recognised by the United States Congress in 1983 that business interests would generally desire limited access to the data they were interested in. As such, it was agreed that a commercial venture would need data protection guarantees or proprietary rights to data (US Congress, 1983). Such measures have been introduced by EOSAT and SPOT.

3.3.3.1 EOSAT copyright regulations

Under the US Land Remote Sensing Commercialization Act of 1984, all users of unenhanced EOSAT Landsat data are required to sign a document known as the "Agreement for Purchase and Protection of Satellite Data", which is filed by EOSAT. Unenhanced data purchased from EOSAT can be reproduced for the sole use of the purchaser group (purchaser and employees, affiliates, contractors and consultants), under the following instructions:

- the digital unenhanced data may not be copied byte for byte to 800, 1600 or 6250 bpi C.C.T.s (this regulation virtually prevents all copying of unenhanced data, since nearly all C.C.T.s are either 800, 1600 or 6250 b.p.i., apart from 3200 b.p.i. C.C.T.s);
- all digital reproductions must be erased after the purchaser group has no use for them (Thomas, 1987).

No direct duplication of Landsat C.C.T.s is allowed, even for back-up purposes. Reduced price back-up C.C.T.s can be purchased, but only at the time of original purchase.

Purchasers may use enhanced data in any way they wish. Data are considered to be enhanced when significant and irreversible changes are made to the original unenhanced data. This could be a significant loop-hole, since it means that enhanced data may be reproduced and circulated freely within a purchaser group.

EOSAT also provides a "Waiver of Purchase Restrictions" to allow, for example, the use of unenhanced data for publication or reproduction in a text or report. (Thomas, 1987).

3.3.3.2 SPOT Image copyright conditions

Copyright restrictions apply to all SPOT data, including a wide range of value-added products. SPOT data may not be disseminated in any form without the written consent of the copyright holder and payment of the appropriate royalty fee. SPOT data is defined as any signal transmitted and recorded on any suitable medium and processed by any method, which does not significantly modify the form of such data by the use of data external to the acquisition system.
It is stated that:

- the Centre National d'Etudes Spatiales (CNES) is the sole distributor of copyrights to SPOT data. The products marketed by SPOT Image are developed on the basis of such data;
- all orders for SPOT data should be processed through an authorised distributor. In the UK there are two official distributors, the National Remote Sensing Centre, which deals mainly with data of the U.K., and Nigel Press Associates, dealing mainly with data of regions outside the U.K.;
- the purchaser shall only use the products for their own purposes and shall not, without the prior written consent of SPOT Image, make such products or reproductions available to a third party. Marketing and reproduction are subject to approval by SPOT Image;
- the purchase of a SPOT image confers a non-exclusive right for private use with the buyer;
- up to a total of nine copies (in any format - C.C.T., negative, print, etc.) can be made of the original master for private or internal use;
- authorisation for collective use of product copies within groups of organizations governed by various statutes, such as national research councils, university departments, affiliate companies, etc., can be obtained from SPOT Image.

No copyright royalty is due in cases when SPOT data is used to illustrate reports or theses, or used as remote sensing promotional material. (Thomas, 1987).

The new copyright regulations would appear to be very restrictive, when compared to the free-flow of data associated with Landsat before commercialization. They would be particularly restrictive in collaborative exercises. Hypothetically, there could be a project, using SPOT imagery, in which a remote sensing consultancy company could be commissioned by an international aid organization to carry out work in a Third World country. It might be that all parties would require the same imagery to monitor the progress of the project. According to the SPOT copyright regulations, it would seem that all three parties would need to buy the same imagery unless they could gain authorization from SPOT Image to collectively use the data. Even in the latter case, royalty fees would be payable.

Those Third World countries that look upon commercialization as a hostile act, will probably view the copyright regulations as yet another obstacle to their use of remote sensing technology. For example, if a developing country required multiple copies of imagery for a survey, it might not be able to afford them, or could be discouraged by royalty fees and the costs of back-up images. The copyright regulations might also perpetuate the fear of some Third World states that commercialization will put remote sensing out of the hands of developing countries, into those of large commercial concerns, such as multinational companies that can afford not to be restricted by various regulations. Such a situation could fuel the belief of some that the 'have-nots', that is the less developed countries, are being exploited by the 'haves', the wealthy Northern states.

3.3.3.3 Monitoring copyright regulations

One must question how SPOT Image and EOSAT hope to monitor compliance with their copyright regulations. Violation of regulations would be very difficult to detect, unless an organization was to flaunt the fact that it was breaking the rules. It would be difficult to discover if a company was making back-up copies of data, although one presumes that many bodies do so to insure against data loss. According to EOSAT regulations, this practice is not permissible. Monitoring would probably require visits to organisations using imagery, but this would seem to be impractical, expensive and probably would not be very successful.

3.3.3.4 Data encryption

It is suggested by Price (1985) that

> "...secondary reproduction and distribution of satellite data by data purchasers is to be expected unless active steps are taken to protect the seller's prior rights."

Price (1985) further suggests that the most effective technique would be to encode data in a format unique to each purchaser. By doing so,

> "any such data may be traced immediately by the seller if unauthorised versions are distributed"(Price, 1985)

The technique suggested by Price would seem to be impractical and probably quite expensive. Voûte suggests that an experimental scrambler might have been tested on SPOT-1 in order that data would only be transmitted to those ground stations contracted to receive it. Indeed, it is possible that

> "...an operational scrambler for this very purpose is scheduled for inclusion in the SPOT-4" .(Voûte, 1987)

3.4 Suitability of imagery

One of the major shortcomings of existing remote sensing systems is that imagery is often inadequate for the needs of developing countries, or imagery is not generally available over areas where it is needed. It would seem that the reason for such limitations is that present systems are usually designed to suit the needs of users in industrialized countries. In the future, in order to increase revenue, a private sector owner and operator may be increasingly tempted to tailor its satellite sensors to the needs of those that can afford satellite imagery.

Landsats 1, 2 and 3 had 80 metre pixels and an area coverage repetition rate of 18 days. These design features were ideal for land use studies and crop monitoring in North America with large fields and a uniform agricultural system. However, in many developing countries fields are small and crops may vary from field to field and 80m resolution imagery would be inadequate. There is also the problem of obtaining good quality cloud-free scenes over heavily clouded tropical areas. Sensors which operate in the visible and near-infrared part of the spectrum are poorly adapted to acquiring cloud-free scenes, and some satellites pass over tropical areas at times of heavy cloud, rather than at times of relatively little haze. It has been stated that in the case of SPOT

> "of the theoretical half-million scenes available for archiving each year, a very approximately estimated 20% will be totally unusable because of ground weather conditions; a larger proportion may have partial cloud cover." (Jaques et al., 1986).

To overcome some problem of non-availability of relevant data for tropical areas, the Netherlands Agency for Aerospace Programmes initiated plans for a Tropical Earth Resources Satellite. This satellite would employ a multispectral linear array and would send its data to a ground station in Indonesia. Orbit and sensor characteristics would be configured so as to meet the needs of sensing equatorial vegetation and atmospheric conditions. It is hoped that TERS might be launched in the early 1990's.

3.5 Value-added industry

The commercialization of remote sensing has led to the growth of the value-added industry, which includes basic digital data processing companies, government agencies and resources companies. An example of a value-added business is Nigel Press Associates, a UK remote sensing consultancy, which, amongst other services, uses remote sensing for hydrocarbon and mineral prospecting. Nigel Press, the owner, claims that the company is kept in the remote sensing business by oil companies that are willing to pay highly for prospecting services. (Jacques et al., 1986). To be commercially successful, prices for value-added services will necessarily be quite high, probably too high for most Third World countries, but affordable for developed countries and wealthy prospecting companies. This might mean that in negotiations, for example between a less developed country and a large oil company, the latter might gain an economic advantage by being able to afford informative, digitally enhanced imagery.

CHAPTER FOUR

OTHER FACTORS RESTRICTING THE USE OF REMOTE SENSING IN THE THIRD WORLD

4.1 Lack of a remote sensing organizational base

If remote sensing is to be employed on a national scale for a variety of tasks, the first requirement has been identified as a coordinating organizational structure (United Nations Centre on Transnational Corporations, 1984). Such a structure would be responsible for the planning, establishment and maintenance of remote sensing programmes. Some LDCs lack this organizational set-up and consequently find its absence restrictive. The importance and the functions of a remote sensing organizational base are discussed in greater detail in Chapter Seven.

4.2 Education and training in remote sensing

Although remote sensing technology is advancing at a rapid rate, it would seem that education and training in remote sensing are not keeping up. Most reports on the subject state that there is a global shortage of qualified personnel and professional staff. The situation is particularly acute in the Third World where it is estimated that the

> "...capacity for these countries falls short of the demand by a factor 10."(d'Audretsch et al., 1981).

This is serious when one takes into account that

> "...education taken in its broadest sense is an essential condition to achieve the required degree of preparedness for the deployment of any new technology." (Voûte, 1983)

As remote sensing moves from the experimental stage to the fully operational stage, adequate educational and technical structures are essential if a state wants to take full advantage of satellite data available now and in the future.

Voûte (1983) suggests that for developing countries, education and training in remote sensing needs to fulfil two major policy objectives. Firstly, there is the need to achieve increased self-reliance, which would involve mastering airborne and space remote sensing techniques. The second objective would be to gain the expertise necessary to negotiate

> "...system specifications and systems implementation for future satellite remote sensing systems suited to the particular needs of developing countries." (Voûte, 1983)

It would seem that there are a number of factors that hinder the developing countries in their attainment of these objectives, for example the global shortage of qualified teachers. Lillesand suggests that the reason for this situation is two-fold. On the one hand, industry and government sectors are luring qualified educators away from teaching and at the same time

> "... the ranks of the World War II vintage interpretation specialists who entered the education field are being thinned by normal attrition." (Lillesand, 1982)

Lack of adequate finance and equipment also prevent the establishment of an effective educational structure in many developing states. For example, in the case of digital image processing, which is now fundamental to image interpretation, a computer, framestore and screen are required. Many states cannot afford such equipment. Also exacerbating the situation is the fear of some developing countries, of 'intellectual imperialism' through the

> "... transfer of models for reasoning and thinking, of scientific concepts, and of complete technological end-to-end systems." (Voûte, 1985).

Linked to this is the idea that such 'intellectual imperialism' might affect socio-cultural norms, since other forms of scientific and technological developments have made a considerable impression upon culture. Voûte cites modern medicine and informatics and telecommunications as examples of developments that have changed everyday life and culture. (Voûte, 1985) Many Third World countries also find it difficult to adjust to alien science and technology from industrialized societies. Conitz argues that when personnel from the Third World are sent to foreign countries for training, they often find:

- "the training exercises address problems foreign to them;
- their newly acquired enthusiasm is not shared or appreciated by their management;
- they have no data or interpretation facilities;
- their 'foreign' training qualifies them for promotion to a different, non-remote sensing job." (Conitz, 1977)

In its National Position Paper presented at UNISPACE '82, Malawi identified the lack of adequate training, especially in the Third World, as a problem requiring international cooperation. In Malawi, staff had been sent to various remote sensing seminars in other countries, but it was felt that this training was good but not sufficient, because seminar periods were too short. It was recognised that

> "...each discipline in natural resources in Malawi should have professionally trained personnel in remote sensing techniques" (United Nations, 1982)

but this could not be achieved because financial resources were very limited and often not available locally. There was also the problem of nonavailability of equipment and facilities with which to practice newly learnt techniques. Malawi called for international aid and development groups, such as the United States Agency for International Development (US AID), to increase the proportion of training in their technology transfer programmes.

4.3 Technology transfer

It has been suggested that the transfer of remote sensing technology is

> "...not associated with building, launching or tracking remote sensing satellites, but rather with the transfer of technology needed to apply the collected data to civilian development processes." (Specter, 1986).

Thus, the transfer of technology includes technical assistance and training as well as data and equipment. It is generally believed that the transfer of appropriate remote sensing technology could lead to economic and social development within the recipient country. However, there are numerous political, economic and cultural barriers to such technology exchange.

4.3.1 Barriers to technology transfer

Research into Remote Sensing Technology Transfer (R.S.T.T.) has recently been completed, employing a questionnaire survey. (Specter, 1986). The following eight major barriers to R.S.T.T. were identified by respondents from developed countries, developing countries and international organisations:

1. Cost of computer compatible tapes;
2. Cost of data processing equipment for computer interpretation;
3. Size of capital investment required;

4. Lack of foreign exchange to pay for remote sensing products, equipment and technical assistance;
5. Anticipated withdrawal of US government financial support for the Landsat system;
6. Anticipated withdrawal of US government from management of the Landsat system;
7. Lack of personnel experienced in using computer compatible tapes;
8. Lack of knowledge about the applications of remote sensing technology among government decision-makers in developing countries. (Specter, 1986)

Clearly, the respondents seem to believe that the major restrictions are economic, since five of the eight barriers are financial in nature.

The following major barriers were identified by respondents from developing countries only:

- lengthy procedure to obtain data processing equipment;
- lack of funding from developed countries and/or multilateral agencies to support remote sensing activities;
- lack of funding for training programmes that provide a general orientation to the applications of remote sensing technology;
- lack of funding for developing country students to attend 4-year degree programmes in hydrology, geology and agriculture;
- lack of interest in applications of remote sensing technology among government decision-makers in developing countries. (Specter, 1986)

From Specter's survey results, financial barriers seem to be considered as much more significant by developing countries. This is understandable in view of the present financial crisis faced by most developing countries. Martin (1986) suggests that it is difficult for developing countries to get loans from commercial or development banks for remote sensing equipment because there are not sufficient numbers of projects using satellite imagery. It is possible that aid agencies consider productive sectors, such as agriculture as being in more need, especially in the light of recent food crises. The present foreign exchange situation, linked to the great increase in the developing countries' external debts, makes highly capitalised investments unfavourable or impossible.

4.3.2 Different cultural values

In most cases, disseminators and recipients of remote sensing technology have very different perceptions of remote sensing technology transfer. The disseminator is concerned with making known what technology is available, implementing the means of transfer and possibly helping with the use of the transferred technology in the recipient state. The recipient must assess the need for the new technology and carry into effect its application. This involves a number of key people that need to make

> "...the necessary changes in the organisations, institutions, policies, procedures and laws" (Glaser et al., 1968).

These key people, with different values and needs, must take into account the economic, social and political implications of the introduction of new technology.

There are several problems associated with the introduction of new technology into developing countries. It is possible that new technology might be considered threatening to traditional industries. There is also the idea that, by adopting the technology of the developed world, a Third World state might become increasingly dependent upon Northern states and might be subjected to 'intellectual imperialism'. Obviously, this is abhorrent to developing states attempting to achieve greater independence. Another problem is that in many cases the technology of the developed world is inappropriate for developing countries because it might not be in line with a developing country's needs and resources, or it tends to be capital intensive, which might exacerbate financial difficulties. Decision-makers have to assess these problems, often without knowledge of the benefits of remote sensing technology to development activities. This presents another barrier in itself, since it is quite probable that this lack of knowledge leads to lack of support for remote sensing technology transfer.

To overcome the differences in opinion between disseminating and recipient bodies, it seems important that there should be greater communication between the two. Through this process, the donors could become aware of the recipient's values and needs and thus, identify obstacles to the acceptance and use of new technology, and also deal with any queries of the recipient.

Another major obstacle to the transfer and use of remote sensing technology in the Third World has been the recent commercialisation of satellite remote sensing. Chapter Three showed that commercialisation has pushed up data prices and tightened access to remote sensing imagery. The longevity of remote sensing companies is not assured, and this situation does not promote confidence among potential customers, especially those of the Third World.

4.4 Financial difficulties

It would seem fair to say that for many developing countries the greatest obstacle to adopting remote sensing technology is an overwhelming lack of money. Many Third World states face debt crises on such unprecedented scales that planning for future development is almost impossible. Early in 1986, the Third World debt reached the $1 trillion mark (i.e. one thousand billion, taking a billion as one thousand million). This figure seems to pale in comparison with, for example, the public debt of the United States, which was $2 trillion in 1986 (George, 1988). However, the $1 trillion figure is significant when one takes into account the total inability of some developing countries to repay their debts.

4.4.1 The Third World debt crisis

The debt crisis which the Third World currently faces has been a predominant feature of the 1980's. The trade deficits of Less Developed Countries (LDC) with the rest of the world began to spiral upwards in the mid-1970's. Hodgson et al. (1983) suggest that factors contributing to this development were:

> "... the increase in petroleum prices during the 1970's, the decline in the price of many primary products following the commodity boom of the mid-1970's and the generally low level of world economic growth, which depressed the demand for many LDC exports (particularly industrial raw materials)." (Hodgson et al., 1983)

As a result LDCs were faced with problems such as high unemployment and soaring inflation. The trade debts of the non-oil exporting LDCs rose from $18.3 billion in 1973 to $73.2 billion in 1979. LDCs have borrowed heavily to finance the rising trade imbalances, putting themselves into enormous debt and widening the gap between them and the developed world. Several LDCs have declared their inability to service external debts. For example, on 18 August 1982, the Mexican government announced that it did not have enough funds to pay its public foreign debt. At that time Mexico owed approximately $80 billion in foreign debt (Lomax, 1986).

Table 4.1, taking Gross National Product (GNP) as a measure of economic development, indicates the differences in development between developed countries and LDCs, and between the latter group themselves. It also takes into account the literacy rates and health standards (measured by life expectancies) of the various countries.

Table 4.1 Per Capita of Selected Nations and Other Demographic Characteristics (1978)

Country and Rank	GNP per Capita US$	Adult Literacy Rate (%)	Life Expectancy
Kuwait (1)	15,970	60	69
United States (6)	9,770	99	73
Italy (22)	4,600	98	73
USSR (26)	3,710	99	70
Argentina (37)	2,030	94	71
Republic of Korea (48)	1,310	93	63
Guatemala (60)	930	47	57
Bolivia (75)	510	63	52
Pakistan (99)	240	21	52
India (107)	180	36	51
Bangladesh (117)	90	26	47

(Hodgson et al., 1983)

From Table 4.1, it can be seen that in 1978 an individual in the US had an average income of approximately 100 times that of an individual in Bangladesh. Table 4.2 presents a broader view of the differences in income between developed and developing countries, categorizing nations into per capita income groups and showing the population of each group.

Table 4.2 Number of Countries and Population by Income Groupings

Per Capita Income Group	Number of Countries	Population mid-1978 (millions)	Cumulative Percentage of World Population (%)
Less than $300	36	2,008	48.3
$300 - $699	38	493	60.1
$700 - $2999	50	571	73.8
$3000 - $6999	29	536	86.7
$7000 and over	25	552	100.0

(Hodgson et al., 1983)

As Hodgson et al. (1983) note, approximately one half of the world's population has an income of less than $300 p.a. and almost three-quarters earn less than $3000 p.a.

The debt crisis that many LDCs face cannot be blamed solely on the greedy financial institutions of the developed world. A number of developing countries have spent enormous amounts of money on militarization. In 1985, the Stockholm International Peace Research Institute estimated that 20% of Third World debt (excluding Organisation of Petroleum Exporting Countries) had been used for arms purchases (George, 1988).

George (1988) claims that it is the poorest countries that spend most on militarization. Ethiopia is cited as a disturbing example: with a GNP per capita of only $110, Ethiopia spends $13 per head each year on its military, but only $7 on health and education combined. George further explains that:

> "Sudan spends $15 for each Sudanese, Tanzania $16, Kenya $17, Somalia $20, Zimbabwe $55 (related to the threat from South Africa). These countries carry debt loads ranging from $1.5 billion to $4 billion; Sudan's is close to $11 billion" (George, 1988).

4.4.2 International implications of the debt crisis

Not surprisingly, the debt crisis has had detrimental effects upon LDCs. One of the most obvious implications is that socio-economic and political development have been restricted. It has been suggested that UN statistics indicate increasing Infant Mortality Rates (IMR), and,

> "since the only really new economic fact in these countries over the past ten years has been runaway indebtedness.... we may conclude that this has more than a little to do with rising IMRs." (George, 1988).

The Third World debt crisis is also having repercussions on the developed world. Ambrosetti notes that,

> "the recession experienced by all countries during the decade beginning with the 1973 oil crisis, the longest period of recession since World War II, illustrates the effect of Third World stagnation on the economies of the developed world". (Ambrosetti, 1985)

In 1973 the Third World took 23% of the developed countries' total exports, rising to 28% in 1980. By 1983, the US was sending 40% of its exports to developing countries. Any downturn in the economic condition of LDCs is bound to reduce their importation of goods and technology from industrialized countries. When Mexico faced its debt crisis in 1982, US exports to Mexico fell by $10 billion. Since it is estimated that every billion dollars sustains 24,000 jobs, it could be said that the Mexican crisis cost the US 240,000 posts in one year.

The 1988 World Bank's 'World Development Report' warned that

> "... the global economy faced a serious risk of recession and financial upheaval together with social unrest in the Third World...." (Huhne, 1988).

One of the major factors prompting this warning was the large transfer of resources from the Third World to its Northern creditors, which have totalled $85 billion since 1982 and remain at $20 billion a year. If the situation continues LDCs face the risk of

> "... prolonged stagnation in real per capita income and greater poverty." (Op cit.)

The effects of the stagnation of the Third World economy on the rest of the world has already been noted, and has been recognised by the former West German Chancellor, Willy Brandt and seventeen other world leaders who concluded that,

> "both peace and continued prosperity in the industrialized nations will depend on success in developing the Third World," and that "the search for a solution is not an act of benevolence, but a condition of mutual survival." (Lomax, 1986).

Clearly development within the Third World is considered an essential requirement for the stability of the international political and economic arenas.

On an international scale, the debt crisis has also indirectly damaged, and will continue to damage the environment. One disturbing example which is receiving international attention is the damage to tropical forests. The top five principal tropical forest countries by area are Brazil, Indonesia, Zaïre, Peru and Columbia, which are also amongst the top debtors. These five countries are responsible for 60% of what is left of the Earth's tropical forests. They face great pressure to decimate this valuable crop for a number of reasons. For many developing countries cash crops are one way of earning debt-service revenue. For example, George (1988) quotes the example of Brazil growing soyabeans as a cash crop. Unfortunately,

> "soyabean prices are low these days because of over-production in the US and ... so more and more must be grown just to keep revenues stable. (George, 1988)

The need for extra production of cash-crops often necessitates deforestation to clear the required agricultural land. Also,

> "the promotion of tropical timber imports into certain industrial countries through low tariffs and favourable trade incentives, combined with weak domestic forest policies in tropical countries and with high costs and disincentives to harvesting in industrial countries, also drives deforestation." (World Commission on Environment and Development, 1987)

Unfortunately it is estimated that once destroyed,

> "... it would take *400* years to re-establish the original components of forest (if seeds and seedlings are still present, which is far from sure)" (George, 1988).

There are several other disturbing consequences of tropical rainforest decimation. Deforestation

> "... reduces the quality of life of millions of people in developing countries; their survival is threatened by the loss of the vegetation upon which they depend for their sources of household energy and many other goods." (World Commission on Environment and Development, 1987)

Deforestation, by removing an important source of oxygen, also contributes to the accumulation of 'greenhouse gases' in the atmosphere. It is believed that this accumulation will lead to global warming in the Twenty-first Century placing immeasurable stress upon ecosystems.

Scientists are concerned about the destruction of various species related to deforestation. For example,

> "Western Ecuador is reputed to have once contained between 8,000 and 10,000 plant species, some 40 and 60 per cent of them endemic. Given that there are between 10 and 30 animal species for every one plant species in similar areas, western Ecuador must have contained about 200,000 species. Since 1960, almost all the forests of western Ecuador have been destroyed to make way for banana plantations, oil wells, and human settlements. The number of species thus eliminated is difficult to judge, but the total could well number 50,000 or more - all in just 25 years." (World Commission on Environment and Development, 1987)

It is estimated that scientists have investigated only one in every 100 of the Earth's plant species, and a smaller proportion of animal species. The contributions that these species can make to agriculture, medicine and industry are inestimable and unfortunately, in the cases of decimated species, will never be known. For example, approximately half of all prescriptions have origins in wild species.

> "The commercial value of these medicines and drugs in the United States now amounts to some $14 billion a year. World-wide, and including non-prescription materials plus pharmaceuticals, the estimated commercial value exceeds $40 billion a year." (World Commission on Environment and Development, 1987)

4.5 Conclusions

In view of the current debt crisis, there is very little opportunity for developing countries to adopt remote sensing technology until their socio-economic positions improve. As Austin A. Usman (1988), of Bayero University in Nigeria explained, two of the main factors restricting the development of remote sensing in most developing countries are the problems of foreign exchange and costs generally.

Third World countries are faced with a dilemma. Some cannot increase their income, basically because they are not adequately developed, and they cannot develop because they have not got the necessary financial and material resources. This is certainly the case in the area of remote sensing, a technology that could contribute to national development by facilitating the exploitation of natural resources.

It is clear that it would be in the interests of all countries if the Third World countries were to improve their socio-economic conditions. Increased development and wealth would probably lead to an increase in trade with the industrialized Northern countries. Development within Southern nations might also contain and limit the global destruction being witnessed this century. Remote sensing could be a contributory link in the process of development. This may seem rather simplistic and quite idealistic, but with unacceptable levels of poverty and widespread ecological disruption, it is an option which warrants serious consideration.

CHAPTER FIVE

BENEFITS TO BE DERIVED FROM SATELLITE REMOTE SENSING

In the preceding chapters, several problems related to the use of satellite remote sensing in the Third World were discussed. In this chapter some examples of the beneficial uses of remote sensing are outlined. It has been suggested that the benefits to be derived from remote sensing can be divided into three main groups:

- "... applications for directly increasing the economic productivity of renewable and non-renewable resources, thereby increasing the material standard of living;
- applications for national or regional planning leading to sustained economic and social development in the long-term, and
- environmental surveillance and management leading to a safer, healthier and more attractive environment, thereby enhancing the quality of life." (United Nations, 1985)

Examples of the beneficial uses are outlined under these broad headings

5.1 Productivity of renewable and non-renewable resources

In this area, the oil and mining industries are the main users of satellite data for information on non-renewable resources.

5.1.1 Oil exploration

In India, satellite data has been used to delineate spectral signatures over established oil fields in order to identify similar signatures in adjoining areas. This methodology was applied in the Brahmaputra valley of Assam, exploration being concentrated in the southern part of the region. The area north of the river was not well explored, and so using signatures extracted from the south, promising northern areas were selected for further exploration. It is stressed that satellite data should be used in conjunction with other conventional data, such as high resolution aerial photography. (United Nations Centre on Transnational Corporations, 1984)

5.1.2 Geologic mapping

Geologic maps of Irian Jaya, Indonesia had been compiled in the early 1960's using aerial photographs and field survey techniques. However, with cloud cover being a persistent feature in this tropical area, aerial photographs were often inadequate and many parts of the area could not be mapped by these means. Geological maps of a high standard were required for petroleum and mineral exploration. The all-weather capability of radar imaging systems was ideal for this purpose, but data from airborne radar systems was very expensive. In November 1981 the NASA Shuttle Mission, carrying the Shuttle Imaging Radar-A (SIR-A), acquired imagery of parts of Irian Jaya at a resolution of 38m and a swath width of 50km. These images provided both lithologic and structural information necessary for exploration of resources at relatively low cost (Committee on Practical Applications of Remote Sensing from Space, 1985).

5.1.3 Use of remote sensing for highway planning and building

It is believed that,

> "in any country, an adequate transport infrastructure is a necessity for economic and social advancement. The improvement of the road network is therefore felt to be one of the most effective ways of promoting economic development in many developing countries where roads can provide the most versatile means of gaining access to and from underdeveloped regions." (Beaumont, 1978)

Satellite remote sensing can provide the information required for the preparation of regional engineering soil maps, inventories of road building materials and details of drainage. The provision of this information can be quite inexpensive when compared with aerial surveys. Planning and construction costs can also be kept to a minimum by selecting the most suitable routes in terms of locating suitable soil foundations, durable road-building materials, and possible ground hazards such as landslides and swamps.

The information derived from satellite remote sensing can also be employed to increase productivity in the areas of assessment and management of land use and water resource development. Data from marine observation satellites can be used to plan optimum ship routes, possibly making commercial shipping more efficient. In most of these projects some degree of aerial and ground survey is required to supplement and complement satellite imagery.

5.2 Regional and national planning

Included under this heading is the use of satellite imagery for agricultural and forest inventories, crop assessments and mapping.

5.2.1 Food and water management

Remote sensing technology has been used as a contributory tool in the battle against the food supply crisis. According to a 1982 report of the Food and Agricultural Organisation (FAO) of the UN

> "... the number of people in developing countries below the critical level of food intake rose from about 360 million in 1969-1971 to about 415 million in 1974-76, while food supply per capita in the industrialized countries remained fifty per cent above that in the Third World. Considering recent forecasts of population growth up to the end of this century, the FAO estimates that a fifty per cent increase in world food production would be necessary to prevent a further increase in the number of malnourished people." (Ambrosetti, 1985)

The same FAO report further estimates that only about half of the Earth's land suitable for cultivation is actually developed. Satellite imagery could be employed to locate agricultural land and associated resources such as water sources. Remote sensing could be used for more effective management of agricultural resources and hopefully lead to the necessary changes in the location of food production and its distribution and consumption. Perhaps this sort of activity may lead to the problems of famine and malnutrition being substantially diminished.

5.2.1.1 Examples of satellite data used to enhance crop production estimates

For the 1983 crop year, acreage estimates of major crops from seven US states were calculated by combining Landsat-4 MSS data with ground survey results. Crops included winter wheat, corn, soyabeans, rice and cotton. Ground data comprised information on crop field acreages obtained from the USDA(United States Department of Agriculture)/ Statistical Reporting Service (SRS) June Enumerative Survey (JES). It was calculated that the estimates that used both JES and Landsat data were twice as efficient as those based on JES data alone. The SRS reduced the project cost per state associated with using Landsat data from $305,000 in 1978 to $120,000 in 1983 (Committee on Practical Applications of Remote Sensing from Space, 1985).

In Thailand a case study was undertaken of rice crop forecasts using satellite imagery. Data was to be interpreted for more accurate estimates of total acreage, cropping patterns and intensity of cultivation. An economic model was then devised to assess the economic gains that would result from more efficient food supply allocation due to more accurate crop forecasts. It was estimated that the economic gains ranged from about $1 million to $49 million annually (United Nations, 1981).

Remote sensing data has been successfully used in water resources management studies in Botswana and Thailand. In Botswana, consecutive satellite images were taken of the Okavango Delta. This information was used to develop a mathematical forecasting model which can be applied to agricultural, ranching and mining activities. In Thailand satellite imagery has provided a synoptic view of drainage and flooding patterns in the Mekong river basin: essential for comprehension of the complex hydrological processes of the region (United Nations, 1981).

5.2.2 Mapping

In 1984, the UN reported that (excluding Antarctica) only about 42 percent of the Earth's land area had been developed. In most Third World countries mapping is very inadequate. Table 5.1 shows the existence of mapping at a scale necessary for development purposes.

Table 5.1 State of World Cartography (United Nations, 1980) (as a percentage of the continent mapped)

	Scales			
Continent	1:25 000	1:50 000	1:100 000	1:250 000
Africa	2%	24%	17%	78%
Asia (without USSR)	11%	51%	62%	80%
Europe (without USSR)	91%	91%	77%	95%
North & Central America	34%	61%	7%	88%
Oceania and Australia	13%	42%	42%	80%
South America	10%	27%	42%	50%
USSR	5%	61%	100%	100%
WORLD	13%	42%	42%	80%

(Konecny, 1986).

It is believed that mapping needs at medium and large scales are not being met by conventional mapping techniques, because of factors such as lack of funds and rugged terrain preventing the conversion of aircraft images to suitable maps. Although current commercial satellite imagery may not be adequate to compile maps at a 1:25,000 scale, it allows the compilation of maps at a larger scale and provides information about land and demographic changes. Remote sensing imagery has also been employed for geological mapping and for charting reefs, shallow seas and changes in marine shipping channels. This mapping and charting is achieved at lower cost and is quicker than conventional methods of mapping. Table 5.2 presents the time-differences associated with different methods of cartography, using Germany as an example.

Table 5.2 Efficiency of Cartographic Methods

Estimated on the territory of 250 000 km^2 (Federal Republic of Germany)

Map - 1:50 000

Method	Duration
Terrestrial Surveys (Plane Table)	
1800-1900 First Survey	100 Years
Photogrammetric Surveys (Aircraft)	
New Survey or Updating	10 Years
Satellite Mapping - Estimate	1 Year

(Konecny, 1986).

Accurate mapping is essential if a country is to undertake development activities, and it would seem that satellite imagery could prove an essential tool in this daunting task.

5.3 Monitoring the environment

Satellite remote sensing data is playing an increasingly important role in environmental monitoring, research and applications. This includes, for example, disaster management, air and water quality and climatic factors.

5.3.1 Disaster observation

Voûte suggests that:

> "... quite a few developing countries are more hazard-prone than many industrialized countries because of their geographical location, climatological conditions and the particularities of their landscape and underground" (Voûte, 1984)

Furthermore, developing countries often lack the infrastructure necessary to prepare for and to cope with disasters. Disasters take the forms of desertification, drought, deforestation, floods, earthquakes, volcanic eruptions, infestation, etc. Satellite data has been employed to combat, or at least to reduce, the more severe effects of disasters.

A great explosion in the locust population can lead to a situation where,

> "a pest causing local inconvenience and limited damage can ..... become a major threat to vast areas, devastating crops and causing the spectre of famine" (Voûte, 1984).

Data has been used from meteorological satellites, including TIROS-N, to survey broad-green scale vegetation levels and changes. If conditions appear favourable for a drastic increase in locust breeding, preventative measures such as spraying campaigns can be implemented in critical areas. This programme followed successful experimental work of 1976-79, which used NOAA-5 and Meteosat imagery, along with higher resolution Landsat images, to check vegetation developments after periods of rainfall (Voûte, 1984).

Malaria has been identified as one of the most critical global health problems: it is the most prominent cause of disability in many tropical areas, affecting more than 250 million people according to the World Health Organisation. The global malaria problem has worsened over the last ten years, as preventative measures have proven unsuccessful. National Aeronautics and Space Administration (NASA) scientists recently initiated a pilot project to use satellites and high-altitude aircraft to predict the location of malaria outbreaks over equatorial regions. Satellite sensors will monitor environmental factors, including rainfall and surface water, which are commonly associated with the breeding of malaria-transmitting mosquitoes. Remote sensing technology is ideal for this project because it allows frequent, fairly reliable coverage of large areas. It may also quickly pinpoint the areas needing malaria preventative measures, such as water drainage and the use of pesticides. (Anon, 1987).

Meteorological satellite imagery is now used routinely by the World Meteorological Organisation to monitor hurricanes, flash floods and tornadoes. The resulting information can provide timely warnings to the inhabitants of the areas that these phenomena will affect, thus possibly diminishing injuries and deaths. In the case of hurricanes, infrared or visible satellite images of tropical cyclones are used to predict their intensity by comparing certain cloud features to 'model' storms of a known intensity at varying developmental stages. For example, features of the 'eye' would be measured. The analysis provides details of the pressure and winds of the storm, as well as an indication of a possible change in intensity.

Flash floods can be predicted by analysing cloud features and movements. Rainfall rates can be estimated to tenths of an inch per hour and these estimates can be accumulated over a specific grid (for example, a state map with county boundaries). Thus, the amount of rainfall over a certain area can be fairly accurately predicted.

Tornadoes cannot actually be forecasted or analyzed from satellite data, but the development of severe thunderstorms that generate tornadoes can be. There are certain cloud features, identifiable from satellite imagery that provide evidence of impending severe thunderstorms and squall lines, for example, a V-shaped wedge of deep cumulus clouds is a general shape of severe-weather-producing clouds. (Committee on Practical Applications of Remote Sensing from Space, 1985).

5.4 Other examples of remote sensing applications

In 1981 the UN Committee on the Peaceful Uses Of Outer Space compiled a list of remote sensing projects carried out in several LDCs. Details and results are presented in Appendix 2.

5.5 Conclusions

Having outlined some of the benefits of using remotely sensed imagery, it is clear that remote sensing technology could be used as an effective tool in the development of Third World countries. In the following chapters the means will be explored by which developing countries might adopt remote sensing technology. India is used as an example of a LDC that has successfully employed remote sensing. It can be seen that India's success is due to a number of factors, including long-term planning, a highly centralised remote sensing organisation and an effective remote sensing education structure. These factors are essential for the establishment of any viable remote sensing programme. Before the establishment of an indigenous remote sensing capability an organisational structure must be established and training must take place.

Developing countries should also consider international and regional cooperation in the various stages of creating a remote sensing capability. Developed countries could contribute technical expertise and training as well as collaboration in space projects, since any development within a Third World country could well benefit other countries.

CHAPTER SIX

INDIA'S REMOTE SENSING PROGRAMME

6.1 Introduction

India is amongst the twenty poorest countries in the world, with a per capita income of approximately $170. The population is over 750 million and expected to reach one billion by the year 2000. India has planned its space programme with the aim of tackling and alleviating some of its major problems, such as natural disasters, overpopulation, illiteracy and lack of knowledge concerning the existence of natural resources. India's space programme has always been motivated towards social and economic development. Vikram Sarabhai, first chairman of the Indian Space Research Organisation explained in 1968:

> "There are some who question the relevance of space activities in a developing nation. To us, there is not ambiguity of purpose. We do not have the fantasy of competing with economically advanced nations in the explorations of the Moon, or the planets, or manned space flight. But we are convinced that if we are to play a meaningful role nationally and in the community of nations, we must be second to none in the application of advanced technologies to the real problems of man and society, which we find in our country. And we should note that the application of sophisticated technologies and methods of analysis to our problems is not to be confused with embarking on grandiose schemes whose primary impact is for show rather than for progress measured in hard economic and social terms." (Von Welck, 1987)

For India, apart from strong socio-economic motivations, an advanced space programme is considered important as a foreign policy tool and to promote self reliance.

6.2. Development of India's remote sensing programme

India, unlike many developing countries, has a long tradition of applying science and technology to national development tasks. The Survey of India, the Geological Survey of India and the Indian Meteorological Department were established over 150 years ago (Moorthi, 1985). The Indian Space Programme began in 1961 when the Indian National Committee for Space Research was established within the Department of Atomic Energy. The aim was to develop the infrastructure necessary to support a national space programme.

The first major achievement of the Indian Space Programme was establishing a sounding rocket launch facility in 1962, to conduct experiments in the magnetic equatorial zone. Recognising the potential of a strong space programme for a developing country, a cost-effective 10-year plan was formulated for 1970-80. The objectives of this plan were:

> "...to develop indigenous competence in designing and building sophisticated hardware involved in space technology including rockets and satellites for scientific research and practical applications, the use of these systems for providing point-to-point communications and a national T.V. hook-up through a direct broadcast synchronous satellite and the application of satellites for meteorology and for remote sensing of earth resources." (Radhakrishnan, 1986).

To a great extent, India attained the objectives of its 1970-80 plan. The Satellite Instructional Telecommunication Experiment of 1975/76, a one-year US-Indian project, assessed the technological, as well as social and educational benefits of satellite T.V. communications. The Satellite Telecommunication Experiment Project enabled India to gather experience in the field of domestic telecommunications. The project ran from 1977-79 and employed the Franco-German communications satellite 'Symphonie'.

Progress was also made in the field of remote sensing with the launch of the earth observation satellites Bhaskara-I (1979), Bhaskara-II (1981) and IRS-1 (1988). Bhaskara-I was launched from the USSR and carried a 2-band (0.54-0.65 and 0.75-0.85 microns) slow scan vidicon camera system with a spatial resolution of approximately 1 km. The 40 kg Rohini satellite, RS-D1 (1981) was launched by the Indian developed launch vehicle, SLV-3. The first Indian Remote Sensing Satellite, IRS-1A (1988) was launched aboard a Soviet Proton booster. Landsat data has also been used in India since the early 1970's and a Landsat Receiving Station was built in 1979 at Shadnagar near Hyderabad, to receive data from the Landsat and NOAA series satellites. Since then, the station has been modified to receive data from SPOT, the Indian Remote Sensing Satellite (IRS) and future satellites (Deekshatulu, 1986). Table 6.1 outlines the indigenous development of remote sensing sensors in India:

Table 6.1: Indigenous efforts towards remote sensing sensors (Deekshatulu, 1986)

Platform	Sensor	Spectral Channels	Applications
Aircraft	Thermal scanner	10.5-12.5 microns	Emissivity studies in conjunction with microwave sensors
Aircraft	Multi-spectral scanner	5 bands over 0.5-3.0 microns and a thermal channel in 8.0-12.0 microns	Different remote sensing application signature studies crop cover classification, land use, thermal inertial maps
Bhaskara I and II	Slowscan vidicon	0.54-0.65 and 0.75-0.85 microns	Land use, snow cover, coastal processes, forestry
Aircraft	Pushbroom solid state camera	0.5-0.7 microns	Test flights
Ground	Ground truth radiometer	Visible and near infrared regions	Spectral signature studies
Bhaskara I and II	Passive microwave radiometers	19, 22 and 31 GHz	Sea surface phenomena, atmospheric water vapour and liquid water content
Aircraft	SLARs	X Band (real aperture)	Experiments to discriminate crops, water bodies, roads, etc.
Ground	Microwave radiometers and scatter-ometers	9.4, 1.5 and 10.5 GHz 1.8 and 8.18 GHz (truck mounted scatterometer system)	Signature studies and dielectric constant determination

The experience gained in the design, development and operation of space-based remote sensing satellites and ground systems, and the experience gained in the use of remote sensing data, led to the inclusion in the space plan for 1980-90 of the following objective:

> "to develop an Indian Remote Sensing Satellite (IRS) for the effective utilisation of remote sensing technology and promote the establishment of a National Natural Resources Survey and Management System" (Radhakrishnan, 1986)

The IRS mission was envisaged as

> "...an intermediate stage between the purely experimental missions represented by Bhaskara-I and -II and the fully operational system of the future." (Deekshatalu, 1986)

IRS-1A was launched early in 1988 and its principle components are:

- a three axis stabilised polar sun-synchronous satellite with Linear Imaging Self Scanning (LISS) cameras taking 70- and 35- metre resolution photographs;
- ground based data reception recording and processing systems;
- a ground system for in-orbit satellite control, including a tracking network;
- hardware and software necessary for the provision of various user oriented data products, data analysis and storage.

Table 6.2 Spectral bands chosen for the IRS cameras (Deekshatulu, 1986)

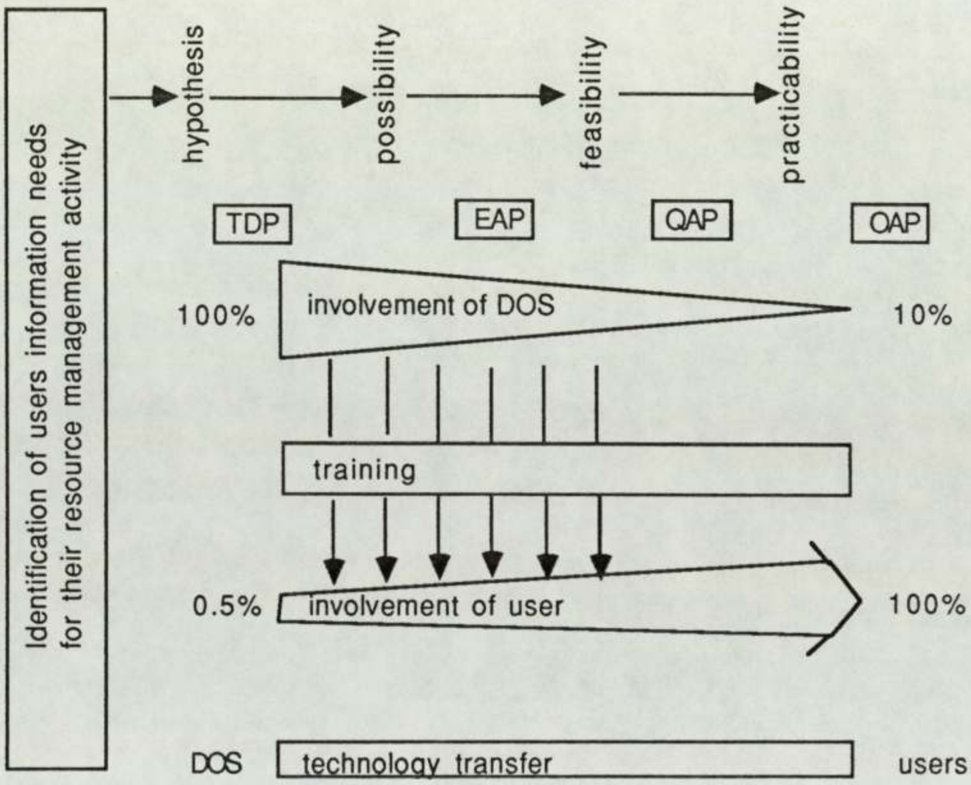
Band	Spectral range	Characteristics
1	0.45-0.52	Coastal environment studies, chlorophyll absorption region
2	0.52-0.59	Green vegetation, useful for discrimination of rocks and soil for their iron content
3	0.62-0.68	Strong correlation with chlorophyll absorption in vegetation, discrimination of soil and geological boundaries
4	0.77-0.86	Sensitive to green biomass, opaque to water resulting in high contrast with vegetation

Since IRS-1A is a non-commercial venture, charges are expected to be reasonable. It is believed that it is the policy of the Indian government to charge for the additional direct material costs only (Mama, 1987). A computer compatible tape of IRS-1A 73 m resolution imagery is expected to cost approximately $200.

6.2.1 IRS utilisation projects

A special IRS utilisation programme has been established by the Indian government, in order that IRS data should be utilised effectively. The programme, designed to extend the application of remote sensing to natural resources survey, has the following main objectives:

- "to use the IRS data for applications in selected areas of resources management, that is, agriculture, hydrology and the environment;
- to transfer the technology of application to the user agencies and to develop an infrastructure which would support the future ongoing remote sensing based information system in the country and
- to provide inputs for the IRS follow-on programme." (Deekshatulu, 1986).



TDP: technique development projects

EAP: experimental application projects

QAP: quasi operational application projects

OAP: operational application projects

DOS: Department of Space

Figure 6.1: Operationalisation of remote sensing-based resource information system (Moorthi, 1985)

About sixty user agencies are collaborating in the IRS Utilisation Programme. These are mainly Central Departments or State Governments that have set up Remote Sensing Centres or Units and have a committed budget for remote sensing. These bodies include:

- Department of Ocean Development
- Geological Survey of India
- Oil and Natural Gas Commission
- All India Soil and Land Use Survey
- National Bureau of Soil Survey and Land Use Planning
- Forest Survey of India
- Indian Meteorology Department

(Radhakrishnan, 1986)

6.2.2 The National Natural Resources Management System

The IRS Utilisation Programme is directly linked to the National Natural Resources Management System (NNRMS). The objective of the NNRMS has been to develop a Natural Resources Information System (NRIS) which combines conventional and remotely sensed information for the effective management of natural resources. Therefore, under the auspices of the NNRMS, IRS data will be analysed, processed and then disseminated to user bodies.

Tied to the NNRMS is the Commission of five Regional Remote Sensing Service Centres (RRSSC) located at Bangalore, Dehra Dun, Jodhpur, Nagpur and Calcutta. These Centres are designed to enhance the capacity for digital analysis and training. The National Remote Sensing Agency provides aid and guidance in the planning and management of projects employing IRS data.

6.3 Achievements of the Indian remote sensing programme

In 1976 when a survey of natural resources was being conducted, it was calculated that only 45% of India's resources were surveyed and assessed. In order to complete the national survey and thus further national development, it was decided to employ remote sensing techniques which

> "...alone would be able to extract the data over large and inaccessible areas and would be less time-consuming and more cost-effective for a large country like India" (Centre of Studies in Resources Engineering, IIT, Bombay, 1983)

Since then the whole country has been mapped by satellite to show forested and non-forested areas, wasteland and snow cover. Remote sensing has also been used for other purposes such as exploration of oil and coal, and for crop assessment.

6.3.1 Forest mapping

Mapping of India's forest cover has been achieved at a scale of 1:1,000,000. Landsat MSS imagery was interpreted during the period 1972-75 and 1980-82, the results of which are presented in Table 6.3.

Table 6.3 Changes in Forest Cover in India, 1972-1982 (Deekshatulu, 1986)

	1972-75 in percentage	1980-82 in percentage	Change in percentage
Total area under forest cover (percentage of total geographical area)	16.89	14.10	(-)2.79 reduction
<u>Categories</u>			
Closed forest	14.12	10.96	(-)3.16 reduction
Open/degraded forest	2.67	3.06	(+)0.39 increased degradation
Mangrove	0.099	0.081	(-)0.018 reduced

Professor Rao (Mama, 1987), the head of the ISRO, estimated that a detailed forest inventory for India was compiled, using remotely sensed imagery, in just seven years, whereas a ground-based inventory would have taken approximately fifty years. Professor Rao further argues that without the use of satellite data to monitor changes in India's forest areas, the problem would have run ahead of any possible solutions, especially when one considers that during 1979-87 India lost another 18% of its forest cover. With the global decline in forest cover, and the subsequent threat to the Earth's environmental equilibrium, it would seem that India's efforts to monitor changes in its forest cover are important on an international as well as national scale.

6.3.2 Mapping of wasteland

To aid the development of a strategy in agriculture, a national survey was carried out of the various types of wasteland in India. This mapping took place during 1980-82, and it is planned that Landsat TM and IRS data will be employed to further monitor wasteland.

6.3.3 Water resources detection

In India, water is essential for agriculture and farming, upon which 75% of the population of between 750-780 million people depend. In 1987 the much-needed monsoon failed once again for the fifth successive year, leading to severe hardship. Cattle died, crops failed and good drinking water became scarce. Remote sensing was used as one method of combating the drought. In the state of Rajasthan, for example, the government dug 180 wells at sites located by satellite imagery by ISRO. Professor Rao claimed that for this particular study,

> "the success rate was 92%. Using conventional methods of ground water location, the ratio would have been closer to 40%". (Mama, 1987)

6.3.4 Other areas of application

Remote sensing has been employed for many other applications, such as snow-melt run-off prediction, flood mapping, mapping of problematic soils and for marine and coastal studies.

6.4 Reasons for the success of the Indian remote sensing programme

It is quite clear that India has efficiently and effectively employed remote sensing to further national development and to monitor various changes. It would seem that the success of the Indian remote sensing programme is due primarily to six main factors:

- long-term planning
- a highly centralised space organisation
- a good remote sensing education structure
- India's view of remote sensing as a foreign policy tool
- co-operation with other countries
- India's technological background

6.4.1 Long-term planning

As explained in section 6.2, India designed cost-effective ten-year plans for the decades 1970-80 and 1980-90. The first ten-year plan aimed at achieving the competence to design and build hardware necessary, in the case of remote sensing, to apply satellite technology for meteorology and for the monitoring of the earth's resources. The second ten-year plan was more ambitious and aimed to design and build an indigenous remote sensing satellite (IRS-1A). The objectives of both of the ten-year plans have been achieved, and it would seem that this is due to the Indian government clearly and realistically defining exactly what is required. Also these objectives have been achieved at relatively low cost. Between 1972-1987, the total space budget was less than $1 billion, which is a small amount compared to the space expenditure of most other countries involved in this field.

6.4.2 Tightly centralised organisation

India's Department of Space (DOS), created in 1972, is directly responsible to the Prime Minister, and covers activities in space applications, space technology and space sciences through the Indian Space Research Organisation (ISRO). Three main bodies involved in remote sensing at the national level fall under the auspices of ISRO:

- the ISRO Satellite Centre (ISAC) at Bangalore, is engaged in the design, development and management of remote sensing satellites;
- the National Remote Sensing Agency (NRSA), at Hyderabad is responsible for the acquisition, processing and dissemination of aerial and satellite remotely sensed data, and for the analysis/interpretation of data for various applications and for training purposes.
- the Space Applications Centre (SAC), at Ahmedabad is involved in the development of sensors, and studies the application of remote sensing techniques (Deekshatulu, 1986).

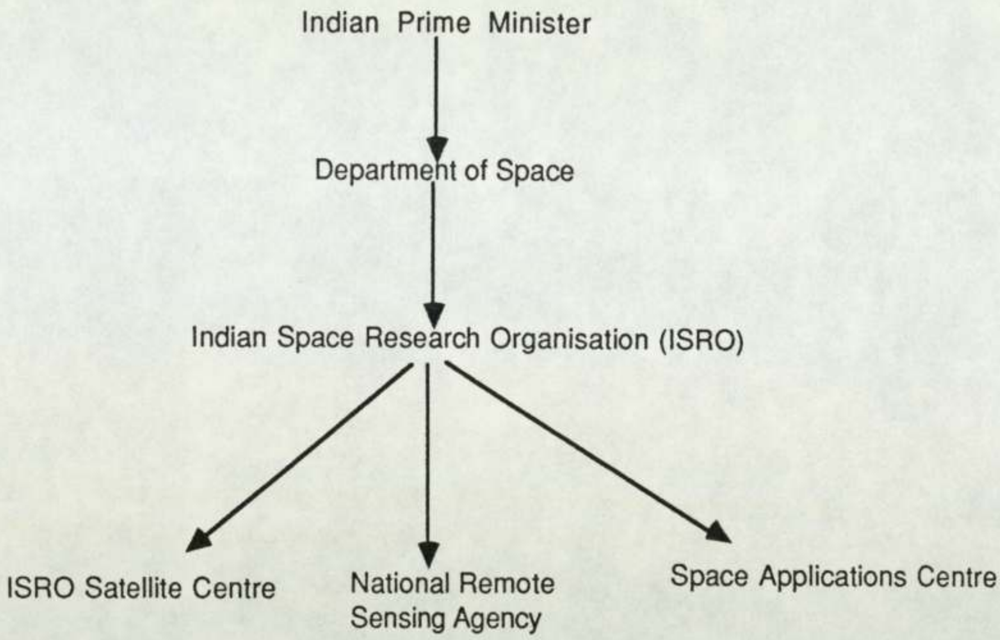


Fig 6.2 Organisation of Remote Sensing Activities in India

6.4.3 Educational structure

Good training facilities in the field of remote sensing exist in India and are continually expanding to satisfy the growing demand in this field. Natarajan et al. (1984) suggest that,

> "while development and applications of remote sensing techniques themselves led to the on-the-job training of many Indian scientists, the need for formal and focussed training of scientists and technicians was recognised as an important element in the overall remote sensing programme of the country."

The Indian Institute of Remote Sensing (IIRS), created in 1966 at the Indian Photointerpretation Institute, Dehra Dun, is the main training body in the field of remote sensing. The Institute provides courses of up to ten months duration in various aspects of remote sensing, mainly in forestry, geology, soils and town planning.

Training is structured on three levels, for:

- decision makers, planners, managers and administrators;
- middle level supervisory officers or scientist managers;
- working level scientists and technicians.

Courses for decision makers are usually short in duration, lasting 3-4 days, and are designed to show the potential of remote sensing technology, as well as the economic, social and political constraints of its utilisation. Natarajan et al. (1984) explain that a typical course for decision makers would introduce the basic principles of remote sensing, such as the use of satellite data from mapping, and the techniques of visual and digital interpretation. A brief description of the applications of remote sensing would also be covered and a discussion session would be included.

A typical course for middle and supervisory personnel would last approximately three months. Such a course would encompass the basic principles of remote sensing, including such factors as sensor characteristics. Basic principles of photogrammetry would be taught including, for example, principles of stereo-photogrammetry and basic cartography and map reproduction. Visual image interpretation and digital image processing would also be covered.

For working level scientists, a course would last approximately ten months. It would be similar to the course for middle and supervisory staff, but would be more intensive in the study of interpretation techniques in the individual's specific field of interest.

Between 1966-84 the IIRS has trained approximately 1400 scientists and technicians. Table 6.4 indicates the growth in training.

Table 6.4 Total Number of Scientists Trained at IIRS, 1966-84

Year	No. of Scientists	Year	No. of Scientists
1966-67	16	1975-76	59
1967-68	17	1976-77	87
1968-69	40	1977-78	63
1969-70	47	1978-79	71
1970-71	56	1979-80	121
1971-72	71	1980-81	108
1972-73	59	1981-82	161
1973-74	68	1982-83	141
1974-75	78	1983-84	133

Total (1966-84) : 1396

(Natarajan et al., 1984)

6.4.3.1 Other training opportunities

The Centre of Studies in Resources Engineering at the Indian Institute of Technology in Bombay offers a variety of short and long courses, including postgraduate courses in remote sensing. The NRSA offers specialised advanced courses at its headquarters. Specialised training is also offered by the Space Applications Centre, concentrating on specific applications such as agriculture, coastal processes and geographic information systems. A few educational institutions such as Bombay, Anna University, Madras, and the University of Roorkee, offer either Master's degree courses in remote sensing, or options in photogrammetry/remote sensing.

6.4.3.2 International trainees

In keeping with the Indian government's policy of sharing relevant experience with other developing countries, by 1984 the IIRS had instructed approximately 67 trainees from Third World countries such as Nepal, Vietnam and Malaysia (Natarajan et al., 1984).

It has been suggested that the existing training facilities in India can meet only 50% of training needs. However, it is hoped that this situation will be resolved through the expansion of existing training facilities and the creation of new regional training facilities affiliated to the Regional Remote Sensing Service Centres.

6.5 International cooperation

It has been suggested that,

> "Co-operation with other countries, especially with the USSR, FR Germany, France and the USA has been a cornerstone of India's space programme." (Von Welck, 1987).

At most levels of the Indian remote sensing programme there are examples of collaboration with foreign countries, for example, the IIRS was established in 1966 through a collaborative programme with the International Training Centre of the Netherlands. India's two experimental satellites, Bhaskara I and II were launched by the USSR under the Indo-USSR Collaborative Programme. IRS-1A was also launched by the USSR company Glavkosmos. Under a Memorandum of Understanding between India and the USA, and between India and France, India receives data from the Landsat and SPOT satellites. India signed an agreement with the Federal Republic of Germany in 1971 to cooperate in the fields of the peaceful uses of atomic energy and space research. This has involved the exchange of scientists and technicians and joint application projects in areas such as forestry and snow hydrology. The Indian space programme has also benefited from cooperation with the UK, Japan, Sweden and Australia.

India also participates in the UN Committee on the Peaceful Uses of Outer Space, and at the second UN Conference on the Peaceful Uses of Outer Space, 1982 (UNISPACE-82) the Indian delegate offered to share Indian space experience with other developing countries. As a result, the programme SHARE (Sharing of Experience in Space) was created and has included the training of scientists and the participation of scientists in Indian remote sensing projects. (Deekshatulu, 1986).

6.6 India's remote sensing programme as a foreign policy tool

Von Welck et al. (1985) suggest that India's space programme

> "...has strong political motivations: it is designed to strengthen India's position as the dominant political power in South Asia, as a medium power between the two super powers , as a leading power within the group of developing countries as well as a political rival of China and an antagonist of Pakistan."

India's attempt to establish an independent space power is also in keeping with its involvement with the non-aligned movement. However, to create such a space power, India has needed to obtain expertise from developed countries. India has avoided too much space cooperation with any one country, but has maintained a balance in joint space projects (Von Welck, 1987).

6.7 Constraints

Von Welck argues that India has faced three main constraints in its space programme:

- Although India has tried to increase self-reliance in its space programme, its attempts have not been altogether satisfactory. For example, India still relies on foreign launch service and the import of electrical components. As such, Von Welck (1987) suggests that,

> "as long as this dependency continues, India's space policy will have to take into account interests of other countries, which may not necessarily be shared by the Indian government."

- It is suggested that the Indian space programme is limited by the lack of a technology base within Indian industry which; in turn prevents Indian industry from co-operating efficiently with ISRO. As with other space programmes there also tends to be some misunderstanding between the various user organisations in India which tends to cause delays.
- Of course, the Indian space programme is also constrained by budgetary limitations.

6.8 Conclusions

The Indian space programme has had to face several constraints which are also characteristic of most other countries' space programmes. Despite the drawbacks, the Indian remote sensing programme has, on the whole, been very successful due to

> "... long-term planning, a broad spectrum of international co-operation with other space countries, a tight organisational structure, which results in the concentration of decision-making power in one single person, and a remarkable continuity of leadership" (Von Welck et al., 1985)

India has proven that a developing country can establish a viable remote sensing programme, but then India has several advantages over other developing countries, such as an impressive history of industrial development upon which to base its remote sensing programme. For example, in the Nineteenth Century, railways were built and canals were dug through both British and Indian enterprise, and the coal and iron industries had been developed.

After the Government of India Act of 1935,

> "...India was certainly not an industrialised country, but it had its own modern machine industries. She was in fact emerging from a colonial phase to her traditional economy of a rural economy strengthened by supplementary industries." (Spear, 1987)

India also has a certain level of political stability which is uncommon in certain countries where revolutions and frequent changes of government hinder socio-economic and industrial development.

CHAPTER SEVEN

ESTABLISHING A NATIONAL REMOTE SENSING CAPABILITY - ORGANIZATION AND EDUCATION

7.1 Organization

Organizational development has been identified as,

> "... manifestly the first requirement, prior even to the creation of a capability to identify problems and find solutions." (United Nations Centre on Transnational Corporations,1984)

when establishing the capacity to use remote sensing technology.

Remote sensing data, by its very nature, can provide an overall view of the environment and resources, linking details of such diverse factors as soils, water resources and land-use. However, in most countries separate institutions are responsible for individual environmental subjects, therefore, a coordinated framework is necessary to ensure full use of the comprehensive satellite data by the different segments of society involved with natural resources. These segments range from the highest administrative level to individual citizens.

The ideal organizational structure must provide the skeleton necessary for planning, establishing goals and laying the paths for reaching them. In the case of remote sensing, the ideal organizational framework would need to be adequately flexible to accommodate the use of the technology at its infant stages, and later as it expands to a complex high technology status. Initially, it would seem that a central space body would have to be established. This body would probably come under government auspices, so as to work within the guidelines of national socio-economic policy and gain national credibility. In India, the Department of Space falls under the responsibility of the Prime Minister. Coordination with various space-related departments and groups is also carried out on a political level through the Indian Space Commission. (von Welck,1987). On the same note, the President of Pakistan is the President of the Space Research Council, the body which directs and controls space science and technology programmes in Pakistan.

A central remote sensing organisation could then be created as a division of the national space organisation. This centralized group would need to be quite flexible in order to deal with the multidisciplinary users of remote sensing imagery. There are a number of examples of individual remote sensing centres that are set up in developing countries and coordinate with ministries and other institutions. Berry (1979) points out that these centres are often the result of individual initiatives. In Bolivia, for example,

> "... the Programa del Satélite de Recursos Naturales was initiated in the Servicio Geológico de Bolivia in response to the possibility of mineral discoveries, but rapidly grew in sophistication and coverage so that now the centre carries out many other studies, including work on resources of less-populated areas, national maps of land-use, a study of population density and population change, mapping of census boundaries, and topographical mapping, as well as the original geological and structural studies." (Berry, 1979)

Also, at the National Scientific Research Council in Egypt, the three research groups in geology, agriculture and physics work in coordination in remote sensing technology, as well as linking with various ministries and agencies in the government.

The first task of the central remote sensing agency might be the identification of other links in the organizational chain. These would be groups that already utilise or could make use of remote sensing data for example, those involved in geology, forestry or water resource studies. The remote sensing body would also be responsible for assessing the ability of the organizational structure to sustain a national remote sensing programme within budgetary and policy constraints. This would initially require forward planning. Cost-benefit studies would have to be conducted to identify the most productive applications, and feasibility studies and pilot projects would be necessary to assess the most economic techniques for solving particular problems.

The Food and Agriculture Organisation (FAO) of the United Nations has made numerous suggestions for pilot action studies in developing countries, for example, the FAO recommended to Argentina a study entitled 'Reconnaissance mapping of land-use potential and land degradation studies in semi-arid zones', which was planned to last 12-15 months. It was believed that the

> "Advantages envisaged in carrying out this study were:
>
> - national interest in increasing agricultural and livestock production in this vast region would lead to greater food production;
> - the National Agricultural Technology Institute would support the study with its well-trained staff and the use of its experimental stations;
> - other organizations which have the facilities to receive Landsat data, process digital imagery and obtain weather information could participate in the study;

- training facilities would be set up for technicians from Argentina and other countries in the region with similar problems, and these facilities would continue to be used after termination of the Pilot Action Study."(FAO, 1985)

It would seem that these pilot studies are necessary for the demonstration of the usefulness of remote sensing techniques to various sectors of society, from decision-makers to the potential user community. Analysis of the use of remote sensing in other countries might also be helpful, for example, an equatorial country could look at the results of a specific remote sensing project in another equatorial country where conditions are comparable.

Another important consideration when developing an organizational structure is the socio-cultural effects that operational remote sensing will have. Rapid technological changes are bound to cause some degree of structural change in society. Exactly how society will cope with such changes is a matter of important consideration. This is especially true in developing countries where a choice needs to be made between 'alien' technologies developed in the 'North' or the use of more appropriate technology which would need to be developed in the Third World (Voûte,1984) Voûte recommends that research into socio-cultural effects of remote sensing

> "... should be based on a proper time horizon, taking into account the time scale of technological developments and the duration of social cycles." (Voûte, 1984)

It is possible that changes in various strata of society will be necessary for optimal utilization of remote sensing data, for example, changes will invariably be necessary in the legal and educational structures.

7.1.1 Regional remote sensing centres

For those developing countries which have limited personnel and financial resources, it is suggested that they should consider involvement with a regional remote sensing centre before establishing a national remote sensing centre. Examples of regional remote sensing centres include those at Ouagadougou, Upper Volta and Nairobi, Kenya. It would seem likely that regional remote sensing centres could provide the managerial and technical knowledge necessary for a developing country to establish its own national remote sensing centre, beginning with the establishment of an institutional structure.

One very important task of any remote sensing organizational structure would be the provision of a well defined educational framework, designed to provide remote sensing training at all levels. The establishment of any remote sensing programme would necessarily require manpower planning to assess the number of people that need training. Educational programmes may take the form of multidisciplinary remote sensing training at the central body and more specialised training at other subject-specific organizations.

7.2 Establishing a viable remote sensing educational programme

Theodore W. Schultz, awarded the Nobel laureate in economics in 1979, stated that

> "for any country to benefit fully from the advances of science, whenever these are made throughout the world, and the new productive technologies that emerge from these advances, it must have a corps of competent scientists and technicians" (Bartolucci et al., 1980).

In other words, the organization of human resources within a country is essential before exploiting the full potential of modern technology. This is especially true in the case of developing countries adopting remote sensing technology. Long-term educational planning is required along with the necessary changes to educational and remote sensing institutions. Socio-economic and socio-cultural factors have also to be taken into account so that the new technology, mostly designed in the developed world, is modified and accepted according to regional or national needs.

Adequate planning for education and training becomes increasingly important when one takes into account the global shortage of personnel in the field of remote sensing. It was estimated in 1981 that the developing countries with a population of 3,000 million had

> "... an annual educational capacity demand for remote sensing application of approximately 18,000 man-years during the 1980's and 1990's. The present capacity available for these countries falls short of the demand by a factor 10." (d'Audretsch et al., 1981)

D'Audretsch et al. (1981) believe that it is possible to assess the required capacity and educational curricula for short- and long-term surveying activities using remote sensing data. Three rules must be considered when making such an assessment. Firstly, in an establishment with a roughly constant number of staff, the annual educational capacity should be able to cope with 10 percent of personnel so as to maintain a balance with people removed by natural depletion. The second rule specifies that, to establish a body using satellite data requires an annual educational capacity able to cope with approximately 30 percent of the personnel to be employed for full operation. This figure is large because it takes into consideration factors such as 'drop-outs'. The third rule is concerned with the fact that rapid technological developments will create new educational demands. It is estimated that allowances should be made for a possible 20 percent of employees to apply new technology in their conventional work. The use of satellite data in mapping and inventory activities is such a case.

7.2.1 Objectives of education and training

For LDCs the ultimate aim of education and training in remote sensing would appear to the development of a strong capability to make full use of the technology. However, Voûte argues that this aim is not sufficient in itself. According to Voûte, education and training in this field should fulfil two major policy objectives:

> "one is to achieve increased self-reliance, including mastering airborne and space earth observation techniques and applications and using them for the inventory and management of natural resources. The other is to attain a sufficient level of expertise to be able to negotiate at equal level system specifications and systems implementation for future satellite remote sensing systems suited to the particular needs of developing countries." (Voûte, 1983).

In addition, Voûte believes that education and training should contribute towards the acceptance of rapidly changing technology in the society of a developing country, as well as allowing necessary technology assessment and the building of an adequate national research and technology base. These factors are essential for technology transfer and the establishment of an infrastructure for employing remote sensing in line with national objectives (Voûte, 1983).

7.2.2 Identification of trainees

d'Audretsch et al. (1981) suggest that there is a distinction between remote sensing education and training. Education would

> "... bring the individual to an understanding of a subject so that he or she may form independent opinions, establish priorities, understand and discuss the methodology, the techniques used and their applications. The objectives of *training* are to teach individuals to carry out specific tasks based on an accepted methodology and for which known techniques are available. Understanding of the context is not always required; often only the ability to apply the technique is needed." (d'Audretsch et al., 1981)

The sectors of society requiring education or training are identified as follows:

- decision-makers and planners, including politicians and senior officials that need a general overview of remote sensing and its practical and policy aspects;
- managerial persons in institutions, agencies and private enterprises, that should have enough technical knowhow to coordinate activities and to establish remote sensing facilities;
- personnel carrying out satellite surveying tasks at various levels that need to be educated or trained to interpret and employ imagery and digital data for various mapping and monitoring projects;
- technical support staff, from engineers and technicians, that deal with the construction, operation and maintenance of facilities and equipment and need manuals to undertake certain technical tasks;
- research workers that need interdisciplinary skills and in-depth expertise on several aspects of remote sensing;
- teachers that would be responsible for the education and training of the various personnel and should have a knowledge of technical matters and earth sciences, and experience of educational methodology (d'Audtretsch et al, 1981; Voûte, 1983)

These potential trainees will require education or training of different content and at different levels.

7.2.3 Course design

Curricula and aids for teaching need to be designed for all the different strata in society requiring remote sensing education. As d'Audretsch et al. (1981) explain, the diversity of these groups would make it impractical to design standard curricula. It has therefore been suggested that there should be different types of training for different personnel (United Nations, 1985). Seminars, short courses or workshops are recommended for introducing the basics of remote sensing. These modules could be provided for decision-makers and preparers, journalists, teachers, technical staff and any of the endless groups that need a general awareness of remote sensing. Medium-term courses of about three to nine months duration are considered;

> "... most useful for training technicians to work under the supervision of experienced scientists or engineers; or to enable scientists or engineers with experience in resource management to introduce remote sensing into their work." (United Nations, 1985)

Long-term training of one or more years would establish remote sensing specialists that could apply remote sensing methodology to specific disciplines, and pass on their expertise to others. Refresher courses, such as summer schools and workshops would enable personnel to keep up-to-date with new techniques and methodologies in remote sensing.

An awareness of remote sensing can also be brought to society on a large-scale through the educational system. Remote sensing constitutes an excellent educational tool in environmental sciences, for example, with applications in the study of geology, geography, water resources, vegetation, etcetera. As Voûte (1985) points out, hard-copy images can be used as map substitutes, and,

> "exercises in processing of digital remote sensing data can be used in courses in mathematics, statistics and computer sciences."

Remote sensing can also provide suitable material for meteorological, astronomic and cosmographic studies. It seems clear, therefore, that the benefits of using remote sensing in the educational system are two-fold, namely:

- to instil an awareness of the possibilities of remote sensing and its applications;
- to use remote sensing material as an effective and diverse educational tool.

7.2.4 Course type

The content of course would depend upon several factors, including:

- the group being taught, their education and experience, and hence the type of applications dealt with;
- course length;
- educational and remote sensing materials available.

In the first case, the type of group undergoing remote sensing education or training will dictate the scope and subject(s) of the course. Decision-makers might attend a course that would broadly explain the basics of remote sensing, covering data acquisition, data processing, interpretation methods, illustrations of actual applications, and an idea of the political, legal and social implications of remote sensing. On the other hand, high-level scientists might attend a course that would concentrate on a subject as specific as the optimum applications of particular sensors for water resources studies.

To a certain extent, course content will be dependent upon course duration. This is an obvious point, but nonetheless important when planning courses. It would be counter productive if a course were to cover too much of the subject in too little time.

The type of materials available is of vital importance to any course and will dictate the development of educational activities. As Voûte (1985) explains, if a sufficiently large section of society is to be exposed to remote sensing and its manifold effects

> "... the educational effort has to involve many teachers and many classrooms at the same time, requiring the training of large numbers of teachers and the production of a great volume of teaching materials"

As such, there seems to be a need for the provision of structured materials. These materials would include audio, visual and written units. The development of such materials would depend upon the objectives of planned curricula and also ethical considerations, since for many students and teachers the new technology would clash with

> "... the national scholarly, technological, social and cultural traditions, as is the case with many facets of space technological applications." (Voûte 1985).

Examples of materials that could be employed are hard-copy photographs and video-tapes and slides that can be used by non-experts.

7.2.5 Modular courses

It has been suggested that although it would be effective to introduce remote sensing into existing educational programmes, for example, using hard copy photographs in environmental studies, there needs to be a greater emphasis on separate well-defined course modules (Voûte, 1983). The same author recognises that such courses on space science and technology, and the associated materials, are only available in a limited number of countries and are narrow in subject and scope. As such, it is important that developing countries assess the suitability of nationally and internationally available modular courses and decide whether to develop some of their own, for example, a developing country might find a course designed overseas incompatible with its socio-cultural norms. Appendix 3 outlines examples of modular courses.

Examples of modular courses produced in the developed world are numerous. The Training Library of the WMO holds a number of suitable materials, including:

- "some 400 slides on meteorological satellites from the Regional Seminar on the Interpretation, Analysis and Use of Meteorological Satellite Data (Tokyo, 1978) and the training course on satellite data interpretation and application (Colorado, 1979), available for reproduction for member countries;
- WMO publication no. 258, Guidelines for education and training of personnel in meteorology and operational hydrology, containing detailed syllabi for curricula for the training of class I and class II meteorological personnel specializing in satellite applications;
- a compendium of lecture notes on meteorological satellites for training class1meteorological personnel, publishing date 1981;
- WMO publication no. 333, The use of satellite pictures in weather analysis and forecasting (edited by R.K. Anderson and N.F. Veltishchov);
- WMO publication no. 473, The use of satellite imagery in tropical cyclone analysis...." (Voûte, 1985)

The National Remote Sensing Centre of the UK offers a range of slide sets and video sets, including:

- 'Remote sensing: an introduction' - a set of 18 slides and accompanying descriptive booklet prepared by members of the Education and Training Working Group (also available with audio commentary tape). The set covers the basic physical concepts of the subject together with selected examples of representative imagery;
- 'Remote sensing of Coastal Processes' - a set of 18 slides and accompanying booklet prepared for the NRSC by the Coastal Processes Working Group;
- 'Remote Sensing - Geological Applications' - a short video intended as a broad introduction to geological remote sensing. The film emphasises the wide-perspective use of satellite imagery and illustrates its applicability as an important geological mapping tool;
- 'Introduction to Satellite Remote Sensing' - a video outlining the basics of satellite remote sensing techniques and a selection of applications. (National Remote Sensing Centre, 1986)

Training material is also available on climate and marine impact assessments, from the Assessment and Information Services Center of the National Environmental Satellite Data and Information Service, US National Oceanic and Atmospheric Administration. A set of visual materials, consisting of films and video-tapes using meteorological satellite images to illustrate the processes of weather phenomena and to help understand meteorological actions are available from the Institute for Geophysical Sciences at the Free University, Berlin (Voûte, 1985).

The materials outlined above may not be acceptable to those developing countries wary of 'intellectual imperialism', namely the transfer of ideas and standards developed in the North. Such materials may also not be suitable due to linguistic and cultural barriers. Nevertheless, these educational aids are usually of a high standard, and if incorporated, could play an important part in remote sensing education and training. It is quite likely that developing countries themselves would need to produce visual materials and workbooks to suit educational needs and the objectives of the national remote sensing programme.

7.2.6 The role of remote sensing centres in education

As discussed earlier, an awareness of remote sensing could be brought to a large section of society through existing educational structures within developing countries. For those outside the educational system, remote sensing education and training needs to be provided at other venues, namely remote sensing centres. Conitz (1977) believes that

> "for developing countries, which have limited human and financial resources it is visualized that user assistance and training centres should be organized initially on regional and/or national levels. Such centres would provide data interpretation facilities, training and consultation on a readily available basis."

Furthermore, Conitz (1977) notes that demonstration projects by centre staff can illustrate the potential of remote sensing to a wide audience, thus promoting a general awareness of the subject. Remote sensing centres also seem to provide an ideal setting for learning the organizational and management skills necessary for establishing an indigenous remote sensing programme.

Pakistan's Remote Sensing Applications Centre (RESACENT) at Karachi provides a number of short training courses, consisting of lectures, workshop sessions, reading assignments and fieldtrips. The aim of these courses is to familiarize participants with theoretical aspects of satellite remote sensing techniques and the use of image processing equipment (Woldai, 1986).

The Regional Remote Sensing Centre (CRTO), at Ouagadougou is one of five Regional Centres established as a result of the Conference of Ministers of the UN Economic

Commission for Africa (ECA) held in March 1977 at Kinshasa, Zaire. The other Centres are located in Kinshasa, Nairobi (Kenya), Cairo (Egypt), and Ile-Ife (Nigeria). One of the aims of CRTO is the development of a programme for training and assistance to users. The fifteen member states are Algeria, Benin, Burkina Faso, Cameroon, Congo, Côte d'Ivoire, Ghana, Guinea, Liberia, Mali, Mauritania, Niger, Senegal, Sierra Leone and Togo.

Education and training programmes at CRTO are designed to enable

> "... engineers and technicians to be able to deal with problems of preservation, conservation and utilization of renewable and non-renewable resources using remote sensing techniques which permit rapid and efficient methods of data collection and analysis by researchers and resource managers." (Okang et al., 1987)

Trainees are introduced to photographic and non-photographic sensors such as radar, thermal and multi-spectral scanners, and the interpretation of imagery using visual and digital processing techniques.

The training programmes provided by CRTO are split into six categories:

- "sensitisation, which aims at introducing new ideas and developments to policy and decision makers;

- courses, offered on a regular basis aimed both at education (that is, giving insight and understanding) and at training (for acquiring skills);

- seminars, usually of short duration, offer excellent opportunities to introduce a new concept to a few participants;

- conferences, generally open to a large audience, offer opportunities to participants to discuss research and other reports of experts;

- workshops may have a somewhat longer duration than seminars and are, by the very nature of putting the participant to work, much more geared to training than education;

- projects, usually lasting several months, are the most direct way to transfer knowledge and procedures to a limited number of people." (Okang et al., 1987).

Details of a typical sensitisation course and a regular remote sensing course offered by CRTO are presented in Table 7.1.

Table 7.1 Sensitisation and regular remote sensing courses offered at the Regional Remote Sensing Centre (CRTO), Ouagadougou

<u>Sensitisation Course (2 weeks)</u>

Objective: To present to decision makers achievements and potentialities of remote sensing techniques in national development, by lectures, demonstrations and discussions.

Week one: Orientation and introduction to the CRTO.

Fundamentals of Remote Sensing

- Image formation
- Satellite systems
- Principles of aerial photography and satellite image interpretation
- Principles of digital image processing
- Acquisition of aerial photographs and satellite images

Week two: Introduction of remote sensing applications in various disciplines (agriculture, geology, hydrology, rangeland management, human settlements, etc.)

Discussion of specific problems pertaining to remote sensing activities at the national level: advantages, limitations, financial and legal implications.

<u>Regular Remote Sensing Course (nine months)</u>

Objective: Aimed at preparing the participant to understand the basic principles of remote sensing technology, and to be able to apply them in his field of specialisation.

Entry qualification: The minimum entry qualification is a Bachelor's degree or its equivalent in any of the fields of remote sensing applications.

Part one: <u>Principles of Remote Sensing (4 months)</u>

- History of remote sensing
- Fundamentals of remote sensing
- Elements of photographic systems
- Elements of aerial photo interpretation
- Photogrammetry
- Radiometric characteristics of aerial photographs

- Aerial thermography
- Multispectral scanners and pattern recognition
- Microwave remote sensing
- Spaceborne remote sensing
- Ground truthing

Part two: Remote Sensing Applications (2 months)

The applications programme includes two two-week courses in Remote Sensing Management and in Digital Image Processing, stressing the application of remote sensing techniques in the fields of agronomy, cartography, forestry, geology, hydrology, etc.

Part three: Individual Project (3 months)

Participants work on projects in their own fields of specialisation under the supervision of experts. They must submit an acceptable project report on which they are examined orally. (op.cit)

Okang et al. (1987) report that between July 1978 and October 1986, twenty-three training courses in remote sensing techniques were offered, and a total of 228 engineers and technicians from twenty-one countries graduated in more than twenty disciplines of the environmental sciences. The major fields of application were:

Geology	43 Trainees	(18.9%)
Forestry	33 Trainees	(14.5%)
Cartography	22 Trainees	(9.6%)
Agronomy	21 Trainees	(9.2%)

A large proportion of these trainees are now actively involved in applying remote sensing techniques in their particular fields.

The Asian Regional Remote Sensing Centre (ARRSTC), Bangkok, was established in 1979 by the Asian Institute of Technology as an attempt to co-ordinate technology transfer within the Asian and Pacific region. The ARRSTC is dominantly concerned with education and runs three courses a year for anything between 100 and 150 students. Entrants, who are selected from remote sensing centres within the region, are highly trained in modern computerized techniques of digital image analysis, as well as more traditional aspects of remote sensing (O'Connor et al., 1987).

More specialised training could be provided at more subject-specific institutions and departments, for example, in India, national organizations like the National Bureau of

Soil Survey and Land Use, Central Ground Water Board, Forest Research Institution, Forest Survey of India and the Photogeology Group of Geological Survey of India offer short in-house training courses to scientists in relevant fields (Deekshatulu, 1986).

Having set up adequate institutional and educational structures, a Third World country could consider the establishment of an indigenous operational remote sensing programme.

CHAPTER EIGHT

MAKING REMOTE SENSING OPERATIONAL IN A DEVELOPING COUNTRY AND COOPERATION IN REMOTE SENSING

8.1 Establishing an indigenous remote sensing programme in a developing country

When planning the establishment of an indigenous, operational remote sensing programme in a developing country, it seems essential to consider exactly what technology should be used. Factors to be taken into account are the suitability of technology in connection with programme objectives, and the origin of the technology. Given the lack of a suitable industrial base in most LDCs and the present Third World debt, it is quite unlikely that many developing countries would or could consider producing their own remote sensing technology. India is one notable exception, having developed remote sensing satellites and launch vehicles. However, India has a long tradition of applying science and technology to national development, and a relatively strong industrial base which was established during the colonial era. Thus, for most LDCs it would seem likely that they would have to adopt foreign technology.

The remote sensing education and training stage should prepare certain sectors of society to assess the 'suitability' of remote sensing technology, often referred to as 'appropriate technology'. Appropriate technology has been described as an approach rather than a technological package because it involves

> "... tools adapted to actual problems and existing capabilities and thus permits local needs to be more effectively addressed." (Malingreau, 1981).

Therefore, those assessing and acquiring remote sensing technology need to be fully aware of national objectives, capabilities and socio-economic constraints. Malingreau (1981) argues that emphasis should also be placed

> "... on self-reliance in the local utilization of an adapted form of the available technology"

Many developing countries are wary of technology transfer from the North, fearing the possibility of 'technological dependence'. However, if national alternatives do not exist (one of the primary reasons for technology transfer from the North to the South) then it seems logical to facilitate the exchange of acceptable and appropriate foreign scientific developments. It is possible that experience with foreign technology might lead to the development of 'intermediate' technology, a combination of imported and locally developed technology. The use of foreign tools should also enable developing countries to negotiate with the space powers in the design of remote sensing satellites that would suit their particular needs. Certainly, as remote sensing becomes increasingly commercialized, satellite operators such as Landsat and SPOT are probably more likely to listen to the requests of potential Third World customers. This is important if there is to be a reduction of technological dependence which can obstruct acceptance of remote sensing within developing countries.

The experience gained by using foreign technology might give developing countries a clearer idea of what they need or wish to develop indigenously. This will require multidisciplinary research and

> "... considerable financial and technological resources and highly qualified manpower. At present it is within the power of only a small number of nations or groups of nations to mobilize such resources (USA, USSR, and COMECOM members, France, ESA member states, India, Canada, Brazil, China)" (Voûte, 1984).

For many developing countries the idea of internal development of space components is quite unrealistic, given the lack of financial and other resources. However, it would seem to be a worthwhile aim, since indigenously developed products are more likely to be geared to national requirements, and in addition a country with its own remote sensing capability would probably not suffer quite so much from the present fluctuations associated with the commercial remote sensing market. Another advantage of developing space components is that such production can stimulate certain sectors of national industry, for example in India, most of the Indian Space Research Organization's (ISRO) technology is developed in-house and then licensed to industrial suppliers. In the field of remote sensing,

> "... licenses cover anything from simple light-tables and diazo printers, to multiband ground-truth radiometers and a micro-processor based multispectral interactive data analysis system." (Mama, 1987)

The producers of such equipment have formed the Federation of Remote Sensing Companies of India. Prices for Indian-produced equipment are usually much cheaper than imported products and it was recently reported that some of the low-cost equipment is to be marketed commercially (Anon, 1988).

Those developing countries that wish to be involved in indigenous development of products, but are restrained by financial constraints could consider collaborative work with other developing and/or developed countries.

8.2 Cooperation in remote sensing

The idea of creating an indigenous remote sensing potential without any outside assistance is daunting, and in most cases unrealistic for many LDCs. Indeed, the idea of using remote sensing satellite imagery without collaboration with other countries or international bodies can also be viewed as unrealistic for most nations. The types of cooperation range from assistance in training from an international aid organization, such as the US Agency for International Development (US AID), to the establishment of an internationally owned satellite data system. Certainly it seems that cooperation in remote sensing at any level is usually mutually beneficial. Participants can share expertise, hopefully save valuable time and resources and forge diplomatic links.

The main types of cooperation in remote sensing can take one of three main forms:

- bilateral
- multilateral
- international

8.2.1 Bilateral cooperation

Bilateral cooperation involves two countries or organizations, for example, US AID is involved in bilateral cooperation in remote sensing on a number of levels, namely

- training and workshops
- research in applications
- grants
- training and user assistance centres
- using Landsat data in projects
- AIDSAT - a programme to create an awareness of remote sensing at high levels, for example government officials. (Conitz, 1977)

An example of a bilateral US AID project is the Agro-Climatic/Environmental Monitoring Project in Bangladesh (1982-85) which was designed to improve the planning and management of resources in Bangladesh, and especially those resources linked to agricultural and water development. A meteorological ground station was established, enabling the Space Research and Remote Sensing Organization (SPARRSO) to receive satellite data from the US Tiros series satellites, the Japanese Geostationary Satellite (GMS), the Indian Geostationary Satellite (INSAT) and the Russian Meteor series. Training was provided at all organizational levels, from operations and maintenance personnel to managers of user agencies. This training was supplemented by on-the-job training during installation and system checkout (US National Report, 1986).

US AID also offers grants to enable developing countries to achieve broader use of remote sensing data in developing countries. These grants consist of financial awards (nominally $20,000), technical assistance in the form of training, acquisition of materials and supplies, and occasionally data processing. In 1974 the Philippines were awarded a grant to initiate a project providing natural resource information for the integrated economic development of the Island of Mindoro, and Thailand was awarded a grant for a project providing acreage statistics to annual crop surveys of corn, rice and sugar cane. (Conitz, 1977)

Bilateral cooperation has been an important feature of India's remote sensing programme. The two Indian experimental satellites Bhaskara-I (1979) and II (1982) were launched from the Soviet Cosmodome under the Indo-USSR Collaborative Programme and the first Indian Remote Sensing Satellite, IRS-1A was launched on a Soviet Proton booster, and under a Memorandum of Understanding between India and the USA, India receives data from the Landsat satellites.

8.2.2 Multilateral cooperation

Multilateral cooperation involves three or more parties, usually with common objectives. Various regional remote sensing centres provide this type of cooperation. The Regional Remote Sensing Centre, Ouagadougou (CRTO) has fifteen member states (Algeria, Benin, Burkina Faso, Cameroon, Congo, Côte d'Ivoire, Ghana, Guinea, Liberia, Mali, Mauritania, Niger, Senegal, Sierra Leone and Togo). The CRTO aims to promote the use of remote sensing by its members by:

- operating and maintaining a receiving station;
- recording, reproducing and distributing data to users;

- providing data analysis facilities to users;
- developing training and assistance programmes for users.

CRTO activities are funded by contributions from member states and from organizations including the Euro Fund for Development, FAC (French Government), FAO, John-Paul Foundation for the Sahel, USAID and the University of Ougadougou. Some funding is also internally generated by CRTO from projects, training programmes and other activities.

The East African Regional Remote Sensing Facility in Nairobi is another example of multilateral cooperation, providing training and technical assistance to nineteen countries in East and Southern Africa. Also the Asian Remote Sensing Training Centre in Bangkok provides remote sensing technology training for Thailand and surrounding countries. The advantages of regional remote sensing centres and training centres are their cost-effectiveness, since expenses are shared, and their facilities for introducing and testing new ideas and technology. For many LDCs the idea of establishing a ground station would be ludicrous because of the expense. However, sharing the costs of a ground station with several countries can be a much more acceptable proposition.

8.2.3 International cooperation

Examples of international cooperation in satellite remote sensing, involving a wide range of nations, includes the Committee on Earth Observation Satellites (CEOS). CEOS was formed in 1984 by the merger of the international coordinating groups, the Coordination of Land Observation Satellites (CLOS) and the Coordination of Ocean Remote Sensing Satellites (CORSS). CEOS serves as a forum for the exchange of information and ideas amongst current and potential remote sensing operators to improve complementarity and compatibility in terms of mission specifications and data type. Members of CEOS include Brazil, Canada, European Space Agency, France, India, Japan and the United States.

There have been suggestions for a more broadly based international organization to coordinate or even own and operate remote sensing satellites. It is believed that,

> "if user countries want a satellite system able to meet their needs continually, a forum for voluntary coordination is not sufficient. An international organization to design and operate the satellites would be required, as well as a global network of national or regional ground stations, with financial participation of all countries wishing a voice in the decision-making process." (United Nations Monthly Chronicle, 1985).

Proposed models for such an organization include the World Meteorological Organization (WMO) and the International Telecommunications Satellite Organization (INTELSAT). WMO provides a forum in which member countries can so-ordinate their nationally owned and operated meteorological satellite systems; INTELSAT owns and operates communication satellites with members contributing in proportion to their use of the system and with services provided on a commercial fee-for-service basis.

One drawback of an INTELSAT-type remote sensing organization would be costs, since,

> "expensive satellite technology would prevent such an organization from covering expenses by selling its product - information - for reasonable fees." (United Nations Monthly Chronicle, 1985)

To overcome this problem, it might be an idea to adopt a model similar to that of the European Space Agency. Under this system, member states would agree on a common programme, common budget and the division of expenses amongst themselves. All nations could join, while staffing and work would be contracted in proportion to the financial share of each member. To ease the burden for poorer member states, financial contributions could be worked out by taking into account the Gross National Product (GNP) of each country. This might be an attractive proposition for those developing countries that because of the expense, are unable to establish an indigenous remote sensing programme.

It seems important that if an international remote sensing organization is to have international credibility, it should perhaps be a specialised body in the United Nations system, and to function normally,

> "... its regulations must be precise and realistic, and ... its capacities must be accepted without reserve by the majority of the countries." (Dupuy, 1984)

It is to be hoped that the various types of cooperation in the field of satellite remote sensing might promote increased complementarity and compatibility amongst the various existing and future satellite systems.

8.3 <u>Complementarity and compatibility of satellite remote sensing systems</u>

With the increasing diversity of remote sensing satellite systems being introduced, it will be important to assess their complementarity and compatibility in order that the full potential of remote sensing can be realised.

> "Satellite systems may be said to be complementary when one provides information or services that are particularly useful in conjunction with information or services provided by another" and "satellite systems can be called compatible if a ground system for one can be used for another with only minor adaptation" (United Nations, 1981)

It is believed that cooperation among remote sensing operators could produce the following benefits:

- "complementarity between systems to improve diversity of observation, while enhancing continuity, availability and timeliness of data;
- compatibility between systems to minimize capital and operating costs of ground systems to acquire, process and use data from all available sources" (United Nations, 1981).

Coordination activities have taken place through a number of working groups in order to promote the complementarity and compatibility of systems. The United States and France, through a joint working group, ensured the compatibility of satellite-to-ground transmissions (X-band) of image data from the Landsat-D and SPOT systems (United Nations, 1981). Groups such as the Landsat Ground Station Operators Working Group and the Groupe des opérateurs de stations SPOT hold regular meetings in an attempt to coordinate the acquisition, processing and distribution of data.

8.3.1 The World Weather Watch

Organizations, such as the World Meteorological Organization (WMO), effectively promote compatibility and complementarity between satellite systems through programmes such as the World Weather Watch (WWW). All existing national and regional meteorological satellite programmes are involved in this global plan. Under the WWW Plan and Implementation Programme for 1980-83, meteorological satellites were divided into two groups, those in near-polar orbits and those in geostationary orbits.

Near-polar orbiting satellites observe almost the entire globe twice a day, and so two satellites in complementary orbits can provide the four sets of daily data required by the WWW. Altitudes for near-polar orbiting satellites range from 600-1500 km. Geostationary orbiting satellites orbit at an altitude of approximately 36,000 km. At this altitude the orbital period is about 24 hours, equal to the rotational characteristics of the earth. If a geostationary orbiting satellite operates in the same plane as the equatorial plane, it will remain fixed over the equator. A geostationary satellite provides almost continuous data in areas within a range of about 50° (approximately 5,500 km) from the subsatellite point. Consequently, five geostationary satellites are needed to provide full global coverage within the range 50°N to 50°S latitudes.

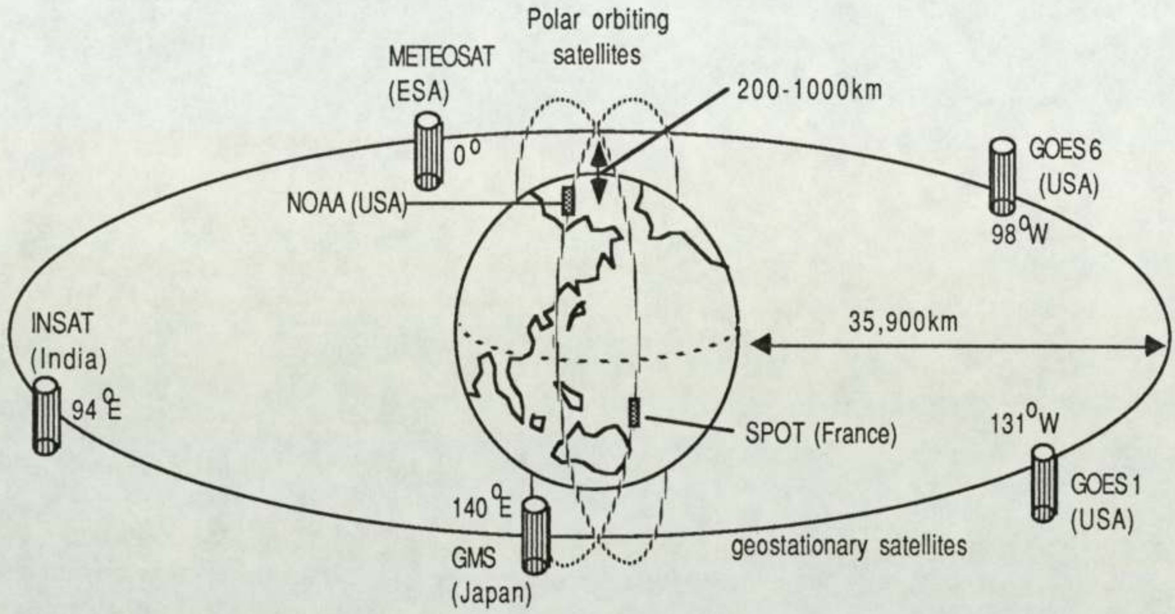


Figure 8.1 Polar and geostationary orbits used for meteorological and Earth observation satellites (Harris, 1987).

The capabilities of both types of meteorological satellites are different, but complement each other and are essential components of the space network of the Global Observing System. Both types of satellite are capable of collecting data from fixed and moving Data Collection Platforms (DCPs), such as ships, and transmitting them to central ground stations for further processing and dissemination. This data includes information concerning the atmosphere, cloud features and ocean and land surface conditions.

Transmission frequencies for the Meteorological Satellite Service are set by the International Telecommunication Union. Near-polar orbiting satellites use the 137 MHz band for medium-resolution imagery and the 1690 MHz band for high-resolution imagery. The geostationary satellites use the 1690 MHz band for image transmission and the 402 MHz band for transmissions from DCPs to the satellites. These standardized frequencies ensure that ground receiving stations have a considerable amount of compatibility. Also a network of complementary and compatible data distribution centres makes data internationally accessible. The WWW established the structure for the reception, processing and interpretation of both conventional and satellite data at three levels:

- "World Meteorological Centres (WMCs), whose primary job is to provide the products required for the analysis and forecasting of large- and planetary-scale processes;
- Regional Meteorological Centres (RMCs), which primarily provide the products required for the analysis and forecasting of large-, meso- and, to some extent, small-scale processes;
- National Meteorological Centres (NMCs), which process data at the national level, using the products of the WMCs and RMCs, in conjunction with data which may be received directly from satellites." (United Nations, 1981)

The UN (1981) believes that the level of cooperation in the WWW is high and that there appears to be little conflict between national and international priorities.

8.3.2 Orbit compatibility and complementarity

It has been postulated that in order to increase complementarity and compatibility of remote sensing systems, factors such as orbits and sensors should be taken into consideration. Choice of orbit is dictated by the planned functions of the satellite, for example, Meteosat, a meteorological satellite, was placed in a geostationary orbit, where it acquired data of the complete Earth disc (approximately a quarter of the Earth's surface) every thirty minutes. Meteosat stays over the Gulf of Guinea near West Africa at the intersection of the Greenwich meridian with the equator.

It is stated that

> "... because of different requirements, synchronization of orbit between different systems has not been achieved or even considered. The obvious exception has been the synchronization of satellites with each other within multi-satellite systems." (United Nations, 1981).

However, coordination of orbits is a desirable goal, since it can increase the diversity and improve the timeliness of observation, while simultaneously reducing conflicts for ground facilities that wish to acquire data from two satellites. In any case, coordination of orbits will become increasingly important as orbits such as the geostationary orbit become overcrowded to saturation point, and as such the use of orbits will need to be carefully monitored.

8.3.3 Sensors

Choice of sensors and spectral bands is dependent upon ultimate mission objectives, for example, the American Seasat employed L-band Synthetic Aperture Radar(SAR) to monitor the surface wave field and polar sea ice; Scanning Multi-spectral Microwave Radiometer (SMMR) to measure sea temperature, wind speeds, rain rate, liquid and water vapour content of atmospheric ice conditions; Visible and Infra-Red Radiometer (VIRR) to image ocean and coastal feature and measure sea surface temperature. Cooperation in the scientific community concerning sensor and other technology design could be promoted to facilitate the production of instruments of a higher quality and reduce the risks of unnecessary duplication of efforts.

8.3.4 Data distribution and coordination

It is believed that

> "if maximum benefit is to be obtained from the use of remote sensing data, they must be made widely available to users the world over." (United Nations, 1981)

The UN Food and Agriculture Organization (FAO) has made efforts to promote the use of the ever-increasing volume of aerial photography and satellite imagery by developing countries. This has been attempted by compiling a World Index of Space Imagery (WISI) and a World Aerial Photography Index (WAPI). The development of these indexes has been based on the following objectives:

- "to link the national and international remote sensing data bases to obtain timely information on available remote sensing coverage relevant to thematic mapping and inventorying of renewable resources in developing countries.
- to establish a computer-based, operational indexing system for remote sensing data which will permit integration of information on air-photo and satellite remote sensing coverage. In addition, the system should permit retrieval of stored information according to selected parameters such as dates of data acquisition, type of imagery, scales, etc.
- to assist in upgrading the national remote sensing data bases in developing countries." (Kalensky, 1983)

The WISI consists of the following four components

- telecommunication link with participating remote sensing databases;
- Landsat data bank;
- Landsat microfiche library;
- Landsat microfilm.

The WAPI is based on questionnaire responses from all participant countries.

8.3.4.1 Data transmission

In order to maximize the use of data from a variety of satellites, it is important to be able to receive and process these data with little or no duplication of equipment. One recent example of compatibility between various remote sensing systems is the new ground station designed by MacDonald Dettwiler. The station is able to receive and process data from Landsat satellites, SPOT, and the planned radar satellites to be launched by the European Space Agency and the Canadian and Japanese governments. The ground station includes a 10 metre tracking and receiving antenna and full digital image correction, analysis and output subsystems. The station provides a Geocoded Image Correction Subsystem which corrects satellite images to align with map coordinates, permitting direct extraction of map information. The process allows merging of image data from different sensors and satellites and the combination of image data with conventional graphics data produced and stored by digital mapping systems and geographic information systems. (Anon, 1988).

8.3.4.2 Data products

To ensure widespread use of data from different satellite systems, it seems important that data products, such as computer compatible tapes (CCTs), should be standardized. The UK National Remote Sensing Centre converts data, irrespective of satellite or sensor to a standard format. Under this format, each image is written on 9-track, 1600 or 6250 bpi magnetic tapes and uses ANSI standard tape labels. Such a practice would seem to promote the use of several types of data without the need for additional equipment.

CHAPTER NINE

THE CONCLUSION

This thesis considers the adoption of satellite remote sensing as a global data source and attempts to identify the consequent implications for the Third World. Satellite remote sensing has great potential as a tool in global development and the management of natural resources. Being a complex subject that can influence various aspects of life, it has necessarily touched upon many issues in the international arena.

Remote sensing has caused endless legal debates concerning issues such as the 'right to sense', and the call for 'prior consent'. This is because of the unique ability of satellite remote sensing devices to collect information - currently one of the most valuable international commodities - without regard for national boundaries and the concept of state sovereignty. By its very nature this modern technology has highlighted and exacerbated the conflict between the rich Northern states and the poorer Southern states, especially when it concerns the exploitation of natural resources in the latter areas. The issue of remote sensing is directly linked with the call by Less Developed Countries (LDC) for a New International Economic Order which is essentially a demand for a more equitable economic system.

The privatisation of remote sensing has posed several commercial problems. It is a relatively new technology which is not yet widely enough used by paying customers, therefore its commercial future is uncertain. This places private remote sensing companies in an insecure position. Prices have risen as remote sensing companies have become competitive and attempted to meet revenue expectations. As a result, some Third World customers, as well as parts of the research and development community of the rest of the world, are unable to afford the imagery they require. In this situation, many Third World countries have complained that the commercial policies of remote sensing companies act against the interests of the poorer countries. The newer, and much higher costs of materials have to be paid for in hard currency - always in short supply in the Third World.

The supply of remotely sensed material is not adequately guaranteed either in space, as total global cover is not now being collected, or in time, as there is still some doubt on the continuation of the supply of data in the future. The stringent (and complex!) copyright regulations (especially for SPOT) require giving details of where and for what purpose the material is to be used. This creates problems of confidentiality, even in the non-military field, and is a sensitive area in many Third World countries, for example in Iran and Iraq.

Where profit is the basis of supply then, even though a country has purchased an image, additional payments have to be made for each particular use. Finally the types of data - scale, resolution and waveband - are not currently designed for the acquisition of data required by the Third World.

Other factors that have inhibited the use of satellite remote sensing in LDCs, include the lack of a sufficient organizational base capable of planning, establishing, and sustaining a remote sensing programme. Remote sensing is multidisciplinary by nature, and as such, the required organizational and managerial structures need to coordinate the programme at various levels, ranging from individuals to regional and national administrative bodies. In a number of Third World countries, such as Nigeria, that have possessed the necessary financial resources to develop a remote sensing programme, the lack of effective managerial and organizational ability has restricted its progress. Usman (1988) of Bayero University, Nigeria, believes that lack of effective management has

"in all aspects of remote sensing, in Nigeria, restricted its development."

The global shortage of skilled personnel in the field of remote sensing presents a serious problem for most Third World countries. Lack of the necessary finance and equipment can prevent the establishment of an adequate remote sensing educational structure which could produce the required trained staff, and also prevents the attraction of skilled personnel from other countries.

It would seem that some Third World countries view remote sensing, and other high technologies with a sense of national pride, in the sense that only the best technology is good enough and they do not want to be seen to be choosing an inferior technology. Therefore, on the one hand, it could be the case that an LDC would purchase an expensive image processing system instead of a less costly, possibly more appropriate workstation. On the other hand, it could be the case that some Third World countries, not being able to buy the best technology, would not purchase any remote sensing equipment at all. For some developing countries, remote sensing is a high technology that would be too complex to utilise without external help, whether it be from a developed or Third World country.

Another factor restricting the acceptance of satellite remote sensing in Third World countries is the fact that the technology does not appear to be cost-effective. The initial process of establishing a remote sensing programme would, in most cases, be expensive and there would necessarily be a time-lag before there were any positive results which clearly showed some economic benefit. If a Third World country already has other means of survey, such as ground truth collection (which could employ local semi-skilled personnel) or aerial surveying, that country may decide that there would be no point in adopting a new, economically risky and expensive technology. In those LDCs that depend on a mono-economy, such as Nigeria's oil-based economy, they might not realise any need to map out potential and actual untapped resources (Usman, 1988).

The lack of well-developed technology transfer media also presents a major barrier to the adoption of remote sensing in the Third World. Factors that restrict technology transfer include a lack of awareness as to its immediate and longer-term value, lack of knowledge in using remote sensing equipment, different cultural values and lack of confidence in the present commercial remote sensing companies: but the major constraint would appear to be the over-whelming lack of money in LDCs. Indeed, until the debt crises of some Third World states are lessened it is quite unlikely that those states will become involved in remote sensing without substantial external aid, probably from developed nations. The dire financial positions of some LDCs are inevitably having serious repercussions on the developed world, in environmental as well as economic terms. As such, it might be an idea for developed nations to encourage the use of satellite remote sensing in LDCs, which might further global development and improve global environmental monitoring, from which all countries could reap some benefit.

Despite the various problems in adopting remote sensing technology, it is clear that satellite imagery can be used as an effective tool in the development of LDCs. India has shown that a developing country can successfully establish a remote sensing programme which can aid the country's social and economic development. The Indian remote sensing programme owes much of its success to long-term planning, a highly centralised space organization, an effective remote sensing education structure and cooperation with other countries. Without such factors, it would seem impossible for any LDC to establish a viable remote sensing structure.

The research found that to make easier the process of initiating a remote sensing plan, LDCs should consider some form of cooperation, whether it be with other developing countries within the framework of regional remote sensing centres - as in Kenya and Ouagadougou - or with one or more developed nations - as in the cases of Indonesia with the Netherlands, or India with West Germany. Without some degree of cooperation, it would be unrealistic for some LDCs to consider the establishment of a remote sensing programme. Cooperation can ease the burden and costs associated with adopting satellite technology and has the added advantage that remote sensing operations can be standardised to some degree, for example by enhancing the complementarity and compatibility of remote sensing systems.

It is very clear that remote sensing technology is not the panacea for all global resource management and environmental problems, and certainly is not capable of changing the world overnight, but despite its associated difficulties, it is essentially an efficient tool that can cost effectively aid global development and global monitoring It is now widely recognised that the ecology of the world is one, very delicately balanced, inter-related environment, where action in one part can markedly affect other, sometimes quite distant parts. The growing pollution of the world's air and water, and the wholesale destruction of the few remaining forests - not to mention the affects of nuclear disasters - all confirm the fragility of the ecosystem.

It is in the interest of all to work to improve global environmental monitoring systems, and this now urgent need justifies a far more liberal approach, and more generous financial support to Third World countries in their efforts to establish and develop their own remote sensing facilities and capabilities.

APPENDIX 1

Principles Relating to Remote Sensing of the Earth from Space

Adopted by the General Assembly, United Nations
December 1986

Principle I

For the purposes of these principles with respect to remote sensing activities:

(a) The term "remote sensing" means the sensing of the Earth's surface from space by making use of the properties of electromagnetic waves emitted, reflected or diffracted by the sensed objects, for the purpose of improving natural resources management;

(b) The term "primary data" means the raw data that are acquired by remote sensors borne by a space object and that are transmitted or delivered to the ground from space by telemetry in the form of electromagnetic signals, by photographic film, magnetic tape or any other means;

(c) The term "processed data" means the product resulting from the processing of primary data, needed to make such data usable;

(d) The term "analysed information" means the information resulting from the interpretation of processed data, inputs of data knowledge from other sources;

(e) The term "remote sensing activities" means the operation of remote sensing space systems, primary data collection and storage stations, and activities in processing, interpreting and disseminating the processed data.

Principle II

Remote sensing activities shall be carried out for the benefit and in the interests of all countries, irrespective of their degree or economic, social or scientific and technological development, and taking into particular consideration the needs of the developing countries.

Principle III

Remote sensing activities shall be conducted in accordance with international law, including the charter of the United Nations, the Treaty on Principles Governing the Activities of States in the Exploration and use of Outer Space, including the Moon and Other Celestial Bodies, and the relevant instruments of the International Telecommunication Union.

Principle IV

Remote sensing activities shall be conducted in accordance with the principals contained in article I of the Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies, which, in particular provides that the exploration and use of outer space shall be carried out for the benefit and in the interests of all countries, irrespective of their degree of economic or scientific development, and stipulates the principle of freedom of exploration and use of outer space on the basis of equality. These activities shall be conducted on the basis of respect for the principle of full and permanent sovereignty of all States and peoples over their own wealth and natural resources, with due regard to the rights and interests, in accordance with international law, of other States and entities under their jurisdiction. Such activities shall not be conducted in a manner detrimental to the legitimate rights and interests of the sensed State.

Principle V

States carrying out remote sensing activities shall promote international co-operation in these activities. To this end, they shall make available to other States opportunities for participation therein. Such participation shall be based in each case on equitable and mutually accepted terms.

Principle VI

In order to maximize the availability of benefits from remote sensing activities, States are encouraged, through agreements or other arrangements, to provide the establishment and operation of data collecting and storage stations and processing and interpretation facilities, in particular within the framework of regional agreements or arrangements wherever feasible.

Principle VII

States participating in remote sensing activities shall make available technical assistance to other interested States on mutually agreed terms.

Principle VIII

The United Nations and the relevant agencies within the United Nations system shall promote international co-operation, including technical assistance and co-ordination in the area of remote sensing.

Principle IX

In accordance with article IV of the Convention on Registration of Objects Launched into Outer Space and article XI of the Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies, a State carrying out a programme of remote sensing shall inform the Secretary-General of the United Nations. It shall, moreover, make available any other relevant information to the greatest extent feasible and practicable to any other State, particularly any developing country that is affected by the programme, at its request.

Principle X

Remote sensing shall promote the the protection of the earths natural environment. To this end, States participating in remote sensing activities that have identified information in their possession that is capable of averting any phenomenon harmful to the Earth's natural environment shall disclose such information to States concerned.

Principle XI

Remote sensing shall promote the protection of mankind from natural disasters. To this end, States participating in remote sensing activities that have identified processed data and analysed information in their possession that may be useful to States affected by natural disasters, or likely to be affected by impending natural disasters, shall transmit such data and information to States concerned as promptly as possible.

Principle XII

As soon as the primary data and the processed data concerning the territory under its jurisdiction are produced, the sensed State shall have access to them on a non-discriminatory basis and on reasonable cost terms. The sensed State shall also have access to the available analysed information concerning the territory under its jurisdiction in the possession of any State participating in remote sensing activities on the same basis and terms, taking particularly into account the needs and interests of the developing countries.

Principle XIII

To promote and intensify international co-operation, especially with regard to the needs of developing countries, a State carrying out remote sensing of the Earth from space shall, upon request, enter into consultations with a State whose territory is sensed in order to make available opportunities for participation and enhance the mutual benefits to be derived therefrom.

Principle XIV

In compliance with article VI of the Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and other Celestial Bodies, States operating remote sensing satellites shall bear international responsibility for their activities and assure that such activities are conducted in accordance with these principles and the norms or international law, irrespective of weather such activities are carried out by governmental or non-governmental entities or through international organizations to which such States are parties. This principle is without prejudice to the applicability of the norms of international law on State responsibility for remote sensing activities.

Principle XV

Any dispute resulting from the application of these principles shall be resolved through the established procedures for the peaceful settlement of disputes.
(UN, 1987)

APPENDIX 2

Remote sensing applications in various Third World countries

Country/ Organisation	Name of project Type of sensors	Objectives and details	Main Results and follow-up activities	Evaluation of the value of the project
Bangladesh Space Research and Remote Sensing Organisation (SPARRSO)	Development potentiality for agricultural development in Rajshahi Division Landsat MSS data	To determine the agricultural development potentiality rating of Rajshahi Division Starting date: July 1978 Completion date: Dec 1979	On the basis of relative assessment of the existing natural conditions of Rajshahi Division, five types of agricultural development	The findings of the study are being used for development planning of the Rajshahi Division
SPARRSO	Inventory of the forest resources of Dacca (Bhawal) forests Research and development project Landsat MSS data and aerial photographs	Preparation of a forest inventory record of the Dacca forests Starting date : July 1979 Completion date : June 1980 Area of study : 160 sq km Mapping scale : 1: 30,000 Location : Dacca	Landsat data and aerialphotographs have been analysed to collect data on forest resources of the study area. On the basis of the findings, the latest position of the forest resources of Dacca forests are being determined	The information will be helpful to the Forest Department for proper planning, careful preservation and scientific management of the forests for qualitative and quantitative improvement of the biomass of the region

Country/ Organisation	Name of project Type of sensors	Objectives and details	Main Results and follow-up activities	Evaluation of the value of the project
SPARRSO	4. Study on St. Martin's land	To study the natural resources and development potentialities of the island Starting date : February 1980 Completion date : April 1980 Area of study : 3. 20 sq km Mapping scale : 1 : 30,000 Location : Southern most tip of the main-land of Bangladesh	The study provided useful information on soil and land classification to assess the agricultural development potentiality of the land. A detailed scientific and ecological study of the island as a follow up activity of the project will be undertaken	On the basis of the study report, development activities in the island have been initiated

Country/ Organisation	Name of project Type of sensors	Objectives and details	Main Results and follow-up activities	Evaluation of the value of the project
SPARRSO	Geological feature studies	To map the geological and geomorphic features of Bangladesh Starting date : July 1978 Completion date : February 1979 Area of study : 143,988 sq km Mapping scale : 1: 500,00 Location : Whole of Bangladesh	Geological and geomorphic maps of Bangladesh prepared. Further studies on geological features are being taken up with the produced maps as base material	The maps have provided information to understand the tectonic features of the country and initiate development plans

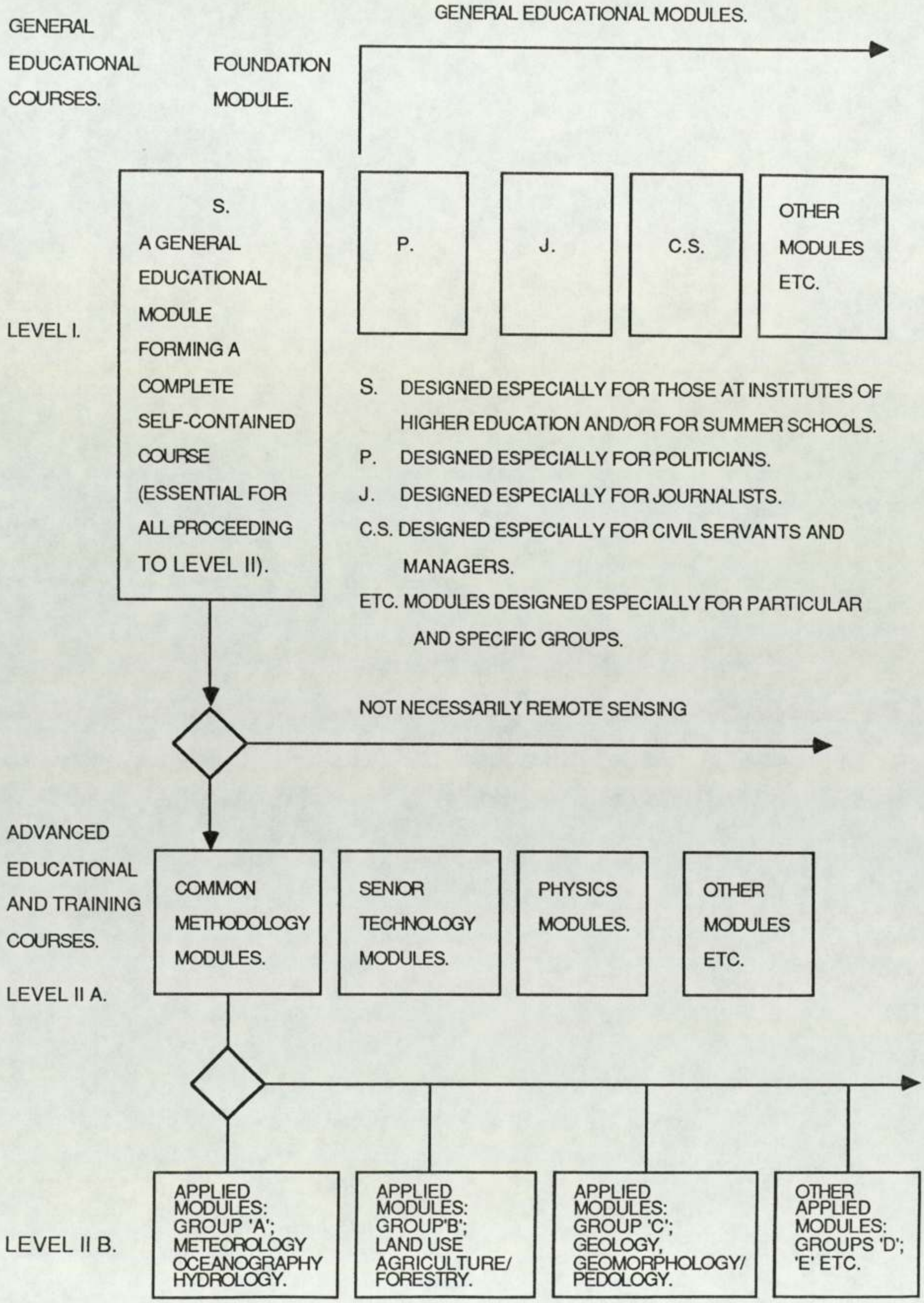
Country/ Organisation	Name of project Type of sensors	Objectives and details	Main Results and follow-up activities	Evaluation of the value of the project
Pakistan Space and Upper Atmosphere Research Commission (SUPARCO) Research Division, Department of Irrigation Govt. of Sind Karachi	Flood plain mapping and study of river course changes Research/ demonstration Landsat MSS	Determining area affected by floods; delineation of active flood plain; locating breaches and points prone to breaching along rivers; study of changes in river courses/channels owing to flooding and other factors; routine river surveying in Sind and Punjab; planning and improvement of flood control/protection measures Date : 1973 Location : Indus Basin Scale : 1: 1,000,000 and 1: 250,000	Area under flood water in the Indus Basin computed for different years. Changes in river courses/channels studied and mapped; existing base maps updated; routine river surveys being carried out; breaches and vulnerable points along rivers identified and flood protective embankments accordingly strengthened Landsat data being used in routine river surveying	

Country/ Organisation	Name of project Type of sensors	Objectives and details	Main Results and follow-up activities	Evaluation of the value of the project
SUPARCO Federal Flood Commission Rawalpindi	Comprehensive flood management plan for Pakistan	Preparation of a comprehensive flood management plan in Pakistan Date :1978 Location : Whole of Pakistan Scale : 1 :250,00	Landsat imagery proved useful in : 1. Developing an overall picture of the overbank flooding 2. Locating vul-nerable breaches of the rivers 3. Marketing correct alignment of canals, e.g. Pat Feeder 4. Conforming different breaching sections 5. Assessing the hydrological con-ditions, vegetation cover etc. in the catchments of hill torrents	

(UN, 1981)

APPENDIX 3

MODULAR COURSES IN REMOTE SENSING


GENERAL EDUCATIONAL COURSES.
FOUNDATION MODULE.
GENERAL EDUCATIONAL MODULES.
S.
A GENERAL EDUCATIONAL MODULE FORMING A COMPLETE SELF-CONTAINED COURSE (ESSENTIAL FOR ALL PROCEEDING TO LEVEL II).
P.
J.
C.S.
OTHER MODULES ETC.
LEVEL I.
S. DESIGNED ESPECIALLY FOR THOSE AT INSTITUTES OF HIGHER EDUCATION AND/OR FOR SUMMER SCHOOLS.
P. DESIGNED ESPECIALLY FOR POLITICIANS.
J. DESIGNED ESPECIALLY FOR JOURNALISTS.
C.S. DESIGNED ESPECIALLY FOR CIVIL SERVANTS AND MANAGERS.
ETC. MODULES DESIGNED ESPECIALLY FOR PARTICULAR AND SPECIFIC GROUPS.
NOT NECESSARILY REMOTE SENSING
ADVANCED EDUCATIONAL AND TRAINING COURSES.
LEVEL II A.
COMMON METHODOLOGY MODULES.
SENIOR TECHNOLOGY MODULES.
PHYSICS MODULES.
OTHER MODULES ETC.
LEVEL II B.
APPLIED MODULES: GROUP 'A'; METEOROLOGY OCEANOGRAPHY HYDROLOGY.
APPLIED MODULES: GROUP'B'; LAND USE AGRICULTURE/ FORESTRY.
APPLIED MODULES: GROUP 'C'; GEOLOGY, GEOMORPHOLOGY/ PEDOLOGY.
OTHER APPLIED MODULES: GROUPS 'D'; 'E' ETC.

FOUNDATION MODULE - A COMPLETE SELF-CONTAINED COURSE
LENGTH: ABOUT ONE WEEK FULL TIME

1. Definition and significance of remote sensing. Basic physics; environmental properties and processes.
2. Data acquisition; platforms, sensors, recording methods.
3. Data processing; methods and instruments.
4. Interpretation procedures; photographs, images, image-forming and non-image forming data.
5. Illustrations of actual applications in several fields, including cost benefit analyses.
6. Political, legal and social implications; potentialities of remote sensing.

ESSENTIAL FOR ALL PROCEEDING TO LEVEL II

GENERAL EDUCATIONAL MODULES - EACH MODULE IS COMPLETE AND SELF CONTAINED LENGTH: ABOUT ONE HOUR
FORM: FILM OR VIDEO-TAPE; SUPPLEMENTED BY DISCUSSIONS AND OTHER MATERIAL AS APPROPRIATE

Subject matter similar to that for foundation course but to be condensed and orientated to provide understanding of value and limitations of remote sensing related to the interests of each group, for example for politicians, on 'Impact of Remote Sensing on Industrial and Agricultural Strategy', or 'Value of Remote Sensing for Monitoring Human and Physical Resources', or 'Importance of Remote Sensing for Disaster Relief'; for teachers, 'Impact of Remote Sensing on Agriculture and/or Industry and/or Urbanisation and/or Defense'.

Other modules can be envisaged, for example, for pressure groups (trade unionists, environmentalists) , engineers, physicists, lawyers, data bank staff, planning agency staff etc. especial orientations could be given to modules for civil servants in agricultural, industrial, or environmental, or socio/economic, or science policy or public works ministries/departments etc.

METHODS OF PRESENTATION

1. A booklet should be prepared for each module and given to each participant in French or English.
2. Film, tapes, slides, photographs, images, digital print-outs, graphs, data sheets must be used as appropriate.
3. The modules must be innovative and attractively presented; examples must be provided whenever possible.
4. The short one hour courses are to be presented as films and, according to the group for whom each film has been prepared and to the occasion of the presentation, additional video-tapes, slide material, etc should be available and incorporated as illustrative material for lecture demonstrations and/or discussions. Every presentation, whatever the occasion, should be associated with a seminar-type discussion.

5. The student`s module is to be supported by exercises,work sheets,discussions and plenty of illustrative material. Individualised learning techniques are required due to the diverse backgrounds and experience of the participants.

OBJECTIVES

1. To show how Remote Sensing can be used; its value and limitations and the implications of its use and development for society.
2. To illustrate the kind of data and information that can be obtained and their applications in several applied fields.
3. To enable the participants to pose answers and discuss questions as: "Can the job be done with Remote Sensing?", "What kind of information can I obtain from Remote Sensing?","How much or less will it cost if I use existing standard methods?", etc.
4. To demonstrate the interdisciplinary nature and integrating role of Remote Sensing studies in education.

COMMON METHODOLOGY

LENGTH: ABOUT FOUR WEEKS FULL TIME BUT CONDENSED FOR SUMMER SCHOOLS.

1. Physics and technology of sensors and platforms, including for example, technology of data acquisition in aerospace and on the ground; deconvolution of output signal, its significance and value.
2. Environmental properties and processes; the terrestrial system; interactive and dynamic mechanisms of the air, oceans and land environments.
3. Basic physics of interactive mechanisms of electromagnetic, gravitational and mechanical waves with natural media; wave propagation and signal production.
4. Information extraction by processing and interpretation procedures valid for all applications: integration of environmental data and information with spectral, spatial and temporal Remote Sensing data and information; strategies for environmental sampling of spectral, spatial and temporal data and information; integration of multi-sensor data and information; logical analysis, inversion, statistical, pattern, modelling, topological procedures; digital, analogue and optical processing systems; subjective and objective visual and machine-assisted (interactive) interpretation procedures.
5. Data and information presentation; graphical and non-graphical methods, data-banking, computer graphics, automated cartography.

METHODS OF PRESENTATION

1. The syllabus proposed for this module may be incorporated,as a whole or in its different (sub-module) components, or (sub-module) units, into existing courses in Institutes of Higher Education, or may be presented in a summer school.
2. All module components must be accompanied by seminar-type discussions and practical exercises and work sheets included, as appropriate, actual or simulated experiments, laboratory and field programmes, including work on own, or otherwise, recorded andderived, ground, air, water and sensor data and information.
3. Wherever possible film, tapes, slides, photographs, images, digital printouts, graphs, data sheets, etc are to be used to provide ample pictorial illustrations. Access to appropriate data and analysis processing equipment is essential. Individualised learning techniques are required due to the diverse backgrounds and experience of the participants.
4. Visits to centres involved in Remote Sensing and its applications, such as National Points of Contact, satellite data receiving stations, Remote Sensing instrument manufacturers, etc should be arranged.

OBJECTIVES

1. To demonstrate the essential importance of the integrated, multi-disciplinary and inter-disciplinary approach to Remote Sensing.
2. To demonstrate and to provide an understanding of known facts and processes common to, and influencing the derivation of Remote Sensing data so that the value of Remote Sensing measurements may be identified.
3. To provide an education and training in Remote Sensing for students in Institutes of Higher Education, for mature and experienced pure and applied scientists and research workers,and certain schools, colleges and higher education institutes teachers,with a capability to understand and to apply Remote Sensing in their professional work.

EXAMPLES OF APPLICATION MODULES

LENGTH: ABOUT FOUR WEEKS FULL TIME, BUT CONDENSED FOR SUMMER SCHOOLS.

The following fields of application were recognised as examples for the development of applied modules although it was recognised that,within each subject area,there are other applications for which modules could, and eventually, should be developed.

METE0ROLOGY:	OCEANOGRAPHY:
CLIMATOLOGY	BIOCLIMATOLOGY
ECOLOGY:	
FORESTRY	LAND USE
PEDOLOGY	GEOMORPHOLOGY

Illustrations of specific applications were considered. Examples are as follows.

HEAT BUDGET PROBLEMS.
SNOW AND ICE SURVEYS.
COASTAL AND RIVERINE FLOOD DAMAGE.
MINERAL SURVEYS.
MARINE AND RIVERINE POLLUTION.

SITE SURVEYS FOR DAMS, BRIDGES,ETC.
ROAD AND BUILDING CONSTRUCTION MATERIALS.
ROUTE PLANNING AND INSTABILITY SURVEYS.

CROP INVENTORY, CROP PRODUCTION, DISEASE DETECTION SURVEYS.
TEMPORAL MONITORING,MONITORING AND EXPERIMENTATION.
OPTIMUM APPLICATIONS OF PARTICULAR SENSORS FOR SPECIFIC APPLICATIONS.

Certain of these subject areas could possess common introductory trunk sub-modules, such as agriculture (sensu lato), or geology, geomorphology, pedology.

METHODS OF PRESENTATION

1. The syllabi to be developed for these modules or sub-modules(components or units) should be designed to be capable of incorporation into existing courses in Institutes of Higher Education, or to be presented in summer schools.
2. The form of presentation of each module or sub-module will inevitably depend on the subject but it is emphasized that every effort should be made to make sure that there are opportunities for seminar discussions and that practical work, including work sheets, should play a large part in the teaching programmes and should include, as appropriate, actual or simulated experiments, laboratory and field-work based on the participants own, or otherwise recorded and derived environmental data and information. Case-histories and summaries of case-histories should be presented and available.
3. Wherever possible film, video-tapes, slides, photographs, images digital printouts, graphs, data sheets, etc. are to be used to provide ample illustrations.Access to appropriate data and information processing equipment is essential. Manuals should be available for practical work.

4. Since the modules or sub-modules are applied it is inevitable that they will be incorporated into courses in institutes or departments where the appropriate applied equipment and expertise is already available. If the appropriate Remote Sensing equipment is not already available, it will have to be obtained if the work of the participants is to be appropriately developed. Where these modules are presented in Summer School-type courses they must be located where both the applied expertise and the appropriate Remote Sensing equipment are available and/or the necessary field conditions and/or problems exist.
5. Summer schools in specialist applications are probably required only every 2-4 years.

OBJECTIVES

1. To demonstrate the applications of Remote Sensing in both general and specific areas of application.
2. To demonstrate and provide an understanding of known Remote Sensing methodologies and techniques capable of being applied to achieve data and information more quickly, and/or more accurately, and/or more cheaply than is possible from the application of other methodologies and techniques.
3. To provide an understanding of appropriately modelling and experimental methods that may be applied to determine the value, limitations and results that may be derived from the application of Remote Sensing.
4. To provide an education and training in applied Remote Sensing for students in institutes of Higher Education, for mature and experienced pure and applied scientists and for research workers, and certain teachers in institutes of Higher Education with a capability to understand and to apply Remote Sensing in their particular area of interest.

Voûte (1985)

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