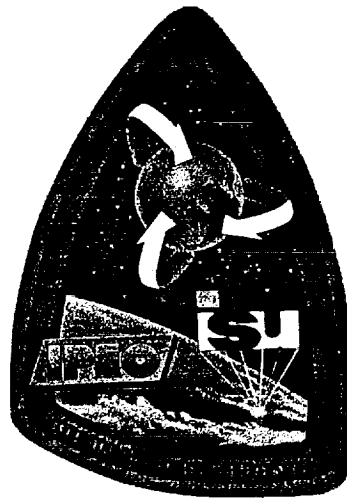

INTERNATIONAL PROGRAM FOR EARTH OBSERVATIONS



FINAL REPORT

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Treat the Earth well.

It was not given to you by your parents.

It was loaned to you by your children.

Kenyan proverb



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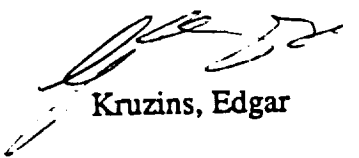
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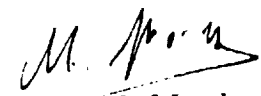
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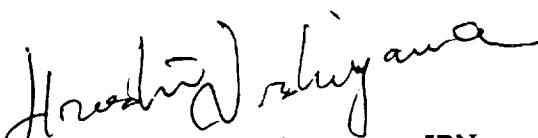
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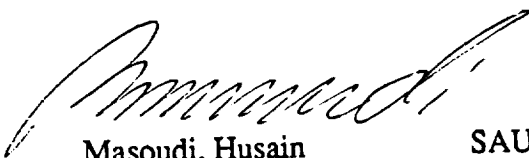
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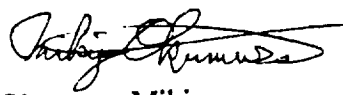

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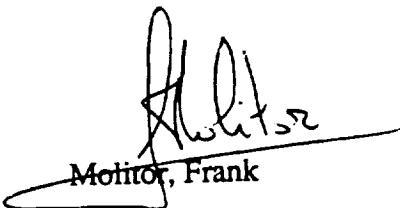

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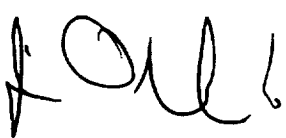

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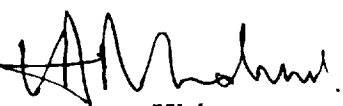

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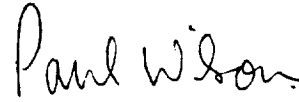
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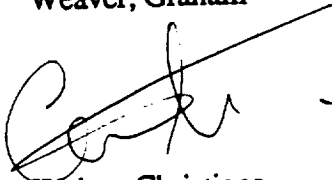
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LIST OF ACRONYMS

| | |
|----------|--|
| ACS | Attitude Control System |
| AN SSSR | USSR Academy of Sciences and Cartography |
| AOCS | Attitude and Orbit Control Subsystem |
| AVHRR | Advanced Very High Resolution Radiometer |
| | |
| BWO | Backward Wave Oscillators |
| | |
| C&DH | Communication and Data Handling |
| CCRS | Canada Center for Remote Sensing |
| CCT | Computer Compatible Tape |
| CERL | Construction Engineering Research Lab |
| | |
| DIS | Data and Information System |
| DFVLR | German Aeronautics and Space Administration |
| DoD | Department of Defense |
| | |
| EIKA | Extended Interaction Klystron |
| EIKO | Extended Interaction Klystron |
| EIRP | Effective Isotropically Radiated Power |
| EM | Electromagnetic |
| EOS | Earth Observing System |
| EOSAT | Earth Observation Satellite Corporation |
| ERS-1 | Earth Resources Satellite |
| ESA | European Space Agency |
| EUMETSAT | European Organization for the Exploration of Meteorological Satellites |
| | |
| FAO | Food and Agriculture Organization (United Nations) |
| FCCSET | Federal Coordinating Committee for Science, Engineering, and Technology |
| FES | Fossil Energy Sources |
| FET | Field-Effect Transistors |
| | |
| GCRP | Global Change Research Program |
| GDP | Gross Domestic Product.(equivalent to Gross National Product or GNP) |
| GEMS | Global Environmental Monitoring System |
| GEOD | Global Earth Observation Directory |
| GIS | Geographical Information Systems |

| | |
|----------|--|
| GPS | Global Positioning System |
| GRID | Global Resource Information Database |
| GTO | Geostationary Transfer Orbit |
| HRSC | High Resolution Stereo Camera |
| HRV | High Resolution Visible |
| ICSU | International Council of Scientific Unions |
| IF | Intermediate Frequency |
| IGBP | International Geosphere-Biosphere Program |
| IGY | International Geophysical Year |
| IMPATT | Impact Ionization Avalanche Transit |
| INMARSAT | International Maritime Satellite Organization |
| INPE | Institute for Space Research (Brazil) |
| INTELSAT | International Telecommunications Satellite Organization |
| IOC | International Oceanographic Commission |
| IP | Internet Protocol |
| IPEO | International Program for Earth Observation |
| IR | Infrared |
| ISY | International Space Year |
| ITU | International Telecommunications Union |
| JPL | Jet Propulsion Laboratory |
| LEO | Low Earth Orbit |
| MALU | Microprogrammable Arithmetic Logic Units |
| MD | Master Directory |
| MEDI | Maritime Environmental Data Informaiton |
| METEOSAT | Meteorological ObservationSatellite |
| MOU | Memorandum of Understanding |
| MY | Man-years |
| NASA | National Aeronautics and Space Administration |
| NASDA | National Aeronautics and Space Development Agency |
| NESDIS | National Environmental Satellite Data and Information Service |

| | |
|--------|---|
| NIR | Near Infra-Red |
| NOAA | National Oceanic and Atmospheric Administration |
| NPV | Net Present Value |
| NRC | National Research Council |
| PRF | Pulse Repetition Frequency |
| RCS | Reaction Control Subsystem |
| RF | Received Frequency |
| SAR | Synthetic Aperture Radar |
| SDTS | Spatial Data Transfer Standard |
| SIMD | Single Instruction Multiple Data |
| SPOT | System Probatoire d'Observation de la Terre |
| SSO | Sun Synchronous Orbit |
| TCP/IP | Transmission Control Protocol |
| TCS | Thermal Control System |
| TDRSS | Tracking and Data Relay Satellite System |
| TM | Thematic Mapper |
| TMS | Topographic Mapping Satellite |
| TR | Transmit-Receiver |
| TT&C | Tracking Telemetry and Command |
| TWT | Travelling Wave Tubes |
| UCC | Universal Copyright Convention |
| UN | United Nations |
| UNEP | United Nations Environment Program |
| VIS | Visible |
| WCRP | World Climate Research Program |
| WHO | World Health Organization |
| WMO | World Meteorological Organization |

EDITOR'S NOTE

The editorial task for this Report presented unique challenges which involved several hundred hours of effort over a three week period. The Report was constructed by nearly 70 student contributors from many countries. By design, a Draft-IPEO Report was compiled, integrated and reproduced for distribution to IPEO students in three hectic days. IPEO students thus were able to take home with them a tangible product of their enormous efforts.

The compressed process of "real time" Report preparation, compilation and integration -- and the immediate scattering of IPEO authors -- required the Editors to adopt several unusual rules:

- The draft organization and sequence of material was maintained, even though textual economy and balance is sometimes sacrificed by this rule.
- The basic integrity of student contributions to the Report was to be maintained, even though this sometimes resulted in repetition of key themes or concepts and even different perspectives about them.
- The original authors were asked in particular to recheck their Tables and Figures in Toronto and many did so; nevertheless, there remain some incomplete or unclear data that invite further work or verification. This condition is often noted within the text. Further, many students prepared their drawings using software tools which required the Editors to have computer access to their original files. Unfortunately, many drawings were not transportable to the Editor's word processing system.
- Substantive additions or changes to draft text was to be made only when supported by faculty and student notes, in some cases, valid faculty critiques and suggestions could not be incorporated fully while still adhering to the basic editing rules described above.
- Citations, documentation of conclusions, bibliographic and other format/content issues were major problems that remain only partially resolved.

Overall, the editing challenges turned out to be one of communication. Does the IPEO Report communicate a vision of what can be accomplished through truly international cooperation and does it take a fresh look at extremely complex issues? The answer, as the reader will find, is "Yes".

The IPEO Report is and should be accepted as a working document. It is unfinished, but makes a major contribution to a global dialog which will continue throughout this decade and beyond.

We would like to sincerely thank our editorial support, Karen B. Maughan and Julie M. Branch, for their many hours of dedicated service in support of this task.

It was a pleasure to be a small part of the IPEO process.

Paul M. Maughan
Timothy M. Alexander

September 21, 1990

FOREWORD

What follows is the Final Report of an ISU'90 Design Project, entitled the International Program for Earth Observations (IPEO). More than 80 students, faculty, project assistants, and visiting lecturers participated in the evolution of IPEO. IPEO evolved in ten short weeks from a study concept to a significant contribution to the global international environmental dialog of the 1990s.

The IPEO Design Project began with four objectives:

- Learn about remote sensing and investigate its potential to help solve global environmental problems.
- Learn about international legal, organizational and economic programs dealing with space and environmental issues, and design improved strategies to implement an international program for Earth observations.
- Learn to work together and make effective decisions about complex issues in an intensive, international, interdisciplinary, multi-cultural setting.
- Produce a report that examines the legal and institutional, scientific, engineering and systems, financial and economic, and market development approaches needed to improve international Earth observations and information systems to deal with environmental issues of global importance.

The reader will see that IPEO is broad in scope and ambitious in its design. The students were asked to identify, define, and developed novel space mission(s) and data innovations necessary to serve unmet needs. This required clear analyses of existing systems and an understanding and ranking of environmental information needs on an international scale. The robust requirements and capabilities analyses undertaken by the entire IPEO group compressed the time allowed for technical systems design, tradeoffs and documentation.

The reader should understand that during the ten week period, IPEO students also attended interdisciplinary lectures, workshops, visiting panels, field trips and a host of social and cultural events. Obviously, many of the issues and challenges of IPEO could not be developed in detail. Further work will be needed to refine the design and to begin the process of IPEO implementation. However, the work accomplished over the last ten weeks has exceeded the faculty's design objectives and our personal and professional expectations.

The student Report which follows represents the results of thousands of hours of serious, creative work, very often accomplished outside the student's area of academic or professional speciality. Sometimes the work was tedious and contentious, at other times

exciting and exhilarating. A significant contribution to the development of an improved global program for Earth observations is the result. We recommend the report to the International Space Year and our global remote sensing colleagues.

The Design Project Faculty wishes to express our deepest appreciation and admiration to all the IPEO Design Project students. In particular, we applaud the Study Coordinator, Susan Turner, and the Working Group Coordinators Bruce Bulin, Max Nelson, Michel van Roozendaal, David Watson, Paul Wilson, and the Advisory Committee Chair, Richardo DePavia, for their talent, dedication and commitment to the project. Special mention also should be made of our initial group leaders Maurits Haeck and Christiane Weber. We also wish to acknowledge the significant contributions of the ISU'90 Faculty, in particular Siamak Khorram, Gerard Maral, Joseph Pelton, Marcel Pouliquen, and Randall Thomas.

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August 28, 1990



1.0 INTRODUCTION

1.1 Background

The **International Space University (ISU)** is a unique educational program. Its goal is to bring together graduate level students from around the world to study the many facets of space. The areas of core study cover many aspects of space, including: Architecture, Business and Management, Engineering, Life Sciences, Policy and Law, Resources and Manufacturing, Satellite Applications, and Space Physical Sciences. The first ISU program was held during the Summer of 1988 at the Massachusetts Institute of Technology in Cambridge, Massachusetts, the second program in 1989 at the University Louis Pasteur, in Strasbourg, France, and the third during the Summer of 1990 at York University, in Toronto, Canada. The 1990 session convened during the last week of June and lasted 10 weeks. An international faculty delivered core and advanced lectures. The faculty also led seminars with students in particular disciplines. Thus each student was introduced to a core body of knowledge covering major aspects of space exploration and development and to acquire specialized knowledge in his or her particular area of interest.

To promote interdisciplinary interaction, and to put the lecture material to use, all students in the Summer Program participate in a Design Project. The Design Project is intended to be an educational experience where Architects, Managers, Engineers, Scientists, Physicians and Policy-makers work together toward completion of a common goal. The students learn the importance of disciplines other than their own as they collaborate to make project decisions. In addition, they are able to do creative work in their own specialty. Each Project is facilitated by space industry experts who have worked on similar undertakings.

Selection of a Design Project has several goals. The project must be multi-disciplinary and multinational in nature. This may be accomplished with one broad based project or with several focused projects. The projects must be plausible and feasible. They must incorporate technology that exists or is theoretically available in the near future. The project must be peaceful in nature and one in which all space-faring nations of the world may participate.

One of two Design Projects of the 1990 ISU Summer Session was the **International Program for Earth Observations (IPEO)**. This Design Project report serves to demonstrate what the ISU program is all about: interdisciplinary, international cooperation to produce work of high quality. The report serves as a discussion point for the world community as it considers further remote sensing and environmental observation initiatives. This document also may be a stimulus within ISU to drive further Design Projects and discussion. The ISU program will grow through further Summer sessions around the world and eventually will become a year-round program with a permanent campus. ISU also seeks progress from study projects to those that will fly in space. The most important result of the Design Projects and the ISU program is to create a body of men and women

throughout the world, linked by knowledge and friendships, to promote peace and human cooperation.

1.2 Project Goals

One of the first tasks of the IPEO effort was to draft a statement of long term goals for the project. The Design Project assumed that the focus of IPEO would be to help meet the most pressing environmental information requirements of international significance in the mid- to late 1990s, that either are unmet or inadequately met by current or planned Earth observing programs. After careful deliberation, the following statement of goals was drafted:

The International Program for Earth Observations (IPEO) is established to gather, process, analyze and disseminate environmental data and information to help solve global environmental management problems of the Earth on a continuous, international basis. Specific objectives of the program are as follows:

- To gather both in situ measurements and remote sensing measurements.
- To analyze data and develop models to understand global environmental problems.
- To facilitate environmental and related data distribution, and provide tools to improve understanding and use of these data. IPEO will distribute existing, planned and new data .
- To investigate environmental problems such as, global warming, pollution, vegetation dynamics, deforestation and biomass inventory.

In order to address global needs in the near future, the following short term statement of purpose was proposed:

As a first step toward gathering and disseminating environmental data, IPEO will explore and design a system using small satellites to assess the status of and monitor deforestation as well as topographical mapping. If the design of a system for topographical mapping compromises the design of a system for deforestation, then only a system for deforestation assessment will proceed. For the task of data dissemination, a comprehensive data system for remote-sensing information resources shall be proposed.

1.3 ISU Design Scenario

Several broad requirements were presented in a Study Guide at the initiation of the project:

- Develop a rigorous identification of environmental management requirements from the broad national, international and disciplinary perspectives of ISU students, faculty and the available literature. Rank, by relative priority the environmental requirements and the needs for information associated with environmental management requirements.
- Survey and analyze current and planned programs for Earth observations to determine the degree to which they meet international environmental management and information requirements. Evaluate current and planned capabilities, not only in technical and system terms, but also in terms of financing, costs and economic efficiency, data handling, user distribution, institutional strengths and weaknesses, applications and international capabilities to use the data. Incorporate "hands on" use of digital image processing capabilities provided by the ISU to develop case studies of current environmental information capabilities.
- Study current and planned space systems design strategies, including a thorough design and development assessment of small spacecraft and their support systems
- Select a design strategy that best meets the international environmental information and management needs of the mid to late 1990's. Develop a comprehensive assessment of costs and finance, applications, institutional and information systems strategies. Document tradeoffs and necessary modifications resulting from an integration of all these perspectives.
- Prepare a comprehensive report on the processes, methods, analyses and recommendations leading to an optimum International Program for Earth Observations. Also, prepare individual Country Notes to be provided to student sponsors and for summary in the IPEO report.

In order to accomplish these tasks, the IPEO students were initially divided into three groups. A requirements group was asked to survey and rank environmental requirements. A technical group assessed current technological capabilities. An implementation group studied the project management structure and assessed the global implementation procedure

for the IPEO program. The initial groups reorganized into four working groups for the remainder of the study. A Working Group Coordinator was elected from each of the four groups: Applications and User Development, Finance and Economics, Legal and Institutional, and Systems Design and Engineering. Study Coordinator was elected by the IPEO student body. An Advisory Committee and its chairman was elected to provide feedback on the progress of the study. The following chapters in this report were composed by these working groups and their report committee representatives.

1.4 Acknowledgements

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Our sincere appreciation goes to the following organizations for funding the Design Project:

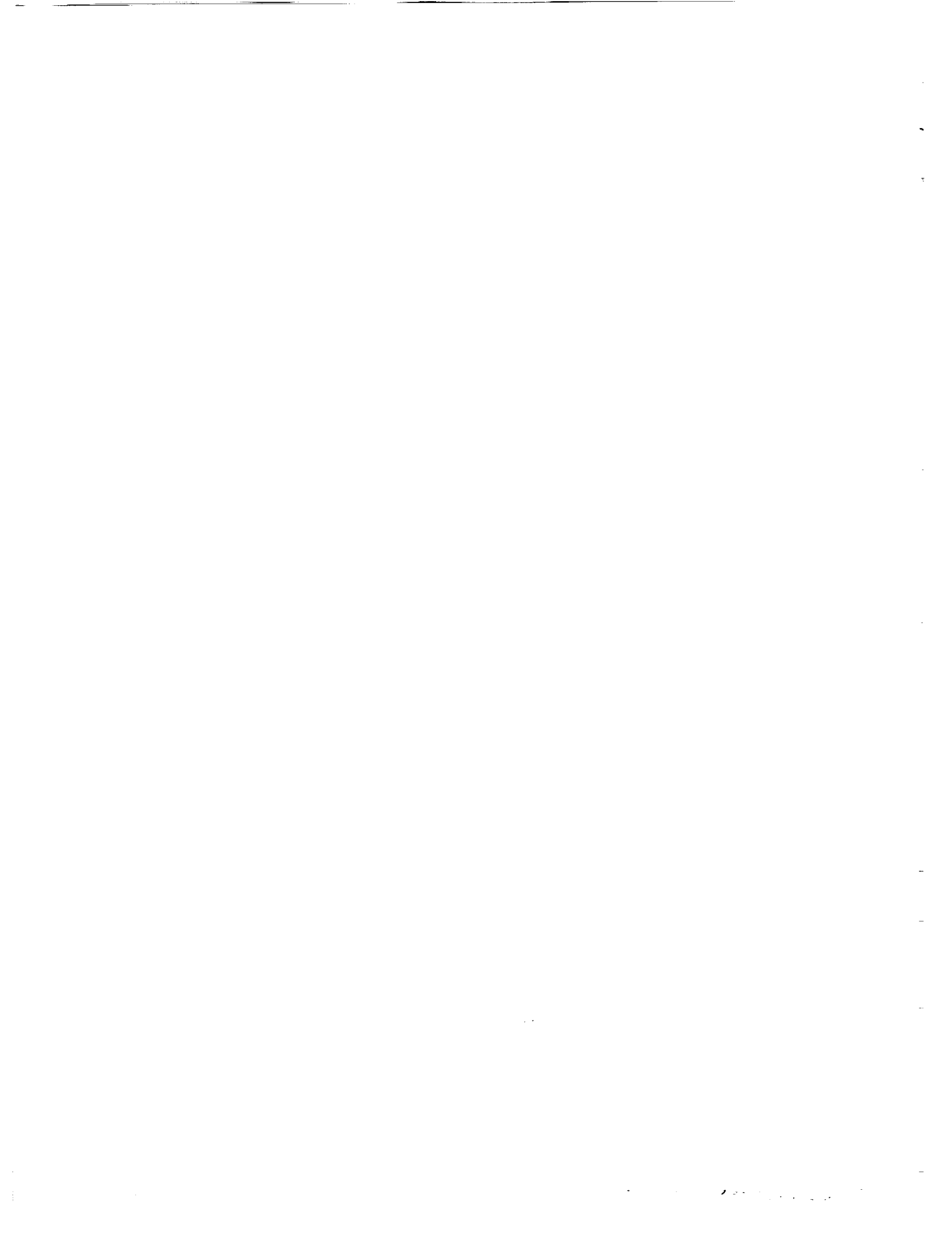
- NASA - Office of Space Science and Applications
- Government of Ontario, Canada

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Finally, the IPEO ISU class of 1990 would like to say that we thoroughly enjoyed working together on the IPEO Project in this incredibly unique and international environment.



2.0 GLOBAL ENVIRONMENTAL PROBLEMS

Ever since humankind first walked on the Earth the species has influenced the environment. In Asia, the Americas and Australia, megafauna species have become extinct much more recently than when people first began hunting them. Agricultural and other human activities have drastically changed the face of the Earth for the last two millennia.

Although it is now fashionable to be concerned about environmental issues, there have been attempts to stem environmental problems for a long time. By-laws in the North of England to control the burning of coal and reduce smoke pollution forty years ago exemplified the growing awareness of environmental problems. Stimulated by the increase of environmental hazards in the 1960s and early 1970s, the Green movement around 1975 demonstrated significant political power in Europe, and has grown in intensity around the world. In 1990, the environment has become an issue which can elect governments, and which has considerable social and commercial impact.

Although it is impossible to reflect the full range of scientific research results in this report, many comprehensive studies on environmental hazards have recently been published. These studies show the current background of important research programs on Earth as a System and on Global Change. The National Geographic Society (USA) identified the following main environmental threats in their presentation 'Endangered Earth':

- Population Pressure
- Greenhouse Gases
- Species Extinctions
- Air Pollution
- Ozone Depletion
- Acid Rain
- Water Pollution
- Water Diversion
- Toxic Wastes
- Radiation perils
- Fisheries depletion
- Deforestation
- Desertification

These topics show just a small number of key issues regarding environmental problems. However, even a cursory look at the main basic interactions between these items, as shown in Figure 2.1-1, permits a general understanding of the complexity of research on environmental problems with regard to Earth as a System and Global Change.

2.1 Population Pressure

The increase of the global population is considered to be both an environmental and a socioeconomic crisis. The highest growth rate of 4.1, observed in Kenya, implies that the population in Kenya by 2015 will be double that of today. Given continued population growth rates, India will challenge China as the highest populated country by the year 2075. Highly condensed populations concentrated in rural areas and the major cities, especially in

the developing countries, create numerous large-sized influences on themselves and their surroundings. The absolute limit of Earth's capacity for humankind cannot be fixed. However, increasing problems, like widespread hunger, desertification, pollution, and reduction of wildlife indicate the stressed situation of the biosphere. Humans form a part of the biosphere. Thus, despite improvements in health, nutrition, and longevity, in the long term, humans experience the consequences of their activities.

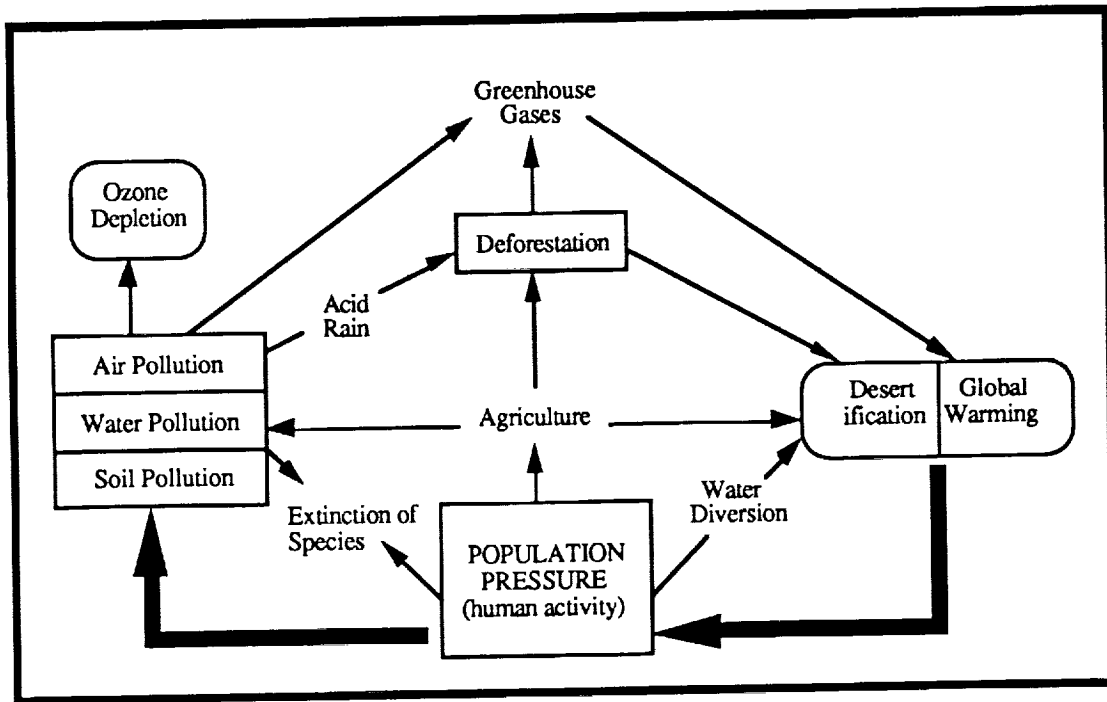


Figure 2.1 - 1 Basic Environmental Interaction Network

2.2 Pollution

One of the major effects of mankind, especially noticeable in crowded areas, is the pollution of the environment with a wide diversity of substances. Pollution occurs in the form of household, industrial or agricultural toxic or non-toxic waste, and also as energy released in the form of heat or noise. Pollution can be divided into three types: air pollution, water pollution, and soil pollution.

2.2.1 Soil Pollution

Major sources for the pollution of soil can be found in pesticide and nutrient release in agricultural areas as well as in direct dumping of often toxic substances out of industrial plants or waste deposits. Under optimal conditions, only the surface is affected; however, in most cases the substances penetrate through the upper soil layers and can even reach the

groundwater. The enrichment of several toxic substances like DDT in the food chain up to human consumers has been observed since the late 1960s.

2.2.2 Water Pollution

Water is essential for any living organism; however, due to condensed populations in certain areas, waste dumping and industrial use, water is becoming a critical factor. In large areas of Middle Europe, ground water is becoming partly unusable due to penetration of pesticides and other hydrocarbons through the soil. More locally, penetration of soluble waste components from deposits or direct waste dumping affect the quality of surface and ground water. Rivers and lakes are polluted heavily by industrial and agricultural activities. Only a few of them, like the River Thames in the UK, have been re-established to life supporting conditions with great effort.

Most of the transported waste is swept into the shelf regions of the seas and oceans. In coastal waters this pollution adds up to direct inputs from the activity centers on the shore, causing major coastal degradation, e.g. in the Caspian Sea, the Black Sea and the Baltic Sea. Traditional life has been widely terminated in these areas eutrophication and to a lesser extent, toxic wastes. Other substances like hydrocarbons and heavy metals affect the health of marine organisms, causing population collapses like the great seal disease in the North Sea in 1988 when about 90 percent of the population vanished within only a few summer months. Finally, oil pollution causes heavy casualties in the form of oil-spills from tankers and drilling platforms as well as, the better known large disasters resulting from tanker accidents like the 'Torrey Canyon'(UK), 'Amoco Cadiz'(France) and 'Exxon Valdez'(Alaska).

2.2.3 Air Pollution

Industrial activities, private households, and traffic are the main sources for air pollution. After several serious occasions of smog in London and New York in the 1950s and 1960s the installation of dust filters reduced the most severe problems at that time. Despite this, the amount of gaseous waste remains large and has increased significantly with the further development of land traffic, especially the use of private cars. The growing air traffic at high altitude puts an even more severe threat on this critical part of the environment. Finally, even unpopulated areas can be reached by air pollutants since the construction of very high industrial smokestacks starting in the early 1970s.

2.3 Deforestation and Greenhouse Gases

Because of the rapid dynamics of the atmosphere, air pollution is perhaps the most critical part of the three pollution types listed above. In contrast to the other two types, air pollutants (like SO₂, CH₄, NO_x and organic compounds) can be transported quickly over long distances. Some of these gases cause acid rain, which caused the disappearance of

wildlife from a number of Swedish lakes and is considered as one main driving force of the so called 'Waldsterben,' the deforestation process in the temperate forests of Middle Europe and North America. Air Pollutants can also remain undetected over long periods in the atmosphere while being concentrated over certain areas due to dynamic transport. An example is given by the fluorocarbons and nitrous gases (NO_x) that are transported in the upper atmosphere from the northern hemisphere over approximately twenty years to Antarctica, where they cause, due to tropospheric chemistry, intensive ozone depletion during the Antarctic spring. This is the so called Ozone Hole, which also may be appearing in the northern Arctic.

An important process is the synergism of increased CO₂-releases from the industrial and private burning of fossil fuels and the large-scale deforestation in the tropical rainforests. Clear-cuts for agricultural and other purposes, estimated to be the size of three football fields a minute or 80,000 square miles a year, is mostly based on the 'slash and burn' method. This deforestation process releases large additional amounts of carbon dioxide and carbon monoxide into the air. The trees, as dominating primary producers that can fix the carbon dioxide during photosynthetic activity, are taken out of the carbon cycle. These processes, anthropogenic release of carbon dioxide and elimination of main CO₂-consumers, are the major reasons for a slight but continuous increase of the carbon dioxide content in the atmosphere.

2.4 Global Warming and Desertification

The importance of greenhouse gases results from their influence on the energy budget of the Earth. The natural greenhouse gases CO₂, H₂O and O₃ absorb certain wavelengths within the electromagnetic spectrum, but leave an absorption gap in the infrared. The Earth's surface heat radiance can be disposed in space through this 'window'. The nominal atmospheric content of the three natural greenhouse gases results in a temperature increase of 25 degrees Celsius against the calculated conditions in a pure N₂/O₂ atmosphere. However, the increase of the CO₂ level in the air as a result of the disturbed carbon cycle is increasing the amount of energy that is absorbed by the atmosphere instead of being radiated into space. In addition, several manmade greenhouse gases like CH₄ and again a variety of fluor- and hydrocarbons show absorption maxima exactly within the infrared radiation window of the atmosphere. Therefore, a large amount of additional energy is conserved in the Earth's atmosphere and increases the normal energy budget and thus temperature of the Earth. Although final scientific confirmation of the temperature trend of the last decade is impossible without sufficient long-term monitoring, the results of only a slight increase of temperature, will result in drastic changes of the Earth's climate and atmospheric system, melting of ice caps and rising sea level, and impacts on the vegetation cover.

As a further major result of Global Warming, a dramatic acceleration of the desertification process can be predicted. The current spread of the deserts depends

primarily on climatic conditions but is coupled with a variety of land-use schemes inadequate to this environment. Over-grazing, firewood collection and overintensive farming expose the soils to wind erosion and the bright irradiance as well as, deforestation in tropical rainforests. The typical biological system structure and the highly eroded soils in these areas do not support a reestablishment of the forests, allowing either a much smaller new vegetation cover or leaving the bare soil open to erosion. Another human activity supporting desertification is the process of water diversion. Some of the major events have been the emptying of Lake Nop Nur in China after diversion of one of the main input rivers and the environmental hazards in Egypt caused by changes in the characteristics of the River Nile due to the construction of the Aswan Dam. A plan of the Soviet Union to redefine the flow of several main Siberian rivers to the agricultural areas of Kasachstan was evaluated at the time as having the ability to change the climate in Middle Europe completely and therefore was cancelled.

2.5 Responses to Mankind

As an integral part of Earth's multifaceted system, man is receiving a variety of feedbacks from his activities. The main feedbacks from the very basic demonstration model of Figure 2.1 - 1 are the following:

- Direct effect of toxic waste, example: mercury in Minamata Bay ,Japan .
- Direct effect of radiation perils, examples: Chernobyl, Harrisburg.
- Direct effect on health and living standards by common pollution.
- Indirect effect of increased UV-light due to ozone depletion .
- Indirect effect of results of Global Warming.
- Loss of agricultural areas due to desertification.
- Loss of further nutrition resources, e.g.fish, due to over-consumption or pollution.
- Mental effect caused by the absence of species after extinction.
- Feedbacks within society causing socioeconomic pressure.

2.6 Final Remarks

Environmental problems, especially those occurring on a global scale, show a great amount of interactions and form a network system of extremely high complexity and dynamics. Sufficient observation data on existing processes and determining factors will be necessary for definitive research in this area, especially for the quantification and modelling purposes considered to be essential for assessing the future role of man in Earth's System.



3.0 RATIONALE FOR INTERNATIONAL EARTH OBSERVATIONS

3.1 Opportunity for Earth Observations

The world is poised at a unique crossroads. This crossroads still allows a choice of direction. The availability of the choice itself is a serendipitous and one-time-only occurrence. Humanity has the ability to see and solve a problem just as that problem is becoming unsolvable. Though one may question whether the technologies for creating the problem will enable the solution, it has nonetheless become evident that the problem and the solution are interrelated. The problem we are faced with is the anthropomorphic alteration of the Earth's environment, as discussed in Chapter 2. One element of the solution is space-based Earth observations. We have a unique chance, given the technological developments and growing political awareness of the problems, to solve these problems before they become irreversible. We must take advantage of this opportunity.

3.2 Environmental Problem Solving as a Global Public Good

3.2.1 Externalities

It is a traditional role of governments to invest in those activities that are accepted as public goods. Public goods are those products or services for which the benefits of investment are not traceable to any specific group. The benefits generated by public goods are assumed to be so widespread that they should not be restricted by prices charged to individuals. Examples of "public goods" include the census of population and weather forecasting. Since it is often impossible or deemed undesirable for a society to charge directly for these goods and services, funding intervention of governments is required.

An example of this type of public good relevant to IPEO is disaster warning systems. The more people who receive disaster warnings, the better off society as a whole becomes. To charge individuals or classes of users for these services would decrease the number of recipients of the information. Since social benefits are thought to be maximized by warning all possible recipients about impending disaster, setting a price on access to such information would result in a reduction in net social benefit.

The nations of the world have long accepted the policy that global disaster warning systems are global public goods. In other words, the benefits of national disaster warning systems can also benefit other nations and thus, can maximize the benefits for the entire world. Thus, they are considered global public goods in the same way that other benefits are considered national public goods. This realization has been made for meteorological data, in which it is also a long-standing policy of all nations to freely exchange weather data to help their own forecasting capabilities as well as, the capabilities of other nations.

3.2.2 Meteorological and Disaster Warning Analogies

Like its remote sensing brethren, meteorological data and disaster warning data, environmental data is also a global public good. Meteorological satellites have had a phenomenal impact on the welfare of society, by some accounts returning approximately \$40 to society for every \$1 invested.

The information garnered from environmental observations helps to solve analogous global problems. The benefits of environmental observations which lead to solving global problems are often external to national boundaries, thus nations will underinvest in these products and services unless provided significant incentives. Solving these problems benefits every nation, since they all share the same planet and biosphere. The situation where one nation can pollute another without cost or consequences is less and less acceptable. This unfortunate point is demonstrated by the U.S. government's failure to act early about the acid rain problem with Canada. The costs of stopping the creation of acid rain will be borne by U.S. government and industry as a result of recent agreements between the U.S. and Canada. Since Earth observation data is a global public good, and since governments are the primary beneficiaries of such data, it is natural and desirable to seek international government production and funding of such data at a higher level than currently exists.

3.3 Reasons Why Nations Invest in Remote Sensing

3.3.1 Foreign Relations, Leadership, and Influence

There are numerous reasons that nations invest in remote sensing beyond the argument that it is a public good. One key reason is the relatively low costs of remote sensing data, coupled with its powerful analytical values. Since Chapters 1, 5 and 6 supply much evidence about the inherent information values of Earth observations, this Chapter focuses on its political and social values.

Three major political reasons for remote sensing are investment, foreign relations, leadership, and influence. These reasons relate to fundamental goals of governments - geopolitical power and world standing. Governments strive to enhance their power. Governments seek to enhance this power by expressing leadership and influence through both military and civilian means. Space programs in general, and remote sensing programs in particular, are highly effective civilian tools for enhancing a nation's leadership and influence in global affairs. Remote sensing data collection and distribution has served as a highly effective tool for enhancing foreign relations and promoting national interests abroad. The collection and distribution of remote sensing data and information demonstrates to the world technological leadership, and thus enhances a nation's prestige. The open dissemination of such data shows a commitment to peaceful goals and a desire to "benefit all mankind" which strengthens international relationships. Geopolitical standing can also be enhanced by the dissemination of remote sensing data, since it portrays an

international image as a leader in the effort to assess and protect global resources - an image that is becoming increasingly politically important.

Other nations' use of such data may enable a supplier nation to affect changes in political and institutional structures of recipient countries, and thus may enhance national influence. This influence has been demonstrated by the Landsat system and through its positive impacts on resource management in countries such as Thailand. Access to, and the utilization of remote sensing data also changes the way that nations treat environmental problems. Dissemination of such data can therefore be used to strengthen implementation of a nation's environmental goals by influencing the policies of other nations in that area. Finally, environmental problems that remote sensing data helps to document and thereby helps to solve might otherwise create social problems that lead to geopolitical instability and tension. Measures to reduce such instability can enhance national interests and security.

3.3.2 Internal Politics

Along with the significant foreign relations benefits to be gained through earth observation programs, governments may also receive internal political benefits. Given the significant and growing emphasis placed on environmental policy and problems in the media and politics of numerous nations, it may become impossible for regimes to retain power without giving considerable attention to solving these problems. Leadership in solving such popular problems may ensure and strengthen a government's political influence within its country - a goal of obvious importance to political decision makers.

3.3.3 Technology Development

Another reason that nations have invested in remote sensing has been the development of advanced natural technology. The remote sensing programs of Brazil, India, ESA and others are justified on their technology development and "spinoff" activities. This technology development has produced new industries and numerous spinoffs. Technology development is as important a rationale for the developing nations as it has been for the developed nations. IPEO; technology may will return \$6 to \$7 for every \$1 invested in the program (see Section 9.6). The case studies on the transfer of remote sensing technology from developed to developing countries (see Section 4.4.2.1) clearly indicate the great need of the technology in the developing nations. In both cases, Thailand and Kenya, what is mostly required in these countries is the development of indigenous technology after the transfer. Indeed, the development of such indigenous technology is necessary to overcome many obstacles noted here and in the literature. With technology development as part of the package, it becomes acceptable and economically justifiable for developing nations to invest in remote sensing.

3.3.4 Applications

As Chapter 2, 5 and 6 show, environmental degradation is an important problem confronting mankind that is observable by remote sensing. There is a consensus in most institutions on the existence of such problems. Indeed developing countries are among those with the most severe of these problems, e.g., deforestation, and are increasingly becoming aware of the domestic need to reduce these problems. Traditionally, most nations have invested in remote sensing for purposes of monitoring their natural resources. The information gathered is then used for the management of natural resources for purposes of economic development. The strong consensus of IPEO students is evidence that these data will increasingly be used for environmental programs in both the developed and developing countries.

3.3.4.1 Country Notes

The general reasons why nations invest in remote sensing have been identified and analyzed. IPEO as a multi-flag program must explore the reasons why each particular participant would be willing to invest it. In an effort to understand national interests in remote sensing, and in IPEO, a survey tool was proposed and tested in the Design Project. Country Note, based on a questionnaire developed at ISU' 90 yields a quick picture of one particular country with respect to a specific issue, as well as a composite picture of all respondents. For IPEO implementation Country Notes provide the first step toward concise and focused information about the capabilities, the priorities and the sensitivity of countries related to Earth observation.

A first set of Country Notes has been prepared during this session and are contained in Appendix A. This set of 27 notes constitutes a sample survey. It has demonstrated the clear interest of many nations in contributing to global change studies. As for the improvement of deforestation monitoring, it is a first priority. These priorities remain whether the responding nation faces the problem itself or indirectly. An example of indirect effects is given by the Netherlands, where an increase of sea level would contain a tremendous potential to shrink reclaimed land.

Most countries appear ready to contribute to new programs dealing with Earth monitoring. It is especially true for most environmental problems. However, it remains evident that for some countries facing serious environmental problems, the first priority in the use of remote sensing is oriented towards economic development applications, such as land mapping and water quality assessment for better management of the resources. Economic development applications will, if taken into account, be supported by a global change program. Many needs of most countries would then be addressed and met. Therefore these countries would likely participate in the program.

3.4 Reasons for an International Approach

3.4.1 Commonality of Interests

Earth observation data collection which attempts to understand and solve global environmental problems transcends political boundaries. The global parameters studied by Earth science do not distinguish between nations. Thus, environmental science is inherently an international activity which requires the cooperation of a great many nations. Existing organizations such as the World Meteorological Organization (WMO) or cooperative efforts such as the International Hydrological Decade are examples of nations' realization of this fact.

3.4.2 Raising National Awareness and Commitment

One goal of environmental research is to apply the findings of analysis to solve environmental problems. National participation in the examination of such problems increases a nation's commitment to the application of the findings, and thus helps leverage the commitment to use the data. Environmental problems, however, have multinational policy implications, and any attempt to leverage the findings to solve the problems, will benefit from a multinational venue.

3.4.3 The Synergistic Interchange of Data

It is a long-standing international policy to provide meteorological remote sensing and in situ data freely and without charge to any nation interested in accessing the data. This interchange of data has had an incredibly useful effect for those nations that have participated in such endeavors (e.g., the International Geophysical Year). Through these efforts, nations have received far more vital data from other participating nations than they have given away. For example, the US has received much more information from the WMO than it has contributed to the organization.

Synergistic enhancement is accomplished by countries contributing data about local in situ measurements that are crucial to the refinement of the supplier's satellite data. Participation of many suppliers in international organizations makes critical data, such as in situ measurements, available to nations that they would otherwise be unable to acquire. Furthermore, international participation enables a nation's experts to gain an awareness of technical and scientific advances occurring throughout the global scientific community. Given the importance of global data coverage in any attempt to understand global environmental problems, such an approach is essential for any endeavor, such as IPEO, to succeed.

3.4.4 Access to Resources and Diminished Redundancy

It is a commonly found benefit of international cooperation that such cooperation reduces any particular nation's investment in a program by the other nations providing key components of a mission or co-investing with money. Without access to multi-national resources, national programs would have been far less comprehensive and, therefore, far less successful than they have been. Landsat, for example, would have been greatly diminished without the cooperative efforts of other nations (e.g., data receive Earth stations) which expanded the scope of the mission. Furthermore, international cooperation amongst programs of Earth observation allows a more efficient allocation and utilization of global resources by reducing the redundancy that would occur through independent national programs. Involvement in an international program for Earth observations could diminish global investment in such observations by an estimated 25 percent through simple reduction in redundant systems, a savings that could range between \$0.7 billion and \$0.8 billion (see Section 9.6).

3.5 Summary

The drastic and growing changes that humanity is inducing in the environment, the numerous important benefits to be gained through international investment in Earth observation programs, the many advantages of proceeding with such ventures in an international context, and the potential total national return on investment of \$6 to \$7 for every dollar of funding IPEO makes it clear that there is a pressing need and sufficient justification for an international organization.

4.0 THE INTERNATIONAL PROGRAM FOR EARTH OBSERVATIONS

4.1 THE IPEO NICHE

4.1.1 IPEO's Goals

IPEO must determine its overall objectives. To implement these objectives over the long-term it must also determine a set of short-term goals which help to realize the overall objective. Given the various needs, constraints, and considerations for such a program, the following statement of goals was adopted and is repeated here for emphasis.

The International Program for Earth Observations (IPEO) is established to gather, process, analyze and disseminate environmental data and information to help solve global environmental management problems of the Earth on a continuous, international basis. Specific objectives of the program are as follows:

- To gather both in situ measurements and remote sensing measurements.
- To analyze data and develop models to understand global environmental problems.
- To facilitate environmental and related data distribution, and provide tools to improve understanding and use of these data. IPEO will distribute existing, planned and new data .
- To investigate environmental problems such as, global warming, pollution, vegetation dynamics, deforestation and biomass inventory.

In order to address global needs in the near future, the following short term statement of purpose was proposed:

As a first step toward gathering and disseminating environmental data, IPEO will explore and design a system using small satellites to assess the status of and monitor deforestation as well as topographical mapping. If the design of a system for topographical mapping compromises the design of a system for deforestation, then only a system for deforestation assessment will proceed. For the task of data dissemination, a comprehensive data system for remote-sensing information resources shall be proposed.

4.1.2 IPEO's Roles

It is clear from IPEO's goals that IPEO should be a non-profit, international, inter-governmental organization that is designed to provide a global service to the citizens of the world. It must be realized, however, that IPEO products and services will have commercial applicability as well as providing a public good. Therefore, IPEO must be structured in such a way that it does not exclude commercial sales to enhance its collection of revenue and diminish the funding that the Member States must provide. Yet this effort must be subject to the priorities of the IPEO's goals, and its obligations to its Member States. The allocation of IPEO resources to commercial sales will be made only if resources are available after the organization fulfills IPEO's first two priorities.

The global service that IPEO performs is to provide information and data that is needed to formulate national policies, implement national programs, and empower cooperative international politics. The information provided by IPEO will allow the nations of the world to implement policies through which they may solve the global environmental problems confronting them through domestic enforcement of policies and through international influence to alter or enforce existing policies. IPEO's focus is on the solution, not only the determination, of global environmental problems. It is recognized that the data, information, and tools that are generated while working towards these public goals will have commercial applicability. Therefore, IPEO has taken into consideration commercial applications and potentials to increase the global social benefits that can accrue from its work. IPEO will provide data to commercial vendors and applications-oriented national agencies, but will be performed after IPEO has fulfilled its obligations to its goals and its Member States.

4.1.3 Niche Identification

Figure 4.1.3 - 1 describes the functions needed for an organization or a program to help solve global environmental problems. For each of the main existing organizations dealing with such missions, that is EOS, IGBP or GEMS, the features provided by the organization are highlighted. The first obvious conclusion to simple comparative analysis is that, except for IPEO, none of these organizations offers the complete range of features necessary for meeting IPEO goals.

When compared to EOS, IPEO presents the definite advantage of being fully international and of providing education and training for end users. In addition, due to its international nature, IPEO is in a position to support solutions to environmental problems by using existing global capabilities and by coordinating specific programs, therefore avoiding redundant programs as much as possible.

When compared to IGBP, IPEO highlights the potential capability to implement a new program addressing unmet needs. This capability relies first on the critical size of IPEO in

terms of funding, staff and facilities, but also on its broad and continuing knowledge of end user requirements and applications.

GEMS is close to offering all the features necessary for meeting IPEO goals. However, as with IGBP, GEMS is not in a position to respond to unmet needs by setting up a new program, a satellite for example. GEMS relies on space programs decided and specified by other entities. IPEO will provide consulting capabilities which will indirectly coordinate potential environmentally related programs.

It is clear from first order comparative analysis that none of the existing programs sufficiently meet the users needs. IPEO's role in enhancing these capabilities through coordination and expansion is an unique niche that will greatly increase the capabilities and results of the world community.

From this comparative analysis, the main specificities and strengths of the IPEO niche appear to be the following :

- IPEO provides an efficient approach to the solution of global environmental problems by relying on existing international capabilities and on coordination of programs external to IPEO through consultation, data exchange, and specific program management.
- IPEO is in a position to fill the gaps of unmet application needs, by deciding and developing new space or ground systems.
- IPEO addresses environmental problems from research to the end user point of view.

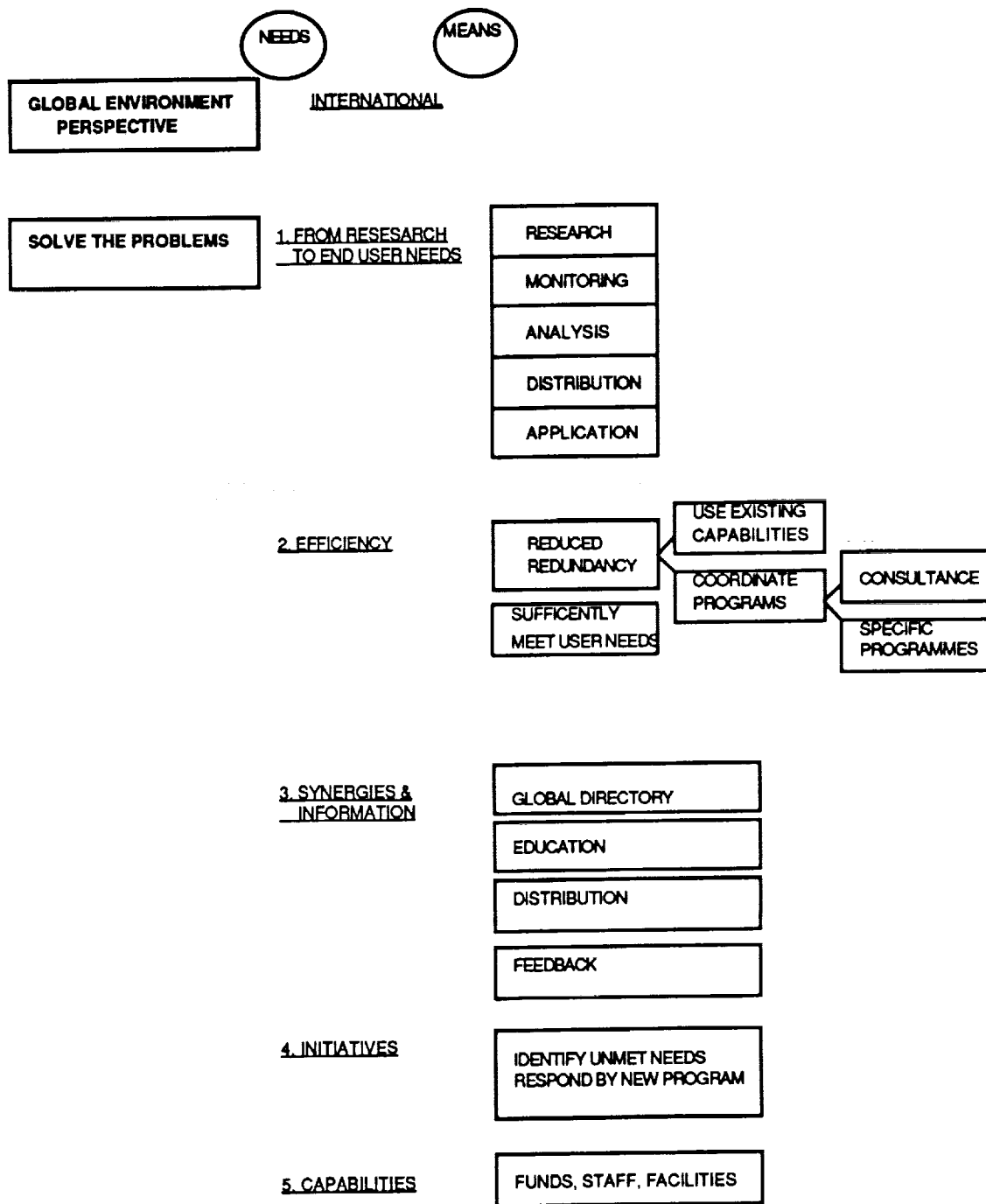


Figure 4.1.3 - 1 How to Solve Global Environmental Problems

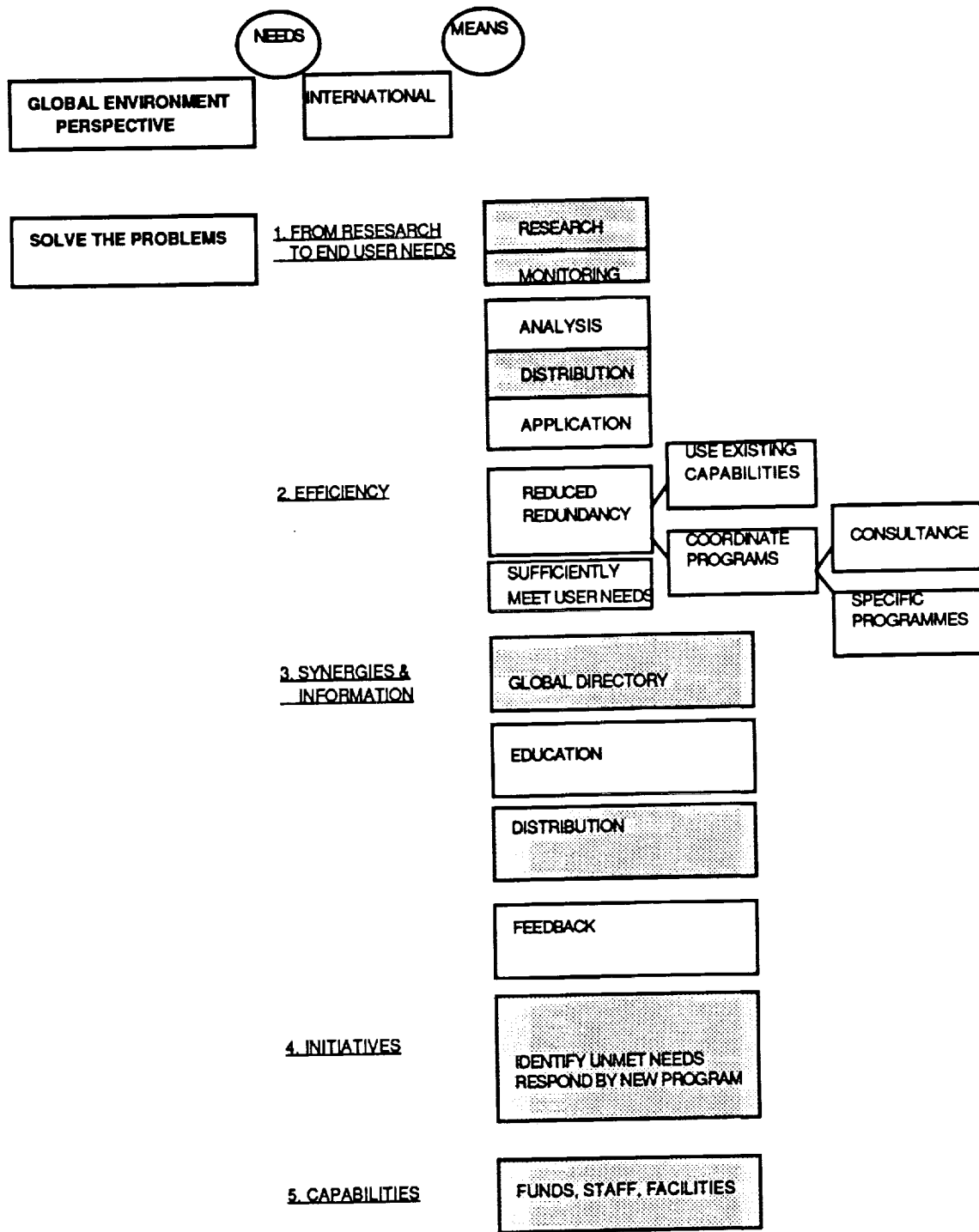


Figure 4.1.3 - 2 EOS Case

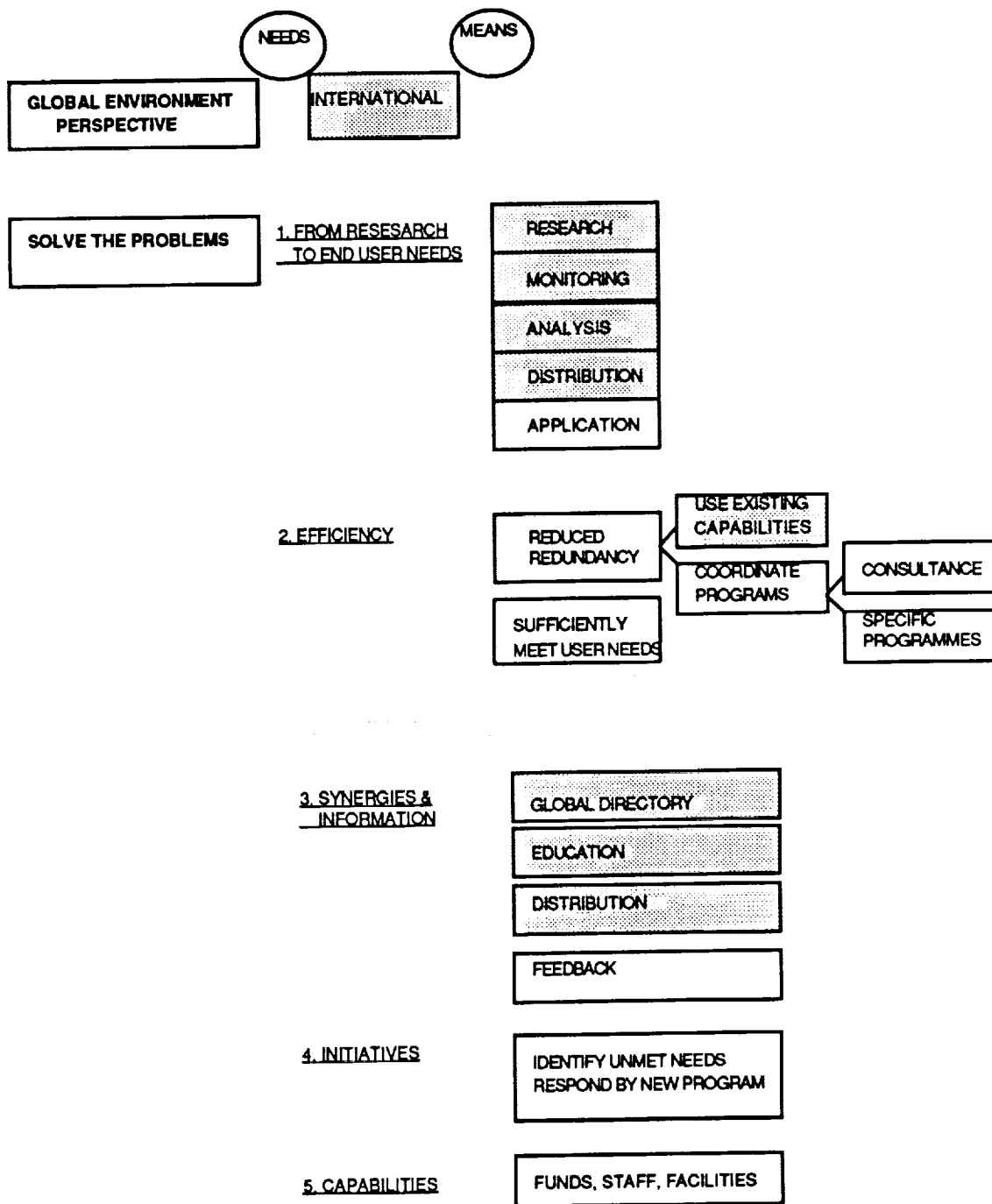


Figure 4.1.3 - 3 IGBP Case

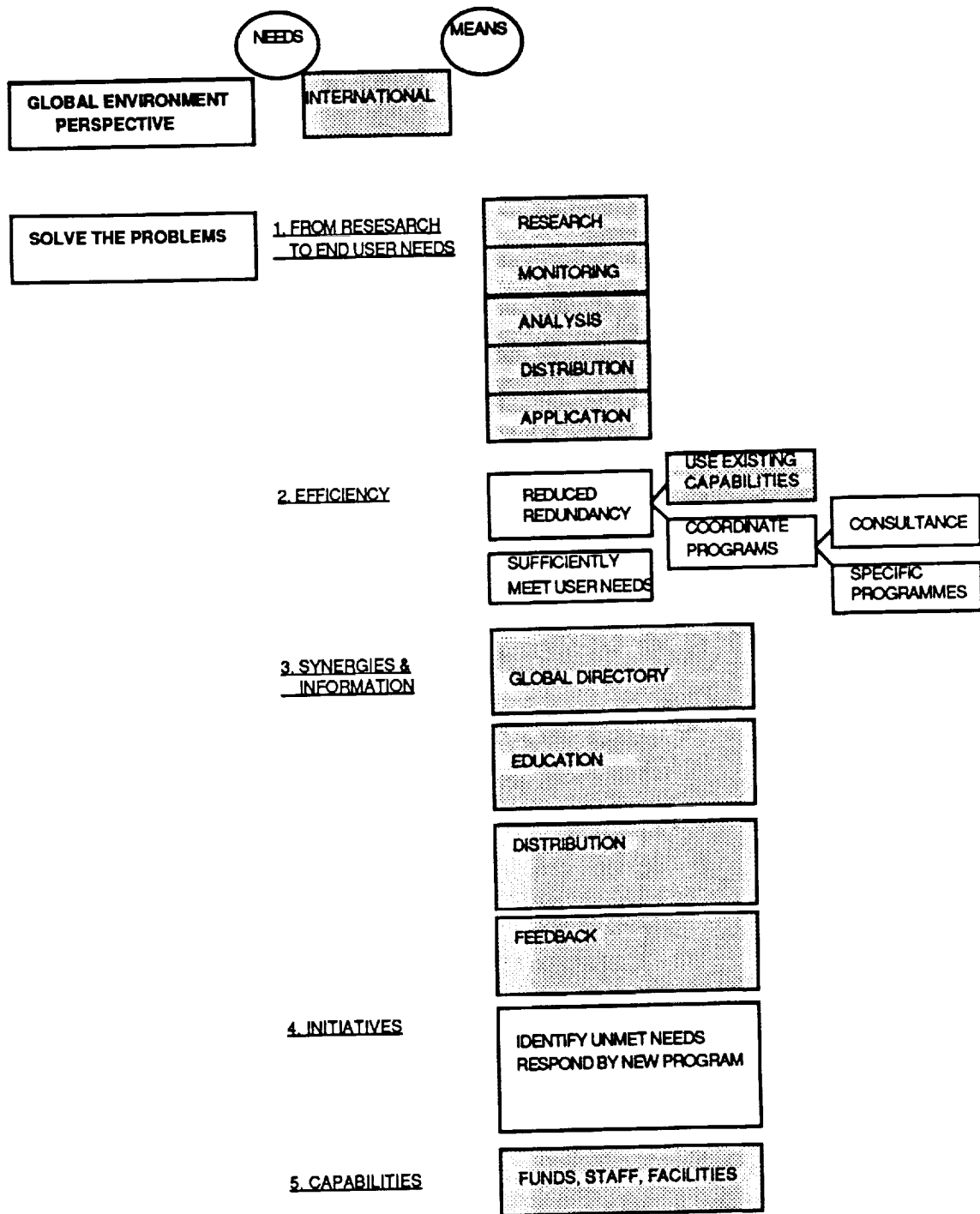


Figure 4.1.3 - 4 GEMS Case

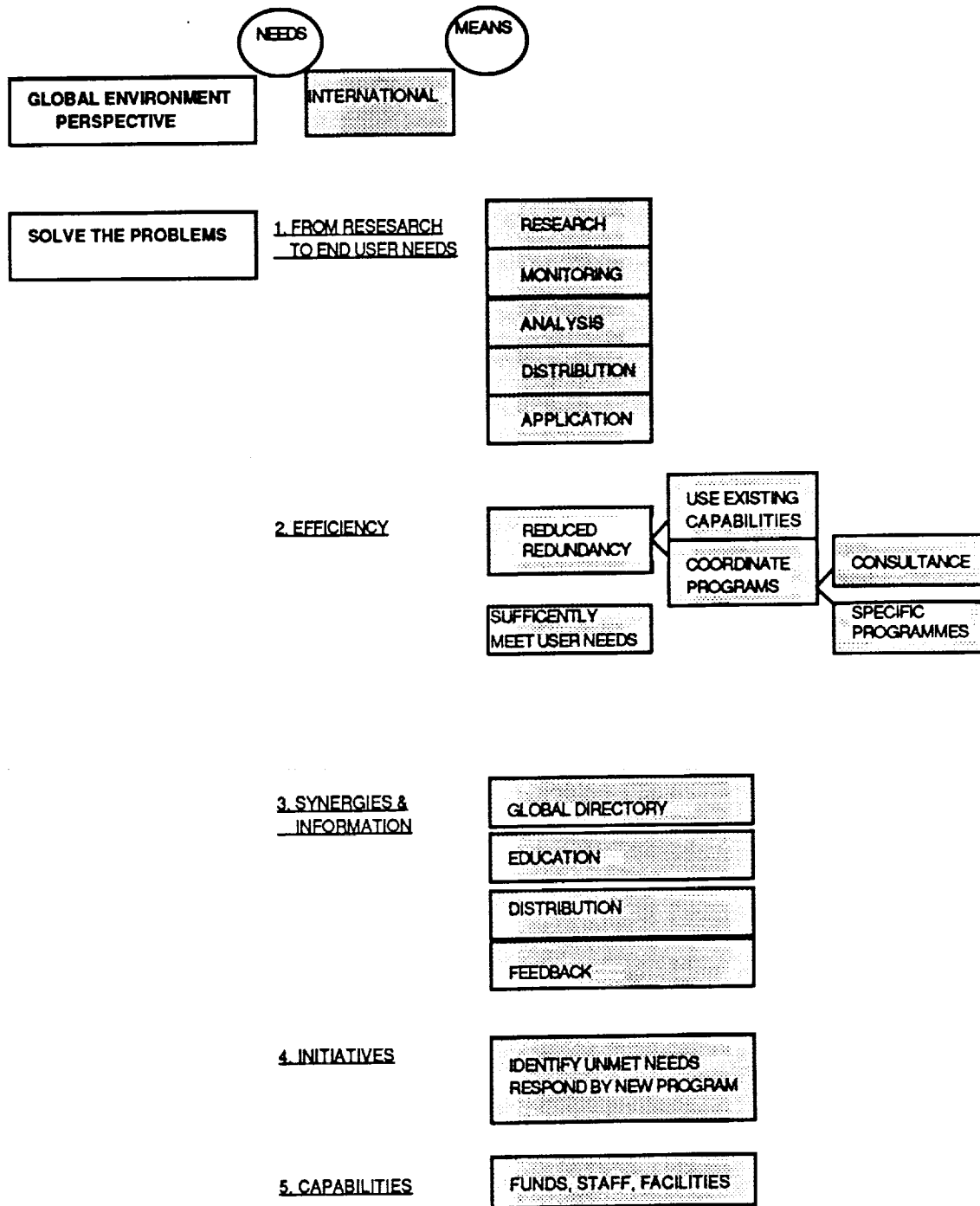


Figure 4.1.3 - 5 IPEO Case

4.1.4 IPEO Interactions with Other World Remote Sensing Programs, Organizations and Networks

Global Earth remote sensing efforts require the cooperation of national, multi-national and international programs, organizations and networks. IPEO is one of many organizations involved in remote sensing, and to coordinate our efforts with them, plan for the future of the IPEO, and properly justify our place among these organizations, an initial reference was prepared of their features, technical capabilities and products. The following tables of features, capabilities and products is a first cut tool the IPEO will use and expand upon as a means of coordination with other organizations. Fully developed tables of this sort will be a useful tool for users of remote sensing requiring information about world remote sensing organizational structures and technical features to know what organizations fit their needs, monetary constraints and political/legal frameworks.

Public features of remote sensing organizations are important to consider because laws and policies concerning the use of remote sensing data and cooperation with other nations and international bodies differ in each nation. If a nation conducts it's own research and will not allow outside organizations to apply the data, such a policy limits the programs or organizations it can interact with.

Technical capabilities are important considerations for remote sensing organizations and users in order to purchase systems and products, and to determine who is most capable of providing them. Needs for long-term information of several types may not be well served by an organization that has no satellites of its own or is restricted to one class of environmental data. A nation may have political conflicts with nations that operate some of the world's satellites and may need the services of a more neutral body with access to that information through its own ground stations.

Earth remote sensing institutions are divided in the following tables into programs, organizations and networks. Programs tend to have a full array of technical capabilities and many user-oriented features, while organizations tend to apply data obtained to public or scientific use. Networks are mostly concerned with disseminating the data and data services of programs and organizations. Knowledge of which institution deals with which aspect of remote sensing is paramount to timely and cost-effective use of their products.

IPEO has the combined attributes of an organization, program and a network. "Thinking locally and acting globally" will require a user-oriented program like the IPEO to expand and may eventually include the capabilities currently possessed by other remote sensing organizations to reduce redundant functions in the future. Further deveeloping and using the interaction table, will assist IPEO, the users, and other organizations to anticipate these challenges.

| FEATURES I | | PROGRAMS | | | | |
|------------------------------|-------------|----------|--------|-------------------|----------|----------|
| | | I.G.B.P. | E.O.S. | JAPAN G.E.M.S. | W.C.R.P. | G.E.M.S. |
| PUBLIC SERVICE | | • | • | • | • | • |
| DATA USE | Scientific | • | • | • | • | • |
| | Application | • | • | • | | • |
| | Operation. | • | • | • | • | • |
| | Experiment | | | | • | |
| MISSION OBJECTI- VES | Research | • | • | • | • | • |
| | Monitoring | • | • | • | • | • |
| | Production | • | • | • | | • |
| | Distributes | • | • | • | | • |
| INSTITU- TIONAL DOMAIN | National | | • | • | | |
| | Internat. | • | | | • | • |
| | Multi-Nat. | | | | | |

Figure 4.1.4 - 1 Features I

| FEATURES II | | ORGANIZATIONS | | | |
|------------------------------|-------------|---------------|----------|--------|--------|
| | | EUMET- SAT | U.N.E.P. | W.M.O. | I.O.C. |
| PUBLIC SERVICE | | • | • | • | • |
| DATA USE | Scientific | | • | | |
| | Application | • | • | • | • |
| | Operation | • | • | • | • |
| | Experiment | | | | |
| MISSION OBJECTI- VES | Research | | • | | |
| | Monitoring | • | • | • | • |
| | Production | • | • | • | • |
| | Distributes | • | • | • | • |
| INSTITU- TIONAL DOMAIN | National | | | | |
| | Internat. | | • | • | • |
| | Multi-Nat. | • | | | |

Figure 4.1.4 - 2 Features II

| FEATURES III | | NETWORKS | | | | | | | |
|----------------------|---------------|-------------|------------|-----------|---------|-----------|------------|------------|------|
| | | NOAA NESDI. | UNEP/ GRID | EARTH NET | NASA MD | IOC/ MEDI | INFO-TERRA | INFO-CLIMA | IPEO |
| PUBLIC SERV. | | • | • | • | • | • | • | • | • |
| DATA USE | Scientific | • | | | | | | | • |
| | Application | • | • | • | • | | • | • | • |
| | Operational | • | • | • | • | | • | • | • |
| | Experimental | | | | | | | | |
| MISSION | Resear. | • | | • | | | | | • |
| | Monitoring | | | • | | | | | • |
| OBJECTIVE | Production | • | | • | | | | | • |
| | Distributes | • | • | • | • | • | • | • | • |
| INSTITUTIONAL DOMAIN | Nation. | • | | | • | | | | |
| | International | | • | | | • | • | • | • |
| | Multi-Nation. | | | • | | | | | |

Figure 4.1.4 - 3 Features III

| CAPABILITIES I | | PROGRAMS | | | | |
|------------------------------------|--------------------|----------|--------|----------------|----------|----------|
| | | I.G.B.P. | E.O.S. | J. G.E.M.S. | W.C.R.P. | G.E.M.S. |
| SPACE SYSTEM | Own | | • | • | | |
| | Develop | | • | • | | |
| | Operate | | • | • | | |
| | User | • | • | • | • | • |
| CON- TROL STATION | Own | | • | • | | |
| | Develop | | • | • | | |
| | Operate | | • | • | | |
| | User | • | • | • | • | • |
| RECIEV- ING STATION | Own | | • | • | | |
| | Develop | | • | • | | |
| | Operate | | • | • | | |
| | User | • | • | • | • | • |
| DATA NTWRK. | Archiving | | • | • | • | • |
| | Distributes | • | • | • | • | • |
| PRODUC- TS AND SERV- ICES | Raw Data | | • | • | • | • |
| | Informat. | • | • | • | • | • |
| | Analysis | • | • | • | • | • |
| | Education | • | • | • | | • |
| | Consulting | | | | | |
| | Global Database | • | | | | • |

Figure 4.1.4 - 4 Capabilities I

| CAPABILITIES II | | ORGANIZATIONS | | | |
|-----------------------------|----------------------|---------------|----------|--------|--------|
| | | EUMETSAT | U.N.E.P. | W.M.O. | I.O.C. |
| SPACE SYSTEMS | Own | • | | | |
| | Develop | • | | | |
| | Operate | • | | | |
| | Use | • | • | • | • |
| CONTROL STATION | Own | • | | | |
| | Develop | • | | | |
| | Operate | • | | | |
| | Use | • | • | • | • |
| RECEIVING STATIONS | Own | • | | | |
| | Develop | • | | | |
| | Operate | • | | | |
| | Use | • | • | • | • |
| DATA NETWORK | Archiving | • | • | • | • |
| | Distributes | • | • | • | • |
| PRODUCTS AND SERVICES | Raw Data | • | • | • | • |
| | Information | • | • | • | • |
| | Analysis | • | • | • | • |
| | Education | | • | | • |
| | Consulting | | • | • | • |
| | Global Data- base | | | | |

Figure 4.1.4 - 5 Capabilities II

| CAPABILITIES III | | NETWORKS | | | | | | | |
|-------------------------|---------------|-------------|------|-----------|---------|----------|------------|------------|------|
| | | NOAA NESDI. | GRID | EARTH NET | NASA MD | MEDI IOC | INFO-TERRA | INFO-CLIMA | IPEO |
| SPACE SYST-EMS | Own | • | | | | | | | • |
| | Develop | • | | | | | | | • |
| | Operate | • | | | | | | | • |
| | Use | • | • | | | | | | • |
| CONT-ROL STAT-IONS | Own | • | | | | | | | |
| | Develop | • | | | | | | | |
| | Operate | • | | | | | | | |
| | Use | • | • | | | | | | • |
| RECIE-VING STATI-ONS | Own | • | | | | | | | |
| | Develop | • | | | | | | | |
| | Operate | • | | | | | | | |
| | Use | • | • | | | | | | • |
| DATA NET. | Archiv. | • | | • | | • | • | • | • |
| | Distrib-ution | • | | • | | • | • | • | • |
| PROD-UCTS AND SERV-ICES | Raw Data | • | • | • | | • | • | • | • |
| | Informa-tion | • | • | • | | • | • | • | • |
| | Analy-sis | • | | • | | • | | | • |
| | Educat-ion | | | | | • | | | • |
| | Consul-ting | • | | • | | • | | | • |
| | Global Data. | | • | | • | | | | • |

Figure 4.1.4 - 6 Capabilities III

4.2 User Needs Assessment

The previous section showed the kinds of international capabilities that provide dissemination of information relevant to the field of the global environmental studies. In this section, the emphasis is on the potential users and their needs in IPEO. This identification provides a first cut evaluation of the specific needs of the IPEO "users".

4.2.1 Categories and Profiles of Users

Before analyzing the needs, some profiles of the IPEO users should be understood. Even rough classification of the different user-types is difficult, because of the very nature of this international and ambitious program in which efficiency, capability and synergy are combined. However, a helpful distinction between two classes of users seems to emerge with respect to needs.

The scientific community involved in diverse programs could be (without discrimination by discipline) considered as an important category of "users." In this case, the remote sensing data are used to improve models, and to reach a better understanding of the Earth's mechanisms. Of course, all the scientific community does not use remotely sensed data, but interactions between the scientific community are more and more likely to depend upon large perspectives. The scientific community is rather well organized through various structures (national and international) and is used to exchanging knowledge and information.

A second category of users is defined as "end-users" in the sense that they investigate more in terms of application studies. In this case, remote sensing data are most often used as one source of information among others. The applications community is more heterogeneous, and in certain areas less familiar with remote sensing techniques than is the scientific community. The reasons for end-user diversity can be summarized as follows:

- The very wide range and various different national uses of applications;
- The different levels of user familiarity with remote sensing techniques;
- The different maturity of operational uses, versus experimental uses (land-use classification versus pollution monitoring);
- The analysis resources available vary greatly, as do financial means; and
- Regular communication, sharing of technology or techniques may be lacking.

Obviously, there is no easily defined separation between those two categories. Without discrimination of disciplines, the scientists involved in environmental programs at varied levels may be considered as the first or "main" IPEO users, as distinguished from end-users who are not involved in research. A rough profile can be set up to try to classify users. More specific needs of the main IPEO users are explained later.

Table 4.2.1 - 1 IPEO Users

| Type | International | National | Products | Purposes |
|----------------------|---|---|---|--|
| Scientific Community | International Programs, e.g., "Global Change" | Research & Universities, e.g., France: ORSTOM CNRS IFREMER | All Photo R.S. Radar In situ measurement | Modelling in different scientific fields Processing |
| End Users | Statistical services, e.g., EEC WMO | Governmental monitoring entities, e.g., National geological services Oil & mining cos. | Processed data Photo Idem Raw & processed data | Inventory Forecast Alarm Inventory Inventory modelling |

4.2.2 User and Needs Assessment

An identification of users is required prior to the assessment of their needs. Who is a potential user of IPEO?

- Any individual or institution involved in environmental studies, either from a local, regional, national or global perspective; and
- Any individual or institution devoted to research, analysis and modelling, or applications.

Given the wide spectrum of "Users" identified in this study, only a broad definition of the users needs can be provided at this point: "An IPEO User needs information about the Earth environment in terms of characterization and/or mechanisms."

But when? How? Under which format? Where? The answers to these questions depend on very specific profiles of each user. This section addresses only the general needs of the IPEO users. Precise requirements for the environmental data, for technical information and for research problems are described in the further chapters. The next section attempts to determine more precisely the kind of services which are required by the users.

4.2.3 Data Types

Most users will need remotely sensed data in order to improve their models and gain a better understanding of one of several Earth mechanisms. These users may prefer raw data, and they would process them accordingly to their specific field of research. Other applications users would need remote sensing data that are already processed and analyzed. They use models that have been previously established and are primarily interested in applying some values, measurements, or maps. These users would be anxious to receive the latest results or information relevant to their work. For applications users, a stronger interaction with the scientific community may open large opportunities.

In the case of the end-user class, remote sensing data are used as a piece of information among others (i.e. photographs, geographical or geological maps, land-cover maps, etc.). They most often need processed and analyzed data in order to make decisions or forecasts. Even if this class of users is not considered as central with respect to Global Environmental Studies, their needs must be understood clearly. Both for political, commercial and operational reasons, meeting their requirements is important. Their needs will be taken into account by IPEO and harmonized with scientific ones.

As a reasonable assumption, it is possible to say that remote sensing data alone are less valuable to users than GIS products, because of the qualifications needed to process remote sensing data, and because a map or a layer is far more understandable to most users than is an image. The requests formulated by the users are usually linked to their computer capability. This assumption could provide an interesting parameter for further user-profiles. For example, poorly equipped users may only be able to process low resolution maps, and/or end-products. Small departments or some individuals equipped with personal computers may operate with GIS packages and ask for adapted data sets. More sophisticated facilities possess workstations with GIS, and image processing capability. Mainframes are used by laboratories in which larger models are run, or specific measurements made. All these different configurations imply varied levels of capability and perhaps knowledge, and may need tailored IPEO services.

4.2.4 Needs for Specific Tools

Usually, users expect not only a set of data, software or a single product by itself, but look for services as well. One of the main points which arises from this study is the need

for improved information services, whatever is the specification of the needs. Information as a generic term includes remote sensing data, processed and analyzed data, but also information about the different space actors (distributors, agencies, space programs, research results, international or national programs, etc.).

IPEO will have to develop and operate a data base in response to this need. Included in this data base it will be worthwhile to add essential information concerning all relevant space activities, in order to allow diverse users to find a broad spectrum of information and to handle this easily and in a convenient way. To be really efficient on a scientific level this data base has to be a resource in which users can find more specific information on the research pursued, the laboratories involved in different programs, the location of the headquarters managing these programs, an up-to-date review of all the articles edited on a particular topic. IPEO as a node of information must be able to provide scientists with the relevant information they need for their studies.

A second point is certainly the necessity for applied study products. Many users prefer obtaining processed and analyzed data without having to pre-process it, in order to introduce the result in to a decision making process. According to the users it will be relevant to create a service able to use new tools like GIS, strongly adapted to this applied task. This opportunity could be developed further in IPEO in response to specific requests on environmental problems.

In order to meet this need, IPEO must create a specific service to which the end-users could address requests in order to get processed and analyzed information. This service will have to provide different kind of products from the simplest to the most sophisticated.

A third point to be highlighted is the need to determine particular research programs according to environmental problem area which are not, or only partly, covered by studies at the moment. This service activity could provide some impulse to the research, stressing precise goals, and by this way assure the awareness of important issues among the scientific community. It could also serve the totality of users. A common research structure has to be created to define some directions of investigation, for example, in terms of particular research programs or in collaboration with the existing ones. Scientific and technical advances for sensors is an example of this type of support.

Finally, one of the better ways to avoid the lack or the deficiency of information, is to provide users with a focused educational and training service.. This important task in IPEO must be adapted to the needs and the levels of knowledges of the users.

4.2.5 Conclusion

Being aware of the requirements of the potential users even in a broad outline allows IPEO to supply adapted services and products. By emphasizing the supply and dissemination of the sources of information, IPEO can achieve a real leadership position filling a gap which has not yet been addressed adequately. The distribution of different kinds of scientific, technique, economic and environmental studies to all the potential users

should be a key IPEO function. In this way IPEO differs strongly from most other international programs which provide information and data only or primarily to the scientists who are involved in the specific programs. Supplying particular services which are really needed by the users will provide a real opportunity to all the users involved in Global Environmental Studies. Chapter 5 responds to these needs by developing program implementation strategies for GIS, GEOD, Application and Emergency Programs, networks and Regional Offices.

4.3 Organizational Framework

4.3.1 Organization Chart

In order to meet its goals and respond to the understanding of user needs, a structure and organization for IPEO was formulated. This organization and its rationale are discussed in the following section.

The model for the IPEO Convention consists of a Council of States, a Board of Governors, and a Director-General who is assisted by a Secretariat staff. An Advisory Board is suggested that will recommend to the Director General and Board of Governors research and development programs directly related to the goals of IPEO.

IPEO is operationally organized in five Directorates, which are: Operational Programs, Marketing, Administration and Finance, Education and Training, and Advanced Programs and Research.

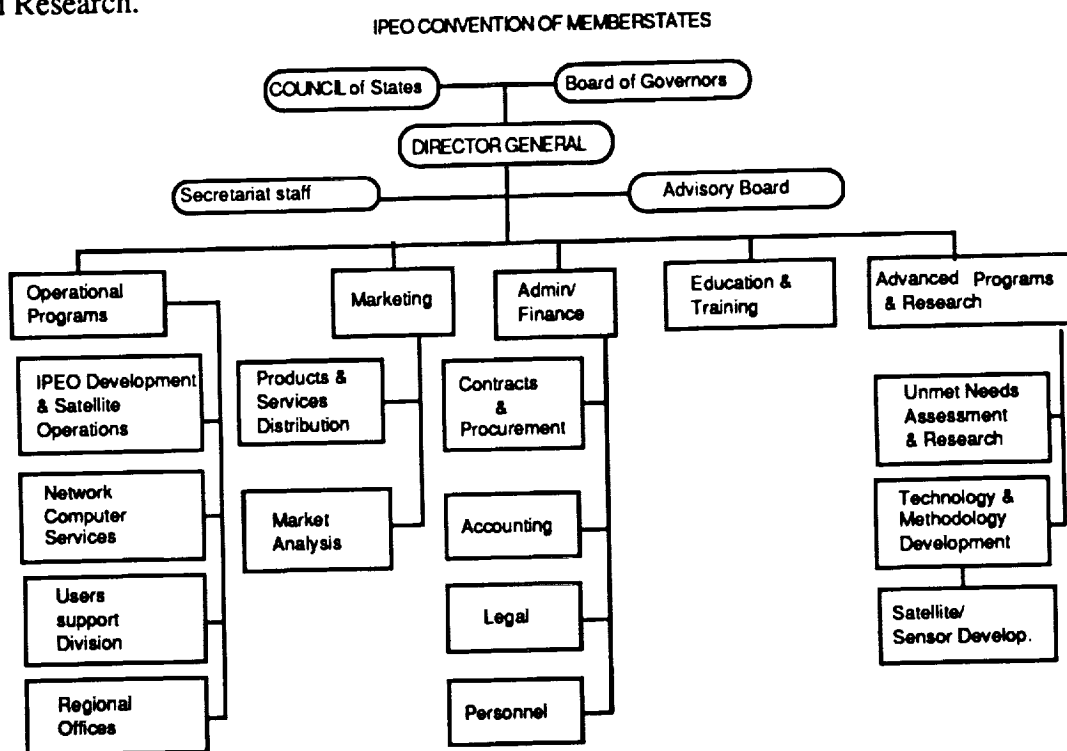


Figure 4.3.1 - 1 IPEO Organizational Chart

4.3.2 The IPEO Convention

As the constituting document of IPEO, the Convention must be carefully considered. For this purpose, the study used as models the INTELSAT Agreement (Agreement Relating to the International Telecommunications Satellite Organization) as well as, the EUMETSAT Convention (Convention for the Establishment of a European Organization for the Exploitation of Meteorological Satellites).

The INTELSAT agreement was considered because of the similarity of that organization with IPEO, i.e. both are international inter-governmental organizations with a space segment. The EUMETSAT model was considered because the main purpose of that organization, i.e. the establishment and exploitation of operational meteorological satellites, is similar in nature to that of IPEO: Both deal, *inter alia*, with the dissemination of data acquired by satellites and are public service organizations.

The negotiation, development, drafting and eventual signing and ratification of an IPEO Convention will take considerable time and effort on the part of interested states and is therefore outside the scope of this study. However, in order to help start such discussions and negotiations, a general outline of the IPEO organization is provided.

4.3.2.1 The Council of States

The Council should be the principal organ of IPEO. It should be composed of all Member States and each State should have one vote. Generally, the Council should be empowered to determine and review IPEO's general policy and long-term objectives, consistent with the principles, purposes and scope of activities of the organization, as provided in the Convention.

The Council should give due consideration to any recommendation or resolution originating from the Board of Governors, before voting on them (e.g. annual report and financial statements, proposed amendments to the Convention, future programs, policy changes, etc.).

The Council should make annual determinations for the purpose of representation on the Board of Governors, such as establishing the minimum and maximum number of Governors for the entire Board and for each Member State, and determining the amount of participation allowed for representation by a Governor.

For voting procedures, it is recommended that decisions on substantive issues be taken by an affirmative vote cast by at least two thirds of the representatives. Decisions on other procedural matters should be taken by an affirmative vote cast by a simple majority of the representatives. Disputes about whether a specific matter is procedural or substantive should be decided by a vote cast by a simple majority of the representatives.

The Council should determine conditions and procedures for the entry and exit of States in the Organization. In this respect, universal membership open to United Nations members might be considered.

4.3.2.2 The Board of Governors

The main purpose of the Board of Governors should be to carry out all activities undertaken by the Organization pursuant to the Convention and directives of the Council. In order to discharge these responsibilities, the Board of Governors should have the power, inter alia, to adopt procurement procedures, approve procurement contracts, adopt financial policies and annual financial statements. The Board should also approve budgets, set minimum contributions, and formulate recommendations to the Council for allocating data and resources. It should appoint or remove a Director General, establish internal rules and regulations regarding IPEO operations, and so on. Certain major decisions of the Board should be subject to approval by the Council (e.g. annual financial statements, appointment or removal of a Director-General).

The representation of a Member State on the Board of Governors should be based on its contribution to the Organization. The more it contributes, the more representation through Governors it should have. A minimum as well as a maximum number of Governors will have to be determined for each Member State and for the whole Board. The contribution should be understood as meaning both the annual Member fee, based on Gross Domestic Product (GDP), as well as for contributions to IPEO facilities and data in the past year. Contributions in kind should be taken into account for this purpose.

One or more Governors could represent several Member States making small contributions if their combined contributions are sufficient to meet the minimum contribution required.

One or more Governors could represent any group of a specified minimum number of Member States from a particular geographical area not otherwise adequately represented, and regardless of their contribution levels.

4.3.2.3 Rationale for Two IPEO Bodies

An organization such as IPEO gives rise to the problem of determining where the decision-making power rests. The options analyzed included:

- a) The rule of one state, one vote;
- b) A weighted voting procedure; or
- c) A combination of both.

Option c) was selected in order to attract as many states as possible to become members of IPEO.

Option a) would have enticed developing countries and other nations with small GDPs, and therefore small contributions to IPEO, since they would have had as much weight in decision-making as any other state. On the other hand, states with larger GDPs, and therefore larger contributions, would have been reluctant to join, for that same reason.

Option b) was also a problem, because its adoption would have resulted in de facto exclusion of developing countries and other nations with small contributions, since these states would get only as much decision-making power as their GDPs warranted. Therefore, the preferred alternative was a hybrid system (Option c).

A hybrid system should allow every state to be heard and have an impact on decision-making since every Member State has one vote in the Council, independent of their degree of contribution. This vote is also significant because the Council determines, inter alia, IPEO's general policy and long term goals.

To satisfy the states with larger GDPs, there is a weighed voting procedure in the Board of Governors, i.e. the more a Member State contributes, the more weight Governors will have to represent that Member State.

This organizational structure is designed to help strike a balance between conflicting interests and ensure wide participation in IPEO.

4.3.2.4 The Director General and the Advisory Board

The Director-General should be the Chief Executive and the legal representative of IPEO and should be directly responsible to the Board of Governors for tenure and the performance of all management functions.

The Director-General must act in accordance with the policies and directives of the Board of Governors and the Council, and should appoint Advisory Board Members, subject to approval by the Board of Governors.

The Advisory Board should give advice to the Director-General about research and development programs. The Advisory Board should consist of knowledgeable representatives from industry, academia, government, and other institutions, organizations and governing bodies which are specialized in space and environmental activities, research and policy. Advice from the Advisory Board is not binding. The purpose of the advice is to obtain as much relevant information as possible for establishing programs and policies, to improve the decision making process, and gain further commitment for IPEO in the world community.

4.3.2.5 The Advisory Board

The Advisory Board guides the Director General by providing relevant information and perspectives for establishing future programs and policies, and to improve the decision making process. The Board will seek to assure that IPEO is focused on Earth observation programs related to priority environmental issues, and that IPEO programs respond effectively to the scientific, business, and political communities.

4.3.2.6 The Secretariat Staff

The Secretariat Staff will perform daily management and administration functions of IPEO under the direction of the Director General.

4.3.3 Directorates

There are five directorates as shown in Figure 4.3.1 - 1 and discussed below.

4.3.3.1 Operational Programs Directorate

The Operational Programs Directorate is responsible for the following IPEO products and services: Satellite Data, Geographic Information Systems (GIS), and the Global Earth Observation Directory (GEOD). The Operational Programs Directorate consists of four Divisions: IPEO Satellite Development and Operations, Network Computer Services, Users Support, and Regional Offices.

The Satellite Development and Operations Division is responsible for all tasks related to the development and launching of the IPEO satellite, and satellite operations.

The Network Computer Services Division performs data archiving and provides computer and network services.

The Users Support Division will develop a comprehensive data base that identifies sources of remote sensing data and users called GEOD. This Division will also be responsible for analysis of selected processed data in the form of remote sensing, GIS, and research, for example on "emergency hot spots".

The Regional Offices Division is responsible for management of the IPEO Regional Offices.

4.3.3.2 The Marketing Directorate

The Marketing Directorate consists of two Divisions: Products and Services Distribution and Market Analysis. The Products and Services Division distributes the IPEO satellite data, GIS and GEOD products, and educational products. The Market Analysis Division searches for and develops new markets for IPEO products, and provides ideas for new products. It also provides a strong market analysis function, in cooperation with the other Directorates.

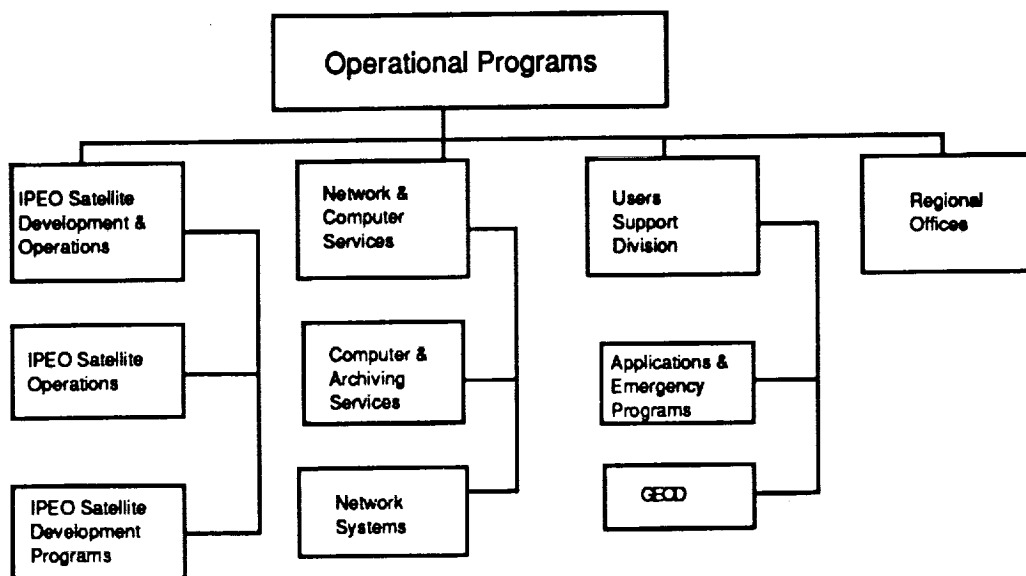


Figure 4.3.3 - 1 Operational Programs Directorate

4.3.3.3 Administration and Finance Directorate

This Directorate has four Divisions to perform administrative and financial functions. The Divisions are Contracts and Procurement, Accounting, Legal, and Personnel.

The Contracts and Procurement Division is responsible for developing and managing contracts and license agreements entered by IPEO and assures that IPEO policies are adhered to in such areas as the purchase of data, satellites and launch services. An example of this function would be to verify that IPEO adheres to its data agreements with SPOT Image. Procurement management is necessary to ensure that less developed Member States have equal opportunities to benefit from IPEO procurements.

The Accounting Division will manage the overall funds of IPEO. This includes receipt of Member State contributions, revenues from the sale of data and services, and expenditures for the purchase of data, IPEO satellite and launch, ground station services, payroll, and training.

The Legal Division will ensure IPEO adherence to the international treaties and agreements, as well as to assure proper construction of IPEO contracts and license agreements.

The Personnel Division is responsible for employee hiring policies, hiring employees, and managing employee benefits.

4.3.3.4 Education and Training Directorate

This Directorate is responsible for increasing the number of people able to understand and solve environmental problems. It does so by ensuring that IPEO users understand the

technology of remote sensing, GIS, and applications of IPEO products, in addition to training teachers and managers. All IPEO goals, products, and services will be addressed in the training. This includes training of technicians who process data on a computer, postgraduate students, and analysts and advisors who assist with the formulation of government policy. Training locations may be at either the IPEO Central location, at the Regional Centers or some other location. IPEO will also assist countries to develop their own training facilities.

4.3.3.5 Advanced Programs and Research Directorate

This Directorate is responsible for performing remote sensing research, identifying the state of the art and unmet remote sensing needs, the potential design of future satellites or sensors and development of remote sensing technology and methodology. Administering these responsibilities are two Divisions: the Unmet Needs Assessment and Research Division and the Technology and Methodology Development Division.

4.4 Key Issues

4.4.1 Legal Issues

4.4.1.1 Agreements and Memoranda of Understanding

IPEO will receive data from existing satellites owned by different organizations, as well as from its own satellite. Data originating from outside IPEO require license agreements with each of the organizations providing data to IPEO. These organizations include SPOT Image, ERS, Landsat and Soyuzkarta. License agreements may only concern environmental data which will be processed and analyzed by IPEO. A provision should be included in these agreements indicating that IPEO will only use the data provided by these organizations for environmental purposes, therefore reassuring them that IPEO will not become a competitor. In turn, such a provision may make the data more affordable to IPEO.

Memoranda of Understanding (MOUs) will have to be negotiated with the governments whose ground stations will be used to receive data from the IPEO satellite.

For the building and launching of the IPEO satellite, additional contracts, agreements and MOUs will have to be concluded with various companies, organizations and governments, covering a wide range of topics.

IPEO will need to enter into several agreements in order to have its own sensor(s) built and flown on satellite(s) of its own manufacture or on other satellites.

4.4.1.2 Information Technology Management

IPEO is an international organization for information service, therefore information management technology and its transfer will be a major concern once IPEO is operational.

Raw data has been an unresolved issue from both policy and legal aspects. "Open sky" policy has provided the environment for obtaining data freely. Yet the international legal system has not provided any means of protection for the owner of raw data. According to conventional copyright protection, raw data are not considered as the subjects for protection of copyright. Processed data is protectable, but the Berne Convention and the Universal Copyright Convention, the relevant international treaties, are not self-executing and provide only in very general terms for minimum data ownership standards. These conventions are not ratified by many countries.

The application of the Berne Convention is further complicated by the fact that there are six roughly similar conventions. Countries accepting the Convention are bound by all previous texts, but countries which accepted an earlier Convention are not bound by a new Convention. An even bigger problem in this respect is the great degree of variance in the national legislation of the ratifying states. The Conventions oblige Member States to give foreign copyrights "national treatment". Many countries have not adopted copyright protection and if they have, it might be totally different from the law of a neighboring country. This creates a confusing legal situation in which a person, company or organization has different rights in different countries. Whether raw data received from an IPEO satellite is the intellectual property of IPEO is an issue of technology management which must be determined. If IPEO decides that raw data will be considered intellectual property, the only practical way for protecting it may be to utilize encoding technology.

Software produced by IPEO, such as information management software (e.g. GEOD, GIS), distribution network software, and so on, should be managed under copyright protections. It will be necessary to set up in IPEO three basic principles common to both the Berne Convention and the Universal Copyright Convention (UCC). These three principles are (1) the "national" principle, (2) the "automatic" principle and (3) the "independence" principle. These principles require the participating countries to respect the copyrights of the software.

Because IPEO will have its own technical capacity in both hardware and software, know-how and invention management will be inevitable issues. Know-how and invention can be protected by the patent system in an inventor's country. Other countries in IPEO will be called upon to respect patents in terms of the "national" principle. If the technology transfer issue for a patent is raised, it should be managed under licensing agreement.

4.4.1.3 Procurement Policy For Launch Vehicle and Satellite Services.

The goals of IPEO call for the design of and data collection from the program's own satellites. Major political and legal issues surround such high -technology undertakings on an international scale. Some of the most significant issues are listed below:

- Technology transfer between major space powers and emerging or non-space powers wanting technology for commercial or military reasons;
- Theft of technology;
- Loss of trade secrets from space service corporations.
- Restrictions on launch locations;
- Whether contracts are allocated among Member States or open market is utilized; and
- The separation between application/user technology and satellite and launcher technology.

As an autonomous body the IPEO must carefully weigh how it interacts with governments, businesses and its users. The IPEO procurement policy takes the above issues and others into account.

IPEO will have procurement policy that uses the commercial aerospace market to procure satellite construction and launch services. Member States concerned with "fair play" with respect to who will construct IPEO's satellites should have little conflict with the open market as all nations with significant satellite construction and launch capability have offered their services on the open world market. The use of competitive market forces will favor cost-effectiveness for IPEO. The procurement program can stay reasonably objective if it concentrates on cost-effectiveness instead of trying to allocate contracts to specific groups. This open procurement system has proven effective for INMARSAT and INTELSAT.

Delivery to orbit of the satellite will be by the commercial entity offering the most value for the least money. This relieves the burden from IPEO of stealing technology, loss of trade secrets and what countries can launch another countries payloads and transfers it to successful IPEO contractors. Contractors will guard their trade secrets as best they can as it is in their own interest, and they will take into account each country's abilities to launch as the ability to do so may mean they get the contract. Contractors must act within the laws of their country, so technology transfer between space powers is again dealt with by the contractor. There is also built in quality assurance according to market criteria. IPEO will receive as much quality as it is willing to pay for.

IPEO will not transfer technology to non-space powers or procure services from a party that does not already have the technology necessary. This is partly for security reasons, as ballistic launch vehicle technology cannot be allowed to proliferate to aggressive powers, and satellite technology cannot be available to parties not willing to abide by treaties protecting countries flown over or who will use satellite data for aggressive purposes. IPEO will transfer and develop application and user technologies with non-space powers. Space development and operations segment will be staffed by

internationals that possess the necessary technology to perform the task. The staff will be prohibited from transferring technology outside of IPEO.

Space technology transfer between major space powers will not happen within the IPEO. This will be enforced by the prohibition of space-segment technology transfer within IPEO and due to the fact that construction and launch services will be contracted to private entities.

Contributors of hardware and system components at no cost to IPEO may have that contribution taken from their fee. If such contribution exceeds contributor GDP they will not gain any greater voting power than GDP fees within IPEO. This is to protect the balance of the IPEO balance decision-making process oriented toward greater scientific and applied use based on need, not contribution.

4.4.1.4 International Conventions

Because IPEO plans to develop its own satellite(s), several international treaties will come into play.

First, the Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space Including the Moon and Other Celestial Bodies (the "Outer Space Treaty") will be applicable. Article VI states, that when activities are carried out in outer space by an international organization, "responsibility for compliance with this Treaty shall be borne both by the international organization and by the States Parties to the Treaty participating in such organization". Consequently, IPEO will have to abide by the following key Outer Space Treaty provisions: use outer space in accordance with international law (art. III), inform the Secretary-General of the United Nations as well as the public and international scientific community of the nature, conduct, locations and results of its space activities (art. XI), and so on.

Art. XIII of the Treaty states that "any practical questions arising in connection with activities carried on by international inter-governmental organizations in the exploration and use of outer space(...) shall be resolved by the States Parties to the Treaty either with the appropriate international organization or with one or more States members of that international organization, which are Parties to the Treaty".

The Agreement on the Rescue of Astronauts and the Return of Objects launched into Outer Space (the "Rescue Agreement") also has some limited application to IPEO.

Article 6 of the Agreement states that where an international inter-governmental organization "declares its acceptance of the rights and obligations" provided in the Agreement "and a majority of the States members of that organization are Contracting Parties" to both this Agreement and the Outer Space Treaty, and that organization is responsible for launching a space object, then this organization is considered a "launching authority" under the Agreement. This status confers rights and obligations to the launching authority, such as: The right to be notified in case of the return to Earth of its space object or a component part thereof (art. 5.1), the right to request the recovery and return of the

fallen object (art. 5.2 and 5.3), the duty to furnish identifying data prior to the return of a fallen space object (art. 5.3), the duty to eliminate possible danger of harm from a space object of a hazardous or deleterious nature (art. 5.4), and the duty to pay recovery and return expenses in certain circumstances (art. 5.5).

The Convention on International Liability for Damage Caused by Space Objects (the "Liability Convention") may be applicable to IPEO in certain circumstances. This Convention provides for an international inter-governmental organization, which conducts space activities, to be treated as a State Party to the Treaty, if it declares its acceptance of the rights and obligations provided for in the Convention and if a majority of the States members of the organization are also Parties to this Convention and the Outer Space Treaty (art. XXII.1). Therefore, pursuant to articles II and III, and if IPEO would fulfill the above criteria, it would be absolutely liable to pay compensation for damage caused by its space object. If IPEO would be liable under the Convention, its members which are States Parties to this Convention shall be jointly and severally liable if the claim is first presented to the organization (art. XXII.3).

The Convention on Registration of Objects Launched into Outer Space (the "Registration Convention") provides for an international inter-governmental organization to be treated as a States Party to the Convention if it fulfills the same criteria enumerated above when discussing the Liability Convention and the Rescue Agreement (art. VII). If IPEO meets these criteria, article II states that it has to register the space object it launches by means of an entry into an appropriate registry. The organization shall also inform the Secretary-General of the United Nations of the establishment of such a registry.

IPEO will have to notify the International Telecommunications Union (ITU), in accordance with ITU's rules and regulations, of the frequencies to be used in order to avoid harmful interference.

4.4.1.5 Technology Transfer Issues

Besides the technology transfer activities considered as part of procurements, IPEO will need to handle other kinds of technology transfer issues. These will include technology transfer issues in the training and education program and from other organizations to IPEO.

Because IPEO will consider the technologies which it provides as its property, the training and education program should be offered to Member States. If non-Member States or individuals would like to be trained by the IPEO education program, a contract or an agreement should be signed to control technology transfer.

If IPEO adopts optional programs or accepts in-kind contributions, the contributors will keep ownership of the technology which they provide.

Technology transfer between countries under different categories of technology control regulations, for example in the COCOM or in the U.S., must be resolved.

4.4.2 Political Issues-Developing Country Perspectives

4.4.2.1 Technology Transfer

The training and education program (see Chapter 5) should be purely beneficial to the Member States. Quality of education and training will be crucial for the reputation of IPEO as well as the success of IPEO in the long run. The courses offered by IPEO should consider the different absorbing capacity of the countries, especially developing countries. IPEO educators and trainers should have experience to deliver the technology to people who are on different education levels and have different cultural backgrounds. In a developing country, an educator or a trainer should use "hands on" programs.

Training and education are one of the most important aspects of the technology transfer process from the point of view of the developing countries. The educational structure that has been proposed is basically composed of two nodes i.e. IPEO central and regional centers. It is important that these centers should not be limited to uses of data alone. There should also be training on the management of the transferred technology. In this respect, seminars and workshops should be held, within budgetary constraints, to ensure appropriate technology transfer. Within the training context it is important to ensure that decision makers in the developing countries view the technology transfer process from a systems perspective (holistically). To this end IPEO could hold workshops such as those held by U.N.E.P.

An analysis was made of prior uses undertaken and current international initiatives related to Earth observations such as the International Geophysical Year (IGY) and the International Space Year (ISY). Case studies were made of remote sensing technology transfer to two developing countries, Thailand and Kenya. The results of the case studies indicate major obstacles must be overcome if the developing countries are to participate fully in IPEO. These obstacles include:

- Funding from international organizations and foreign assistance agencies must increase substantially.
- Careful consideration has to be given to the flow of information and communication about IPEO to the developing countries.
- Education and training opportunities have to be given to a wide audience of developing country participants.
- Steps have to be taken to relieve political and socio-economic tensions between North and South nations.

- When planning the transfer of technology from IPEO to the developing countries, limitations in infrastructure in these countries has to be considered.

The rationale for a holistic approach to transferring remote sensing technology to developing countries is the following:

- A holistic approach would facilitate the smoother flow of the technology since the importance of remote sensing will be understood by not only the users but also by policy decision makers. Decision maker understanding will help to give priority for investing in and using IPEO.
- A systematic approach will help to relax the tensions between nations of the North and South.
- It would encourage the participation of developing countries in I.P.E.O. as they relate to their interests and benefits in the program.

Because actions based on IPEO information will be beneficial for global health, developing countries should play a very important role in IPEO. Therefore, IPEO should be highly concerned with the requirements from developing countries and should keep developing countries involved in all activities of IPEO. For encouraging the participation of developing countries, IPEO should set up principles in the Convention of IPEO on the voting rights (such as one country one voting right in the Council of States). To have developing countries more actively involved into IPEO, it should strive to have the governments realize the goals of IPEO will be beneficial for them in the long run as well as the short run, so that they can support IPEO not only as receivers of benefits, but also as contributors.

Given IPEO's procurement policies (see 4.4.1.3), the development of advanced technology in any space segment will be controlled by the agencies or companies building the hardware, and use the national policies and international legal constraints that those entities work under. Since IPEO is not itself building any hardware, but simply purchasing such products from producers, technology transfer concerns are minimized. However, there has been a raging debate in the past few years concerning foreign launching of a nation's satellite. It appears that resolution of this debate is in sight and that foreign launch vehicles (with certain exceptions) will be allowed to launch the advanced technology of the satellite developer's state. Furthermore, given the seven year lead-time before the IPEO deforestation satellite is ready for launch, these concerns should be minimized and will permit launch from the Chinese Long March launch system.

4.4.2.2 Data Access

The political issues which may be raised about data access within IPEO reflect the political realities of the world. Among the political issues, unrestricted data distribution among the members of IPEO may be contrary to the national security concerns between

countries having some kind of political conflict. An example could be Saudi Arabia having concerns about Iraq using remote sensing data to obtain information about its territory if both were IPEO members. However, IPEO must maintain a free, open access data policy.

Respecting copyrights will be a significant political issue within IPEO. Even if IPEO has its software protected by copyrights, copyrights still could be violated by the countries which do not respect copyrights given the state of current international law.

4.4.2.3 Tensions Between Developing and Developed Nations

The viability of IPEO in developing countries will mainly depend on its political acceptability in these nations. Political tensions obviously exist between the developed and developing nations on various issues. IPEO will not be an exception. For example, the perspective that the major reason for countries participation in IPEO will be for political prestige would certainly not be politically acceptable to most developing countries.

Another major problem area is the inequality in the relationship between developed and developing countries. A conflict that may arise is a "pseudo-role" that developing countries may be given in IPEO. In earlier international programs it has been common for developing countries scientists to be treated as second class participants. The perspective of the developed countries was to accomplish purely scientific objectives. Time spent involving developing country personnel was seen as taking time away from strictly scientific objectives. In this respect various perspectives of developed countries have, over time, emerged on the intentions of international observation initiatives. One of the most pronounced perspectives is that the developing countries are mainly included for public relations purposes. Avoiding this in philosophy and in practice is a particularly important consideration in IPEO's institutional approach. A weaker but equally detrimental perspective is raised by those who suggest that observation programs are mere labels hiding technological imperialism. Developing country participation in IPEO may be impeded unless significant efforts are expended to overcome the obstacles in the technology transfer process. Given the importance these nations must play in any attempt to solve global environmental problems, these political and considerations are vital to the development and implementation of solutions such as IPEO.

The voting rights in the Board of Governors discussed above at 4.3.2.2 will be a continuing issue. Since the share of the voting rights in the Board of Governors will be determined by percent GDP, developed countries will have more voting rights, which could result in conflicts between developing countries and developed countries.

4.4.3 Financial and Economic Key Issues

4.4.3.1 Introduction

As a non-profit intergovernmental organization, IPEO resolution of financial and economic issues are critical success factors. The proper consideration of such factors will

allow for the creation of IPEO and provide it with a long lifetime. This success can only occur, however, if IPEO can find the funding (after having convinced most of the world's governments to join the IPEO) and then to ensure that the members will commit themselves, from an economic viewpoint, to support the development of new programs and to manage the organization efficiently.

4.4.3.2 Key Success Factors

The key success factors which must be followed do not deal directly with finance and economics, but they are all linked to the success of IPEO which is tightly bound to its financing. Financing of the organization is IPEO's most important success factor. Financing IPEO and finding a viable and long-term method for such financing is critical. Financing will come from the participation of the Member States as a percentage of their Gross Domestic Product (GDP), and from any other external sources of revenue that IPEO can generate. Financing is treated in depth in chapter 9.

The second success factor is a destructive matter if it is not realized. IPEO products have to match and fit the user needs. That affirmation seems so evident that one might wonder if it's necessary to reemphasize it here. However, it must not be forgotten that the remote sensing industry is relatively young, and its market is even younger. It is not easy to define exactly what the real needs are and which data will truly be used. Confirmation of this fact can be seen in the amount of non-utilized remote sensing data throughout the world. Some estimates are that less than 2 percent of all satellite data is actually applied. The reality of the remote sensing market is largely unknown. At the current stage of knowledge, it would be wiser to look for a precise needs than to attempt to create a new need. IPEO has to be:

- Operational (i.e. output-oriented) in order to provide the following:
 - Efficient archiving of data
 - Efficient distribution of data
 - Standardization of data
 - Information valuable to the end-user
 - Training and education to current and new users
- Serve user needs and market in order to achieve:
 - High data utilization
 - Quick response to user needs
 - Fair and equitable data costs.

IPEO will need, to ensure its long-term existence and viability, to maintain the political balance that deals with:

- The committed full participation of the developing nations

- The permanent commitment of governments
- Continuity in programs
- Cooperation which allows for continued development of national programs

IPEO must avoid the production of redundant data. By attempting to reduce redundancy amongst national remote sensing programs, IPEO can save its Member States money (See 9.6 Financial Strategy).. Furthermore, reducing redundancy can enhance the diversification of remote sensing systems, greatly improving global Earth observations.

4.4.3.3 Conclusions

The present trend in remote sensing is for nations to develop and maintain their own systems for various, largely political, reasons. At the start of the IPEO organization, it may be easiest to begin its operations through cooperation with operating national centers (e.g. World Meteorological Organization). As IPEO grows, it might begin with managing the coordination of national remote sensing programs as well as, the development of an international standardized data bank.

5.0 PROGRAM IMPLEMENTATION

5.1 Products and Services

The following chapter lists and explains the spectrum of products and services to be developed by the IPEO organization. It is divided into five sections. The first two sections describe activities within the Operational Programs Directorate and its Users Support Division: the GEOD service and the GIS group, which is part of the Applications and Emergency Programs. The third section deals with the IPEO research groups located within the Advanced Programs and Research Directorate. The fourth section explains how IPEO support is envisioned for Education and Training. The fifth section attempts to bring all the products and services together and explains relationships between them, and how external parties interface with the various IPEO service groups.

5.1.1 GIS Services

5.1.1.1 Introduction to GIS

Geographic Information System (GIS) is the name given to a rapidly developing information technology which analyzes, stores, and employs together both spatial and non-spatial data. A GIS consists of a computer program with analysis and graphical capabilities, a hardware platform for processing display, output, and data storage, and data representing geographical information and other information relative to particular questions of interest. Spatial data are represented as vectors: points, lines, and polygons and rasters: cells of spatially related data. When representing spatial data, the computer must be told: 1) where each feature is located, 2) what each feature is, and 3) what each feature's relationship is to other features. Many layers of data for the same geographical area can be stored, representing many types of information. (GIS Sourcebook, 1989).

Spatial data is usually represented in map form and must be digitized in order to be used in a GIS. Satellite data, which is already in digital (raster) form, provides much information on numerous subjects and can be best understood with analysis and interpretation as provided by a GIS. A GIS can answer questions and perform many analysis functions on the same data set. It is this ability of a GIS to merge selected data sets and perform diverse spatial analyses that differentiates it from computer mapping systems (Tom, 1990).

Applications of GIS technology are virtually unlimited. GIS technology has many commercial applications such as civil engineering, petroleum geology, urban development, transportation, marketing, and utilities to name a few. Innumerable environmental issues are addressable with GIS including deforestation, pollution, vegetation dynamics, bio mass inventory, soil assessment, etc. The ability of GIS to provide visual and analytic representations of environmental trends and decisions regarding the environment will be of great significance to decision makers.

5.1.1.2 Data Analysis and Modeling

A GIS analysis addressing a research issue or a specific application develops from the appropriate data and provides links between the information retrieved. Links are realized by means of a process that starts from the basic data management functions and ends with the execution of an appropriate model.

In the first level of operations can be included the data input procedures (spatial and non-spatial data input and their matching), data storage and retrieval, data verification and data output. Beyond this level a GIS provides analysis capabilities that enable operations on both spatial and non-spatial aspects of geographical data, manipulating their attributes either separately or simultaneously. These capabilities extend from the data updating and cleaning procedures, through statistical analysis, to neighborhood and interpolation functions.

The database on which the GIS functions operate consists of maps. Each map consists of a separate "theme" or layer. These layers are geographical, so that the same coordinate is represented in each map in the same location. Each layer may contain both spatial and non-spatial data. The simplest region is a point; the most complex are represented as sets of polygons or matrices.

Each layer consists of set of mutually exclusive contiguous regions associated with a particular area. The assumption of any GIS analysis is that for any point on the map a new attribute can be generated as a function of attributes on the overlays already present in the database.

It is useful to classify the functions that a GIS provides to the user. The first class of functions enables operations that extract new attribute values referring only to the value of the attributes of the same location. This leads to the independence of the new property from neighboring patterns present in the map.

The second class consists of functions whose output is related to the attribute of the region to which the data value belongs. The functions of the third class relate the new property to the values of the attributes of the neighboring location. Finally, a dynamic analysis may be necessary in the study of processes at which the time variable is relevant and a static approach is not sufficient.

Among these advanced functions special attention can be drawn to the interpolation and extrapolation functions. By means of these procedures values of a property between data points (the digitized databases have discrete distribution of value) can be interpolated by fitting some plausible model of variation to the values of the addressed attribute. The key element in this type of analysis is the choice of an appropriate model to suit the data.

A further level of approach is a procedure that leads to the definition of a proper cartographic model. This approach consists of the linking of a set of primitive functions belonging to the various classes, in such a way that the output of one is the input of another.

To develop such a model it is necessary to identify the main issues relevant to the problem addressed in such a way to produce a clean flowchart that allows modelling. This technique is a very powerful tool and a very challenging methodological issue, since it requires higher understanding of the spatial analysis development.

Finally, it is very important to identify, in addition to all the powerful features of the GIS a key problem concerning the reliability of this tool. GIS rests on the assumption that the data collected, entered, stored and processed are sufficiently reliable and error free for the purposes for which they are required. The cartographic operation dealing with the combination of different maps together by means of overlay assumes that the source data can be considered as "perfect", i.e., completely deterministic documents with uniform levels of data quality over the whole study area. Due to the procedures and various functions applied to these data a quality control concern arises; this quality problem can be seen as the loss of information as well as, creation of misinformation.

The factors that govern the generation of errors in the GIS data processing can be classified in three different groups: obvious source errors, errors resulting from natural variations or from original measurements, and errors arising through processing. The first group includes the age of the data, mainly found in terms of different standards or procedures in data collecting as well as in the processing. Other sources of error can be partial data coverage and the different scale or density of information over an addressed area.

In the second group of error are included positional accuracy as well as, variation errors. These errors can arise from the measurement phase or from the methodology used in the laboratory or field activities. Error detectability here largely depends on the range the faulty values errors which may appear.

The third class of error includes the errors generated by the limited precision levels the computer allows in storing and processing the data. Most important, and tied to the modelling activity itself, are the errors generated by the overlay procedures. Great attention must be given to the management of the information in the neighborhood of the boundaries. In this area a loss of information or the generation of misinformation can easily take place. Specific attention to this problem should be given in the development of new tools.

More subtle errors can be incurred during the analysis phase when data are processed that lack proven relevance to the addressed issue. A wide range of this kind of mistakes is related to the methodological approach chosen. The risk of misuse of such a powerful tool as GIS could be extremely dangerous in the decision making process.

5.1.1.3 GIS Data Products and Users

The first part of this section will describe the data products of GIS and give a brief definition of each term. The second part will describe the different types of users and which product(s) they will require.

GIS Products

There are three types of data available to IPEO participants. The first of these is raw. This is data in its original form. The user will need the facilities to calibrate this data to recognized standards. The main users of raw data are research groups. The second type of data is calibrated. There are three main types of data calibration: geometric, radiometric and thermal. The user could require one or a combination of all these techniques depending on the application. This data can then be used on any GIS system, allowing the user to interpret the information. The final type of data is analyzed. This form will be provided to users who require specific information on a particular application but do not have the ability or desire to do prior data analysis before its application.

GIS Users

GIS users may be divided into two groups. One is a non-profit group, the other a commercial group.

The non-profit group can be divided into three sub-groups, international/national government agencies, local government agencies, and universities. International/national government agencies generally have the ability to calibrate raw data and are able to analyze calibrated data. Analyzed data will be used for further research or study. Local government agencies take an interest in analyzed data but are unlikely to require raw or calibrated data. Universities have a special interest in the research area, so they need raw data and will also require calibrated and analyzed data for further research and study.

The non-profit group covers a large range of applications, so the examples shown have been classified depending on their priority in the IPEO program. Table 5.1.1-1 classifies the top non-profit priorities. Topographical mapping is a necessary geographical analysis, because a large amount of information can be easily obtained from the combination of the mapping data and the analyzed data. Therefore topographical mapping uses raw, calibrated and analyzed data. Deforestation can be analyzed in many ways, so calibrated data will be the main source of information. The coverage of this is global, and the frequency of request is quarterly because forest monitoring may be needed quarterly in some areas.

Table 5.1.1 - 1 Non-profit Applications Uses

| Top Priorities | Main Type of Data | Frequency of Request | Coverage | Main Sources of Information |
|-----------------------|--------------------------|-----------------------------|-----------------|------------------------------------|
| Global Warming | raw | weekly | global | satellite / statistics |
| Pollution | processed | weekly | global | all |
| Vegetation Dynamics | processed | weekly | global | all |
| Topographical Mapping | all | monthly | global | satellite / in situ |
| Deforestation | processed | quarterly | global | satellite |
| Bio Mass Inventory | raw | yearly / quarterly | national | satellite |
| Water Quality | analyzed | monthly | regional | satellite / in situ |
| Geological Mapping | processed | decade | local | satellite |
| Soil Assessment | analyzed | quarterly | national | satellite / in situ |
| Urban Development | analyzed | yearly / quarterly | national | satellite / statistics |
| Ground Water | processed | monthly | regional | in situ |

The commercial group seeks to enhance IPEO revenues by using information obtained from processed or analyzed data. Table 5.1.1 - 2 shows the preliminary classification of markets in the commercial group and what data they may require.

The range of commercial applications is large, so only a few examples will be discussed here. Surveying uses analyzed data, for instance, lineament (fault) location, classification of rock and soil, and coastal erosion. The variation of landscapes is not rapid, so information will only be required on a yearly basis, corresponding to the time required to build or alter some structures. Main sources of information for this application are satellite and in situ measurements. Data from satellites are used for mapping in inland areas especially where photo surveying from an airplane is not possible. Civil engineering uses processed data for the purpose of planning projects such as dams, railroads, waterfront improvements and highway projects, and also for the purpose of surveying the dangers from collapsing slopes and avalanches. At the very first stages of the project, concept design is based on this information so the data are used only once.

Table 5.1.1.3 - 2 Commercial Entities Users

| Customers | Main Type of Data | Frequency of Request | Coverage | Main Sources of Information |
|--|--------------------------|-----------------------------|-----------------|------------------------------------|
| Surveying | analyzed | yearly | local | satellite / in situ |
| Civil Engineering | processed | once | local | satellite / in situ |
| Petroleum Industry | processed | once | local | satellite / in situ |
| Hydroelectrical Industry | processed | yearly / quarterly | local | all |
| Urban Development | analyzed | decade | national | satellite / statistics |
| Transportation | processed | once | regional | all |
| Network Management (power, comm, water) | processed | monthly | local | all |
| Cartography | processed | yearly / quarterly | national | satellite / in situ |

5.1.1.4 Software Survey

A review of available GIS software packages was performed and a recommendation of a package was made for implementation in IPEO. It should be understood that the recommendation is made for the purpose of the IPEO organization itself and shall not be seen as a general recommendation for future IPEO clients. Additionally, it should be understood that any recommendation is subject to revision, since software packages are updated continuously and new packages increasingly appear on the market.

In order to perform the selection, the following criteria for software package selection were established:

- User transparency and flexibility;
- Technology transfer;
- Costs for software and associated hardware;
- Availability of source code;
- Continuous improvement, new editions;
- Compatibility and integration capabilities with other systems; and
- Support for global geographical analysis.

Two different documents were consulted which were seen as giving the most objective background for the software package selection; the GIS Sourcebook and Burrough's GIS textbook. It was concluded that the Geographic Resources Analysis Support System (GRASS) provided the best choice considering the above criteria.

The GRASS package is a public domain system, developed by the US Army Corps of Engineers at the Construction Engineering Research Laboratory (CERL), Champaign, IL, USA. In private discussions with a CERL representative (Mr. R. Lozar), several issues were raised including the continued support by the US Army, and transfer of the software package to foreign countries. All questions were answered to a satisfactory level, confirming our selection, and no critical areas could be identified which would impair the use of GRASS by IPEO.

One of the most appealing attributes of GRASS is the development policy of new versions, ensuring that all users have access to modifications written at the many user sites, counteracting any fragmentation of the system into many parallel versions.

An additional advantage is that the development of GRASS has been accomplished on a variety of UNIX machines, written primarily in the C language and making a substantial use of UNIX commands. This ensures a high level of flexibility and compatibility when using GRASS and makes GRASS relatively portable. Also, the GRASS global data base is the most extensive data base of its kind and, because it is public domain, can be distributed to IPEO users.

5.1.1.5 GIS Cost and Marketing Estimates

This section will first estimate the costs of establishing and running the IPEO GIS services. Next, the present and future use of GIS and related technologies are assessed and a possible GIS program developed which will considers these trends.

GIS Cost Estimates

The initial cost of establishing a GIS function at the IPEO Headquarters and the Education Centers has been estimated by first identifying the hardware and software required for the center then taking an average price of a similar existing system as a model. It should be noted that the computer hardware facilities will be shared by the GIS and the research groups, although separate GIS workstations will be required for information processing.

The required hardware has been identified as follows:

One large mini computer system (UNIX standard) with 5 to 8 Gigabytes of storage for archiving. A standard system will allow for easy expansion and lower cost.

Cost: \$250K

Ten individual color workstations (24 bit true color) with an Ethernet server for processing and analyzing data at the IPEO central office and five in each education center. These numbers will increase as demand rises.

Cost: \$15K per

station

Facilities for hardcopy outputs, digitizing tables, high resolution digital scanner

Cost: \$50K

An IPEO AVHRR receiver will be required if the location of the central base does not have access to a reliable source of AVHRR data.

Cost: \$60K

The estimated cost for initially setting up the GIS center at the IPEO office will be:

| | |
|----------------------|--------|
| Main Computer System | \$250K |
| 10 Workstations | \$150K |
| Hardware facilities | \$50K |
| AVHRR receiver | \$60K |
| Total | \$510K |

The total cost for initially setting up the GIS center at four education centers will be:

| | |
|--|--------|
| Five Workstations at each of the centers | \$300K |
| Total initial hardware costs | \$810K |

The operating costs for the GIS group are estimated to be \$150K per person. This value is based on current costs and includes salary, facilities and computing time. A number of the people required for GIS can also be used for the research group (for example the remote sensing analysts), however, an additional five GIS experts will be required in the first year to ensure the development of the GIS system, build the database, identify

where GIS can best aid the Member States and locate revenue enhanced areas. This number may increase to 20 or more as GIS becomes fully operational.

| | |
|-------------------------------|---------|
| First year's operating costs | \$750K |
| Second year's operating costs | \$1500K |
| Third year's operating costs | \$3000K |

It should be noted that research will require a further five workstations at the IPEO central office and 16 people (some of which will work in both areas).

Marketing Estimates

This section examines the current trends of GIS and related technologies and uses this information to assess the future markets open to IPEO. By using these trends an attempt is made to describe the development of GIS within IPEO over the next ten years.

A number of marketing surveys have been conducted recently. However, these have been based on individual developed countries. Information on a global scale is scarce, however, even from these national predictions it is clear that there will be a rapid growth in the use of GIS in the immediate future. This growth depends on a number of factors including technology development, improved communications, and increased education in both developed and developing countries.

Technology development is the first area which must be encouraged. Past surveys show rapidly increasing markets reflecting this development. An IBM survey conducted in the USA concluded GIS (hardware, software, and services) will be a \$5 billion market in the USA by 1995. The results of general GIS industry trends in the USA are summarized in Figure 5.1.1.5 - 1. The data hardware market has been growing at an estimated rate of 25 percent to 30 percent annually since 1985 and will continue to do so in the immediate future. There has been a major move towards the development and implementation of new GIS software (for example, ARC-INFO, ERDAS). This is reflected in the increase in sales at rates exceeding 30 percent to 40 percent per annum. This growth is expected to continue in the immediate future, particularly as GIS is standardized and used to its full potential. The third area of growth is in conversion services (data base digitizing and related support). Governments have been increasingly supporting digital map conversion, a vital part of the GIS system. The effect of digitizing on the GIS market can be seen in Canada which predicts a period of ten years is necessary to develop a fully digitized GIS data base (Singhroy, 1990). It should be noted, however, that a complete data base is not needed to operate a GIS.

The addition of satellite data has been an important step for GIS. This information is digital requiring no conversion process; therefore, the integration of satellite data may be far quicker than for present data.

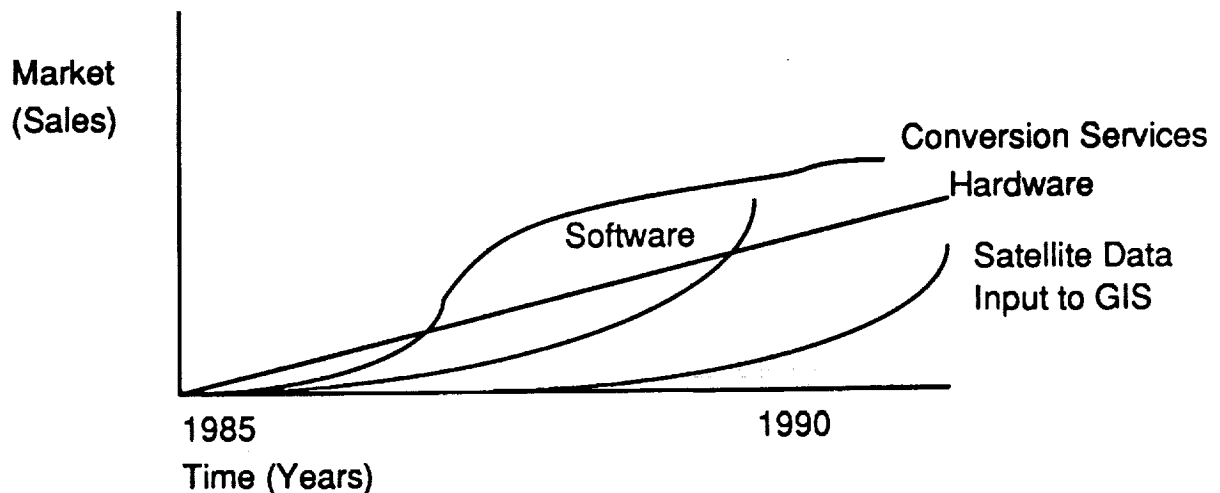


Figure 5.1.1.5 - 1 General GIS Marketing Trends

The trends presented above are for the USA and represent only a very general model for the global development of GIS. It should be noted, however, that the time scale will be much longer on a global level.

GIS Program Development

It is apparent that the GIS market has great potential, however unless the program development is carefully considered, potential markets may not be fully utilized. This section describes the operations of IPEO GIS Services and how those operations may expand over the next ten years.

At the beginning of IPEO a number of things will need developing regarding GIS. The first of these is a digital database. Large amounts of data need to be digitized. Some areas, particularly in developing countries, do not have existing data of any kind, and it will be a major task to obtain it. The process of creating a full GIS database on a global scale will be a continuous one. Information will be integrated from three main sources. Remote sensing will make an important contribution and be a relatively quick way to gather input since the data is already in digital form. A detailed global data base of terrain is a vital component of a GIS data base but has not yet been compiled. This is an area which could be aided by the use of an IPEO Topographic Satellite. By having its own IPEO satellites, topographic information could be collected from missing areas in a very short time frame. This is an area which requires further investigation. In-situ data is abundant in developed countries, however, there are still large areas which have little or no data of this kind. Again it is the developing countries who lack information in this area and need GIS data base services. Statistics will be needed which either exist already or need to be gathered and updated. A large amount of work is needed in all three of these areas and the compilation of this data will be vital to IPEO.

One of the main tasks in the first few years of IPEO will be to develop the data base described above. Information covering the major hotspot areas should first be gathered, gradually expanding to become global. During this period IPEO will coordinate the global development of a GIS network, using standardized procedures for digitizing, levels of accuracy, metric measurements, common storage facilities, and many other factors which must be standardized if the GIS system is to be used effectively on an international basis.

While GIS data is being gathered, an education program will be implemented to teach technical and managerial GIS skills and coordinate an educational network worldwide. This program will increase the number of GIS users and also be an important method of market development. By making countries aware of the potential of GIS, they will be able to recognize problems which could be solved by using GIS.

A third important operation in the initial few years is to encourage and coordinate research into GIS and related technologies. This will be vital in order to be able to respond to new technologies and markets as they arise. An example of this is the use of in-situ probes to monitor a parameter (water levels, for example) and inform the GIS user as soon as this parameter has exceeded its 'safe' level (potential floods). If technological developments such as this can be coordinated, it will greatly improve the ability to respond quickly as problems arise. With the rate of technology development increasing, the market growth rate is predicted to be high. It is important to be prepared for this.

It may be possible to stimulate GIS markets immediately. The revenue enhancement areas of GIS are areas which would be ideal for initial development as they are mostly specialized cases which need information on defined areas, not on a global scale. It is important to give the Member States a return on their investment as soon as possible. The initial implementation of the IPEO GIS system will take a large amount of effort and money. It would be advisable, therefore, to start a project at the beginning of IPEO which gives immediate help to the Member States and allows IPEO to apply what is learned to revenue enhancement programs.

A small scale project could be initiated into an area which has been identified as a problem area, yet may have commercial potentials. Pollution for example, is a major problem for most countries, and much money is being invested by both governments and private companies to address this problem. By studying pollution, Member States could begin to have some immediate return, and IPEO would gather experience to offer private companies in their battle to become 'green'. This could be effective immediately since pollution control is one of the largest investments of many industries such as materials manufacturers. With early development of this expertise, IPEO may be able to play a major part in the near future to control pollution on an international scale.

In conclusion, despite the large amount of time required for complete data base development, IPEO GIS services can still offer valuable products and services during the build up period. It may provide an immediate return for Member States and also has the potential to be involved in IPEO revenue enhancement programs.

5.1.1.6 Evolution of GIS

The rapid evolution of Geographical Information System (GIS) technology over the last ten years provides evidence that a substantial market exists for systems capable of managing and interpreting geographical data. GIS has proven itself as an extremely powerful tool among its users, and is being widely accepted as the most important means for remote sensing data interpretation.

In the near-term future, a great variety of remote sensing satellites will be put into operation with data rates exceeding 1 Terrabyte/day. GIS technology is of crucial importance for any global Earth observation system in general and for IPEO in particular, in order to be able to interpret the large quantities of data involved. GIS will also be necessary to facilitate the increasing use of spatial data in decision making. The pace of GIS development is likely to be sustained during the next 10 years and finally level off at a level of usage corresponding to the world market demand. This period of time will vary a great deal from one country to the other depending primarily on the availability of digitized geographical data sets, and the rates that old "analog" data sets are being integrated.

Specific near-term developments will be due largely to increased hardware capabilities and standards adopted by the GIS industry. Decreasing hardware costs and increasing capabilities of desk-top workstations support the trend in the GIS community toward decentralized single workstations or workstations configured in local networks to support a broad range of projects. The development and standardization of high speed communication networks will facilitate data access and exchange, while optical disk storage systems will facilitate the inexpensive storage of large amounts of data in a reduced format. Automated methods for data capture should also improve, reducing the associated costs of data entry.

The GIS community has recognized increases in productivity due to the use of standards, and users are driving the industry's development and acceptance of standards. Several reasons support the adoption of standards. Standards increase system portability. Standards-based systems can be ported to different hardware platforms with relative ease. The interoperability provided by the use of standards supports the use of network communications for data exchange and remote access. The use of standard user interfaces and query methodologies lowers the learning curve between different systems.

Standards influencing the GIS community are of two types: those standards developing within the computer industry itself, called information technology (IT) standards and those applicable to specific GIS needs. In order to take advantage of rapidly advancing computer technology, GIS systems are beginning to adhere to the emerging IT standards. These standards include the X-Window interface standard for the development of user interfaces and the use of TCP/IP (Transmission Control Protocol / Internet Protocol) for the transfer of information and remote access in a multi-vendor environment.

Regarding operating systems, MS-DOS is the de facto standard for personal computers while UNIX is the rising standard for the desk-top workstation.

Standards related to specific GIS needs are those associated with the transfer of spatial data and the querying of databases. The development of the Spatial Data Transfer Standard (SDTS) by the National Mapping Division of the U. S. Geological Survey is an attempt to establish a data transfer standard that will ensure that data will not be lost during transmission, the fidelity of the data is preserved, and that the file can be interpreted by the target GIS system after the transfer. SDTS facilitates the transfer of data between different GIS systems even if the systems are on different hardware platforms with different operating systems. Standard query languages for the analysis of GIS information are also developing and should also promote increased productivity.

A developing technology which will lend much power to GIS systems in the near and long-term future is that of the USA Global Positioning System (GPS) and related satellite positioning technology. A GPS system determines the location of any point on the earth's surface based on satellite ranging. These locational data are expressed in geographic coordinates and do not require transformation from any coordinate system. GPS data are digital. Data can be recorded from the field and inserted directly into a GIS database with no need for specialized processing. The inclusion of GPS information in a GIS database will make it possible to accurately identify locations during GIS modeling and analysis.

In an outlook for the longer term, a second "great leap" in GIS technology can be envisioned if hardware developments continue to produce smaller, less expensive, but more powerful computers, and if the spatial resolution of remote sensing data can be improved by an order of magnitude with respect to present capabilities. Also influencing GIS technology in the long term will be the inclusion of advanced methods for describing spatial data and of dealing with errors in the human thought process which impact the interpretation of the data. Developing areas which could influence the long term future development of GIS are fractals, fuzzy logic, and methods of artificial intelligence. This evolution may mean that GIS systems become part of everyday applications using general household information equipment and on-board navigation tools in future vehicles.

5.1.2 GEOD

5.1.2.1 Introduction

The Global Earth Observation Directory (GEOD), is the computer database at the heart of the IPEO organization. Its design contains all the basic information available from IPEO which is vital to the effective internal administration, research, education and GIS, as well as to the external client. There are four main groups of external clients identified: a) Governmental, b) Industrial/Commercial, c) Scientific and d) Public.

Information concerning data gathering, data processing and data using organizations may be accessed through GEOD together with current and planned global sensor

capabilities and Earth observation programs. A Geographic Search capability is included which enables the client to assess the satellite coverage of a particular location, including which satellite(s), the temporal resolution of coverage, the next satellite pass, the last satellite pass, and, if relevant, the cloud cover. A quick look facility will be available to those clients suitably equipped to enable assessment of the available images of a particular area ensuring adequate coverage before purchase of the image.

GEOD acts as the 'front desk' to all IPEO clients, being the single point through which to access the many facilities of the IPEO organization. This front desk feature, as well as being convenient to the user enables details of all accesses to be retained in the GEOD database to provide statistical analysis of information and demand trends for research and marketing activities, for example. GEOD also provides standard Boolean search functions.

5.1.2.2 Operational Outline

When a client requests access to the GEOD database he is required to select from the following list:

- 1) Enter Password - for subscribing clients.
- 2) Organizations registration label - for registered users evaluating database.
- 3) First time client.

If the client answers 1), he is asked to enter his password (issued to subscribing clients). If the client answers 2) this indicates that he is a client evaluating the database. A check is made as to whether he has exhausted his three free trial accesses to the database and if not, is allowed to proceed.

If the client answers 3) he will be asked a number of subsequent check-in questions. First, the client is asked whether he is a data gatherer, processor or user. Depending on which group the client fits, he will then be asked further specific questions comparable to those of business reply cards. The answers given on these requests will allow GEOD to recognize the clients' specification, considering location as well as nature of business, organizational structure and expertise, and to create a specific identification label for each of them. Based upon these labels GEOD can rapidly address any group of institutions and individuals dealing with remote sensing data specified by the requests of the GEOD clients. For identification purposes, GEOD will provide 11 mandatory questions for gatherers, 12 for processors and 13 for users. In addition, there will be three optional questions, allowing GEOD continued research on remote sensing networks, main research areas, etc. to support optimization of the relationship between data distributor capabilities and user needs. These questions are detailed below.

Further questions for data gatherers/processors:

- 1) Name of Organization (including Department/Division)
- 2) Address/Location: includes street, number, city, state, country, postal code
- 3) Contact Person (Name and Function)
- 4) Phone, Telex, FAX, E-Mail
- 5) Business or topic addressed by offered data: e.g.data on marine pollution, crop statistics, highway maps
- 6) Covered Area: either geographical/political like countries, continents, international organizations, or environmental, e.g.specific climate or vegetation belts
- 7) Offered Data Type (raw, processed, analyzed)
- 8) Number of years in operation (experience level)
- 9) Data Source(s): satellite system(s), airborne sensors or in situ data
- 10) Name of Sensor System: e.g. SAR, Wide Field Camera
- 11) Resolutions: spatial, spectral, radiometric, temporal

According to the division between gatherers and processors by question 7 (data type), processors only will be asked to answer the following question:

- 12) Type of data processing facility (computer system and software used)

Further questions for users:

- 1) Name of Organization (including Department/Division)
- 2) Address/Location: includes street, number, city, state, country, postal code
- 3) Contact Person (Name and Function)
- 4) Phone, Telex, FAX, E-Mail
- 5) Nature of Business/Research Topic/Field of Interest
- 6) Covered Area: geographical/political or environmental specification
- 7) Purpose: commercial, educational, political, public, scientific
- 8) Required Data Type: raw, processed, analyzed
- 9) Access to Data Processing Facilities (Y/N): if yes, specify processor type and software
- 10) Number of people involved (e.g.employees, group or class size)
- 11) Total Annual Budget
- 12) Prior Access to remote sensed data (Yes/No); if yes, specify data resource
- 13) Number of years dealing with Remote Sensing (experience level)

Optional questions for optimization purposes:

- 1) Main involvements in international, national or local programs

- 2) Major supervising or supervised institutions
- 3) Affiliated Institutions (e.g. within super-institutional networks)

Because of the great variety of topics that are addressed by the offered data as well as by the users' activities (see question 5) a keyword list will be used to handle this item within the GEOD database. To avoid overlaps of already existing keywords with new entries (up to six), the client can pick up the preferred items from this list over a search path. Only if he is not able to find a sufficient description of his aim in the existing list, may he add new keywords to it. However, a large amount of initial keywords must be prepared by GEOD itself during the setup phase to provide a basic list for the first operations.

The functions of the GEOD database are to be as automatic and free from human support as possible. To reach this aim, GEOD will operate on the basis of self-generating updates. All new entries of clients will be recorded automatically as well as further connections to provide current information about access frequency and size and to update database content. In addition, a data collection staff will seek information that is not directly entered into GEOD by the consumers' operations, and add them to the database content. This will ensure an up-to-date status of GEOD which is necessary to reply to consumers' requests properly.

5.1.2.3 Data Gatherers, Processors, and User Groups

Examples of the various data gatherers, processors and user groups identified during this project are listed below.

Data Gatherer Groups:

Group 1: Satellite Operations

Examples: Spot , ESA, NASA, NASDA, NOAA

Group 2: Airborne Operations

Examples: NASA, CCRS (Canada)

Group 3: Ground Truth Operations

Examples: ESA, NASA, NOAA, WMO Network

Data Processing Operations:

Group 1: National Remote Sensing Centers

Example: NRSC (UK), CNES (RF), Nairobi (Kenya)

Group 2: Companies

Example: Eosat, Spot Image, RADARSAT International

User Operations:

User Type I: Governmental

User Group 1: International Organizations

Examples: UNESCO, UNEP, WHO, WMO

User Group 2: National Governments

Examples: Executive and Legislative Bodies

User Group 3: Decision Makers/Ministries

Examples: Agriculture Forestry and Fisheries, Environment/ Pollution, Meteorology, Traffic/Public Transport, Postal Services/ Communication, Industry, Energy, Interior, Statistical Offices, Land Development & Management, Research & Technology, Cultural/ Academies of Sciences (research strategies/education)

User Group 4: Public Information

Examples: Press Secretaries

User Group 5: Regional/Local Governments

Examples: City Mayors

User Group 6: Disaster Response Teams

Examples: Earthquake, Flood, Typhoon/Hurricane

User Group 7: Space Agencies

Examples: NASA, ESA, NASDA, etc.

User Type II: Industrial/Commercial

User Group 1: Companies

Examples: Civil Engineering, Cartographical Service, Press, Petroleum/Gas/Mineral Exploitation, Land Development Advisors/ Risk Analysis Groups, Transportation (Land,Sea,Air), Environmental Supervision Consultants, Construction Companies, Insurance, Market Research

User Group 2: Private Educational Institutes

Examples: ISU, Stanford Research Institute

User Group 3: Satellite Business

Examples: Matra-Marconi, SPAR, Dornier

User Group 4: Picture Advertising

Examples: Poster, Postcards, Photos

User Type III: Scientific

User Group 1: International Scientific Organizations

Examples: ICSU (International Committee of Scientific Unions)

User Group 2: Universities/Colleges

User Group 3: Other Research Facilities

Examples: National Laboratories or Institutes

User Group 4: Weather Forecast

Examples: National Weather Services

User Type IV: Public

User Group 1: Schools and Colleges

User Group 2: Libraries

User Group 3: Rescue Survey

Examples: Search and Rescue (SAR)

User Group 4: Emergency/Disaster Aid Supply
Examples: Red Cross/Red Half Moon

User Group 5: Non-Profit Scientific Societies
Examples: National Space Society, WWF

5.1.2.4 Services

The uses for which GEOD services may be used are largely limited only by the imagination of IPEO and the client. A few examples of GEOD's potential capabilities will be given below.

a) Basic Data Search

Data users may interrogate the database to establish which data processing organization has expertise and facilities to deal with his particular requirement. Data processing organizations can identify current and planned satellite capability and coverage areas. Research organizations may interrogate the database to survey sensor capability and identify gaps requiring further research and development.

b) Market Research

Statistical analysis may be conducted on the database to discover many factors of interest to market researchers:

- The market demand for a particular type of product;
- The geographical split of demand for particular types of product;
- The geographic split of clients.

c) Internal Management Tool

IPEO units may use GEOD to assess demand for their services, analyze volume of demand per product, geographic split of demand and clients and so on. This information may be used to help ensure that resources are targeted efficiently to meet demand, identify unmet needs and required research, and to assist in the location of IPEO regional centers.

d) Geographic Search

A client may request information such as which satellites cover a particular geographic area, when was the last pass, what was the cloud cover on that pass, temporal resolution, spatial resolution, radiometric resolution and spectral resolution. If the client has suitable equipment a 'quick look' image may be obtained from the satellite operator by GEOD and forwarded to the client over data links. This enables the client to ensure clouds or other factors do not obscure the area of interest and to confirm the overall quality of the satellite image prior to purchase.

5.1.2.5 GEOD Structure and Evolution

Although the final structure of the GEOD system will be defined later, a setup system structure was created for initial operations. This structure is shown in Figure 5.1.2.5 - 1. The primary GEOD system will handle creation of the database itself, its provision with data content, installation of supporting facilities and the start of GEOD's operational functions. The primary GEOD structure is shown as an internal network with two interfaces, one for interactions with the consumers (operational gate) mainly based on computer use, and the other for Public Relations and Information Requests addressed to GEOD by the public (information gate). This second gate will depend more on traditional forms of communication like mail and telephone, but will also take advantage of modern systems like electronic mail.

The internal structure of GEOD at this time consists of six major components:

- **The GEOD Database:** The main database itself will contain all information that was given to it by the check-in and further requests of the consumers. It provides direct access to the client's requests and also helps supporting IPEO staff, in case problems are experienced in operation of the database or assessing the exact data required. A technical staff from the IPEO Computer Network Services group is in charge of proper function of hardware and software.
- **Internal Database:** This smaller database contains information about number and size of accesses to the main database for billing purposes and analysis. All accesses of consumers to the main GEOD database will be reported automatically to the small database. Because the internal database handles information about the operational statistics of GEOD, it will be for use of the GEOD operational team only.

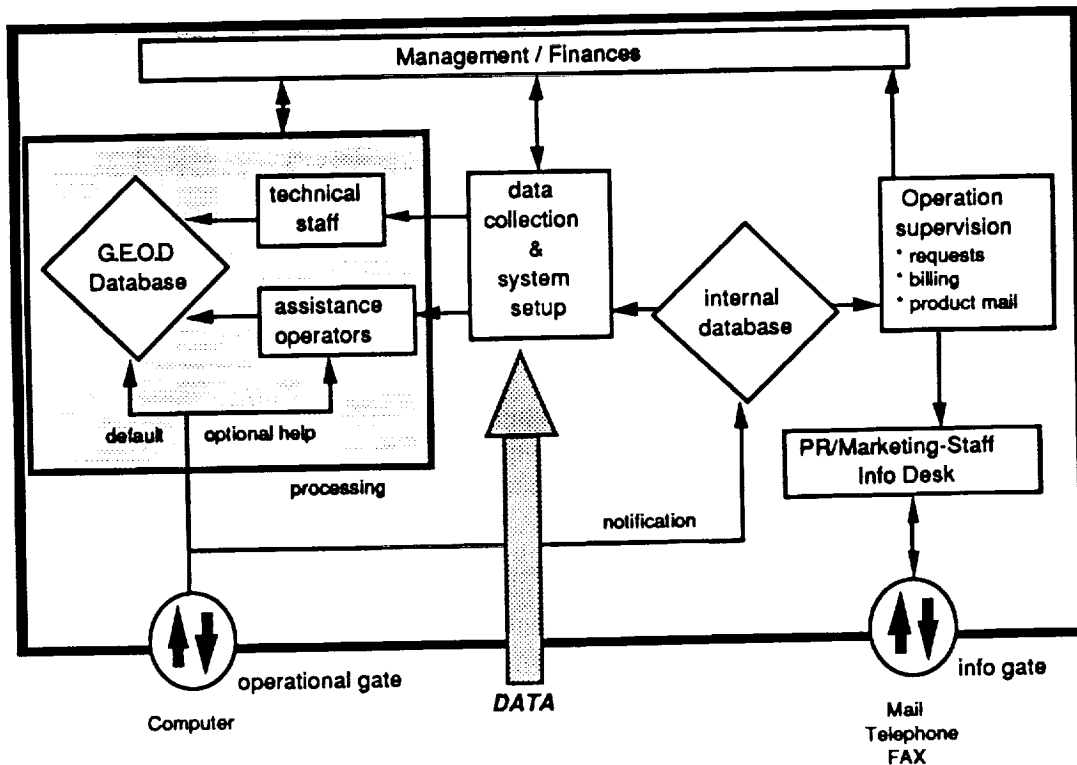


Figure 5.1.2.5 - 1 Initial Operational Structure of the GEOD System

- **Data Collection and System Setup Staff:** The most critical point in the initial phase of GEOD will be data collection and the implementation of these data into a proper database structure. Since GEOD's growth and value will depend mainly on the number of consumers it is able to serve, this task is of major importance for the success of GEOD and IPEO. For this reason, the Data Collection and System Setup staff will form the largest component of the initial GEOD structure. Primary data sources for the GEOD database can be provided by existing directories and documentation, e.g. the National Directories provided by several countries, expanded IPEO Country Notes and other existing databases.
- **Operation Supervision:** This small staff will oversee day to day GEOD operations. This staff will refine the information and statistics produced by the internal database. A main objective in addition to the supervision of the operational status of GEOD (considering request handling, billing and product transfer) will be reporting request patterns (e.g. a significant dominance of certain addressed topics or areas) to IPEO management to optimize GEOD

services. The supervisors also will transfer general information to the Public Relation Staff.

- **Management:** The Management Group will set up the operational outlines of GEOD referring to the reports prepared by the Operation Supervision Staff. There must be a smooth interface between Management, GEOD Database, and the Data Collection and System Setup Staff.
- **PR/Marketing Staff:** A special task team of the IPEO Marketing division will be formed for public relations/marketing purposes and to set up an information front desk to serve the public. Presentations for potential consumers, e.g., on scientific or industrial symposia, will be organized by this staff.

The Setup Plan for the GEOD System suggests an initial core of five managers for the execution of the setup procedures. The selection of a Data Collection and System Setup Panel will be one of the most important early tasks for IPEO management. Additional management support may consist of the Advisory Board with technical and scientific experience for the recruitment of the collectors and system setup staff.

Before setting up the database, a careful check of the current availability of hardware and software is recommended. These checks must be supported by additional research about the needs and suggestions of potential clients, e.g. in form of canvassing and from the Country Notes.

The data collectors should provide an initial amount of information which can be introduced into the database as basic contents. System checks with prototype operations, provided by GEOD staff as well as by cooperating potential clients, should be run to check out proper function of the system and data validation before the first public runs. This setup phase could last from 12 to 15 months.

Objective system observation will be critical especially during the early phases of public operations which must be supported by a large Public Relations initiative. Canvassing may be useful to achieve clients responses after a running period of about three months. For further developments, GEOD should be as free as possible to make its own decisions for operational optimization.

Within this primary phase the Data Collection & System Setup Staff will contain the largest total number of participants as well as the most specialists, followed by the staff for the main GEOD database.

| | |
|---|-----|
| • Technical Staff & Assistance Operators for GEOD Database: | 30 |
| • Data Collection Staff & System Setup Advisors: | 65 |
| • Management and Finances: | 10 |
| • Operation Supervision: | 3 |
| • PR-Staff and Information Desk: | 7 |
| <hr/> | |
| • Estimated Total Setup Personnel | 115 |

This estimation of needed personnel for the GEOD setup is valid for the initial phase of this institution. However, there will be a change in the distribution and size of the GEOD operating team when the primary system evolves to operational status, attracting more and more clients and therefore increasing the size of its database. Although the quantitative aspects of this evolution cannot be foreseen at this point, a rough estimation of the development shows a large decrease in the Data Collection and System Setup staff after implementation of the database. As the system becomes operational there will be a shift in its major data source from manual input by GEOD Staff to automatic recording of consumers' information. In contrast, the size of the supporting staff for the GEOD Database will remain about the same as efficiency of operating practices increases to handle the growth of the database and the number of client accesses. When fully operational, the data collection and system setup staff is expected to be not larger than ten people, while the technical staff and assistance operators of the main database will remain at about thirty people. Only slight modifications are expected in the other groups, and GEOD therefore is estimated to employ about sixty people.

5.1.2.6 Country Notes

A Country Note was designed during the project to contain a set of information about the needs, interests and sensitivities of a particular country with respect to specific topics. For IPEO, focus has been put on information about remote sensing and/or data processing capabilities, current and/or planned programs of Earth observation and environmental problems of national significance. This information (see Appendix A) may bring answers or add new ideas about who the users of IPEO will be, how IPEO could be implemented at the national level, where the potential sources of funding may be found, what infrastructure already exists, and what role IPEO can have among existing programs and organizations.

The Country Notes were used for the IPEO design process. They provide a useful tool for political as well as marketing perspectives. They will then be transformed into IPEO products. They thus constitute an important part of the information service that is one of the strengths of IPEO.

In order to get quick feedbacks from the potential users of IPEO, a preliminary questionnaire was established for the Country Notes. The issues addressed are set in such a way that national points of view are highlighted. The questions are related to:

- The involvement in space activities;
- The involvement in international activities;
- The concern about environmental issues;
- The utilization of remote sensing data;
- The access to complementary data; and
- The financial involvement in remote sensing of the country.

A list of the main remote sensing centers of the country was requested. Specific references as well as the most important features (fields of application, computing capability, use of GIS, etc.) were queried. Finally, direct questions are formulated about the potential interests of the country for the services of IPEO. Additional questions are intended to permit the identification of new needs. Short answers, crosschecking, no/yes, or synthetic tables were enabled.

The 27 Country Notes completed so far by the ISU students with the help of the faculty are gathered in Appendix A.

Examples of Country Notes questions are given in Figure 5.1.2.6 - 1 below:

- Which of the following environmental issues (or common interests) are of importance to your country or to specific regions of your country?
- * Deforestation (1); Global Warming (2); Pollution (3); Land Resources (4); Vegetation Dynamics (5); Bio-mass Inventory (6); Water Quality (7); Soil Assessment (8); Urban Development (9); Ground Water (10); Acid Rain (11); Ozone Depletion (12); Crop Forecast (13); Insect Migration (14); Snow / Ice (15); Ocean Resources (16); Wildlife Monitoring (17); Flood (18); Desertification (19); Other (be precise).

| Priority | Issues | Is your country actively involved in modelling and monitoring the problem? If <i>yes</i> , how? | Annual Budget or Percentage of Environmental Budget Spent on This Issue. |
|------------------------------|--------|---|--|
| <i>1st prior.</i> | | | |
| ... | | | |

- Considering previous answers or more personal views, do you think that new data or information related to the deforestation phenomenon would be useful to the country?

No Yes Maybe

- What is the annual space budget (in U.S. \$) of your country?
- What is the annual space budget for Earth Observation from space?
- Does your country foresee an expansion of its involvement in remote sensing activities? In which directions?

Figure 5.1.2.6 - 1 Examples of Country Notes Questions

Before the setup phase of GEOD begins, the current questions must be crosschecked, full answers must be completed, and more countries must be included. New questions could be formulated also. All the new information will be useful for refining the IPEO design. It will help keeping track of national needs in the field of remote sensing and more specifically on environmental research and management. Provided that general interests are valid, taking into account national needs will greatly reinforce the survivability of the IPEO organization and the quality of the IPEO programs.

The information gathered in the Country Notes will be used as one of the principle sources of preliminary data for the GEOD. Part of the information may directly enter the database, and be adapted to the GEOD framework. Part of the information may be utilized as a source of further information and other parts of the information may be compiled in the

database listing all points of contacts, centers in specific fields (e.g. remote sensing laboratories dealing with research in deforestation).

As it is designed now, GEOD could retain the information produced by the Country Notes in three categories: mandatory, optional, and additional. Mandatory and optional parameters are already defined for the GEOD. The series of additional parameters could be organized in sets of specific issues. For example, the IPEO organization may want to know more about research on deforestation and reforestation. It may want to handle these information and make statistics, compare the needs of contiguous countries. Country Notes inputs to GEOD are visualized in Figure 5.1.2.6 - 2.

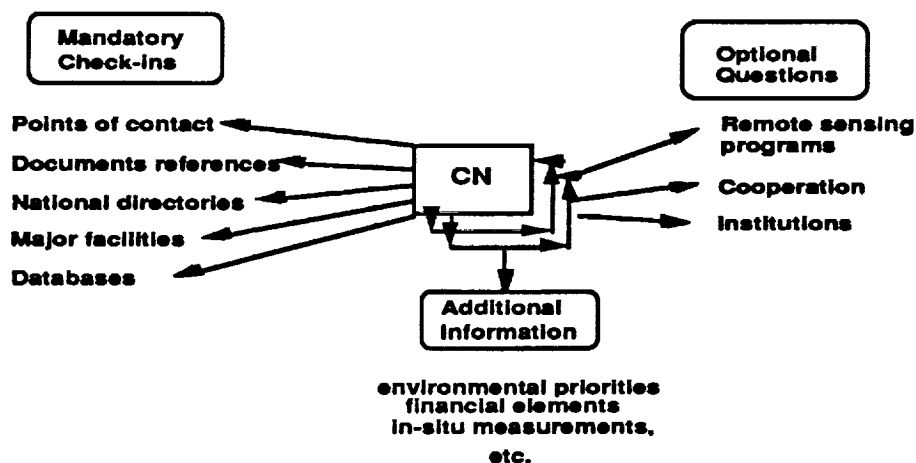


Figure 5.1.2.6 - 2 Country Notes Inputs to GEOD

New questions of general interest could be added to the questionnaire, in order to enhance the "standard" format of the Country Notes. Some questions may be entered temporary in the questionnaire for the sake of a marketing survey. An example question of this type could be: "Would your country be interested in getting maps about forest cover, on a regular 30 day basis? The answers to such questions are not necessarily limited to the national level. In each Country Note, a grid of prime institutions can be established, and a customized answer may be provided from each institution.

Country Notes questions require updating. For instance, prices could be mentioned for a given remote sensing product, or annual updates of space budgets. Because the current maintenance of the information is very important, the IPEO staff must carry out continuing investigations. They may collect information through the IPEO regional

centers. They may also receive the data through the IPEO users network. An additional regional questionnaire may be created for that purpose.

Incentives should be found so that those users, either research or application oriented, would release to IPEO new information as quickly as possible. For instance, they would mention the growth of their computer facilities or the production of new models. In so doing they would be in effect be advertising their improved facilities.

Several features stress the uniqueness of the Country Notes. Some of them that have an impact on the performance of GEOD, are:

- User-friendly presentation of information. The information extracted for GEOD and presented in a Country Note format are not raw. They are rationally selected, processed and sorted out, on a case by case basis.
- The adaptability of the Country Note format, as well as the growth potential of the database. Several sets of Country Notes may be created, some specific, some permanent, some temporary.
- Up-to-date information, thanks to a good maintenance process as well as an interactive system of communication between the users.
- The multi-purpose function of the Country Notes. Users may be governmental bodies or private entities. They may look for local, national or international information. They may access a broad variety of products, as shown on Table 5.1.2.6- 3.

Table 5.1.2.6 - 3 Country Notes Utilization

| <u>USERS</u> | <u>EXAMPLES OF UTILIZATION</u> |
|-------------------|--|
| Individual | Search for partners, or local remote sensing specialist. |
| End-users | Advertising about one's laboratory, one's product. |
| Local entities | Listing other entities specialized in same area. Quicklook over programs, public information. |
| National entities | Description of major facilities. Statistics, financial elements. |

| | |
|----------------------------|---|
| Government bodies | Directory of main centers dealing with a range of subjects. Overview of other nation needs, of neighboring capabilities. |
| International institutions | Look at existing cooperation teams. Reference of national policies. |
| IPEO itself | Identification of new needs, new users Information about national policies |

The products extracted from GEOD may range from a question, on one country note, to a whole set of country notes, depending on user needs. Questions may be created for a temporary survey and in that case, users will be suppliers of information as well as consumers.

5.1.2.7 Financing

Three main methods of raising revenues from GEOD have been identified: password access fees; database file fees for data gatherers and processors; and sales of database sections by disks tapes.

Password Access Fees

All clients are allowed 3 free accesses to the GEOD database to evaluate the worth of the system. After this they are invited to join as subscribers to the database and receive a password upon receipt of the fee. The amount of this fee could be dependent upon the number of accesses to the database that the client wishes to make per month. An example pricing structure is given below.

| | |
|---------------------------|-------------------|
| 1-5 accesses per month | \$ 250 per annum |
| 5-20 accesses per month | \$ 1500 per annum |
| 20-100 accesses per month | \$ 5000 per annum |
| >100 accesses per month | \$10000 per annum |

An additional fee will be required if access is desired to the 'quicklook' satellite picture facility.

Database File Fees

Data gatherers wishing to have a detailed entry file in the GEOD database will be charged a fee dependent upon the number of information retrievals from their file per

month. In this way the large organizations having greater business pay more than small scale organizations with a small client base. Any data gatherer or processor who does not wish to pay the fee would have his record maintained on the database with all information retained except his name and address. In this way the information needed for statistical analysis of market capability and size is still available while not allowing any business to be generated for his organization from that entry file. An example pricing structure is given below for file fees.

| | |
|-----------------------------|-------------------|
| 1-5 retrievals per month | \$ 750 per annum |
| 5-20 retrievals per month | \$ 2500 per annum |
| 20-100 retrievals per month | \$10000per annum |
| >100 retrievals per month | \$25000per annum |

Sale by Disk

This service would allow sections of the database to be available on disk or tape for use on the client's host computer. For example a standard selection of data samples could be made available for use by educational establishments for training. If a client wishes to access a particular data set repeatedly (tropical rain forests, for example), then a selection could be made up to the client specification for use at their establishment. Some example costs are given below:

| | |
|-----------------|---------------------|
| Educational | \$ 150 single user |
| | \$ 500 site license |
| Client specific | \$ 500 single user |
| | \$1500 site license |

Costs

The cost of the initial start up phase is estimated below:

| | |
|---------------------|--------|
| Salaries | \$4.0M |
| Hardware/Software | \$3.5M |
| PR/Marketing budget | \$1.5M |
| Total | \$8.5M |

The annual cost of the operational phase is estimated below:

| | |
|---------------------|---------|
| Salaries | \$1.75M |
| Hardware/Software | \$1.0M |
| PR/Marketing budget | \$1.0M |
| Total | \$3.75M |

Market

A possible market for the GEOD products has been estimated and is detailed below:

| | |
|---------------------------|---------|
| After 6 months operation, | |
| Data Gatherers | 35 |
| Data Processors | 400 |
| Data Users | 1000 |
| Estimated revenue | \$2.05M |
| | |
| After 5 years operation, | |
| Data Gatherers | 125 |
| Data Processors | 1500 |
| Data Users | 4000 |
| Estimated revenue | \$7.05M |

5.1.3 Research Groups

5.1.3.1 Current Status of Global Environmental Research

Many programs of international scope have been set up in response to crucial environmental problems of the planet Earth. Examples include the International Geosphere-Biosphere Programme (IGBP), Global Change, EOS, and WCRP. All of these have been initiated by the scientific community, with funds primarily provided by governments, in order to try to understand the complexity of Earth mechanisms. A wide variety of research laboratories in the world are involved in these programs, working more or less in cooperation, often in the same range of disciplines. The potential of using such a scientific network could be of the greatest importance for IPEO research functions. This scientific network has to be understood as the potential network available for IPEO in the scientific community.

Effective interactions are often difficult to obtain between groups involved in different programs addressing similar environmental issues. The programs may have been created by one organization like NASA for EOS, or promoted by an international organization like the UN for GRID or initiated after consensus of various scientific bodies such as ICSU for IGBP. The reasons for the difficulty of interactions may relate to different organizational objectives and perspectives resulting from the type of organization involved and the different knowledge, perceptions, and cultural environment of the individuals formulating the programs. For instance, EOS and IGBP are two important programs dedicated to science in order to enhance the understanding of the Earth. The data and information

gathered are available for the scientific community primarily. This implies that the IPEO research structure must be created carefully to present IPEO as a possible scientific coordination structure, to promote cooperation, communication, and effective initiatives. A strategic approach has to be defined for this purpose.

Close exchange between scientists is limited by physical distance between scientific institutions and the increasing specialization within each scientific subject area. The propagation of information about key studies necessary for global environmental understanding is quite difficult to assure even in scientific community. The difficulty of the "public" to understand what scientists do in order to solve the problems of the Earth, also indicates the weakness of scientific communication with the "non-scientific" public. It is often problematic to address a specific request to the scientific community unless a minimum of knowledge exists in the field concerned.

One of the key issues for the IPEO research structure is its scientific credibility. To achieve high credibility, IPEO must demonstrate its capacity to deal with scientific problems on a global and local scale and to pursue rigorous research in relevant disciplines. In the IPEO context its missions may be defined as the following:

- To define the specific research needs in non-covered fields;
- To develop research studies with other research organizations or laboratories on specific subjects; and
- To cooperate with the most efficient scientific partners.

Credibility to achieve these missions may be obtained by the participation of well-known scientists in the IPEO structure at a scientific decision level in the Advisory Board.

To provide leadership as a resource organization in Global environmental studies, IPEO has to establish an effective and timely coordination and multidisciplinary cooperation on the international level. To achieve this goal, it is necessary to have a good idea about all the operational or planned research programs in order to examine carefully the types of interactions that could be applied. Most programs are involved in the creation of specific data-bases which could be of real interest for IPEO. The cooperation from a multidisciplinary perspective could be achieved by the promotion of research programs involving several scientific fields. For instance, relative to the pollution problem, physicists, chemists, life scientists and resource specialists could be brought together.

One example of cooperation would be to have the IPEO research team define the design of new sensors with the IPEO satellite/sensor development people and with industry involvement.

The IPEO research team has to be aware of scientific advances in order to be able to integrate and adapt them to the research program direction IPEO wants to promote. One of the main features of the IPEO research structure is that it must be in tune with the scientific

networks involved in the different research programs. This is required for the following reasons:

- To be aware of the advances in the different research fields;
- To collaborate with different research organizations around the world;
- To foster a high level of interaction and cooperation within the scientific community;
- To assure the longevity of the system, means to assure the input from the scientific network to GEOD, and maintain the high quality of the services available for scientists;
- To improve GEOD, that means to meet the need of the GEOD data-base in terms of communication, search of information, but also in terms of up-dating the data about studies, laboratories, new methodological products, research results; and
- To optimize the potentials of the Users Support Division through the Application and Emergency programs (GIS).

The Scientific network is a part of the dynamic constituents of the IPEO research structure. As shown in Figure 5.1.3 - 1, the interrelations between the components would be intense in order to provide the enrichment of GEOD and to assure a high level of interactivity.in research.

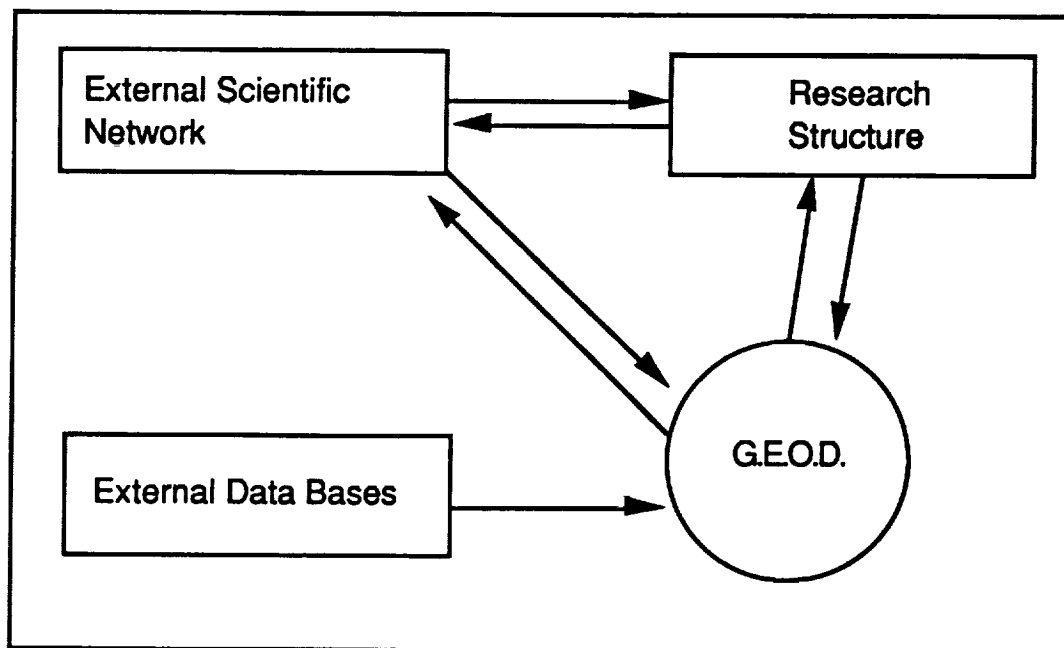


Figure 5.1.3 - 1 Scientific Network

In conclusion, several major objectives have to be achieved in order to provide leadership as a resource organization in global environmental research.

- The scientific credibility is important to assure the support of the scientific community to the IPEO Project in a long term perspective. The relationships between IPEO and the research organizations are one of the bases of the IPEO project. The scientists involved in the IPEO research programs or the ones which are supported by IPEO, around the world will provide both interactions with the studies and with the other international programs, and dynamic input processes.
- Among the tasks which could be assigned by the IPEO research structure, one is to act as a unique structure providing information, cooperation, and communication with the external partners and to support, as an internal service, the updating of the IPEO data-base, GEOD, by the scientific network.
- Important characteristics of the IPEO research structure will be the integration of relevant results responding to perceived environmental assessment needs, to be flexible according to scientific evolution, and to be able to develop research direction programs to the representatives of the scientific community.

5.1.3.2 Internal IPEO Research Structure

The IPEO research structure has two main levels of intervention, one internal as a service to IPEO operations and one external, as a support and also as an essential node in the Global environmental studies scientific network. The interactions are illustrated in Figure 5.1.3 - 2.

Research must support the constituents of IPEO through Application and Emergency Programs (GIS), and Education and Training and GEOD. Research will analyze specific problems, interpret processed data, develop specific products in terms of modelling, methodological treatments in remote sensing and GIS, and support studies in case of emergencies. Research will participate in the design of teaching support for the Education and Training.

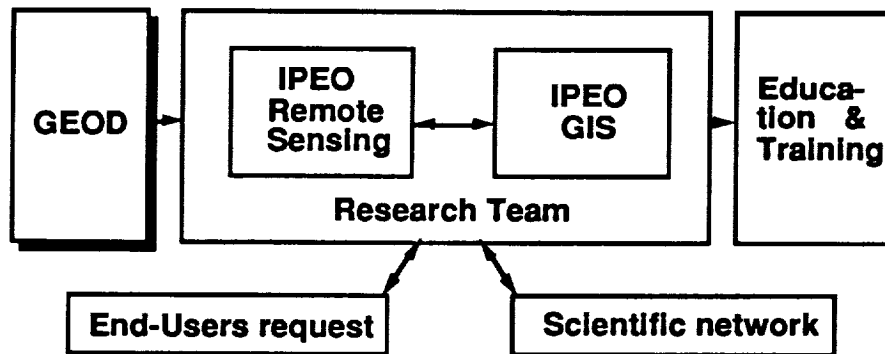


Figure 5.1.3 - 2 Research Structure

Research will support "Unmet Needs Assessments and Research" included organizationally in Advanced Programs and Research. The following main tasks were identified in this area:

- Research on unmet needs, in order to identify scientific and/or technical problems which are not studied at the moment and to define basic research directions for collaboration with other research organizations.
- Specific analysis and modelling.
- Analytical and synthesis of studies pursued in the different research organizations.
- Promotion of scientific research programs proposed to and adopted by the representatives of the scientific community sitting on the IPEO Advisory Board.
- Plan specific measurement campaigns or research in collaboration with outside research organizations and/or end-users.

In Chapter 6, the study of the deforestation problem provides a methodological and technical approach which could be applied in other areas by the research structure.

Finally, part of the "Methodology and Technology Development" process facilitates transfer to users. Two aspects are covered here.

- Knowledge and experience is transferred (software development in Remote Sensing and GIS, methodological developments); and
- Designs are proposed for new sensors in collaboration with the satellite sensors development team and/or with industrial partners.

Processes validated by the IPEO research structure can be considered as IPEO "products" and be placed eventually in the public domain to be used by end-users. These products could be disseminated through the educational and training sessions.

5.1.3.3 Implementation of the International Research Program

Another output of the IPEO research structure is to propose international and multidisciplinary programs. This can be done under the supervision of the representatives of the scientific community which would interact with the Advisory Board.

Members of a Scientific Committee would be those sitting with the Advisory Board as representatives of the scientific community. This small working group would give IPEO scientific credibility. The Scientific Committee has to define research directions taking into account existing research programs and programs proposed by IPEO research. The following types of programs initiated or supported by IPEO can be foreseen:

- Bilateral programs between two or more research organizations, or end-users;
- Bilateral research programs with industrial partners; and
- International research programs.

As IPEO cannot give financial support for international research studies, all the efforts proposed by the IPEO structure would be based on available resources. In this context, some agreements could be made with governmental agencies and international organizations, in order to favor the most efficient collaboration and interaction. It may be possible for IPEO to initiate small scale studies on precise goals.

IPEO research proposals will be reviewed by the scientific community in order to ensure scientific credibility. The resources IPEO is able to provide to the international research programs (free access to IPEO data, in-situ measurement campaign, international coordination) has to be defined by the Board of Governors. One requirement which should be considered is that IPEO participation in international research programs, or all programs promoted by IPEO, have to be made available to IPEO as a final report.

The designation of scientific representatives to the Advisory Board could be made by the Council of IPEO or by the Director General following recommendations from national

or international scientific organizations. The duration of Advisory Board membership is proposed for either two or four years, on a rotating basis.

Another relationship, more subtle to define, could be long term agreements on scientific problems, to perform "gray research" with industrial and institutional teams. International influence of the scientific community must be powerful enough, to push the different governments to favour such joint developments. As an example, it could be interesting to address such joint efforts to international pollution problems.

A limited survey among the ISU students representative of different countries provided interesting results on three questions concerning the notion of a scientific network, international research program, and some scenarios to promote specific environmental studies. The results of this survey are presented in Table 5.1.3.3 - 1 and Table 5.1.3.3 - 2.

Table 5.1.3.3 - 1 Student Survey Results (1)

| Network | High level Knowledge | Communication | Access Data | Access GEOD | Synergetic process |
|----------------|-----------------------------|----------------------|--------------------|--------------------|---------------------------|
| U.K. | | Y | | Y | |
| USSR | Y | Y | | | |
| CHINA | Y | Y | Y | | |
| INDIA | | | Y | | |
| BRAZIL | Y | Y | | Y | |

Table 5.1.3.3 - 2 Student Survey Results (2)

| International program | Sc.credibility | Precise Directions | Funding | Free access to the data |
|------------------------------|-----------------------|---------------------------|----------------|--------------------------------|
| U.K. | Y | Y | | Y |
| USSR | Y | Y | Y | |
| CHINA | Y | Y | | Y |
| INDIA | | | | Y |
| BRAZIL | | Y | | |

What should be noticed here are the remarks made by the students concerning the first table on the necessity to avoid redundancy in research, and to optimize the dissemination of the information all around the world. Access to information seems to be an important point for people who have to handle a large amount of data in order to model some particular mechanisms.

Table 5.1.3.3 - 2 emphasizes the necessity for an international research program to have scientific credibility. This credibility is necessary to assure the image of the organization sponsoring the research. Precise research directions are stressed more than the access to the data. These two points should to be taken in account as further IPEO research design unfolds.

In Table 5.1.3.3 - 3 it is interesting to notice that partnerships with industrial entities are strongly emphasized. The exchanges of students or staff are desired more by "newcomers" on the space scene. Seminars sponsored by a central body also received favor.

Table 5.1.3.3 - 3 Student Survey Results (3)

| Impulse | Bilateral research | Exchanges | Seminar | Bilateral indus. | Intern. prog. |
|----------------|-------------------------------|------------------|----------------|-----------------------------|--------------------------|
| UK | | | | Y | Y |
| USSR | | | | | Y |
| CHINA | | Y | Y | Y | |
| INDIA | | | | | Y |
| BRAZIL | | | Y | | Y |

5.1.3.4 Staff, Equipment, and New Products

When the IPEO structure will begin to be operational about 1996, a qualified staff will be put in place. Initially, the research team will be composed of five people, one involved with the management structure and links with the overall IPEO structure, one to develop contacts with the scientific network and the headquarters of different international programs, one to define equipment needs and to prepare requirements benchmarks, and two others to facilitate the recruitment of the staff.

The responsibilities of the Director will include links with the IPEO scientific and management structure. This person will develop relationships with other research organizations, represent the IPEO research structure, and assure the dissemination of the internal information. He/she will be responsible for the development of priority studies and management of the team. Collaboration programs will be signed by the Director. He/she will be responsible to the Director General.

A secretary will conduct the administrative part of the work for the research structure. A librarian will be in charge of the search for literature information and for the input of information in the GEOD data-base coming from the research team.

Two GIS Specialists, highly qualified in spatial analysis studies and applications, will be in charge of the research and the development of the GIS and other spatial analysis tools in collaboration with the "resources staff". They will provide an interface with the international GIS research network (NCGIA-US and UK, GIS network in France, etc).

Three remote sensing specialists will have to deal with remotely sensed data in the fields defined in the research programs. These staff will facilitate the links with the international scientific network involved in international programs.

Two physicists will deal with basic questions of sensor design and signal response in collaboration with the other members of the team. Two computer scientists will work in coordination with the other members of the team to provide software maintenance and development as required. One image processing statistician is needed to provide support to the team in order to develop good statistical tools for image processing, GIS analysis and modeling. Four technicians will be involved in the research program development as support to the team.

At the starting point of IPEO, research equipment will be shared by the Application and Emergency program (GIS) team .

The products the research structure can provide are normally used by the internal components of the IPEO project, or the end-users :

- New techniques / algorithms for global modelling.
- Software developments in remote sensing and spatial analysis.
- Educational and Training support (material and lectures, handbooks).
- Technological designs.
- Specific products in terms of synthetic and analytical compilation on research topics. Publication of an annual or biannual review would be for IPEO a good means to disseminate the information available in GEOD.

5.1.3.5 Conclusions

To conclude this chapter it is important to stress several points from a scientific point of view. To provide the leadership as a resource organization in Global environmental studies, IPEO has to achieve scientific credibility . The importance of GEOD as a unique tool gives IPEO the ability to become a distribution node among other international programs. GEOD and its distribution provide IPEO the international location for the convergence of data (in generic terms) and information. The resources located in GEOD must be validated and enriched by the scientific network , and assured over time.

Access to the information over all the remotely sensed data (Meta data) by IPEO's Geographic Search system is an incredible asset. The possibility to obtain data at distribution cost for cooperative research also may be an asset. In terms of communication facilities, the scientific network will benefit from an enormous amount of information, but one of the more interesting products could be the analysis and the synthesis of research studies enabled by GEOD on different research fields of the Global Environmental areas. Conferences and seminars could profit from the synergistic processes that IPEO will initiate and maintain.

The most important asset of IPEO is its possibility to centralize crucial information which could be used by all the scientific community and the end-users. Scientific credibility is necessary to this function. The more IPEO contributes as a scientific resource

organization to Global environmental studies, the more the international scientific network will participate and cooperate.

5.1.4 Education and Training

The Education and Training Division within IPEO constitutes a major part of the effort to deal with the global problems of the environment. Through this division, it is intended that technical expertise around the world be improved and increased. The expertise covers all levels from the technician who is processing data on a computer, to analysts and advisors who assist with the formulation of government policy and help to implement campaigns to correct environmental problems. Though much of the training effort will be directed at countries which do not, as yet possess necessary expertise, some will also be directed at developed countries in order to alter management styles, redirect effort and change attitudes.

5.1.4.1 Policy

From the general statement of education objectives IPEO education and training policy was developed. Each point in the policy is taken here, one item at a time.

- A. In general, students should be taught in, or close to, their home country.

This policy has been developed for practical reasons. It has been found that a high proportion of students from developing nations, who study for extended periods abroad, do not return home at the end of the study period. This tends to defeat the purpose of targeting specific countries for education programs. Training programs should therefore be put in place in the target countries.

- B. IPEO should use existing educational institutions wherever possible.

Since there is an existing infrastructure of educational institutions around the globe, and since they represent more teaching expertise than can realistically be developed within IPEO, they should be used in the training network.

- C. IPEO headquarters should only be used for specialized training and for short courses.

This item follows on from items A and B. It would be expected that IPEO regional centers should be able to run more extensive training courses, but still within the constraint of policy.

D. IPEO headquarters should train teachers and managers.

In general, technician-level trainees would be educated in the field and only teachers would come to IPEO for training on IPEO courseware and techniques. At the same time, managers and policy-makers would be trained by IPEO in the IPEO philosophy, capabilities and methodology.

E. IPEO would identify countries which need to have training facilities put in place.

The Education and Training Division would use GEOD and other tools to identify those countries which do not have adequate training facilities to meet the needs of a global program for environmental management. IPEO would seek to establish training facilities in those countries through encouragement, provision of expertise, teacher training and supplying of courseware.

F. Development of courseware for training is an IPEO function.

The Education and Training Division would use all the internal expertise of other IPEO divisions and whatever external sources are available to develop resource material for training courses.

G Postgraduate level training should be developed in close cooperation with the IPEO Research Division.

Since training program courseware would be expected to reflect the latest techniques in the field, it is necessary for staff in the Research Division of IPEO to assist in the development of education resource materials.

5.1.4.2 Levels and Types of Training

There are several levels of training to be addressed, as follows:

- Technician level
- Local expert level
- Educator
- Manager
- Research (postgraduate) level

It has been stated that training at the technician level would be carried out locally, in, or near the home country of the student. This would also apply to local experts. Training

would be of two types: classroom and on-the-job training. The former can be carried out by technical college or at a technical university. The latter can be done in the place of work where Earth observation processing and analysis is taking place. The job-training program can be enhanced by the use of Computer Managed Learning (CML) programs, whereby a computer is used to supervise the training program, set tasks and test the student. The computer is not used to present training material. A suitable CML program would be the *ELMS Limited* product or some similar package.

Technicians who are acknowledged as experts could visit IPEO for short courses on the latest techniques. This new knowledge would be transferred to the field as the student would be expected to be or become a supervisor or educator in his home country.

IPEO would need to present, on a continuous basis, short courses of four to eight weeks duration for teachers and managers. The courses would provide training in the latest techniques, methodology and philosophical development of the IPEO technology and programs. The courses for teachers would be substantially different from those for managers.

Postgraduate level training would be open to the Masters, Doctoral or postdoctoral levels. Although it would be possible to use whatever IPEO technical facilities are available for this, it would be expected that students at these levels would work both in some research facility whether at university or elsewhere, or in cooperation with a university. Students at this level would be more closely related to the Research Division of IPEO than with the Education and Training Division.

5.1.4.3 Suitable Training Institutions

There several suitable training institution types which are appropriate for the IPEO training program:

- Technical Colleges
- Universities
- Data and information processing centers
- Private colleges
- IPEO headquarters and some regional centers
- The planned international Space University Masters program

5.1.5 IPEO Interrelationships

The heart of the IPEO internal working environment, as discussed earlier, will be GEOD which will also serve as the central front desk for IPEO as described in Figure 5.1.5 - 1 The chart and its interrelationships are explained in some detail below:

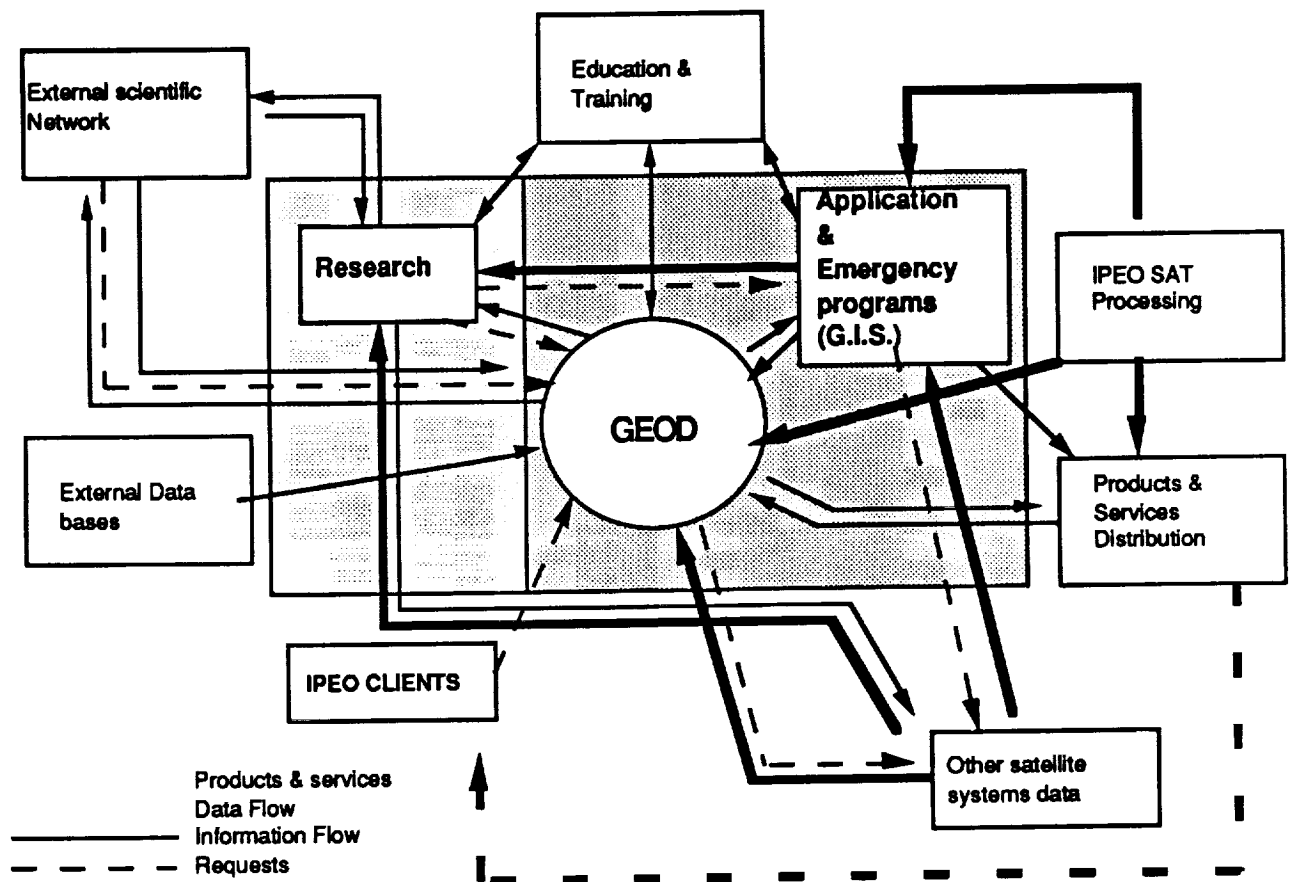


Figure 5.1.5 - 1. IPEO Interrelationships

- All requests from external clients to IPEO will be routed through GEOD, which in turn will direct the clients to the relevant IPEO services.
- The IPEO Products and Services distribution office is responsible for any distribution to meet the requests by the clients.
- Remote sensing data from the IPEO satellite will be used by Application and Emergency Programs (GIS), Research and, to a limited extent, by GEOD in a quicklook browse service.
- Remote sensing data from external satellite systems will primarily be used by Application and Emergency Programs (GIS), Research and to a limited extent by GEOD in the browse service.
- Information from external data bases is used by GEOD to update its directory.
- The information from external scientific institutions is primarily used by the Research group. Relevant information will also be used to update the GEOD directory.
- The GEOD, Application and Emergency Programs, and Research groups mutually support Education and Training.

- The internal flows between the three main components of the user support division will be permanent and extremely intense in nature, but cannot, at this stage, be worked out in more detail.

5.2 Technical Systems

5.2.1 Ground Technical Services

In order to provide the services made available by IPEO Operational Programs special care must be dedicated to the design of the technical facilities. Ground Technical Services will consist of a Central Facility, Ground Stations, Regional Centers, and data networks.

The Central Facility shall interface with the users, non-IPEO data sources (interconnection network), and the stations for collecting the data gathered by the IPEO satellites (data acquisition network).

5.2.1.1 Central Facility

The architectural concept of the Central Facility is illustrated in the Figure 5.2.1.1-1.

IPEOSAT Operations

IPEOSAT operations provides the facilities necessary for the control, monitoring and data acquisition of the IPEO satellites.

The Mission Management Center is equipped with several workstations. The software allows the planning of the IPEOSAT mission taking into proper account mission constraints (energy available on-board, ground station visibility, etc.) and user requests. It also supports management with respect to mission assessment, mission definition, and mission preparation.

The Operations Control Center is equipped with several workstations. It controls and monitors the orbiting spacecraft. It is responsible for the execution of the defined mission plan and the operations of the payload. Its software allows the translation of the mission plan into telecommands to be sent to the spacecraft, taking into account telemetry and tracking data. It interfaces directly with the TTC&M ground station(s) providing up and downlink with the satellite(s).

Data Processing & Calibration carries out level 1 processing (geometric distortion correction, SAR processing, data calibration, etc.).

Computer & Archiving Services

A data archive provides storage and archiving (several Terabytes) for raw and processed IPEOSAT data, as well as for other IPEO Technical Services. Limited on-line accessibility (e.g.: the last two months of observations) is provided.

The SuperComputer is utilized by the Applications & Emergency Programs group in order to generate the products requested by the users, and by the Research group.

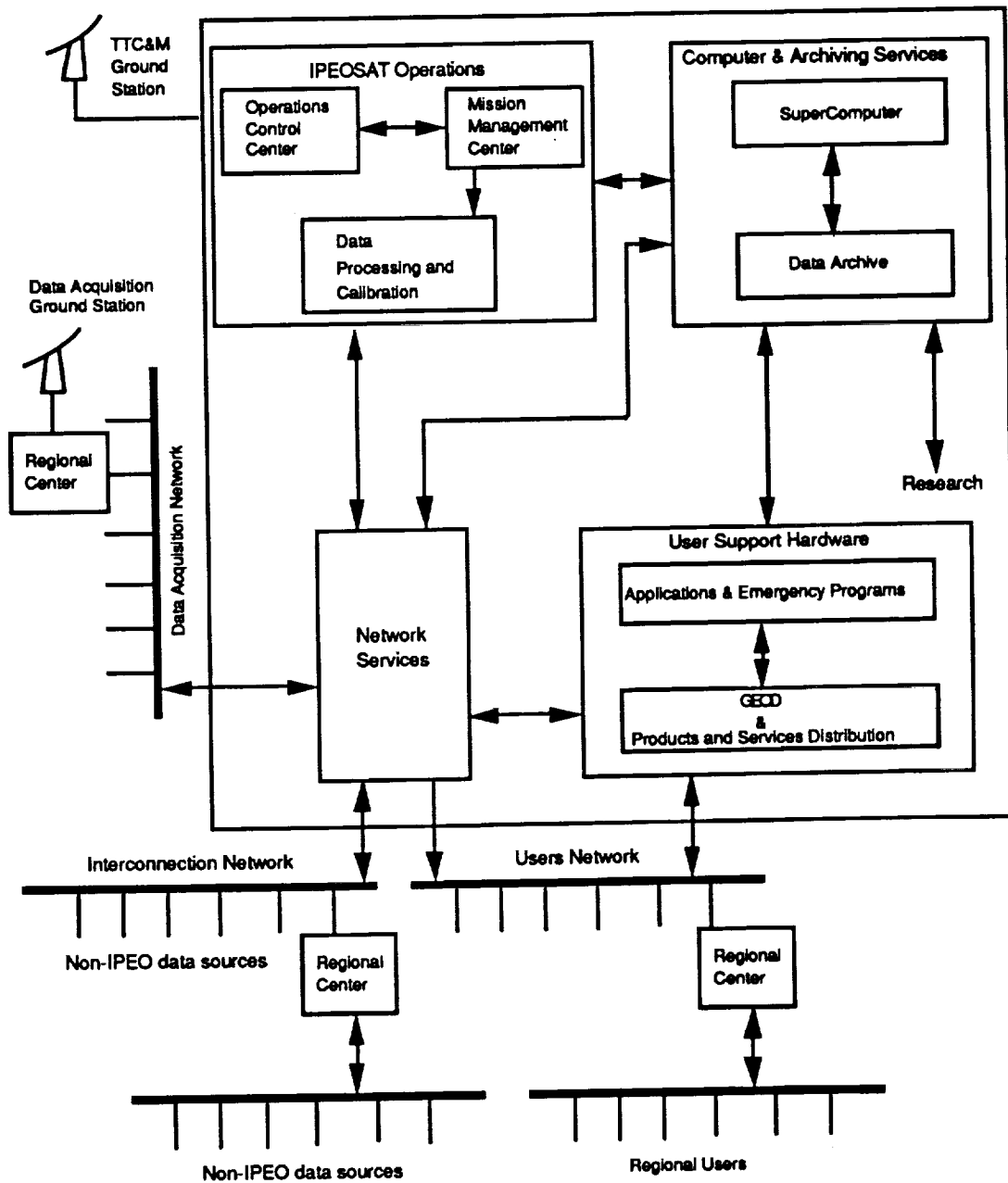


Figure 5.2.1.1 - 1 Operational Programs Central Facility

Network Services

Network Services includes all the equipment necessary for the operations, monitoring, and management of the IPEO Local and Wide Area Networks. This covers a very high speed backbone network to link the major entities of the Central Facility.

User Support Hardware

The user support hardware makes it possible for GEOD to address the user with desired services. Workstations and software are made available to the Applications & Emergency Programs and Product & Services Distribution groups to efficiently manage user requests and product distribution.

5.2.1.2 Regional Center

The architectural concept of a regional center is illustrated in figure 5.2.1.2 - 1.

Data acquired by the Ground Stations are routed through the regional Network Services which also handle the interfaces with the regional non-IPEO data sources and regional users.

The Regional Center functions described mimic on a smaller scale the corresponding functions of the Central Facility.

Regional Network Services are under the control of the Centralized Network Services.

5.2.1.3 Data Networks Subscribers Requirements

Introduction

Wide area IPEO data communications or networking can be carried out in many different ways, as discussed below.

The public telephone network provides low data rates, typically 2.4 to 9.6 Kbps. Depending on the utilization of the line, it can be advantageous to lease it on a fixed basis for a flat rate.

The public switched packet data network (PSPDN) is offered by all European and North American telecommunications authorities, but some developing countries do not yet have this service. It provides equipment and lines designed for and devoted to data transmission. Medium data rates up to 56 Kbps are offered. The charging structure is relatively independent of distance but strongly varies by the amount of data transferred.

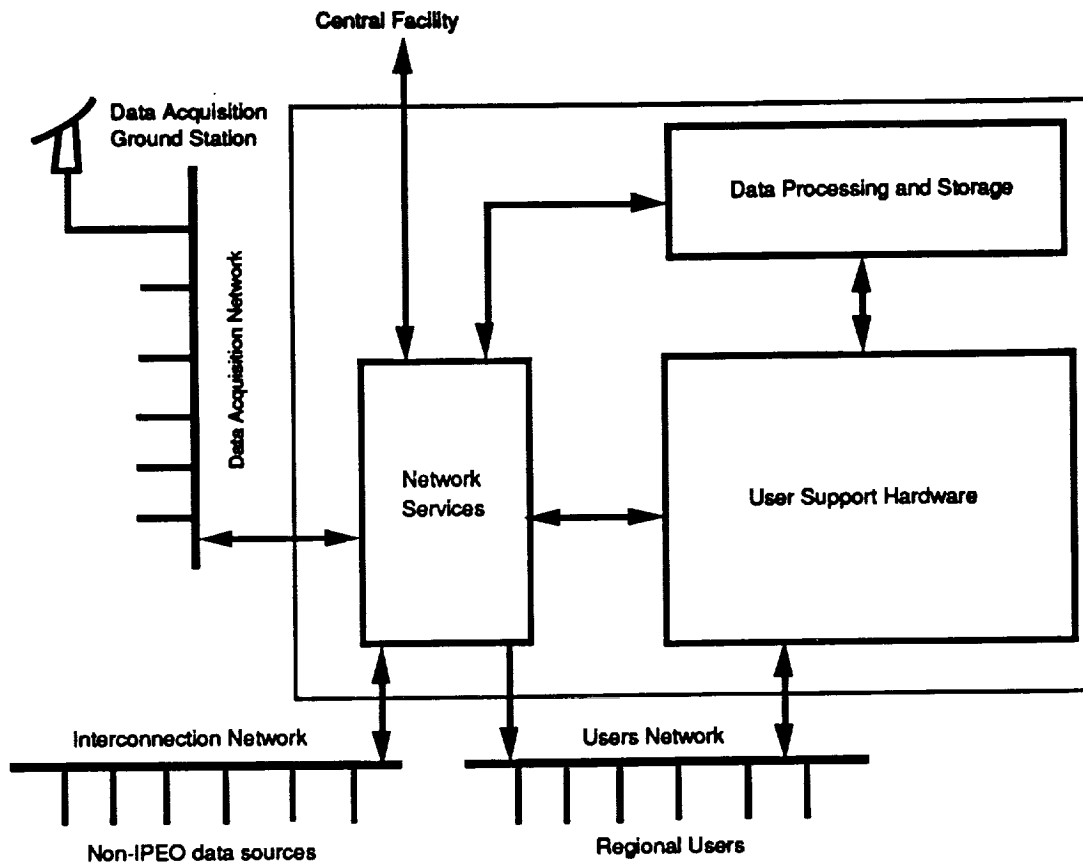


Figure 5.2.1.2 -1 Operational Programs Regional Center

The Integrated Services Digital Network (ISDN) is appearing in the telecommunications market place. It provides basic access at medium data rates of 56 (64) Kbps and primary access at high data rates of 1.544 Mbps (T1 carrier) or 2.048 Mbps (E1 carrier). Intermediate data rates of n times 56 (64) Kbps, with n varying from 1 to 30, are also possible.

The three logical networks interfacing with the Central Facility and the Regional Centers are described below. The subscribers of the networks and their requirements in terms of transmission speed are illustrated in Figure 5.2.1.3 - 1.

Data Acquisition Network

This network is composed of the ground stations that will acquire the data from the IPEO satellite(s), perhaps others. The network will route the stream of raw or preprocessed data to the IPEO Central Facility to be archived and processed.

The objectives of IPEO, in terms of operational monitoring and management of the environment, imply time constraints for the availability of products. The user may, for example, request the results to be on his desk within a couple of hours (or days) after the actual observation took place.

It must therefore be possible to transfer rapidly to the Central Facility data that have been acquired by a given ground station. Accordingly this study made the following performance assumptions:

- Payload instrument data rates in the 20 - 100 Mbps range;
- Average duration of spacecraft visibility from a station (downlink) around 7 minutes; and
- Transfer to the Central Facility of the acquired data within 90 minutes.

Permanent circuits offering 2 to 4 Mbps data throughput may be necessary between each data acquisition ground station part of the network and the IPEO Central Facility.

Non-IPEO Data Sources Network

This network links the Central Facility to several organizations, institutions or companies that provide environmental data. The Global Earth Observation Directory (GEOD), the Applications and Emergency Programs and the Research groups will heavily rely on these data sources to carry out their tasks.

A tentative list of the non-IPEO data sources is as follows :

- Earth Observation Satellite Company (EOSAT)
- EOS Data and Information System (EOSDIS)
- Earthnet Programme Office (EPO)
- Global Resource Information Database (GRID)
- IGBP Data and Information System (IGBP/DIS)
- National Environmental Satellite Data and Information Service (NESDIS)
- RADARSAT International (RSI)
- SPOT IMAGE
- World Meteorological Organization (WMO)

The databases and catalogues that they provide will be accessed on-line from the Central Facility via the GEOD. To allow real-time review of low resolution images, permanent medium speed data circuits will be required.

The IPEO itself will be an important user of external data sources, possibly with strict time constraints on the delivery to the end user of products combining several data sources. The transfer of high resolution images from a remote archive (e.g. SPOT IMAGE, ERS-1, EOSAT, etc.) will have to take place very early after an order has been placed. A system based on delivery by mail of tapes or disks will not meet these deadlines.

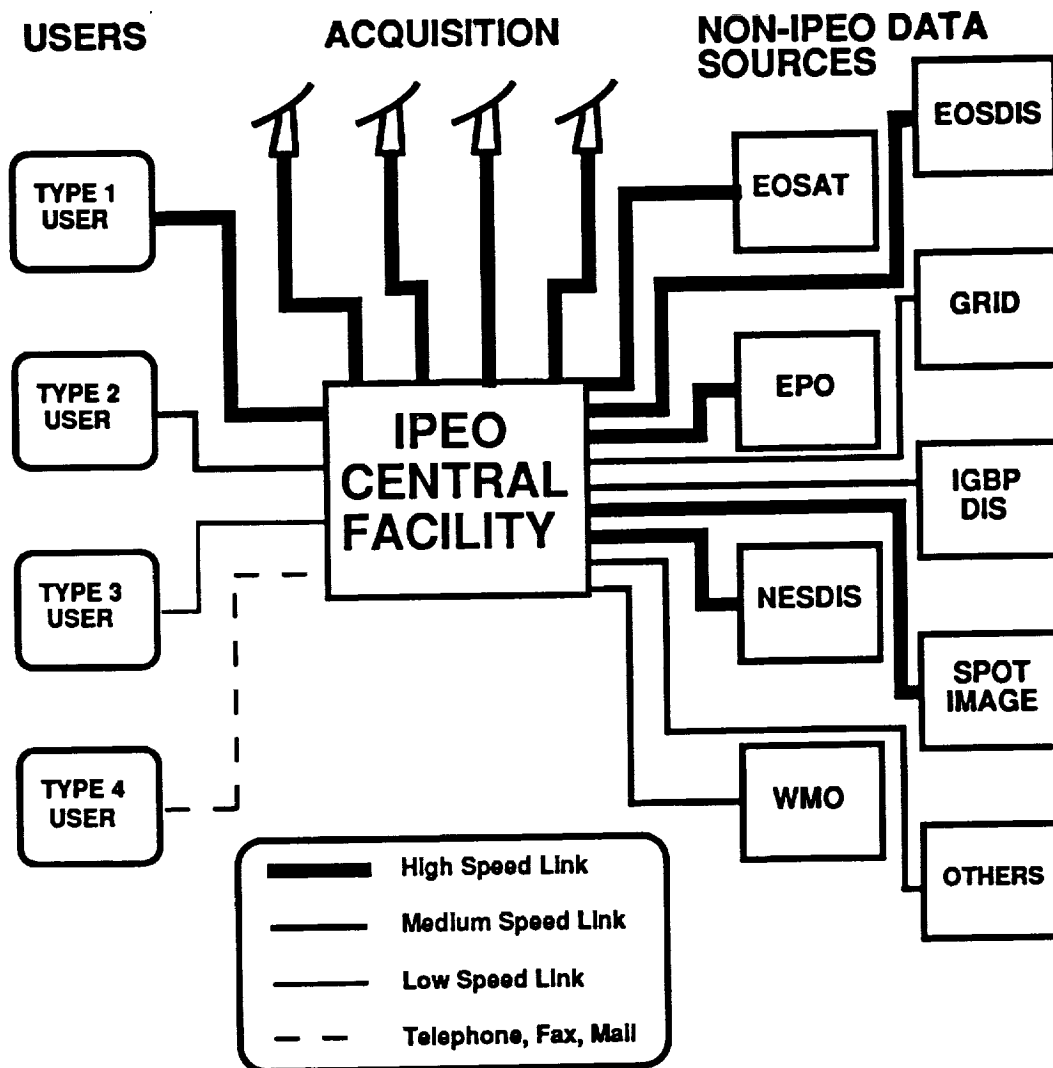


Figure 5.2.1.3 - 1 Data Network

The interconnection network therefore will require the availability of high speed (1.5 Mbps or more) digital circuits between the IPEO Central Facility and the remote data archives offering high resolution image products. The other data sources, which contain only text information or low resolution images, can be connected via lower speed data circuits.

Users Network

This network links the various users to the IPEO Central Facility. They will be connected to the Global Earth Observation Directory (GEOD) to request any information,

product or service. Satellite data catalogues, quick-looks, references, reports, etc. will be accessible on-line for display on the users' screen.

The users have been described earlier and classified into four different types, according to the capabilities of their computer processing facilities. From these assumptions their data communications requirements can be assessed:

Type 1 users are large consumers of remote sensing environmental data. They possess extensive facilities for the processing of data. They have to be able to receive rapidly full resolution images, hence will require permanent circuits with a medium or high data rate.

Type 2 users have one or more medium-size workstations for image processing. They need to receive textual information and low resolution images. Full resolution image files can be transmitted by mail, or use the network outside of peak periods. They will require a low or medium speed data link. Depending on the average amount of time spent on-line, and of the quantity of data transferred, this link can be permanent or established on demand.

Type 3 users possess a personal computer with limited capabilities. They might be able to display an image but cannot process it. To gain on-line access to the textual part of GEOD and possibly to transfer low resolution images, they will require a low speed data channel.

Type 4 users have no computer equipment and will interact with the IPEO Central Facility by means of telephone, telefax and mail services.

5.2.1.4 Data Network Architecture

The overall wide area network architecture that is proposed for the IPEO organization is shown in figure 5.2.1.4 - 1. It aims at minimizing the number of high speed links and maximizing their utilization ratio, by multiplexing on a single physical network the traffic of the three logical networks described above: data acquisition network, interconnection network, and users network.

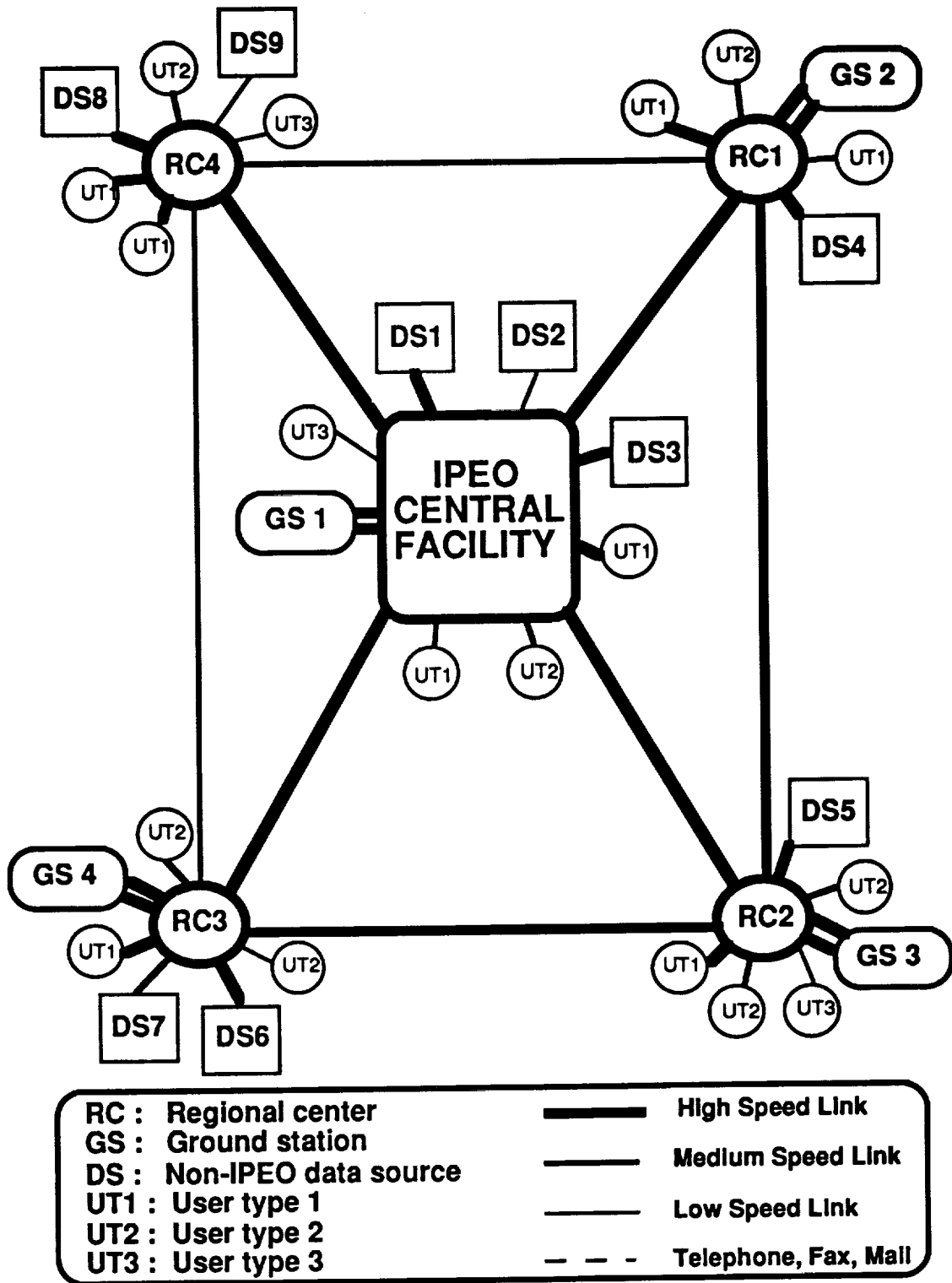


Figure 5.2.1.4 - 1 Data Networks Architecture

The basic architecture is a two-tiered star network, composed of links radiating from the IPEO Central Facility to the main nodes of the network, e.g., the regional centers. A second level star network radiates from each of these regional centers to the users and the non-IPEO data sources. The ground stations of the acquisition network will also be connected to the closest regional center using one or more high speed data circuits.

Links between different regional centers have been added to provide these main nodes with alternate routes to reach the Central Facility. This allows better load-balancing and improves the overall utilization, hence improving the cost efficiency of the system.

To manage the assignment of network capacity and to avoid conflicts, it is necessary to grant different priorities, depending on the urgency and importance of the data transfer.

The data acquisition network will receive the highest priority when transmitting newly acquired data. This means that whenever a station must transfer data to the Central Facility, it can take advantage of larger throughput rates by using not only the direct link but also alternate paths.

If, for example, a spacecraft passes overhead and transmits data to the ground station GS2, this station will temporarily store the data and start transferring it to the closest regional center, RC1, using the double high speed link that is available. RC1 will send the data to the Central Facility (CF) via different routes:

- Direct link between RC1 and CF;
- RC1 - RC2, then RC2 - CF links; and
- RC1 - RC4, then RC4 - CF links.

A limited capacity of the links can still be earmarked to handle traffic over the interconnection and users network. The throughput of these networks, however, will be severely scaled down during the ground station transmission periods, e.g., no high resolution image transfer can occur.

Outside the peak periods when a station is transmitting a large surplus capacity is available for traffic with a considerably lower priority than ground station transmission. This will allow the transfer of large data or image files appreciably faster than by using conventional mail or overnight delivery systems. These considerations lead to the following opportunities:

- Reducing the overhead cost of establishing high speed links with remote archives to service the IPEO Applications & Emergency Programs, and the needs of Research groups; and
- Proposing value-added network services to IPEO users, such as electronic mail, bulletin boards, electronic conferences. On demand, the IPEO network, utilizing the existing infrastructure can, make available high speed links to build end-to-end connections with remote data archives. They can then arrange

for transfer, into a user's computer, of large data or image files, that are stored either by IPEO or provided by another organization, such as SPOT IMAGE, EOSAT, and WMO.



6.0 ENVIRONMENTAL DATA REQUIREMENTS ANALYSIS

6.1 Existing Earth Observation Capabilities

6.1.1 Introduction

This section is an overview of the current state of the capabilities in Earth Observations. Part of the section is a definition of terms and concepts. Part of it summarizes data about Earth observation subsystems.

Summaries are presented of existing systems in terms of type, scale, capability, and objective. Also included are definitions of technical terms and an explanation of concepts. No assessment is made in terms of effectiveness or applicability to intended mission. This section provides information to determine the degree to which environmental needs are being met by existing Earth observations capabilities.

6.1.2 Spacecraft and Launchers

6.1.2.1 Satellites and Orbits

This section provides the reader with enough information to appreciate the technical specifications of Earth observation satellites. A satellite consists of a platform and a payload where, in the context of an Earth observation satellite, the payload is an instrument such as a spectrometer, imager, or other device that senses a desired phenomenon. The platform is designed to support the payload and consists of subsystems such as attitude and orbit control, thermal control, power, and communications.

A satellite's orbit or position about the Earth is described by six parameters called the classical orbital elements. The two most important parameters for remote sensing satellites are inclination and semi-major axis. The semi-major axis for a circular orbit is the sum of the satellite's altitude and the Earth's radius. Since most remote sensing satellites are in a circular orbit and the Earth's radius is approximately constant, the semi-major axis element is usually expressed as the satellite's altitude. The inclination of an orbit can be defined as the angle between the orbit normal and equatorial plane normal.

The three most common orbits for remote sensing are geostationary, low Earth orbit (LEO), and sun synchronous (SSO). A geostationary orbit is circular with an inclination of zero degrees and an altitude of 36,000 km. The orbital period is 24 hours, so it remains in an (approximately) fixed position in the sky relative to an observer on Earth. Low Earth orbit is a term used to describe a circular orbit of low inclination and low altitude. A sun synchronous orbit is circular with an inclination and altitude such that the angle between the orbit normal and the Earth-sun vector is approximately constant.

Satellites attitudes in orbit can be expressed as rotations about three axes; pitch, roll and yaw axes. The yaw axis is the Earth-spacecraft vector. The roll axis is the spacecraft's velocity vector. The pitch axis is parallel to the orbit normal but is measured by attitude

angle. The spacecraft's attitude about these axes must be carefully controlled so that the remote sensing payload faces the Earth in a stable fashion.

There are three basic types of attitude control or stabilization. The gravity gradient technique uses the Earth's gravity to provide torques that correct disturbances. Gravity gradient stabilization, however, is rarely sufficiently accurate for Earth observation systems. The spin stabilization technique relies on spinning the spacecraft to provide gyroscopic stiffness. Three axis stabilization techniques, the most preferred mode, use direct feedback control of the spacecrafts attitude. Many different actuators are used for three axis stabilization.

6.1.2.2 Launchers

An overview of existing launchers, or those available in the near future, is made in this sub-section. To undertake the overview, the team defined primary and secondary criteria. A rough selection should be based on primary criteria and detailed selection on the primary and secondary criteria. These criteria are outlined in Table 6.1.2.2 - 1.

Table 6.1.2.2 - 1 Launcher Criteria

| PRIMARY CRITERIA | SECONDARY CRITERIA |
|------------------|-------------------------|
| Mass | Orbit |
| Altitude | Reliability/Safety |
| Cost | Ground Support |
| Country/Site | Accuracy of Orbit |
| | Commercial Availability |
| | Volume |

Analysis of a launch system should include spacecraft mass and mission. The mass and altitude of a satellite directly drives launcher cost. Cost is one part of cost benefit analysis which helps determine the project's feasibility. This explains why mass, altitude and cost are the primary criteria for the selection of a launcher.

During a detailed design phase of a project, more criteria can be considered when making a final launcher selection. For example, issues such as reliability and safety are important in managing project risks. Other technical issues such as the useable volume of a launcher, the orbit accuracy, and the quality of the ground support also must be assessed.

At least seven classes of launchers exist. Pegasus, one of the first launchers reviewed, has a small mass to orbit capability. Cost is still in excess of \$10 per gram however. A small satellite thus may cost less to launch. But performance limitations of a small satellite must also be considered.

The following data emphasize polar orbits, since most observation satellites are in sun synchronous orbits. However some remote sensing satellites are in geosynchronous orbit and low Earth orbit and so some consideration will be given to them.

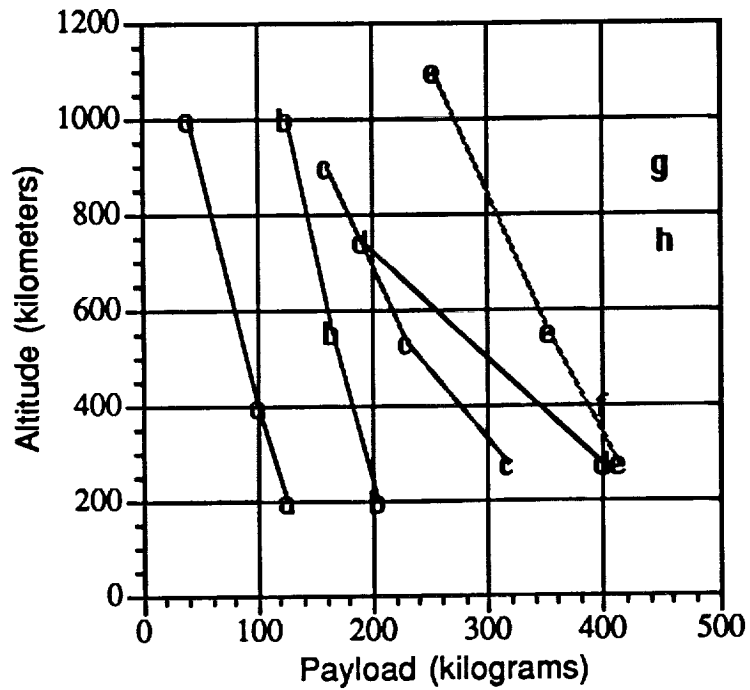


Figure 6.1.2.2 - 1 Launch Capabilities for Mini Satellites

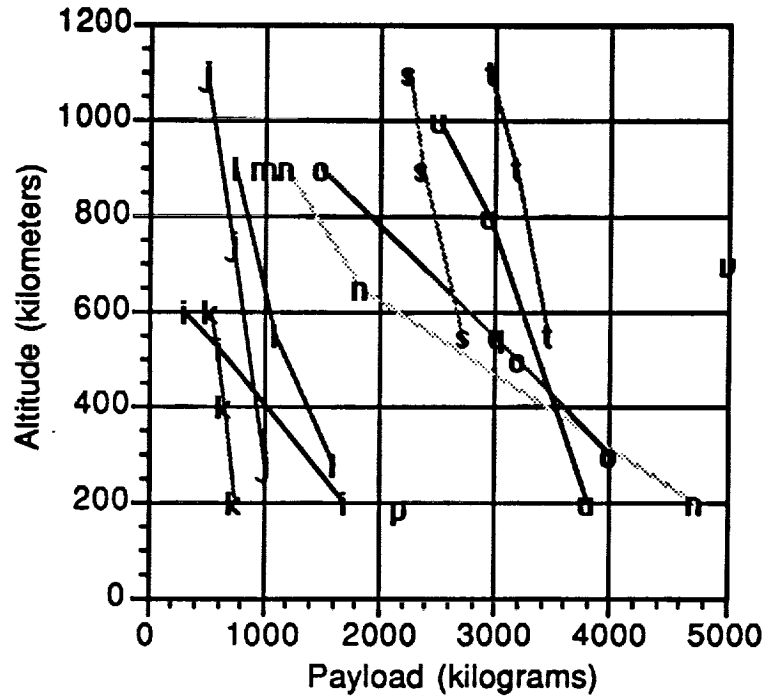


Figure 6.1.2.2 - 2 Launch Capabilities for Low Altitude Medium to Large Satellite

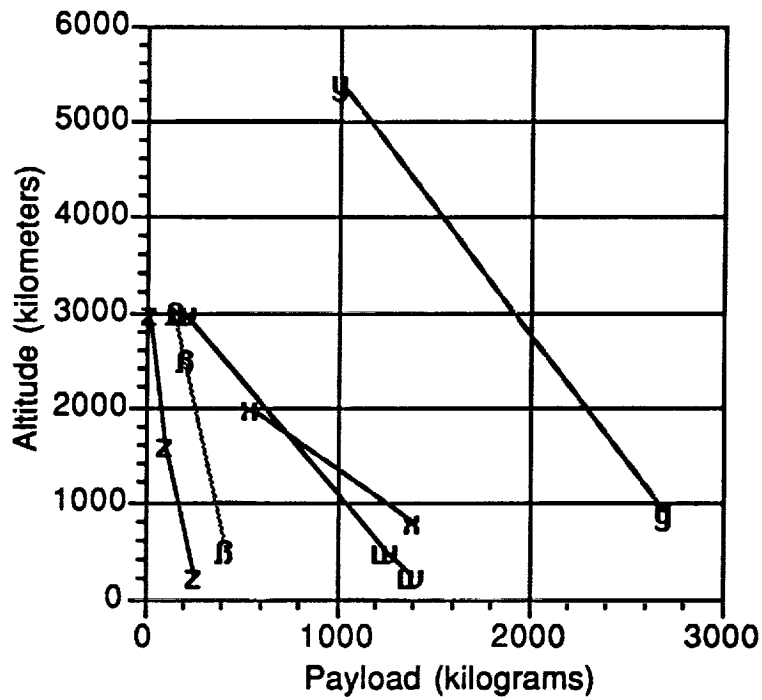


Figure 6.1.2.2 - 3 Launch Capabilities for High Altitude Large Satellites

Tables 6.1.2.2 - 2 and 6.1.2.2 - 3 summarize the available data about polar, and LEO-geosynchronous, launch systems.

Table 6.1.2.2 - 2 Summary of Polar Launch Capabilities

| | Launcher | Country | Site | M\$ | Com | Mass | Height |
|---|--------------|---------|-----------|-----|-----|--------|--------|
| a | ILV/S-3 | USA | Vndnbrg | | Yes | 100 kg | 400 km |
| b | Scout-1 | USA | Vndnbrg | 12 | Yes | 165 | 555 |
| c | Pegasus | USA | Aircraft | 8.5 | Yes | 230 | 530 |
| d | Conestoga 2 | USA | | 12 | Yes | 190 | 740 |
| e | Scout-2 | USA | Vndnbrg | 15 | | 353 | 555 |
| f | L.March 1C | China | Juquan | | | 400 | 400 |
| g | L.March 1M | China | Juquan | | No | 450 | 903 |
| h | Conestoga 3 | USA | | 12 | Yes | 454 | 740 |
| i | L. March 2 | China | Juquan | 24 | | 300 | 600 |
| j | Conestoga 4 | USA | Vndnbrg | 20 | Yes | 720 | 740 |
| k | Littleo | Europe | Andoya | 12 | Yes | 530 | 600 |
| l | L. March 2C | China | Juquan | 30 | Yes | 750 | 900 |
| m | PSLV | India | Sriharino | | No | 1000 | 900 |
| n | Vostok | USSR | Tyuratam | 14 | Yes | 1200 | 900 |
| o | L. March 4 | China | Juquan | | No | 1500 | 900 |
| p | Titan-2 | USA | Vndnbrg | 25 | Yes | 2177 | 185 |
| q | Titan-2+37 | USA | Vndnbrg | | Yes | 3028 | 546 |
| s | Delta/6920 | USA | Vndnbrg | 33 | No | 2360 | 900 |
| t | Delta-2/7920 | USA | | 38 | Yes | 3180 | 900 |
| u | L. March 3 | China | Juquan | 30 | Yes | 2950 | 800 |
| v | Japan H2 | Japan | | 115 | No | 5000 | 700 |
| w | ILV-1 | USA | | | | 1250 | 500 |
| x | Japan H1 | Japan | | 98 | No | 1400 | 800 |
| y | Delta/6970 | USA | | 30 | No | 2700 | 900 |
| z | ILV/S - 5 | USA | Vndnbrg | 12 | Yes | 250 | 250 |
| β | ILV/S - 7 | USA | Vndnbrg | | Yes | 450 | 500 |

Table 6.1.2.2 - 3 Summary of LEO and GTO Launch Capabilities

| Name | Country | LEO Mass | GTO Mass |
|-----------------|---------|-----------------|--------------------|
| Ariane 4 | Europe | 2500 to 5000 kg | 1900 to 4200 kg |
| ASLV | India | 150 kg | n/a |
| Atlas I | USA | 5.9 t | 2.3 t |
| Atlas II | USA | 6.8 t | 2.7 t |
| Cosmos | USSR | 1.1 - 1.3 t | n/a |
| Long-March 1D | China | up to 750 kg | n/a |
| Long-March 2C | China | 2.5 t | 1.2 t |
| Long-March 3A | China | ≈ 6 t | ≈ 2 t (not flying) |
| Long-March 2E | China | 8.8 t | n/a |
| Delta 3925 | USA | 3.5 t | 1.2 t |
| Delta II (7925) | USA | 5 t | 1.8 t |
| Energuya | USSR | up to 120 t | up to 19 t |
| H1 | Japan | 2 t | 1.1 t |
| H2 | Japan | 10 t | 4 t |
| Proton | USSR | up to 21 t | 2.2 t |
| M-3SII | Japan | up to 770 kg | n/a |
| M - V | Japan | 2 t | n/a |
| Pegasus | USA | 450 kg | 200 kg |
| PSLV | India | 3 t | n/a |
| Scout G1 | USA | up to 300 kg | n/a |
| Soyuz/Vostok | USSR | up to 7.5 t | 1.6 t |
| Taurus | USA | 1.5 t | 375 kg |
| Titan III | USA | up to 14.7 t | ≈ 1.2 - 4.9 t |
| Titan IV | USA | 17.7 t | 2.3 to 5.6 t |
| Tzyklon | USA | 0.5 - 4 t | n/a |
| VLS | Brazil | 200 kg | n/a |

6.1.3 Earth Observation Systems

This section considers remote sensing and land and meteorological systems. Each of the systems is described in terms of platform parameters such as mass and power, and payload parameters such as wavelength and resolution. Some of the terminology used in Earth observation systems is first described in sufficient detail to understand the technical summaries of the systems.

6.1.3.1 Remote Sensing

Electromagnetic (em) radiation can be thought of as waves travelling at the speed of light. Two properties of em radiation are its wavelength and frequency. In remote sensing work, the units of measure of wavelength and frequency are micrometers or nanometers and megahertz or gigahertz, respectively. Polarization describes the uniform orientation of the electric field with respect to the target. For example, when one speaks of cross polarized, V H radar (radio detecting and ranging), the electric field of the transmitted em radiation is aligned vertically with respect to the target and only the horizontally polarized em radiation will be received.

The resolution of a satellite remote sensing payload is described in terms of four parameters: spatial resolution, spectral resolution, radiometric resolution and temporal resolution. Spatial resolution can be defined as the ability to discriminate the presence of line pairs. "30 meter resolution" means two lines 30 m apart on Earth can be distinguished as two lines rather than as one broad line in a remotely sensed image. Spectral resolution can be expressed as the ability to distinguish between different frequencies. Frequencies are expressed as "bands", the width of a band would be the spectral resolution. Radiometric resolution or sensitivity distinguishes the amplitude of a band, and the units are decibels (db). Temporal resolution is how often a given area of the Earth passes within the field of view of the payload.

The following are some other terms which will be encountered with respect to remote sensing.

- Nadir: the vertical direction to the Earth.
- Range: the distance between the spacecraft (sensor) and the Earth (target).
- FOV: field of view, expressed as the area that a sensor covers each pass
- Incidence angle: angle between nadir and the center of the FOV.
- Signal to noise ratio: the ratio of the signal amplitude to the noise amplitude.

Figure 6.1.3.1 - 1 shows an example of the layout of the payload, antenna, and other subsystems of a remote sensing system.

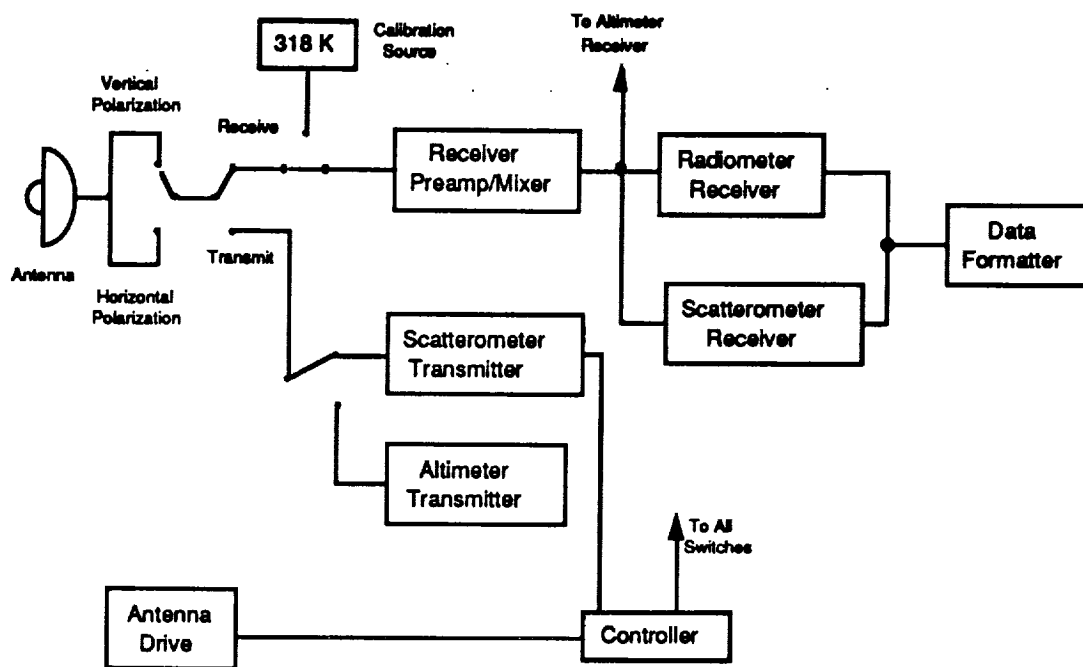


Figure 6.1.3.1 - 1 Example of Remote Sensing System

The remainder of this section is devoted to summarizing the capabilities of some key remote sensing systems in the world today.

| | |
|------------------|--|
| System: | Spot 1 and 2 (System pour L'Observation de la Terre) |
| Country: | France, Belgium and Sweden |
| Objective: | Geological mapping, forestry, agriculture |
| Instrument: | Optical and IR imager 0.51 - 0.73 μm @ 10 m & 60 km (PAN) 0.50 - 0.59, 0.61 - 0.68, 0.79 - 0.89 μm @ 20 m & 60 km |
| Orbit: | sun synchronous, 832 km, 98.7° |
| ACS: | 3 axis stabilized, 0.15° accuracy |
| Mass/Power/Life: | 1830 kg, 1 kw, 2 y |
| | |
| System: | Landsat |
| Country: | U.S.A. |
| Objective: | land use inventory, geological/mineralogical exploration, crop and forestry uses |

Instrument: Enhanced Thematic Mapper (ETM)
0.40 - 0.90 μm @ 15 m & 185 km
0.45 - 0.52, 0.52 - 0.6, 0.63 - 0.69, 0.76 - 0.9 @
30 m & 185 km
Multispectral Scanner (MSS)
0.5 - 0.6, 0.6 - 0.7, 0.7 - 0.8, 0.8 - 1.1 μm @
78 m & 185 km

Orbit: SSO, 705 km, 98.21°
ACS: 3 axis, pitch < 0.7°, roll & yaw < 1°
Mass/Power/Life: 900 kg, 1.4 kw, 5 y

System: MOS -1 Meteorological Observation Satellite
Country: Japan
Objective: Experimental observation of Earth in particular
oceans, and technology development.

Instrument: MSSR
0.51 - 0.59, 0.61 - 0.69, 0.72 - 0.80, 0.80 - 1.1 @
50 m & 100 km
Radiometer
0.5 - 0.7 μm @ 900 m & 1500 km
Microwave Scanning Radiometer (MSR)
23 GHz @ 32 km & 320 km
31 GHz @ 23 km & 320 km

Orbit: SSO, 909 km, 99.1°
ACS: 3 axis (controlled bias momentum), pitch & roll
0.45°, yaw 1°
Mass/Power/Life: 740 kg, 640 kw, 2 y

System: POES Polar - Polar Orbiting Operational
Environmental Satellite
Country: USA/NOAA
Objective: Meteorological observations, measurements of
sea-surface temperature, sea ice and snow cover

System: IRS Indian Remote-sensing Satellite
Country: India
Objective: Agricultural, hydrological and geological data
for natural resource management.

| | |
|-------------------|---|
| System: | Geosat Geodesy Satellite |
| Country: | USA/DoD |
| Objective: | Geodesy, shape of the geod, ocean and atmospheric properties |

6.1.3.2 Sensors

The following are descriptions and examples of the most commonly used sensors in remote sensing: spectrometer, radiometer, scatterometer and altimeter.

Spectrometers are used to collect information in many bands of the spectrum. They can be thought of as passive, wide band scatterometers. There are three basic types: frame, push broom (linear), mechanical scanner. Some important parameters include spatial resolution, spectral bands, FOV, time of day, sensitivity, and radiometric accuracy.

Radiometers are a non imaging (i.e.. no picture) sensor that produce a spectral curve or other quantities of the em power emitted from, reflected by and/or transmitted through space. A radiometer measures the radiant flux integrated over time, space and wavelength.

Microwave radiometers have an advantage over conventional IR systems since they can penetrate cloud cover to provide uninterrupted coverage. However, they are fairly crude instruments in terms of resolution. To improve spatial resolution requires large antennas. The next generation of microwave radiometers will overcome this problem by raising the frequency of operation to the millimeter bands up to 183 GHz.

Scatterometers usually are microwave radar. Many scatterometers are used to measure backscatter cross section for an area at different incidence angles (0-90°). They are also used to measure, indirectly, wind velocity over oceans.

An **altimeter** is a nadir looking radar used for topographical mapping and the calibration of radar. Laser altimeters are also being developed.

6.1.3.3 Meteorological Systems and Sensors

| | |
|-------------------------|---|
| System: | TIROS |
| Country: | USA/NOAA |
| Objectives: | Meteorological observations and the measurement of sea surface temperature |
| Instruments: | AVHRR - advanced very high resolution radiometer 5 bands from 0.58-12.5 μm @ 1000 m & 2700 km HIRS - high resolution infrared scanner |
| Orbit: | 20 channels 3.8-15 μm @ 17.4 km & 2240 km SSO, 833 or 870 km, 98.7° |
| Mass/Power/Life: | 736 kg, (), 2 years |

| | |
|-------------------------------|---|
| System: | Meteosat 2 |
| Country: | Europe/ESA |
| Objectives: | To meet the needs of the European meteorological services, and to contribute to the World Weather Watch Programme and Global Atmospheric Research Programme (GARP). The system will provide cloud wind vectors, sea surface temperatures, cloud top height maps, maps of distribution of water vapor and a basic climatological database. |
| Instrument: | High Resolution Radiometer |
| Mass: | 61 kg |
| Power: | 27 W (Average), 66 W (Peak) |
| Channels: | 2 Visible 0.4 um - 11 um 1 IR (Water vapor) 5.7 μm-7.1 um 1 IR (Window) 10.5 um -12.5 um |
| Spatial Resolution : | 2.5 km (Visible) |
| (Subsat. point) | 5 m (IR) |
| No. of bits: | 6 |
| Data Rate: | 166 kbits/s (normal), 2.7 Mbits/s (backup) |
| Frequency of pictures: | 1 per 30 minutes |
| Orbit & ACS: | Spin stabilized Two shacked cylinders main body covered with solar cells. The S band antenna is in the top body electronically-despun. Various hydrazine thrusters to control spin, attitude and GEO orbit. |
| Mass/Size: | BOL mass 320 kg, 2.1 m in diameter and 3.195 m long |
| System: | GMS Geostationary Meteorological Satellite |
| Country: | Japan/NASDA |
| Objective: | Operational weather data, cloud cover, temperature profiles, storm monitoring and severe-storm warning |

System: GOES Geosynchronous Operational Environment Satellite
Country: USA/NOAA
Objective: Operational weather data, cloud cover, temperature profile, real-time, storm monitoring, severe-storm warning, and sea-surface temp.

Table 6.1.3.3-1 International Radiometer Summary

| | GMS | GOES | Meteosat |
|---------------------------------------|------|------------------|---------------|
| Spin rate (RPM) | 100 | 100 | 100 |
| Line scan direction | W-E | W-E | E-W |
| Telescope step direction | N-S | N-S | S-N |
| Number of scan lines for full disk IR | 2500 | 1750 | 2500 |
| Resolution at SSD VIS (km) | 1.25 | 1.0 | 2.5 |
| | IR | 5.0 | 8.0 |
| | WV | --- | 5.0 |
| Full disk scan time (minutes) | 25 | 17.5 | 25 |
| Sensor type | VIS | Photomultipliers | Si Photodiode |
| | IR | HgCdTe | HgCdTe |
| | WV | --- | HgCdTe |
| Spectral Response (μm) | VIS | 0.55 - 0.75 | 0.5 - 0.9 |
| | IR | 10.5 - 12.5 | 10.5 - 12.5 |
| | WV | -- | 5.7 - 7.1 |

System: INSAT Indian National Satellite
Country: India
Objective: Meteorology, domestic communications and TV distribution

| | |
|------------------|---|
| System: | DMSP Defense Meteorological Satellite Program |
| Country: | USA/DoD |
| Objective: | OLS Scanning microwave radiometer 19.35, 22.24, 37.0, 85.5 GHz @ 14 km & 1394 km |
| Orbit: | SSO, 833 km, 98.9° |
| Mass/Power/Life: | 468 kg, 300 w, 2 yrs (block 5D-1), 698 kg, 400 w, 3 yrs |
| ACS: | 3 axis |
| System: | Nimbus - 7 |
| Country: | USA |
| Objective: | Monitor atmospheric pollutants, ocean chlorophyll concentrations, weather and climate. |
| Orbit: | SSO, 955 km, 99.3° |
| Mass/Power/Life: | 907 kg, , |
| ACS: | 3 axis |

6.1.4 Synthetic Aperture Radar

Synthetic Aperture Radar or SAR uses wavelengths of 1 mm to 1 m. Radiometers are used with SARs to correct for attenuation, and altimeters are used to measure the satellite altitude, both of which are needed to correct and interpret SAR data.

Table 6.1.4-1 Selected Parameters of All Civilian SAR Satellites¹

| Parameters | Seasat | Almaz | ERS-1 | JERS-1 | SIR-C | ERS-2 | Radarsat | EOS |
|--------------|--------|--------|-------|--------|--------|-------|----------|--------|
| | USA | USSR | ESA | Japan | USA | ESA | | USA |
| Operation | 1978 | 90-93 | 91-93 | 92-94 | 93,4,5 | 94-96 | 94-99 | 99 (?) |
| RadarBands | L | S | C | L | C,L,X | C | C | C,L |
| Polarimetry | | | | | yes | | | yes |
| Swath width | 100 km | 30-300 | 80 | 75 | 15-90 | 80 | 50-500 | 50-500 |
| Resolution | 25 m | 15-300 | 30 | 18 | ≈ 30 | 30 | 10-100 | 10-100 |
| Max N. Lat. | 72° | 73° | 80° | 80° | 53° | 80° | 90° | |
| o/b recorder | | yes | | yes | (yes) | | yes | (yes) |

¹Taken from R. Keith Raney design notes

Summarized below are some of the existing SAR systems, including , ERS 1, JERS and RADARSAT.

System: ERS-1 (ESA)
Objectives: Take all-weather images over polar caps, coastal zones and land areas (Image Mode). Can also operate in a sampled mode (Wave Scatterometer) to measure the spectrum of ocean waves. Derived parameters and applications are imaging, for example sea and iceberg monitoring, pollution detection, coastal processes, land applications and polar oceans; wave, for example sea state forecast, ship routing, ship activity, wave direction and length, and polar oceans.
Instrument: Synthetic Aperture Radar (SAR)
Mass: 350 kg (Mass of Advanced Microwave)
Power: 1270 W (SAR mode)
 540 W (Wave Scatterometer mode)
Frequency: 5.3 GHz at 6.1.8 kW (peak)
Swath width: 80 km (min.)
Geometric Resolution: 30m x 30m (a) 100m (b) Image
Radiometric Resolution: 2.5 dB (a) 1 dB (b) Mode
Wave Direction: 0 - 360 degrees Wave
Wavelength: 50 - 1000 m Mode
Orbit: SSO, 777 km, 98.5°
ACS: 3 axis stabilized, nadir pointing
Mass/Power: 2400 kg/1.8 kw
Operational life: 1991 - 1994 (ERS-1) 1994 - 1997 (ERS-2)

System: JERS -1
Country: Japan
Objective: To verify optical and SAR performance and to survey land, forestry, costal mountains and the environment.
Instrument SAR L band (1.275 GHz) @ 18 m & 75 km (HH, 35°)
 Optical Sensor
Orbit: SSO, 568 km, 97.7°
ACS: 3 axis stabilized (zero momentum), accuracy +/- 0.15°
Mass/Power/Life: 1450 kg, 1.85 kw, 2 y

System: Radarsat
Country: Canada
Objective: High resolution studies of arctic area, agricultures, forestry, water resource management and oceans.
Instrument: SAR - C band (5.3 GHz) 4 modes
Basic 28 m x 25 m @ 100 km (20° - 49°)
Wide 28 m x 40 m @ 150 km (< 35°)
Fine 10 m x 10 m @ 40 km (> 35°)
ScanSar 100 m x 100 m @ 500 km (20° - 49°)
Orbit: SSO, 792 km, 98.6°
Life: 4 y
ACS: 3 axis stabilized

6.1.5 Ground Systems

6.1.5.1 Introduction

This section describes ground capabilities related to existing and planned remote sensing satellite systems, such as data acquisition, processing and archiving, and distribution networks. First some aspects of these data handling functions are discussed.

Data Reception

Data can be received on the ground from three different logical data streams:

- Real-time, when a receiving station is in the visibility of the spacecraft.
- On-board recorder tape dumping, when a receiving station is in the visibility of the satellite.
- Data Relay Satellite, when a geostationary satellite is used to link data from the remotely sensed satellite to a receiving station.

Data Processing and Archiving

In general data downlinked from a satellite cannot be used directly in the form in which it is received. Several levels of processing and formatting can be identified. The resulting products are classified according to processing level. Examples of data processing levels are listed below:

- LEVEL 0: Reconstructed unprocessed data at full resolution. The data stream might be time referenced.
- LEVEL 1A: Reconstructed, unprocessed data at full resolution, including radiometric and geometric calibration coefficients. These calibration data are computed and appended but not applied to the level 0 data.
- LEVEL 1.0 - 1.n: Level 1A data processed to engineering units (1.0), sensor units (1.5), geocoded (1.6) and processed to particular formats (1.7) such as backscatter curves, polarimetry, radargrammetry, phase difference, ratios etc.
- LEVEL 2.0: Geophysical and biophysical parameters in image format.
- LEVEL 3.0: Geophysical and biophysical variables mapped on uniform space-time grid scales. Some completeness and consistency properties have been applied.
- LEVEL 3.1 (incomplete): Mosaicked images.
- LEVEL 3.2 (complete): Mosaicked images converted into map quadrants.

- **LEVEL 4.0:** Information that can be used directly for understanding global hydrologic, biochemical and climate processes. Many level 3.0 products are needed as inputs to the models to generate level 4.0 products.

Raw and processed data usually is archived. In general the archiving system will:

- Preserve data as soon as they are received (at least temporarily);
- Provide a long-term (more than 10 years) archive of all data in a format such that it is possible to reconstruct the raw data stream; and
- Generate sufficient user information for cataloging and retrieval of the archived data sets.

A crucial point is the archiving medium, both because of large data volumes to be archived, and because of problems with degradation due to age. Present technologies include magnetic tapes, "CCTs," and disks, optical disks and photographic methods (microfiche). The technology chosen for a particular system depends on quality and volume requirements, and distribution strategies.

Data Distribution

Distribution channels might be :

- Spacecraft links (existing and planned communications satellites, both commercial and dedicated systems).
- Landlines (public and dedicated services).
- Computer networks.
- Express mail or overnight courier.

The distribution network provides the target distribution points with the various system products.

6.1.5.2 Existing Systems

Introduction

Existing or planned Earth Observation satellite systems such as SPOT, ERS-1, Landsat, EOS, MOS-1, JERS-1 and Soyuzkarta have been summarized on the basis of available documentation. This section describes the ground facilities offered by three of these; SPOT, ERS-1 and Landsat. The following aspects have been considered: data acquisition, data processing and archiving, and data distribution.

Table 6.1.5.2-1 outlines the systems received at the respective ground stations.

Table 6.1.5.2-1 Ground Stations

| Ref | Station | Receiving from |
|-----|-----------------------------|----------------------|
| A | Prince Albert (Canada) | LANDSAT, SPOT, ERS-1 |
| B | GSFC (USA) | LANDSAT, SPOT |
| C | Quito (Equator) | LANDSAT |
| D | Cuiba (Brazil) | LANDSAT, SPOT, ERS-1 |
| E | Mar Chiquita (Argentina) | LANDSAT |
| F | Maspalomas (Spain) | LANDSAT, SPOT, ERS-1 |
| G | Fucino (Italy) | LANDSAT, ERS-1 |
| H | Kiruna (Sweden) | LANDSAT, SPOT, ERS-1 |
| I | Johannesburg (South Africa) | LANDSAT, SPOT |
| J | Riyadh (Saudi Arabia) | LANDSAT, SPOT, ERS-1 |
| K | Hyderabad (India) | LANDSAT, SPOT |
| L | Islamabad (Pakistan) | LANDSAT, ERS-1 |
| M | Beiging (China) | LANDSAT, ERS-1 |
| N | Tokyo (Japan) | LANDSAT, SPOT |
| O | Bangkok (Thailand) | LANDSAT, SPOT, ERS-1 |
| P | Jakarta (Indonesia) | LANDSAT, ERS-1 |
| Q | Alice Springs (Australia) | LANDSAT, ERS-1 |
| R | Toulouse (France) | SPOT |
| S | Gatineau (Canada) | SPOT, ERS-1 |
| T | Kourou (French Guyanna) | SPOT |

SPOT

Data Acquisition

The SPOT payload includes two high-resolution visible-range instruments (HRV). Data generated by the instruments are transmitted to the ground over the payload specific X-band telemetry link or stored by means of two onboard recorders for later recovery by the Toulouse, France and Kiruna, Sweden ground stations.

Telemetry, tracking, command and monitoring of the SPOT satellites is driven from the ground Mission Control Center located in Toulouse. This center operates in the 2 GHz band (S-band) and is in charge of SPOT satellite location measurements and Telemetry reception and sending.

The Mission Control Center also relies on other ground stations distributed worldwide. In particular: Kourou (Guyana), Hartebeesthoek (South-Africa), Kiruna (Sweden), stations centered in Goddard Space Flight Center (USA) and Katsuura (Japan).



A - Prince Albert (CANADA)

B - GSFC (USA)

C - Quito (EQUADOR)

D - Cuiba (BRAZIL)

E - Mar Chiquita (ARG)

F - Maspalomas (SPAIN)

G - Fucino (ITALY)

H - Kiruna (SWEDEN)

I - Johannesburg (SOUTH AFRICA)

J - Riyadh (SAUDI ARABIA)

K - Hyderarab (INDIA)

L - Islamabad (PAKISTAN)

M - Beiging (CHINA)

N - Tokyo (JAPAN)

O - Bangkok (THAILAND)

P - Jakarta (INDONESIA)

Q - Alice Springs (AUSTRALIA)

R - Toulouse (FRANCE)

S - Gatineau (CANADA)

T - Kourou(Fr. GUYANNA)

Figure 6.1.5.2 - 1 Ground Stations Overview of SPOT, LANDSAT and ERS-1

There are two types of SPOT ground data reception stations: Centralized and Decentralized.

The two centralized reception stations (in Toulouse and in Kiruna) receive real-time data as SPOT passes over the north polar region, Europe and North Africa, as well as stored images from other regions. Together, the two stations have a reception capacity of 500,000 images a year. SPOT direct receive receive real-time imagery and are responsible for its distribution in a limited geographic area. Centralized stations can receive data previously recorded on the SPOT satellite.

Decentralized image reception by SPOT at stations other than Toulouse and Kiruna involves real-time imagery reception only and these stations are responsible for their data distribution in a limited geographic area. The decentralized stations can only receive images from the current visible zone directly. Image data is downlinked at 8 GHz (X- band) at 25 Mbps.

Data Processing and Archiving

Both of the centralized stations are associated with a preprocessing center, or a Space Imagery Rectification Center, with the equivalent of 700 scenes archived every 24 hrs. at both Toulouse and Kiruna.

Data Distribution

The data gathered by different receiving stations throughout the world are marketed and distributed to users by the SPOT company, either directly, or through its commercial network spanning more than 50 countries.

SPOT offers a large choice of formats and media to adapt products to user's needs: Computer Compatible Tapes, photographic films, paper prints and quick look.

ERS-1

Data Acquisition

On-board data handling and transmission from ERS-1 includes instrument data collection, data multiplexing, data storage on tape recorders and data transmission via X-band channels either directly or in playback mode. The on-board tape recorder allows storage of low bit rate data, i.e. from all instruments other than the SAR in image mode. The SAR image data are transmitted via a dedicated high bit rate channel (105 Mbps) in real time, while the low bit rate data from all the other instruments (1.1 Mbps) are multiplexed on a single data stream. These data are normally recorded on-board, but can also be transmitted directly in real-time.

Ground stations at Kiruna (Sweden), Fucino (Italy), Gatineau (Canada) and Maspalomas (Spain) are the main facilities for acquisition and rapid processing of ERS-1 data. The key station is Kiruna as it provides good visibility because of its high latitude position. This station is responsible for the TTC&M, as well as for reception of both real-time and on-board recorded data. The Fucino station is used for real-time (SAR and low bit rate) data over the Mediterranean Sea, while the stations at Gatineau and Maspalomas are used for acquisition of recorded low bit rate data.

Data Processing and Archiving

Raw data is stored on High Density Digital Tapes (HDDT's) at each ground station. The ground stations also have fast delivery processing capabilities with one processing chain devoted to SAR processing and the other to the processing of data from other instruments.

Four Processing and Archiving Facilities (PAFs) are located in FRG, France, UK and Italy. They are the main centers for regional archiving and retrieval of ERS-1 raw data, generation of off-line precision products and interfacing with the Central Facility (defined below) for updating of the catalog and supporting user services.

Data Distribution

All user interface functions are carried out by the Earthnet ERS-1 Central Facility (EECF) at ESRIN (Frascati, Italy). These functions include cataloging, handling of user requests, payload operation planning and scheduling of data processing and dissemination.

The individual users and user centers will receive products directly from the ground stations and PAF's according to requirements submitted to the EECF.

Dissemination of products from the ground stations is based on use of existing networks for low bit rate distribution, and use of high-speed satellite data channel for SAR images.

LANDSAT

Data from the Landsat family of satellites is received on ground stations either directly, stored on board and later transmitted, or via data relay satellites. When the data relay satellite is used, data is transmitted to the White Sands ground station and then via domestic satellites to the Goddard Space Flight Center.

Data Processing and Archiving

In the USA government data archiving takes place at the EROS Data Center in Sioux Falls, South Dakota and all other at EOSAT headquarters in Lanham, Maryland. Over two

million images of Landsat data have been archived. Foreign ground stations also pre-process, archive, and distribute data to EOSAT, and to users.

Data Distribution

The Landsat data handling control has recently shifted from Goddard Space Flight Center to EOSAT which has added a regional data receiving facility in Oklahoma.

6.1.6 Conclusion

Section 6.1 supported the process of project development more than it contributed to definitive conclusions. However, even a limited survey of the state of the practical art revealed some tentative conclusions. A statement of these tentative conclusions completes this discussion.

- There is ample choice of launch options among the global resources that now exist. Smaller launch supplier options are expanding rapidly.
- There is an abundance of existing and planned Earth observing systems in the 1990s. The existence of gaps or inadequacies in the Earth observing systems may be in special orbits, faster repeat cycles, and highly targeted sensing missions.
- Linking satellite data to Earth is supported by an impressive data receiving infrastructure. Gaps may be in end-user distribution networks.

6.2 Requirements Analysis and Prioritization

Almost half of the Project personnel participated in a "bottom up" examination of environmental needs, information requirements and priorities. This process is reported here in some detail because it represents a significant case of interdisciplinary, international methods and decision making.

At the outset of the Project, a requirements group led the determination of user requirements and data priorities. In order to define priorities, the group was split into seven teams, each involved in a particular problem area. The areas were Agriculture, Climate, Mineral and Energy, Land-use, Coastal zones and Oceans, Forestry, and Water.

The problem area teams attempted to formalize the needs they encountered. Subsets were listed inside each area.

The goal was to produce a document where needs and sensors could be compiled, with the spatial characteristics identified and initial technical specifications made in terms of performance. To achieve this result, a matrix was developed providing a general framework to help in the compilation of the documents.

The second step for the requirements group , was to develop a methodological approach to go through the different matrices which were produced by each group.

An initial approach was adopted to determine ranking criteria which enabled discrimination of priorities. These criteria were expressed in several questions:

- Is the need international?
- Does the investigation explore areas which reflect long term needs?
- Can the information be applied to many disciplines?
- Is the needed data available now?
- Is the data needed for process study or applications and management?
- Does the data define 'Hot Spots' (environmental issues of immediate critical need)?

These questions reduced the number of candidate areas. A second step in this approach was to select specific parameters and assign weighting scores to the priorities chosen by each group inside their different areas. A list of the criteria is provided in Section 6.2.2.2.

The priorities were selected by an independent group that ranked, in a 'neutral' way in order to avoid pressure on the results. A list of the priorities is provided in Section 6.2.2.4.

At the end of two weeks, each team had filled its matrix on a computer file in order to obtain a general file. This general file was refined, but most of the needs, capabilities, sensors had been detected in the first step. The matrix file was used to merge the requirements and the technical capabilities defined earlier in this chapter.

6.2.1 Initial Categories and Assumptions

6.2.1.1 Agriculture

In order to analyze the documentation about the "Agricultural Area," (requirements verses capabilities), several points must be clarified. Attention was focused essentially on cultivated areas to avoid overlap with the Land-Use Team.

To identify the requirements, an attempt was made to answer the following questions:

- Can we develop prediction models and agricultural planning?
- Can we quantify the effects of weather, soils, fertilizer, pests, etc.?
- Are we able to assess the amount and the quality of soil and water according to agricultural needs?
- What are the relationships between the satellite vegetation indices and the vegetation?
- Can we assess the progress of planting, growth, cultivation, and harvesting of crops?

As all these needs require spatial data, one technical point which appears very important is mapping information. The agricultural team tried to specify needs and the capabilities according to the following nine areas:

- 1) Delineate, locate, and identify the agricultural areas. We need to know exactly where the cultivated areas are and what surfaces are occupied by an agricultural function;
- 2) Delineate, locate, and identify the different types of crops. According to the periods of growth of the different types of crops, it is important to be able:
 - To assess the progress of growth, cultivation, and harvesting of crops;
 - To analyze several times a year according to the vegetation cycle types; and
 - To determine the prediction model needed and for agricultural planning, a large amount of information is needed on the agricultural capabilities.
- 3) Interaction with Soil. Because cultivated production is related to its substratum, we have to know the specificities and the quality of the soils. Relief is of great importance in some countries where terrain conditions are difficult.
- 4) Interaction with Water. Quantity of crops is related to the quality of soil and its ability to retain water. Moisture of the soil is an important factor here. Problems related to the irrigation process are important, for example, the risk of salinity. Drought in many countries leads to catastrophic results.
- 5) Interaction with Weather. The climatic zone of agricultural areas helps determine agricultural potentialities. There is a need to relate productivity to appropriate climate models which predict the effect of the weather trends.
- 6) Agricultural Threats. Threats can be divided into two types - natural ones (diseases, insects, etc.), and the man-induced ones (pollution, pesticides, etc.) There is a need to identify the effects of these threats in the agricultural sectors.

- 7) **Yield Forecast.** For all countries, the assessment of harvesting is very important. Two major reasons were identified:
 - For the industrialized countries, it is important to predict the selling potentials or the prices of agricultural products; and
 - For the developing countries, forecasting is essential in order to buy enough, to assess the distribution of the products, and to avoid the risk of famine.
- 8) **Agricultural Potentialities.** Due to the growth of the population on a global scale and the practices of production, agricultural potentialities must be identified.
- 9) **Anthropogenic Process.** Human practices are important to measure, for example, urban growth often occurs at the expense of agricultural areas. In several countries, agricultural practices, like fire, play a great role in the deforestation problem.

According to the matrix adopted by the Requirements Group, the following subsets have been identified as priorities in the area of Agriculture:

- 1) Forecast;
- 2) Change Monitoring and Mapping; and
- 3) Interaction with Soils.

“Hot Spots” have been identified related to vegetation stress:

- 1) Carbon cycle and pollution; and
- 2) Insect threats.

Change monitoring and mapping consist of the study of the evolution of the agricultural areas, in order to create enough information to define models. Modelling is a long term priority.

6.2.1.2 Climate / Air Quality

To achieve a sound understanding of the global atmosphere, extensive research will be required for decades to come. Specific goals with the promise of significant advance are attainable from a concentrated effort over the next decade. Global atmospheric circulation models would provide an increasingly effective framework for testing new hypotheses for climate sensitivity and change. The same time-scale is required for better understanding the

chemical budgets of the stratosphere and troposphere, and for the incorporation and validation of photochemical schemes in general circulation models.

The atmosphere is a particularly sensitive indicator of chemical processes. Gases released into it can lead to photochemical smog, to "acid rain," to increased tropospheric ozone, to the depletion of stratospheric ozone, and to an enhanced "greenhouse effect" which is predicted to alter the global climate.

In order to satisfy some of these needs, the Climate / Air Quality team proposed a number of priority experiments. The proposed experiments require long-term observations, the results of which can be used for creating more sophisticated models of the dynamics and chemistry of the lower atmosphere.

The experiments of highest priority which were selected were:

- Greenhouse gases namely NO_x , N_2O , CH_4 , CFC11, CFC 12 and CFMs;
- The total energy budget of the Earth; and
- Monitoring the amount of ozone O_3 in the troposphere and stratosphere.

NO_x components are important in the formation of both acid deposition and smog, a product of solar-driven chemical reactions in the atmosphere. The chlorofluorocarbons (CFC11, CFC12) and the chlorofluoromethanes (CFMs) are the agents primarily responsible for depleting the stratospheric ozone layer. Rising levels of chlorofluorocarbons, together with methane (CH_4), nitrous oxide (N_2O) and carbon dioxide (CO_2) are enhancing the greenhouse effect.

Global warming has been the subject of widespread social and scientific concern and attention. The proposed experiments for determining the total energy budget include determination of the total output for radiant heat, reflected solar radiation, incident solar UV irradiance, backscattered UV, and the surface temperature. Most of the measurements could be performed in the near IR range of the electromagnetic spectrum.

Along with the measurements of the absorption of the greenhouse gases, the measurement of the above parameters would allow the collection of information addressing the changing atmosphere and climate and would provide opportunity for climate and chemistry modelling as well as further research in the areas mentioned.

The results from these investigations would relate to such high-priority research areas as:

ATMOSPHERIC POLLUTION

- Deposition of atmospheric nitrogen and sulfur compounds;
- Nitrogen cycling in forests;
- Cloud and rain chemistry and removal processes;
- Impacts of atmospheric pollutants (ozone, PAN and nitrogen oxides) on forests and crops.

CLIMATE CHANGE

- Exchange of carbon dioxide and other radiatively active gases at the ground; and
- Effects of high carbon dioxide levels on soils and vegetation communities

6.2.1.3 Energy and Minerals

The Energy and Minerals team had a somewhat different problem to face than the other teams, in the sense that mineral and energy mining activities are mainly underground. The brief review of the literature showed that the remote sensing activities related to mining operations were less developed than its use for mineral exploration.

It appeared clear to the team that the problem of energy was crucial for the next century. The development of countries is equated with an increase of energy consumption. The situation today, where most of that consumption is made by developed countries, may change in the future. The energy "crisis" and its geo-political implications are painfully obvious today. So, energy appeared as a factor of development and stability for the planet, and an intensive application of remote sensing techniques in this domain is a challenge for the future.

Two categories of energy sources were considered: (1) Fossil Energy Sources (FES) including oil, natural gas and coal, requiring some mining activities; and (2) sources of "free" energy. In the second category are wind energy, solar energy, geothermal energy, and hydro-electricity. Both sources of energy interact with other problem areas, particularly meteorology and land-use.

Regarding minerals, the need for remote sensing techniques in this area is mainly related to the discovery of possible new mining areas. This is possible through direct observation of characteristic wavelengths of elements (radio-isotopes in particular: e.g. uranium), but mostly through indirect ways. The preparation of an accurate geological map is required, and its features (faults for instance) can provide valuable indications of mineral location.

For hydro-electric power plants, remote sensing data contributes to safety requirements. Together with other data, risks of catastrophic events (earthquake, etc.) can be avoided. For the best construction of a pipe-lines, the same principle applies. All these

considerations are related to geological information. This monitoring is also valuable to respond to unavoidable catastrophes, volcano eruptions for instance.

The phenomena involved in geology have not the same time-scale as those related to human activities or meteorology. Thus, frequency of observation is not a major criterion. Annual or even decade observations seem to fit most of the needs.

It appeared that two levels of spatial resolution needs exist. The broadest one is at the scale of a country, which may want to classify its natural resources and locate them by region. A spatial resolution in the range of 100 meters to one kilometer seems appropriate. The second level must be much more precise, to contribute to the exploration and mining process. The scale is then local, and the spatial resolution is about twenty meters.

It appeared that the general topic "geology" had to be taken into account in our area. This activity includes mainly a precise geological mapping, valid for any country. At the present time, such maps are probably only exist for developed countries. The activity of mapping includes also "dynamic" mapping, to monitor the evolutions of geology or events. Once the mapping has been achieved, its analysis can provide information needed for energy and minerals mining activities.

Wind and solar energies overlap with meteorology, and were considered primarily as outputs of an IPEO-meteorological remote sensing program. For wind energy, since the height of wind mills is about fifty meters, we must have an accurate measurement of the direction and velocity of the wind from the ground to about hundred meters of altitude. Solar energy does not require a measurement of temperature, but rather a measurement of radiative energy or sunlight intensity. These data should be included or at least added to the needs of weather monitoring.

6.2.1.4 Land Use

The "Land Use" teams focused on the third compartment of the Earth's structure, the Lithosphere. Coverage of the planet's terrestrial surface shows the greatest diversity and complexity. Main research programs on Earth as a system contain terrestrial studies as an essential component for the understanding of determining processes and the creation of computer models. A major aim of those studies is to monitor the development of terrestrial land use, recognize trends and to determine whether these trends are occurring due to natural conditions or resulting from human activities. Another topic is the estimation of the influences of larger global processes on local environmental events, versus their importance to regional conditions. Data about these relationships would enable scientists and decision makers to formulate models of appropriate scale and come up with proper management strategies to avoid hazardous conditions in the future.

The team came up with three main topics for further investigation: Land Use/ Topographical Mapping; City Development Monitoring; and Wildlife Monitoring.

The major focus of topographical and land use mapping is to provide research and applications programs on environmental or global change items with sufficient data. Such

data contain topographical values like elevation and slope as well as information about the kind of coverage (e.g. vegetation, bare soil, ice and snow, human settlement, infrastructure, agriculture, inland waters) and the amount of each within the viewed area. Continuing monitoring over the years can provide information about dynamics and trends of land use, especially those related to human activities. Considering the fact that the major part of the world shows insufficient topographical mapping, a global topographical/ land use mapping in a uniform resolution and quality is considered to be a key tool for most environmental research activities in the future.

The monitoring of city growth is closely related to the aims of topographical/ land use mapping. However, because of the features of the viewed object a higher resolution is generally needed for city development studies. Monitoring of city development and growth provides data enabling decision makers to support management strategies and to avoid environmental and socioeconomic hazards.

Monitoring of standing stock, distribution and migration of wild animals is a question not only addressed by zoologists and wildlife protection organizations like the World Wildlife Fund, but also by environmental and economic managers and tourist offices. Several pilot projects on whale and seal migration or migration and standing stocks of several major African mammals have already been done using Earth observations. Monitoring on a larger geographical and time scale is still missing and could deliver data of high value for the groups identified above.

6.2.1.5 Oceans/Coastal Zones

In the frame of a policy aimed at better understanding of the mechanisms responsible for "global change," a modeling of the role played by the ocean in the global carbon cycle assumes primary importance.

It is generally recognized that phyto-plankton are a major contributor to the mechanisms which absorb atmospheric carbon dioxide at the ocean-air interface. Subsequently phyto-plankton sedimentation accounts for the storage of carbon at the sea bed.

It has been suggested that storms, internal waves, eddies, ocean currents and ocean dynamics in general play a key role in the dynamic of this process. It is therefore important to study the parameters describing phyto-plankton concentrations together with the parameters affecting their dispersion and health.

Phyto-plankton can be monitored by measuring chlorophyll concentration thanks to its reflectivity at different wavelengths. An example are the measurements obtained from band 1,2,4,5 by the Coastal Zones Color Scanner on board NIMBUS 7. Surface temperature, which also affects phyto-plankton dynamics, can be monitored by microwave radiometers such as the Along Track Scanning Radiometer on board ERS-1. Useful additional information could be provided by spectrometers.

Information relating to ocean dynamics can be extracted by data on sea height, surface roughness and surface temperature, as provided by radar altimeters (ERS-1, C band) and wind scatterometers (ERS-1, C band).

Oceans act as a huge heat sink which absorbs heat from the atmosphere, contributing to the slowing of down of "global warming." In order to better characterize this interaction it is fundamental to measure the amount of energy exchanged at the ocean-atmosphere interface. In this respect useful data can be gathered by monitoring ocean surface temperature, storms and precipitation.

Pollution of the oceans and coastal zones was identified as a problem area. Such pollution can be divided into several categories :

- Organic wastes contributed by domestic sewage and industrial wastes of plant and animal origin which remove oxygen from the water through decomposition;
- Plant nutrients which promote nuisance growths of e.g. algae and water weeds;
- Synthetic/organic chemicals;
- Sediments;
- Radioactive pollutants; and
- Temperature increases from use of water for cooling purposes.

The most widespread and serious sources of pollution are not large oil spills or toxic-waste dumping, but sewage disposal and sedimentation from land clearing and erosion - both of which are enhanced by growing coastal populations coupled with the lack of sewage treatment and erosion control. There is a gradient of reduced pollutant concentration away from the source, and the open ocean stays relatively clean, only low concentrations occur.

Severe pollution is found in the coastal zones. This has a disproportionate impact as most of the ocean life useful to man is found in these waters. The coastal zones play the primary role in supporting the aquatic food chain, and so the pollution of the coastal waters might have overwhelming local impacts, and in the end global impacts, on life in the sea. This means that the connections must be understood between human activities along the coast and variations in the biogeochemical cycles of the coastal ocean. Another area of investigation is the exchange of nutrients and carbon between the coastal zones and the open sea.

Ocean resources include fish/other food resources on one hand, and marine minerals, oil and gas on the other hand. In both cases the needs for further investigations were found to be driven mainly by commercial interests.

Monitoring of fishery resources is presently of interest mostly to those countries with fishing industry. The fishing industry might benefit from what is being done in general

monitoring of the ocean, as indicators such as ocean thermal boundaries and plankton are important for locating the fish. The exploration of deep ocean resources is an area which belongs to the future applications for remote sensing.

6.2.1.6 Forestry

Deforestation has become a very important issue that has impacts on global changes such as the carbon and hydrological cycles. The forests are important sources of moisture and cooling for the global circulation and thus deforestation in the tropical rain forests disturbs the climate in other regions of the planet Earth.

This specific topic(deforestation) is part of the broader subject of forestry. To control deforestation requires, as a first step, a careful inventory of the forest area, the existing species and then constant monitoring and management to evaluate the effective use of deforested areas.

Five sub-areas were identified as important to perform forest management effectively :

- 1) Deforestation;
- 2) Inventory;
- 3) Damage Assessment;
- 4) Forest Management; and
- 5) Hydrological Cycle

For each sub-area a short description follows in order to substantiate the requirements and priorities.

- 1) Deforestation. Deforestation has the following main impacts on the environment:
 - Carbon Cycle. The burning of forests has two immediate effects: production of CO₂ and reduction of a carbon storage;
 - Hydrologic Cycle. Moisture change and soil erosion are direct consequences of deforestation; and
 - Biomass. Extensive biomass reduction occurs when deforestation is made in an uncontrolled manner.
- 2) Inventory. This broad area was subdivided into four different groups:
 - Cartography. The mapping of forests allows the consistent study of forest dynamics and their management. Present

satellites fulfill this need, but higher spatial resolution might be needed.

- Natural canopy. The estimation of natural canopy cover provides an estimation of above ground biomass and the vegetation and carbon dioxide exchange. Synthetic Aperture Radars (SAR) and multispectral optical detectors are considered the most important sensors to use for this application.
- Timber volume estimation. The needs of the foresters was covered by this sub-area which assesses timber quantity. This commercial application helps in planning the harvesting of the forest by measuring the average height of trees and their density distribution. Techniques to accurately measure the height of trees from space are not currently available.
- Identification of species. The evolution of the contents of a forest as well as its general health is useful for both commercial and scientific uses. Current detector technology needs to be improved to obtain higher resolutions for species identification.

3) Damage Assessment.

4) Forest Management. Forest management could be used for:

- monitoring indiscriminate felling of trees,
- monitoring and control of damage to trees by insects/pests,
- monitoring and control of forest burning, and
- Planting of trees as a replacement of damaged ones or in new areas.

Forest management therefore is important in forestation programs and control of deforestation. This eventually may lead to management of chlorophyll in the ecosystem necessary for control of carbon dioxide in the atmosphere.

5) Hydrological Cycle

Water is a primary constituent of man's environment and may be found simultaneously in one area as a liquid, a gas and a solid. Unlike most other resources, water (on land and in the atmosphere) is continuously

variable in its availability in one state or another, and the forests, primarily the tropical ones, play an important role in the water cycle.

6.2.1.7 Water Resources

Ground Water

Ground water is seen as the most scarce resource and has the highest priority in this group. Ground water investigations focus on:

- Presence/ absence of ground water;
- The depth to ground water;
- Quantity/quality of ground water;
- Recharge rates to aquifer systems;
- Overall dynamics of ground water systems(naturally/human induced);and
- Extent of aquifer systems and interaction with surface sources.

Whereas this information is generally sought by hydrogeologists using conventional methods, remote sensing can help in the planning of conventional measurements and can be used to estimate some hydrogeological variables quantitatively and qualitatively.

Snow and Ice

Snow and ice cover an average of 10 percent of the Earth's surface and contain approximately 75 percent of all fresh water resources. The role of the large ice covered areas of the poles in the energy balance of the Earth is of significant importance. Remote sensing provides a unique opportunity to monitor and model the ice /atmosphere interaction as part of the global energy balance. On a more regional level, remote sensing provides powerful means of monitoring the movement of sea ice and surveying the extent and volume of snow cover during the winter season along the prediction of forecasts spring floods.

Flood

One of the best applications of remote sensing to water resources is the delineation of recently flooded areas, if weather permits observations. The delineation of floods in vegetation-covered areas is more difficult, but is possible either by use of radar or through a combination of radiation and topographic data. Remotely sensed data obtained on flood-plain characteristics can be combined with data obtained during floods for flood mapping and delineating flood hazard areas.

Water Quality

Changes in reflected radiation are sometimes a result of variation in soil type, soil moisture availability, or suspended sediment in water, but it could also be caused by the presence of pollution. Consequently, sources and current locations of pollutants are often identifiable from space observation. Analysis of a multispectral image can suggest remedies to some pollution problems by indicating local areas where holding ponds or levees might be placed.

6.2.2 Prioritization

6.2.2.1 Generation of Matrices

This section contains a description of the methodology used to obtain the priority ranking of requirements.

Identification of Required Measurements and Parameters

A matrix structure was identified as the best way to display the results of each problem area assessment. The comparative matrix listed the measurements required within each problem area, identifying the following parameters:

- Area;
- Existing capabilities;
- Indicators used to obtain the information;
- Scale of the measurement e.g. global, continent, etc.;
- Climatic zone affected e.g. tropical, polar;
- Development status of the affected area e.g. industrialized, developing;
- Period of the measurements e.g. every hour;
- Spatial resolution of the measurement e.g. between 1 and 10km.;
- Wavelength for the measurement e.g. visible, IR;
- 3-dimensional aspect of the measurement;
- Use of the measurement e.g. scientific, commercial; and
- References for the information.

The Literature brought from the individual countries participating in ISU was recorded as were sources from faculty and York University. Time precluded a thorough literature review. Measurements were screened using the following broad criteria which had been identified by a 'Tiger Team' set up for this purpose:

- Is the need International?
- Does the investigation explore the area which possess long term needs?

- Can the information be applied to multi-disciplines?
- Is the data needed available now?
- Is the data needed for process study or management?
- Does the data define 'Hot Spots'?

These questions reduced the number of candidate priorities to approximately 250.

6.2.2.2 Prioritization Within the Problem Area Teams

Each team was responsible for ranking the priorities which they had identified by consensus of the group. The results of these rankings are identified in the priorities column of each matrix presented in Tables 6.2.2 - 1 – Table 6.2.2 - 7.

6.2.2.3 Overall Prioritization

Three types of priority data or applications were selected in each problem area. These priorities are summarized below and are further developed in each team matrix.

- 1) Agriculture (Table 6.2.2 - 1)
 - Forecast
 - D.I.areas
 - Interaction with weather
- 2) Climate (Table 6.2.2 - 2)
 - Green house gases
 - Energy budget
 - Ozone
- 3) Minerals and Energy (Table 6.2.2 - 3)
 - Fossile-energy sources (e.g. oil, gas, coal)
 - Minerals
 - Wind energy
- 4) Land-use (Table 6.2.2 - 4)
 - Global mapping
 - Global productivity
 - Urban land use

- 5) Coastal zones and Oceans (Table 6.2.2 - 5)
 - Chlorophyll
 - Ocean dynamics
 - Surface topography
- 6) Forestry (Table 6.2.2 - 6)
 - Deforestation
 - Inventory
 - Damage assessment
- (7) Water resources (Table 6.2.2 - 7)
 - Ground water
 - Polar ice and snow
 - Water quality

6.2.2.4 Final Priorities List / Matrix

Priorities List

From the topics and priorities developed by each team, some were regrouped across several areas, leading to nineteen topics. The scores attributed to each cell of the resulting table were obtained by consensus of the requirements group part of the table and by voting for the rest. The scores were based upon numerical weighting factors. The factors were:

| | |
|-------------------------------|----|
| * International | 10 |
| * Environmental Value | 9 |
| * Multidisciplinary | 8 |
| * Global Unmet | 4 |
| * Technically Unmet | 3 |
| * Commercially Unmet | 3 |
| * Long Term/System View | 8 |
| * Emergency/"Hot Spots" | 5 |
| * Economic/Social Development | 5 |

Table 6.2.2 - 1 Requirements of Agriculture

| AREA | PRIORITY | EXIST. CAPABILITIES | INDICATOR | SCALE | CLIM. ZONE | DEVEL. STAT. | PERIOD | SPATIAL RES. | WAVE LENGTH | 3-D ASPECTS | USES | REFERENCES |
|-------------------|----------|---------------------|----------------|-------|------------|--------------|--------|--------------|-------------|-------------|------|-------------------|
| D.I. Crops | | Landsa | | G | A | A | 16 D | 30 m | VIS | | S+C | |
| | | Landsa Spot | colors | N | TR | D | Q | 20-30 m | VIS | | | RW1-86 |
| | | ERS1 | reflectivity | G | A | A | 72h | 30 m | Micro | | S+C | WEG89 ESJ89 |
| D.I. Areas | 2 | Landsa | T.Color | N | TR | D | | 30 m | VIS | | S+C | INPE85 |
| | | Rad.sat | | G | A | A | 72 h | | Micro | | S+C | RAD. |
| | | Landsa | Veget. Index | G | TE | I | 16 D | 30 m | NIR | | S+C | |
| | | SPOT | | G/N | A | A | | 20/10 | VIS | | S+C | |
| | | ERS-1 | | G | A | A | | 25*25 | VIS/NI | | S+C | |
| | | no TERS | Colors | N | TR | D | | 16 m | micro+.5-.8 | | S+C | Indonesian report |
| | | Bhaska. India | | G | A | A | | 37*73 | ? | | S+C | |
| | | no TERS project | Colors | N | TR | D | | 16 m | micro+.5-.8 | | S+C | Indonesian report |
| | | Y | Colors | N | TR | D | Q | 20 m | VIS | | S+C | RS swedis |
| | | Y? | Colors pattern | N | TR | D | Y | 20 km *20 | VIS | | S | Swed. Space |
| Interact/ weather | 2 | NOAA | | G | A | A | | | VIS/NI | | S+C | |
| | | Sodar | | N | TE | I | | | Micro | | S+C | |
| | | Sodar | | N | TE | I | | | Micro | | S+C | |
| Forecast | 1 | Rad.sat | | G | All | All | 72 h | | Micro | | S+C | RAD. |
| | | Landsa | T.Color | N | TR | D | | 30 m | VIS | | S+C | INPE85 |
| (Forecast) | | Landsa | colors | N | TE | I | Q | 20-30 m | VIS | | C | Appli. Canada |
| | | Spot | Albedo | N | TE | I | Y | 10-20 m | VIS | | S | NRSC |
| In/Water | 2 | ?Brazil | | N | TR | D | ? | ? | VIS/NI | | S+C | RW1-86 |
| | | Landsa | | G | A | A | 16 D | 30 m | VIS | | S+C | |
| Threats | | no TERS | | N | TR | D | | 16 m | .5-.8 | | S+C | 1984 |
| | | Y | T | N | TE | I | Y | 100 m | Micro | | S | NRSC |
| Vegetat.stress | | no TERS | fluorescence | N | A | A | ? | 10 m ? | 0.45-0.54 | | S+C | ESA-SP301 |
| Potentialities | 2 | ? | Colors T | N | TR | I | Q | 10-20 m | Micro VIS | | | RW1-86 |
| | | ? | Colors pattern | N | TE | I | 2 W | 100 m | Micro | | S | NRSC |
| In/Soil | 3 | Spot | pattern colors | N | TE | I | Q | 10-20 m | VIS | | S | NRSC |

SCALE: GLOBAL, CONTINENTAL, NATIONAL, REGIONAL, LOCAL
 CLIMATIC ZONE: POLAR, TEMPERATE, SUBTROPIC, TROPIC, DESERT, ALL
 DEVEL. STATUS: INDUSTRIAL, DEVELOPING, ALL
 PERIOD: HOUR, DAY, WEEK, MONTH, QUARTERLY, YEAR, DECADE
 SPATIAL RESOLUTION: 1m, 10m, 100m, 1km, 10km, 100km
 WAVE LENGTH: VISIBLE, NEAR-IR, THERMAL IR, MICROWAVE, RADIO
 3-D ASPECTS: YES OR NO
 USES: SCIENTIFIC, COMMERCIAL

COMMENTS:
 Priority 2 : Change monitoring and mapping, must be understood as the result of the interaction of the differents factors (water, weather, soil, etc.) in a long term process.

Table 6.2.2 - 2 Requirements of Climate

| AREA | PRIORITY | EXIST. CAPABILITIES | INDICATOR | SCALE | CLIM. ZONE | DEVEL. STAT. | PERIOD | SPATIAL RES. | WAVE LENGTH | 3-D ASPECTS | USES | REFERENCES |
|-------------------------|----------|------------------------------|----------------|-------|------------|--------------|--------|----------------------------|------------------------|-------------|------|-------------|
| green house gases | 1 | NIMBUS 7,ERBS EOS UARS | SPECTRAL BANDS | G | A | A | W-M | 10-100KM | NEAR IR/ MICRO-WAVE | YES | SCI. | 12,13,15,16 |
| ozone | 3 | NIMBUS ERBS EOS | SPECTRAL BANDS | G | A | A | W-M | 1KM VERT. 1-10KM HORIZ. | NEAR IR | YES | SCI. | 12,13,14,16 |
| energy budget | 2 | ERBE EOS | CONTINUUM | G | A | A | D-M | 1-10KM | VISIBLE .IR | NO | SCI. | 13,14 |
| solar constant | | ERBE EOS | CONTINUUM | G | A | A | W-M | - | UV, VISIBLE | NO | SCI. | |
| surface temperature | | EOS MOS | CONTINUUM | G | A | A | D-M | 10-100KM | NEAR IR | NO | SCI. | |
| aerosols | | NIMBUS 7,EOS | SPECTRAL BANDS | G | A | A | W-M | 1-10KM | NEAR IR | NO | SCI. | |
| pollution | | NIMBUS 7,EOS | SPECTRAL BANDS | G | A | A | 0.5HR | 1-10KM | VIS/IR | YES | BOTH | |
| cloud motion vector | | METEOSAT GOES | COMPARISON | G | A | A | 0.5HR | 1-10KM | VIS/IR | YES | BOTH | |
| sea surface temperature | | METEOSAT GOES | | G | A | A | 0.5HR | 1-10KM | THERMAL IR | YES | BOTH | |
| cloud cover development | | METEOSAT GOES | | G | A | A | 0.5HR | 1-10KM | VIS/IR | YES | BOTH | |

Table 6.2.2 - 2 Requirements of Climate, Con't

| AREA | PRIORITY | EXIST. CAPABILITIES | INDICATOR | SCALE | CLIM. ZONE | DEVEL. STAT. | PERIOD | SPATIAL RES. | WAVE LENGTH | 3-D ASPECTS | USES | REFERENCES |
|--|----------|------------------------|---------------|-------|------------|--------------|--------|--------------|-------------|-------------|------|------------|
| vertical temperature profile | | MSG | | G | A | A | HR | 1-10KM | IR (CO2) | YES | BOTH | |
| convective clouds | | - | | G | TR/SUBT R | A | 0.5HR | <1KM | VIS | YES | BOTH | |
| energy transfer over tropics | | - | | G | TR/SUBT R | A | M | 1-10KM | - | NO | SCI. | |
| survey of lightning/forecast | | EOS | | G | A | I | HR | 1-10KM | VIS. | YES | BOTH | |
| tropospheric ozone | | MSG EOS (HIRRIS) | | G | A | A | 0.5HR | 1-10KM | IR | NO | SCI. | |
| vertical profile of tropospheric winds | | EOS (LAWS) | DOPPLER SHIFT | G | A | A | 0.5HR | 1-10KM | - | YES | BOTH | |
| precipitation | | EOS | WATER VAPOR | G | A | A | - | - | - | - | BOTH | |
| upper troposphere humidity | | METEOSAT GOES | WATER VAPOR | G | A | A | - | - | IR | YES | SCI. | |
| water vapour humidity | | MSG | | G | A | A | HR | 1-10KM | IR | YES | SCI. | |
| cloud top height | | METEOSAT GOES | | G | A | A | HR | 1-10KM | IR | YES | SCI. | |

Comments:

- 1) There is an international need to understand the impact of the experiment that the people of the world are conducting with the atmosphere.
- 2) The question of global warming can only be addressed with data which have been obtained over a long period of time in order to segregate perturbations from the natural cycle of the biosphere.
- 3) Understanding the biosphere is a multi-disciplinary problem of which the climate and the atmosphere play a key role.
- 4) The primary need is for long term observations which are not yet available.
- 5) The observations outlined above are needed primarily to improve our knowledge of the processes occurring in the biosphere.
- 6) The unique long term nature of this project has a high degree of potential for identifying new trouble areas.

Table 6.2.2 - 3 Requirements of Minerals and Energy

| AREA | PRIORITY | EXIST. CAPABILITIES | INDICATOR | SCALE | CLIM. ZONE | DEVEL. STAT. | PERIOD | SPATIAL RES. | WAVE LENGTH | 3-D ASPECTS | USES | REFERENCES |
|------------|----------|---------------------|-----------|-------|------------|--------------|--------|--------------|-------------|-------------|------|------------|
| F.E.S (1) | 1 | Yes (2) | Pattern | N-L | A | A | DE | 25m | Visible | Yes(2) | Both | RSM(3) |
| Solar Eng. | 4 | Yes | Spect. | L | A | A | H | 30m | IR | - | Both | EOS VII |
| Wind Eng. | 3 | Yes | (4) | L | A | A | H | 30m | Radar | Yes | Both | EOS VII |
| Geotherm. | 5 | Yes (2) | Pat/Sp | L | A | A | DE | 30m | Vis/IR | - | Both | W. Res. |
| Hydroelec. | 6 | Yes (2) | Pattern | L | A | A | DE | 30m | Visible | - | Both | W. Res. |
| Minerals | 2 | Yes (2) | Pattern | N-L | A | A | DE | 30m | Vis/IR | - | Both | EOS VII |
| | | | | | | | | | | | | |
| | | | | | | | | | | | | |
| | | | | | | | | | | | | |
| | | | | | | | | | | | | |
| | | | | | | | | | | | | |
| | | | | | | | | | | | | |

COMMENTS: (1) Fossile-Energy Sources = Oil, natural gas, coal
 (2) Related to precise geological mapping
 (3) Remote sensing manual
 (4) Laser Atmospheric Wind Sounder

Table 6.2.2 - 4 Requirements of Land-Use

| AREA | PRIORITY | EXIST. CAPABILITIES | INDICATOR | SCALE | CLIM. ZONE | DEVEL. STAT. | PERIOD | SPATIAL RES. | WAVELENGTH | 3-D ASPECTS | USES | REFERENCES |
|---------------------|----------|--|--------------------|-----------|------------|--------------|--------|--------------|------------|-------------|------|------------------------------------|
| Global Mapping | 1 | ModisT ModisN HIRIS TMS | Bare Soil | Global | All | All | Month | 1 km | V,N,T | Yes | C,S | *EOS *ESA *Earth as a system |
| | | | Vegetation | | | | | | | | | |
| | | | Ice/Snow | | | | | | | | | |
| | | | Agriculture | | | | | | | | | |
| | | | Cities/Rural Areas | | | | | | | | | |
| | | | Water | | | | | | | | | |
| | | HIRIS SAR | Topography | | | | | | Radar | | | |
| Global Productivity | 1 | ModisT ModisN AVHRR HIRIS TMS SAR | Vegetation-Index | Global | All | All | Week | 1 km | V,N,T | Yes | C,S | see above |
| | | | PAR | | | | | | | | | |
| | | | Surface Wetness | | | | | | | | | |
| | | | Soil Water | | | | | | | | | |
| | | | Plant Type | | | | | | | | | |
| | | ModisNT IMS | Plant Temperature | | | | | | | | | |
| Global Productivity | | AMSR | Precipitation | | | | | | M | | | |
| Urban Land Use | 2 | TM HRV | ColourParameter | Natio-nal | All | All | QY | 10 m | V,N,T,M | No | C | |
| | 1 | --(SLAR) | ColourParameter | Natio-nal | All | All | QY | 5 m | V,N,T,M | No | C | |
| Wildlife/Life stock | 3 | VC on H,P (XM) | Pat-tern | Regio-nal | All | Devel. | W/M | 1 m | V | No | S(C) | |

AMSR-Advanced Microwave Scanning Radiometer

AVHRR-Advanced Very High Resolution Radar

HIRIS-High Resolution Imaging Spectrometer

MODIS-Moderate Resolution Imaging Spectrometer (Tilt/Nadir)

TIMS-Thermal Infrared Multispectral Scanner

SAR-Synthetic Aperture Radar

SLAR-Side Looking Airborne Radar

PAR-Photosynthetic Apparent Radiance

Table 6.2.2 - 5 Requirements of Coastal Zones and Oceans

(i) OCEAN EFFECT ON THE CARBON CYCLE

| AREA | PRIORIT Y | EXIST. CAPABI LITIES | INDIC- ATOR | SCALE | CLIM. ZONE | DEVEL. STAT. | PERIOD | SPATIA L RES. | WAVE LENGT H | 3-D ASPECT S | USE S | REFERE NCES |
|---------------------------------|--------------|---|----------------------------|-------|---------------|-----------------|--------|------------------|-------------------------|--------------------|----------|----------------|
| Chloro- phyll | 1(a) | Y: CZCS (NIMB- US-7), Sea- WIFS (LAND- SAT) | Colour | G | A | A | W | 1km | M,V bands 1,2,4,5 | N | S+C | |
| | | Y: ATSR (ERS1), SMMR (SEA- SAT), AMRIR (EOS) | Temp | G | A | A | W | 1km | IR,M | N | S+C | |
| Ocean Dynamics | 1(b) | Y: CZCS (NIMB- US-7) | Wave height | G | A | A | D | 10cm | M C-band | N | S+C | |
| | | Y: SCATT (ERS1), SCATT (EOS), N-ROSS | Wind speed | G | A | A | W | 50km | M C-band | N | S+C | |
| | | Y:SAR (SEA- SAT) | Wave direct/ roughn. | G | A | A | D | ? | M | N | S+C | |
| Surface Topo- graphy | 1(c) | Y: Altim. (SEA- SAT), RA (ERS1), TOPEX, ALT (EOS) | Sea height | G | A | A | W | 1m | M C-band | 3D | S+C | |
| Energy Exchange Interface | 1(d) | Y: As above | Temp | G | A | A | H/D | 1km | IR,M | N | S+C | |
| | | Y: As above | Surface rough- ness | G | A | A | H/D | 10cm | M C-band | 3D | S+C | |
| | | Y: ATSR (ERS1) | Moi- sture | G | A | A | H/D | ? | MW | N | S+C | |

Table 6.2.2 - 5 Requirements of Coastal Zones and Oceans, Con't

(ii) OCEAN RESOURCES

| AREA | PRIORITY | EXIST. CAPABILITIES | INDICATOR | SCALE | CLIM. ZONE | DEVEL. STAT. | PERIOD | SPATIAL RES. | WAVE LENGTH | 3-D ASPECTS | USES | REFERENCES |
|-----------------------------|----------|-------------------------------------|--------------------|-------|------------|--------------|--------|--------------|-------------|-------------|------|------------|
| Chlorophyll | 2/3 | Y:As above | Temp, colour | G | A | A | W | 1km | M,IR,V | N | C | |
| Sea height | | Y:As above | Sea height | G | A | A | W | 1m | M C-band | 3D | C | |
| Temp | | Y:As above | Deep ocean temp. | G | A | A | W | 1km | IR,M | 3D | C | |
| Sea bed model | | Y?: Altimeter (SEASAT, ERS1, TOPEX) | Bed model | G | A | A | W | 1m | M C-band | 3D | C | |
| Saline concentration | | N | Emissivity | G | A | A | D | 0.1ppt | M | 3D | S+C | |
| (iii) POLLUTION | | | | | | | | | | | | |
| Chlorophyll | 2/3 | Y:As above | Temp, colour | G | A | A | W | 10m? | IR,M,V | N | S | |
| Temp | | Y:As above | Temp | G | A | A | W | ? | T-IR | N | S | |
| Sediment | | N | Colour | G | A | A | D | ? | V | ? | S | |
| Surface roughness | | Y: As above | Wave height & dir. | G | A | A | D/H | 0.5m | M | 3D | S | |
| Entrained or dissolved org. | | N, except chlorophyll | Color | G | A | A | D | ? | V | N | S | |

Table 6.2.2 - 6 Requirements of Forestry Group

| AREA | PRIORITY | EXIST. CAPABILITIES | INDICATOR | SCALE | CLIM. ZONE | DEVEL. STAT. | PERIOD | SPATIAL RES. | WAVE LENGTH | 3-D ASPECTS | USES | REFERENCES |
|------------------------------|----------|-----------------------------------|--|--------|--------------|--------------|----------------|--------------|------------------------------|-------------|------|------------|
| FOREST | | | | | | | | | | | | |
| Deforestation | 1 | Landsat, SPOT, airplanes (Vis/IR) | color, temperature, contours, pattern, texture | Global | TE, SUB, TRO | All | Q | 15 m | Vis, IR (2 bands), Microwave | N | S | 1,2,4,5 |
| Inventory | 2 | | | | | | | | | | | |
| a) Identification of species | | airplane SAR | color, temperature, contours, pattern, texture | L | TE, SUB, TR | All | Q | 1-10 m | Vis, Near-IR | Y | S,C | 1,6 |
| b) Wood quantity | | Landsat, SPOT, airplanes (Vis/IR) | density height of trees | L | TE, SUB, TR | All | Y-Q | 10 m | Vis, Near-IR | Y | C | 1 |
| c) Natural canopy (biomass) | | SAR | | N | TE, SUB, TR | All | Y-Q | 10 m | Vis, Microwave | N | S+C | |
| d) Cartography | | | | N | TE, SUB, TR | All | Y-Q | 30 m | | | | 1,8,10 |
| Damage assessment | 3 | | | | | | | | | | | |
| a) Fire control | | | | L | A | A | when necessary | 50 m | Thermal-IR, Vis | N | S | 1, |
| b) Insects | | | | | | | M | | Vis, IR | | | |
| c) disease | | | | R | A | A | Y | 10 m | Vis | N | S-C | 1, |
| d) air pollution | | | | L | A | A | Q | 10 m | Vis | N | S | 1, |
| e) storm damage | | | | R | A | A | | 100 m | Vis, Near-IR | N | S-C | 1, |
| f) acid rain | | | | L | A | A | when necessary | 50 m | Vis | N | S-C | 1, |
| | | | | R | A | A | Y-Q | 50-100 m | | N | S | 1, |
| Forest Management | 4 | | | | | | | | | | | |
| a) Timber logging | | Landsat, radar, Airplanes | colour pattern temp. | N | A | All | Q | 100 m | Vis, NIR, TIR | Y | C | 1, |
| b) Reforestation | | | | N | A | All | Q | 100 m | Vis, IR, NIR, TIR | N | C | 1, |
| c) National park creation | | | | N | A | All | Q | 100 m | Vis, IR, NIR, TIR | N | C | 1, |
| Hydrologic Cycle | 5 | | | G | TE, SUB, TRO | All | Q | 15 m | Vis, IR, Microwave | N | S | 1,2,5 |

Table 6.2.2 - 7 Requirements of Water Resources

| AREA | PRIORITY | EXIST. CAPABILITIES | INDICATOR | SCALE | CLIM. ZONE | DEVEL. STAT. | PERIOD | SPATIAL RES. | WAVE LENGTH | 3-D ASPECTS | USES | REFERENCES |
|--|----------|---------------------|-------------------------|-------|------------|--------------|--------|--------------|--------------------------|-------------|------|------------|
| POLAR ICE | | | | | | | | | | | | |
| Ice/atmosphere interaction | 2 | Yes | Colour, albedo | C | P | A | W | 100 m | VIS., MW, NEAR-IR | NO | S | |
| Ice temperature | | No | Brightness | C | P | A | W | 100 m | TH-IR, MW | NO | S | |
| Ice sheet movement - topography | | Yes | Contours | C | P | A | W | 10-100 m | VIS., MW, NEAR-IR | NO | S | |
| Ice sheet thickness | | No | Contours | C | P | A | W | 10-100 m | MW | YES | S | |
| Ice shelves monitoring - movements | | Yes | Colour | C | P | A | W | 100 m | NEAR-IR | NO | S | |
| SEA ICE | | | | | | | | | | | | |
| Ice roughness | | Yes | Contours | C,R | P,TE | I | D | 10-100 m | MW | YES | ALL | |
| Ice temperature | | No | Brightness, Temperature | C,R | P,TE | I | D | 10-100 m | NEAR-IR | NO | ALL | |
| Ice albedo | | Yes | Albedo | C,R | P,TE | I | D | 10 m | VIS. | NO | ALL | |
| SNOW | | | | | | | | | | | | |
| Snow cover area | 2 | Yes | Colour | C,R | P,TE | ALL | D | 10-100 m | VIS., NEAR-IR | NO | ALL | |
| Dry snow extent | | Yes | Brightness | C,R | P,TE | ALL | D | 100 m-1 km | TH-IR | NO | ALL | |
| Dry/wet, thin/deep, frozen/melting | | No | Brightness | C,R | P,TE | ALL | D | 10-100 m | VIS., NEAR-IR, TH-IR | YES | ALL | |
| Wet snow characteristics | | No | Colour | C,R | P,TE | ALL | D | 10-100 m | MW | NO | ALL | |
| Snow pack characteristics | | No | Contours | C,R | P,TE | ALL | D | 100-1km | TH-IR, MW | NO | ALL | |
| Water equivalent | | No | Scattering | C, R | P,TE | ALL | D | 10-100 m | TH-IR | NO | ALL | |
| GROUND WATER | | | | | | | | | | | | |
| Direct detection | 1 | NO | Colour, brightness | R | All but P | ALL | M | 1-10 m | TH-IR, MW | NO | ALL | |
| Derived detection | | YES | Colour | R | All but P | ALL | M | 10-100 m | VIS., NEAR-IR, TH-IR, MW | YES | ALL | |
| Delineate of aquifer systems | | NO | Contours | R | All but P | ALL | M | 10-100 m | TH-IR, MW | NO | ALL | |
| Ground water discharge points | | NO | Colour | N | All but P | ALL | M | 1-10 m | TH-IR, MW | NO | ALL | |
| WATER QUALITY AND POLLUTANTS | | | | | | | | | | | | |
| | 3 | NO | CONCENTRATION | R | TE, SUB-TR | ALL | D, M | 1-10 m | VIS., NEAR-IR, TH-IR, MW | YES | ALL | |
| FLOOD PREDICTION AND ASSESSMENT | | | | | | | | | | | | |
| | 4 | NO | COLOUR, CONTOURS | R,L | TE, SUB-TR | D | W,D | 10-100 m | VIS., MW | YES | ALL | |

The resulting priority requirements table is shown below. After summing up the columns of this table, scores were obtained for each topic and were ranked accordingly in three priority groups.

| | | | |
|-------|---------------------|-----|---------|
| 1) | Global warming | 222 | Group 1 |
| 2) | Pollution | 212 | |
| 3) | Vegetation dynamics | 205 | |
| 4) | Land mapping | 204 | |
| 5) | Deforestation | 201 | |
| 6) | Biomass inventory | 196 | |
| ----- | | | |
| 7) | Water quality | 182 | Group 2 |
| 8) | Geological mapping | 178 | |
| 9) | Soil assessment | 177 | |
| 10) | Urban development | 174 | |
| 11) | Ground water | 174 | |
| 12) | Acid rain | 171 | |
| ----- | | | |
| 13) | Ozone | 156 | Group 3 |
| 14) | Crop forecast | 152 | |
| 15) | Insects | 142 | |
| 16) | Snow / ice | 132 | |
| 17) | Ocean resources | 125 | |
| 18) | Wildlife monitoring | 120 | |
| 19) | Flood | 117 | |

Examination of these results led to the conclusion that several groups of priorities emerged clearly and were not sensitive to slight modifications of the weighting factors or of individual team scores. The first group is comprised of the six highest scores, the second of the six next, and the third of the rest. The methodology and the results were reviewed by the entire requirements group and were presented to the IPEO students and faculty for review during the Preliminary Design Review.

Final Matrix

The final priority matrix is presented in Table 6.2.2 - 8.

6.3 Requirements Assessment

The following discussion moves from ranking priorities to how they should be understood and used in the context of IPEO.

Table 6.2.2 - 8 Final Matrix of all Requirements

(i) GLOBAL WARMING

| AREA | PRIORITY | EXIST. CAPABILITIES | INDICATOR | SCALE | CLIM. ZONE | DEVEL. STAT. | PERIOD | SPATIAL RES. | WAVE LENGTH | 3-D ASPECTS | USES | REFERENCES |
|------------------------------------|----------|---|---------------------|-------|------------|--------------|--------|--------------|--------------------|-------------|------|------------|
| Chlorophyll | | Y: CZCS (NIMBUS-7), SeaWiFS (LANDSAT) | Colour | G | A | A | W | 1km | M, V bands 1,2,4,5 | N | S+C | |
| | | Y: ATSR (ERS1), SMMR (SEASAT), AMRIR (EOS) | Temp | G | A | A | W | 1km | IR, M | N | S+C | |
| Ocean Dynamics | | Y: CZCS (NIMBUS-7) | Wave height | G | A | A | D | 10cm | M, C-band | N | S+C | |
| | | Y: SCATT (ERS1), SCATT (EOS), N-ROSS | Wind speed | G | A | A | W | 50km | M C-band | N | S+C | |
| | | Y: SAR (SEASAT) | Wave direct/roughn. | G | A | A | D | ? | M | N | S+C | |
| Surface Topography | | Y: Altim. (SEASAT), RA (ERS1), TOPEX, ALT (EOS) | Sea height | G | A | A | W | 1m | M C-band | 3D | S+C | |
| Energy Exchange Interface | | Y: As above | Temp | G | A | A | H/D | 1km | IR, M | N | S+C | |
| | | Y: As above | Surface roughness | G | A | A | H/D | 10cm | M C-band | 3D | S+C | |
| | | Y: ATSR (ERS1) | Moisture | G | A | A | H/D | ? | MW | N | S+C | |
| POLAR ICE | | | | | | | | | | | | |
| Ice/atmosphere interaction | | Yes | Colour, albedo | C | P | A | W | 100 m | VIS., MW, NEAR-IR | NO | S | |
| Ice temperature | | No | Brightness | C | P | A | W | 100 m | TH-IR, MW | NO | S | |
| Ice sheet movement - topography | | Yes | Contours | C | P | A | W | 10-100 m | VIS., MW, NEAR-IR | NO | S | |
| Ice sheet thickness | | No | Contours | C | P | A | W | 10-100 m | MW | YES | S | |
| Ice shelves monitoring - movements | | Yes | Colour | C | P | A | W | 100 m | NEAR-IR | NO | S | |

Table 6.2.2 - 8 Final Matrix of all Requirements, Con't

(ii) POLLUTION

| AREA | PRIORIT Y | EXIST. CAPABI LITIES | INDIC- ATOR | SCALE | CLIM. ZONE | DEVEL. STAT. | PERIOD | SPATIA L RES. | WAVE LENGT H | 3-D ASPECT S | USE S | REFERE NCES |
|------------------------------|-----------|---|--------------------|--------|------------|--------------|--------|---------------|--------------------------|--------------|-------|------------------------------------|
| aerosols | | NIMBUS 7, EOS | SPECTRAL BANDS | G | A | A | W-M | 1-10KM | NEAR IR | NO | SCI | |
| pollution | | NIMBUS 7, EOS | SPECTRAL BANDS | G | A | A | 0.5HR | 1-10KM | VIS/IR | YES | BOTH | |
| Chlorophyll | 2/3 | Y:As above | Temp, colour | G | A | A | W | 10m? | IR, M, V | N | S | |
| Temp | | Y:As above | Temp | G | A | A | W | ? | T-IR | N | S | |
| Sediment | | N | Colour | G | A | A | D | ? | V | ? | S | |
| Surface roughness | | Y:As above | Wave height & dir. | G | A | A | D/H | 0.5m | M | 3D | S | |
| Entrained or dissolved org. | | N, except chlorophyll | Color | G | A | A | D | ? | V | N | S | |
| WATER QUALITY AND POLLUTANTS | | NO | CONCENTRATION | R | TE, SUB-TR | ALL | D, M | 1-10 m | VIS., NEAR-IR, TH-IR, MW | YES | ALL | |
| Global Mapping | 1 | ModisT ModisN HIRIS TIMS | Bare Soil | Global | All | All | Month | 1 km | V, N, T | Yes | C, S | *EOS *ESA *Earth as a system |
| | | | Vegetation | | | | | | | | | |
| | | | Ice/Snow | | | | | | | | | |
| | | | Agriculture | | | | | | | | | |
| | | | Cities/Rural Areas | | | | | | | | | |
| | | | Water | | | | | | | | | |
| | | HIRIS SAR | Topography | | | | | | Radar | | | |
| Global Productivity | 1 | ModisT ModisN AVHRR HIRIS TIMS SAR | Vegetation-Index | Global | All | All | Week | 1 km | V, N, T | Yes | C, S | see above |
| | | | PAR | | | | | | | | | |
| | | | Surface Wetness | | | | | | | | | |
| | | | Soil Water | | | | | | | | | |
| | | | Plant Type | | | | | | | | | |
| | | ModisNT IMS | Plant Temperature | | | | | | | | | |
| | | AMSR | Precipitation | | | | | | M | | | |

Table 6.2.2 - 8 Final Matrix of all Requirements, Con't

| | | | | | | | | | | | | |
|-------------------|---------------------------------|-------------------------|-----|-------|---|-----|----------|---------------|-----|------|-----------------|--|
| SEA ICE | | | | | | | | | | | | |
| Ice roughness | Yes | Contours | C,R | P, TE | I | D | 10-100 m | MW | YES | ALL | | |
| Ice temperature | No | Brightness, Temperature | C,R | P,TE | I | D | 10-100 m | NEAR-IR | NO | ALL | | |
| Ice albedo | Yes | Albedo | C,R | P,TE | I | D | 10 m | VIS. | NO | ALL | | |
| energy budget | ERBS EOS | CONTIN UUM | G | A | A | W-M | 1-10KM | VISIBLE IR | NO | SCI. | 13,14 | |
| green house gases | NIMBUS 7,ERBS EOS UARS | SPECTR AL BANDS | G | A | A | W-M | 1-10KM | NEAR IR | YES | SCI. | 12,13, 15,16 | |

SCALE: GLOBAL, CONTINENTAL, NATIONAL, REGIONAL, LOCAL
 CLIMATIC ZONE: POLAR, TEMPERATE, SUBTROPIC, TROPIC, DESERT, ALL
 DEVEL. STATUS: INDUSTRIAL, DEVELOPING, ALL
 PERIOD: HOUR, DAY, WEEK, MONTH, QUARTERLY, YEAR, DECADE
 SPATIAL RESOLUTION: 1m, 10m, 100m, 1km, 10km, 100km
 WAVE LENGTH: VISIBLE, NEAR-IR, THERMAL IR, MICROWAVE, RADIO
 3-D ASPECTS: YES OR NO
 USES: SCIENTIFIC, COMMERCIAL

6.3.1 Priority Analysis

In developing the priorities for IPEO analysis (Table 6.3.1-1), the following aspects were considered:

- 1) Objectives:
 - Define parameters according to goals as global warming, deforestation, etc.,
 - Required data -> evaluation processes
 - Process the information in order to define models
 - Dissemination of the information
 - Stimulate new research / cooperative research (private and industrial research)
- 2) Methodology:
 - Database
 - Statistical analysis
 - Spatial analysis -> Processes
 - Modelling
- 3) Data types:
 - In-situ measurements -> only for local areas
 - Remote sensing -> multispectral data available at different scale
 - Historical data -> acquisition and manipulation problems
 - Qualitative data -> analysis of problems

The analytic or application process consists of four steps:

- Data acquisition;
- Data analysis and interpretation;
- Construction of (and experimentation with) conceptual and numerical models; and
- Verification of the models together with their use to furnish statistical predictions of future trends.

These steps form a cyclic rather than a sequential procedure as the verification of models requires their testing and revision through comparison with the observations. The models, in turn, often provide new insight into the observations required for further research. Attention then turned to more detailed review of the highest priority problem areas.

Table 6.3.1-1 Priority Analysis Matrix

| Subject | Objectives | Methodology | Data measurements | | | | Example of Subsets |
|---|---|--|-------------------|---------|-------|---------|--|
| | | | RS | IS | Qual. | Quant. | |
| GLOBAL WARMING (CFCs, CH ₄ , NO _x , g. gases) water vapor | <ul style="list-style-type: none"> • Monitor • Evolution & monitoring impacts • Predictions | In situ measurements (TBD-location scale) <ul style="list-style-type: none"> • R.S. interferometer spectrometer • Models | Y | | | Needed | Research vs eco& polit. issues |
| | | | Y | | | Needed | |
| POLLUTION | <ul style="list-style-type: none"> • Define parameters • Acquire information • Processing inf • Model | <ul style="list-style-type: none"> • Breakdown in different subset (list) • References and knowledge • R.S. | | | Y | Y | oil spill, smog, acid rain detergents, hazardous waste, solid waste, water quality |
| | | | Y | Y | | Y | |
| | | | Y | Y | | | |
| VEGETATION DYNAMICS | <ul style="list-style-type: none"> • Acquire information • Change detection • Specific param | <ul style="list-style-type: none"> • In situ measuremts. • Key biomass parameters • Change modelling | Y | Y | Y | Need | Forest/biophysical inventory |
| | | | Y | Y | | ? | |
| DEFORESTATION | <ul style="list-style-type: none"> • Prediction according to climate changes | <ul style="list-style-type: none"> • Estimation mapping prediction modelling | N | N | N | N | Cutover flooding fire |
| BIO-MASS INVENTORY | <ul style="list-style-type: none"> • Evaluation of anthropomorph. or nat.. process | <ul style="list-style-type: none"> • L.U./L.C. needs processing • Modelling - in situ parameters to define | N | N | Y | N | |
| LAND MAPPING | <ul style="list-style-type: none"> • Acquire inf. + layers in GIS • Anthropomorphic changes • Dissemination of information | <ul style="list-style-type: none"> • Evaluation DB/GIS • Historical data • Updated data | Y Sc | Y Sc | Y | Y Sc | Land cover, terrain mapping, topography, geology, soils, vegetation |

Where R.S. = Remote Sensing measurements.; IS = In situ measurements; Sc = Scale; L.U./L.C. = Land Use/Land Cover; and DB/GIS = Data Base/Geographical Information System.

6.3.1.1 Global Warming

Three facts are known - that the greenhouse effect is real, that levels of greenhouse gases are rising at unprecedented rates, and that greenhouse gas concentrations have tracked global climate change closely in the past. These, when combined with the predictions of the latest climate models, have resulted in the awareness that global warming is likely within the next century. Two separate evaluations of temperature records taken around the world since 1860 suggest that a global warming of 0.5 - 0.7 C [Jones et al., 1988, Hansen and Lebedeff, 1988] has occurred since that year, with nearly half this rise occurring since 1965. [World Resources, 1990].

Moreover, temperature records show that six of the warmest years on record have occurred this decade; in descending order, they are 1980, 1981, 1983, 1987, 1988, and 1989. [Houghton and Woodwell, 1989]. Many scientists believe that such an aggregation of warm years goes beyond the normal variability expected of the climate and is in line with the predictions for warming based on the present level of greenhouse gases [Monastersky, 1988]. The greenhouse warming effect is predicted to increase rapidly throughout the 1990s and become severe by 2030 with temperature increases up to 4 C globally and 8 C at high latitudes. Sea level rises and droughts are predicted to become severe. [Cihlar et al., 1989].

The following gases are considered to be responsible for depleting the stratospheric ozone layer and enhancement of the "greenhouse" effect: NO_x, N₂O, CH₄, CFC₁₁, CFC₁₂, CFMs, CO₂.

Chlorofluoromethanes (CFMs) of industrial origin have accumulated sufficiently to influence the chemical processes of the ozone layer in the stratosphere. Atmospheric methane is increasing particularly rapidly for reasons that are not yet clear. Methane, CFMs, and other chlorofluorocarbons are examples of a whole class of "greenhouse gases" which, although individually of less significance than CO₂ may collectively be expected to produce an effect of similar magnitude. Thus global warming due to radiatively active gases will probably become the major global change issue in the future. So, the abundance of greenhouse gases has to be carefully monitored. The following two additional factors support this high priority:

- Large uncertainty exists in predictions due to insufficient statistics leading to limitations of predictions models. More elaborate models are needed, with more data input; and
- Global dependence on fossil fuel energy.

There is a pressing need to reduce predictive error. This information could be used by the business community for planning and forecasting their future activity in the area of the energy production on domestic and global scales, as well as determining the international

policies of the responsible organizations. The main research objectives can be defined as follows:

- To monitor the hazardous impacts of chlorofluoromethanes (CFMs), chlorofluorocarbons (CFCs), methane (CH₄), nitrous oxides (NO_x) and other greenhouse gases (CO₂, N₂O, CO); and
- To evaluate and monitor the impacts of changes in atmospheric composition on the Earth system.

The measurements can be carried out by interferometer or spectrometer which provide information about the absorption spectra of the selected minor constituents. Spatial and vertical resolution of 1 km would be satisfactory.

From the methodological standpoint, information obtained must be a combination of satellite and ground observation data. In situ observation data would be used as ground truth for the satellite data and the development of algorithms for the derivation of new information from the satellite data.

Global warming, and in particular, the impact of the "greenhouse gases" on the global environment was determined by the ISU'90 requirements group as the highest priority problem needed to be studied. However, it was considered that the latter is going to be addressed very extensively and multi-directionally by EOS and related programs. In the attempt to address unmet needs of the environmental studies IPEO will not consider the monitoring of the greenhouse gases as a short term goal. However, some aspects of the global change will be addressed.

6.3.1.2 Pollution

Industrial pollution has become one of the most severe threats to the environment in the last decade. For years plants and factories have been emitting millions tons of sulfur dioxide into the atmosphere. The sulfurous smoke contributes to acid rain. Other by-products of coal burning are carcinogenic. The carbon dioxide and carbon monoxide may be adding to long-term atmospheric effects. There are also outpourings from chemical disposal, industrial waste, inadequate sewage treatment, garbage and decaying industrial facilities. A large part of the water resources has been dramatically polluted by the dumping of domestic and industrial wastes. Environmental pollution is one the most urgent problems which needs to be addressed. The complexity of the relationships and interactions between pollution and the different links of the Earth ecosystem makes the research task very difficult.

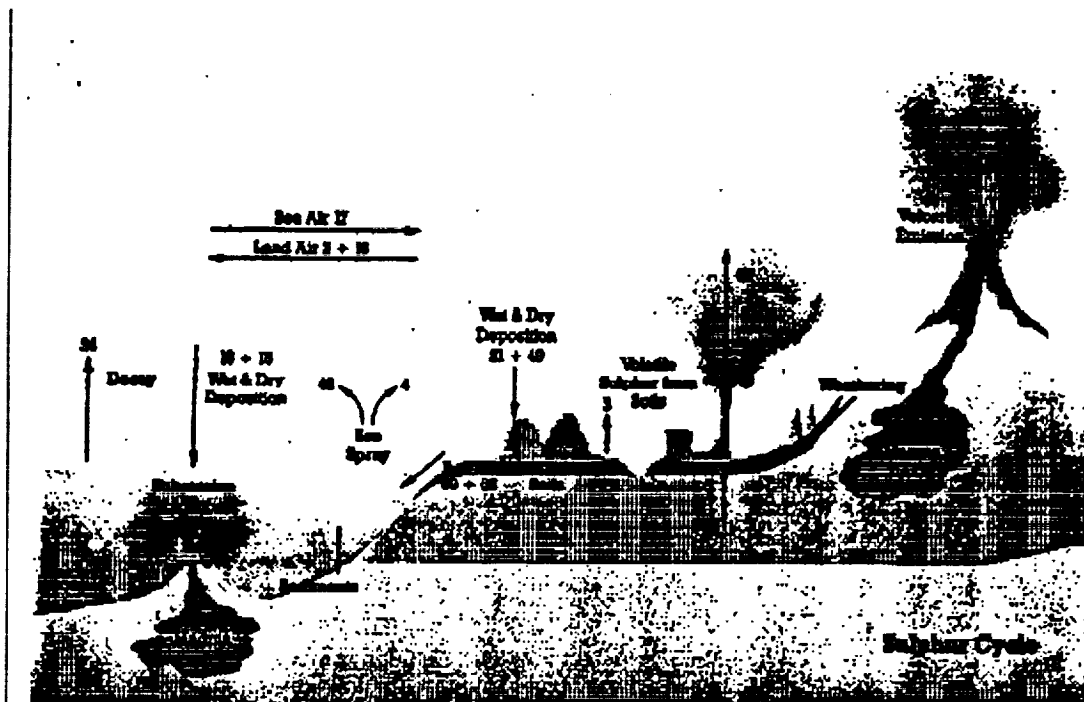


Figure 6.3.1.2 - 1 The Sulfur Cycle showing Fluxes between System Components. (1989)

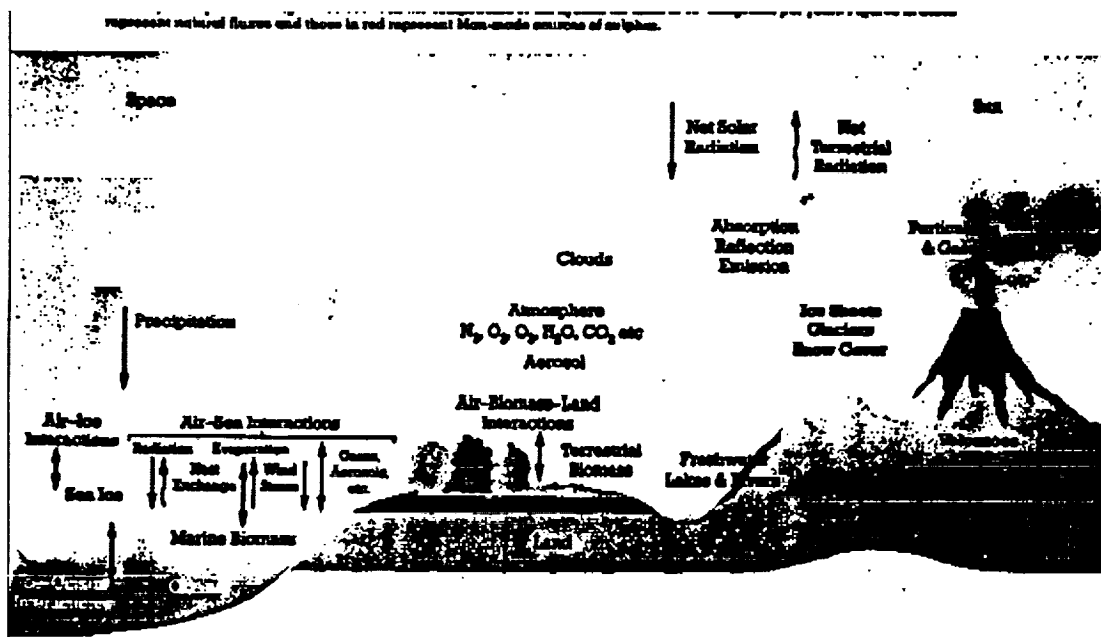


Figure 6.3.1.2 - 2 Generalized Climate Cycle showing Principal Interacting Components. (1989)

Scientific analysis of pollution and its environmental impacts should focus on the following objectives:

- 1) To acquire large amounts of data rapidly;
- 2) To interpret and process these data almost immediately; and
- 3) To determine the specific environmental parameters to be measured and the sensor systems with which they are to be monitored.

The following are two examples of pollution monitoring:

- 1) Oil spill - effective monitoring of extent and amount of pollutants produced by such accidents : visual and thermal infrared observations (scanners). This monitoring could be carried out by:
 - Detecting "sink" of oil - detecting the effects of detergents in dispersing oil;
 - Detecting the object-to- background contrast ratio;
 - Detecting the amount of pollutants spilled (great legal and financial significance); and
 - Monitoring system for sites of potential pollution (may serve as an important early-detection and warning system).
- 2) Detection and mapping of forest decline due to changes in the concentrations of airborne chemicals - airborne oxidants (nitrous oxide and ozone in particular).

One method of measuring the temporal results of pollution is to record the changes that occur in the health, vigor, reproduction, and distribution of long-lived members of the Earth's ecosystem (e.g., monitoring trees). Detection can be carried out by measuring the reflectance spectra from spectroradiometers. The latter can be used for spectral characterization of vegetation.

It was decided that although pollution was the second highest priority, insufficient understanding and time was available to define a space mission candidate for IPEO.

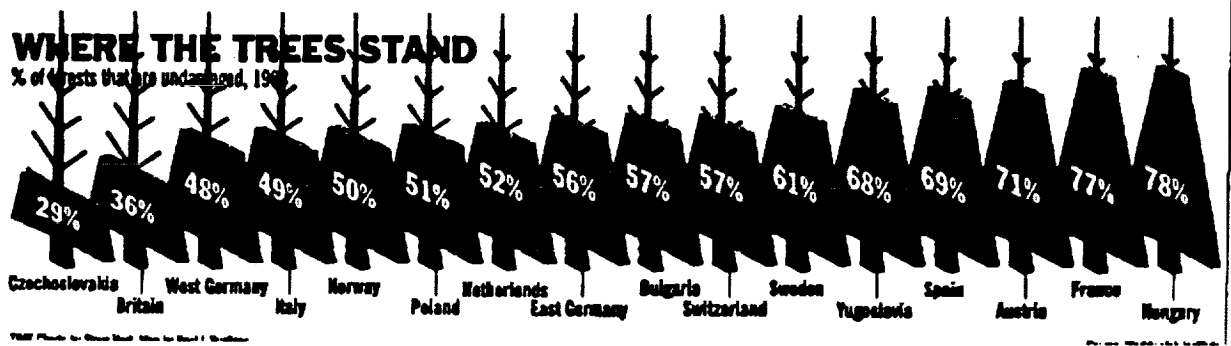


Figure 6.3.1.2 - 3 Undamaged European Forest, 1988 [Painton, 1990]

6.3.1.3 Vegetation Dynamics

Land vegetation is an intrinsic part of the terrestrial ecosystems and as such, it both influences and responds to other components of these ecosystems. This means that vegetation exhibits strong dynamic behavior in both spatial and temporal dimensions. The geographic fluctuations at present are superimposed on variations related to long term environmental trends. Thus it is necessary to determine the magnitude of these variations so that the long term trends may be defined. Satellite observations portray the vegetation condition at the specific time of the satellite overpass. This information must be combined with ground and aircraft observations and models of vegetation behavior to provide a comprehensive, quantitative picture of vegetation condition and their response to changing environmental conditions. In this section three main features of the vegetation processes are detailed. It is assumed that vegetation can be understood in terms of interactions with climate, soil, landforms, fauna, and water. Thus, the objectives of vegetation dynamics research are to:

- Develop techniques to identify locations of vegetation change and to quantify the change;
- Develop methods to determine total phytomass and to estimate the annual net primary productivity and the net change in carbon storage for the vegetation; and
- Develop, verify and apply models of vegetation succession based on observed or postulated changes in climate which make optimum use of remotely sensed data.

The principal satellite data sources could be low resolution optical sensors such as the Advanced Very High Resolution Radiometer (NOAA-AVHRR) visible and near infrared (IR) data have shown to correlate to changes in vegetation [Brown, et. al., 1982, Justice, 1986]. Where the spatial resolution of AVHRR (approximately 1 km) is insufficient, data

from higher resolution sensors can be used with advantage. The Thematic Mapper (TM) and System Probatoire d'Observation de la Terre (SPOT) satellite, as well as Synthetic Aperture Radar (SAR), can provide important data sources. Satellite data should be supplemented by ground observations collected at selected sites. These sites must be representative of the vegetation, and should coincide with comprehensive ground observations where possible.

In order to effectively model the vegetation dynamics and deforestation, both long-term and short-term records should be established and interpreted. The compatibility of the existing data sources and their accessibility should also be established. This includes the verification of remote sensing techniques and the ability to extract pertinent information for the observed environmental changes.

Among the vegetation models required to achieve the above objectives are: a model to estimate phytomass for the different vegetation types; a vegetation growth and decline model; and a vegetation succession model.

A principal methodological step would be the generation of spatially registered, cloud free composite images of different sample areas for 5 to 10 days periods at a resolution of 1 km or less. Higher spatial and spectral resolution scanners such as HIRIS can be used to establish models and methodology based on smaller areas and then applying these models on a large scale/ regional / global basis. Once these composites are available, classification and profile analysis techniques [Badwar, 1982] could be used to determine the condition of vegetation. The models should be optimized for input of remote sensing data.

It was decided that a general vegetation dynamics mission probably was infeasible and that many existing and planned systems provide adequate combined data for this purpose.

6.3.1.4 Deforestation

Until recently, the most authoritative estimate of annual deforestation in the tropics was 11.4 million hectares, based on a 1980 assessment of the Food and Agriculture Organization of the United Nations (FAO) of tropical forestry research, literature, and surveys [Lanly, 1982, FAO 1988]. The most recent results indicate that the annual deforestation is 70 million hectares, based on a survey on 62 tropical countries [Harmon, 1990].

Modelling of the deforestation impact on climate change has shown that on a regional scale the temperature of the air near the surface could increase from 2 to 4 C, the evapotranspiration could decrease by about 30 percent and the precipitation decrease by 20 to 30 percent. With less rain and more heat, significant changes in the vegetation types would also likely occur. The dry season would become longer if the forest is cut down, owing to the decrease of precipitation. Thus there would be likely a large negative impact on the tropical rain forest, since it can only exist in an environment of short dry seasons and a high level of ground moisture. In addition most tropical forest plant species cannot resist burning which occurs when the climate is dryer with a longer dry season. Thus with

conversion of forest to pasture, followed by the interruption of human activities, the forest would be unable to re-germinate because of these new climatic conditions and would give place to other types of vegetation. [NPE, 1990].

The scale of deforestation and its environmental impact could be estimated with the use of remote sensing data as an information source for environmental management. It is estimated that approximately 150,000 km² of tropical forest is destroyed each year, 25 percent of which is for firewood (JRO Topic Map.10, 1988). Thus, image data from the SPOT satellite (high spatial resolution - observations of small scale changes), AVHRR - NOAA (resolution 1km - observation of large scale changes in the vegetation), SAR High Resolution Imaging Spectrometer (HIRIS) of EOS (global changes), as well as electro-optical images from SOYUZ, MOS, IRS, and CBERS could be used in order to determine the unmet needs of the deforestation research.

An example of unmet needs for deforestation study is as follows:

- Vegetation loss
 - long time frame
 - species replacement
 - different spectral characteristics
 - area of observation : mountain areas (Eastern Europe), equatorial belt.
- Ecology
 - Look at the sample areas (different ecosystems) for determining the degree of global changes.
 - Long time frame - very extensive data set.
 - Data collection on a daily basis, for vegetation - a weekly basis.

Both types of measurements are complimentary. The data format will facilitate their use with spatial analysis tools such as GIS.

It was decided that a deforestation mission combined some of the key data needs of climate and vegetation dynamics, was a somewhat neglected area in planned missions (especially in tropical environments), and would provide critical information to both scientific and management applications.

6.3.1.5 Topographical Mapping

Topographic data, including information on elevation, slope, and land use, are considered to be essential for many studies of environment and Global change. Topographic Mapping can therefore support much research. Examples of these are geological mapping, geophysical and drainage modelling, large scale ecosystem modelling,

gravity surveys, hydrological and erosion studies, and study soil forming processes and soil characteristics.

Especially in the key regions of Global change research - polar areas, tropical rain forests, deserts, mountain belts - the actual topographical mapping is poor. Research and application activities in these areas are suffering from inadequate topographic coverage [NASA, 1989]. There are only a few areas, especially Europe and North America, that can provide a comprehensive data set with high quality and resolution. Studies show that the achievable resolutions can allow charts on 1: 50,000 scale for urban thematic maps and 1:100,000 scale for general topographical maps [Togliatti et .al., 1989].

An essential question for environmental and Global change research is the gathering of proper data to form a digitized topographical map of the globe with uniform quality and resolution. NASA studies recommend a global vertical resolution of 10 meters and a horizontal resolution of 50 meters for general purposes. Certain local and more specific questions may need a horizontal resolution of 25 meters [NASA, 1988]. A Topographic mapping data set could contain:

- General topographical data for global coverage in a uniform or standard format;
- The nature and distribution of the land cover;
- The seasonal dynamics of the land cover;
- Long-term trends in change of land cover where permitted by available historical data; and
- Appropriate satellite data.

This data set could then be used to produce:

- Digital Elevation Models;
- Digital Database consisting of land cover overlay;
- Validated methodology for global land cover monitoring; and
- Training and technology transfer (algorithms, etc.) among participants.

The topographic and land use data obtained from satellites, airborne systems and in situ measurements represent the basic layers of Geographic Information Systems (GIS). The implementation and merging of the obtained data in GIS systems is the most promising current strategy to handle this information for global analysis and is therefore a recommended tool for any research. Again, effective use of GIS requires sufficient data input from, among other efforts, uniform high-quality topographical mapping.

6.3.2 Selected Topics of Study

Based on more detailed analysis of the five highest ranking requirements and their applications, and consideration of existing and planned capabilities, it was decided to focus on deforestation as a short term mission goal for IPEO. This section moves from discussion of needs to specification of deforestation satellite requirements. It also sets the basis for a case study of topographical mapping satellites.

One of the often cited arguments for imaging radar is its usefulness in frequent fog or cloud covered forest regions. Data acquisition for inventory purposes by means of optical remote sensing instruments has become especially unreliable or an expensive undertaking in tropical areas.

There are at least four factors that need to be considered in modeling the radar backscatter of trees:

- 1) The forest canopy composition;
- 2) The forest canopy distribution;
- 3) The lack of information regarding the effects of species composition in the attenuation of the microwave signal ; and
- 4) The lack of a consistent set of defined biophysical parameters which allow for a quantitative characterization of forest canopies in terms of their microwave absorption and backscattering properties.

Analysis criteria was guided by the question of how tree characteristics, such as type and density, the condition of foliage, the geometry of trunk and branches, and the stand characteristics, such as diameter distribution, height distribution and density, affect the microwave backscatter as a function of radar wavelength, polarization and incidence angle.

In the following section these considerations will be addressed with regard to the requirements for accomplishing the short term space goals of IPEO, namely deforestation and topographical mapping.

The problem of deforestation is discussed in terms of using P-band SAR for studying the distribution of woody biomass in the tropical forests, as well as examining clearcut areas, productivity of phytomass, and the seasonal variations and stress conditions.

Topographical mapping is considered a complimentary study to the monitoring of deforestation. This opinion is based on the fact that the distribution of forest ecosystems is influenced by topography, and that management applications must have small scale GIS tools.

6.3.2.1 Deforestation

As far the P-band is concerned, Figures 6.3.2.1 - 4 through Figure 6.3.2.1 - 6 illustrate the different possible ways of investigating forestry.

Results from both visual and digital image analysis have shown that the long wavelengths (L-band) are more suitable for determining successful or unsuccessful forest regeneration and the existence of hardwood while the short wavelengths (X-band) were not suitable for distinguishing different regeneration sites, but were found to be particularly useful in delineating cutover boundaries in forest areas [Wedler et. al., 1980].

A P-band radar would also be more sensitive to subsurface morphology than the shorter wavelength channels because the root mean square height of the surface is a smaller fraction of the wavelength, resulting in a lower measured radar backscatter from the surface. P-band signals also penetrate deeper into the soil, which increases the subsurface volume in which scattering occurs, resulting in much greater ratio of power received from the subsurface relative to that received from the surface at P-band than at shorter wavelengths [JPL, 1988].

A comparison of the resulting penetration depth for C-, L- and P-band has shown that a P-band radar would provide a factor of 8 increase in penetration depth over the L-band channel of EOS SAR, for example. (Figure 6.3.2.1 - 7) [JPL, 1988]. This factor comes from the increase in wavelength, as well as from a decrease in the dielectric constant in soil from L-band to P-band.

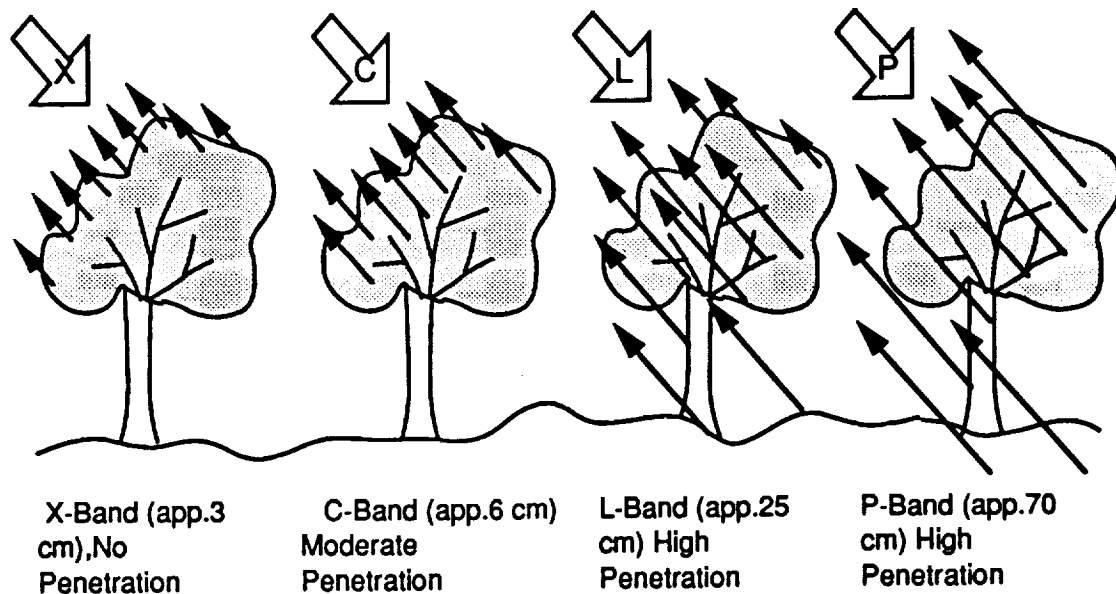


Figure 6.3.2 - 4 Canopy Penetration as a Function of Wavelength [NASA, 1987]

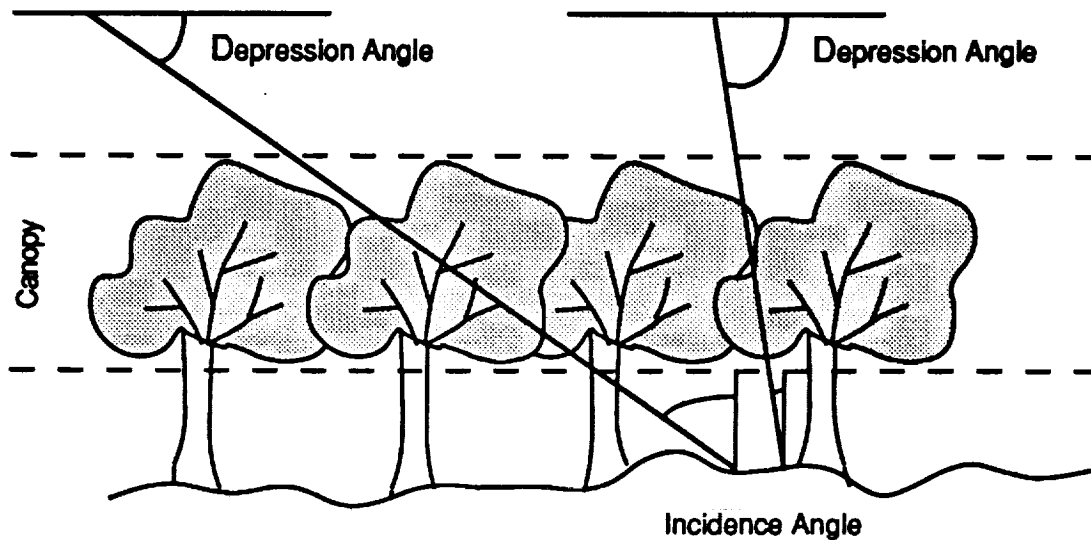


Figure 6.3.2.1 - 5 Radar incidence angle and canopy penetration.

Figure 6.3.2.1-5 shows : (1) small incident angle: short path length through canopy and relatively little attenuation of signal; (2) large incidence angle: long path length through canopy and relatively high signal attenuation.

Based on extensive study of X-, C-, and L-band image data [Werle, 1989], three main conclusions can be drawn in support of P-band SAR for monitoring deforestation:

- The longer wavelength provides increased penetration into forest soil and surfacial materials, soil moisture and vegetation canopies;
- The scatter range is increased for quantifying the canopy roughness; and
- The longer wavelength will also enable delineation of flooded areas under the canopy.

The measurements performed at P-band wavelength in conjunction with C - and L-band data from AVHRR, RADARSAT, JERS I, ERS I, and LANDSAT TM, EOS platforms, ADEOS, etc., will help determine the distribution of woody biomass (especially trunk diameter and height, and stump density) in tropical forest. In addition, the foliage characteristics, tree species, clearcut areas, productivity of phytomass, the seasonal variations and stress conditions (moisture, insect infestation, acid rain) will be examined.

The information that is expected to be obtained would result in:

- Better quantification of canopy composition and determination of biophysical units which is fundamental for forest inventory in the rain forest; and
- Better understanding of the temporal and spatial variation in biomass production and distribution.

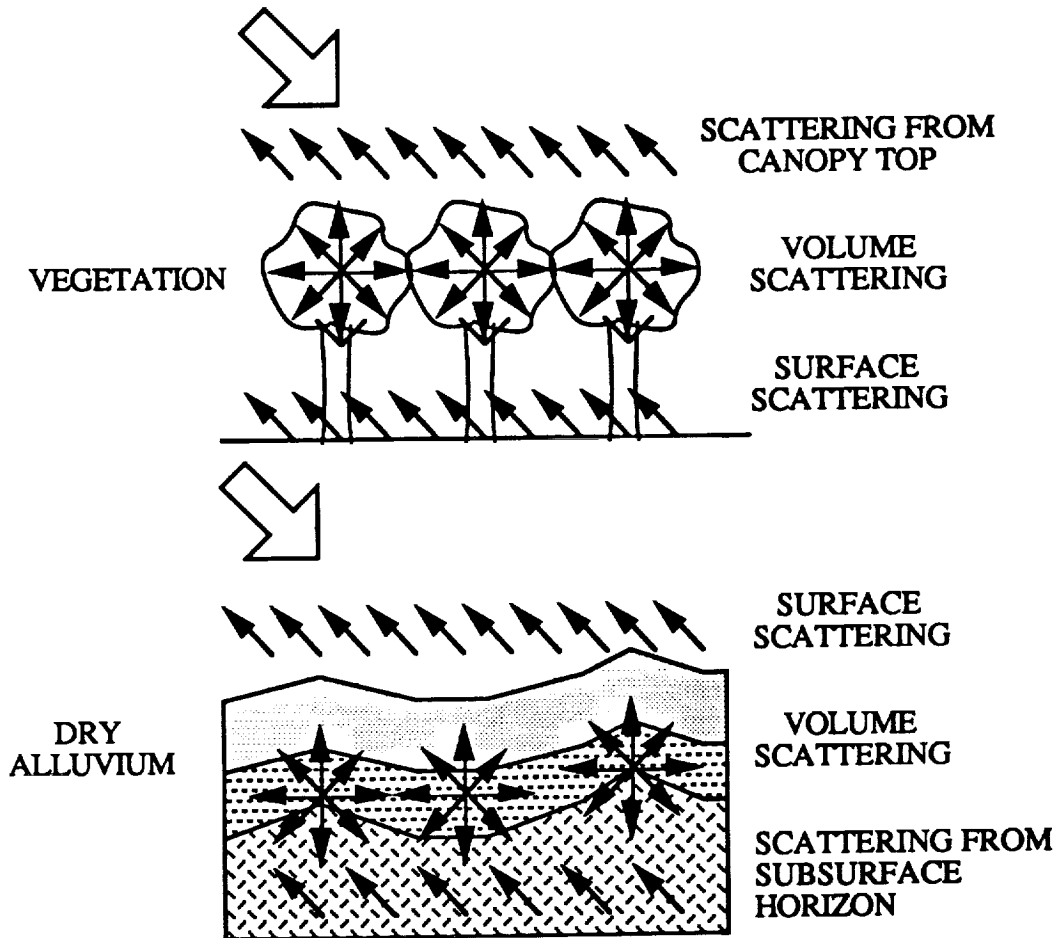


Figure 6.3.2.1 - 6 Like- and Cross-polarized Surface and Volume Scattering Expected from Vegetated Surface and Dry Alluvium.

Basic P-Band research

The formulation of major research tasks is concentrated on obtaining a description and understanding of P - band backscatter with regard to forest applications.

1) Forest canopy in the tropical region

The canopy structure at the edges of forest remnants could provide evidence for patch degradation due to unfavorable microclimatic conditions at the periphery. The scale of the landscape pattern will dictate the spatial resolution of the P-band SAR coverage required. Amplitude and phase, multi-angle, multi-frequency and multipolarization data will all be useful for these purposes.

2) P-band clearcut / reforestation / forest fire

The P-band data would have the potential to determine the above-ground woody mass as well as to distinguish primary and secondary forests [Hoffer et. al. 1986, Richards et al. 1987, Paris and Kwong 1988, Sun and Simonett, 1988 a,b].

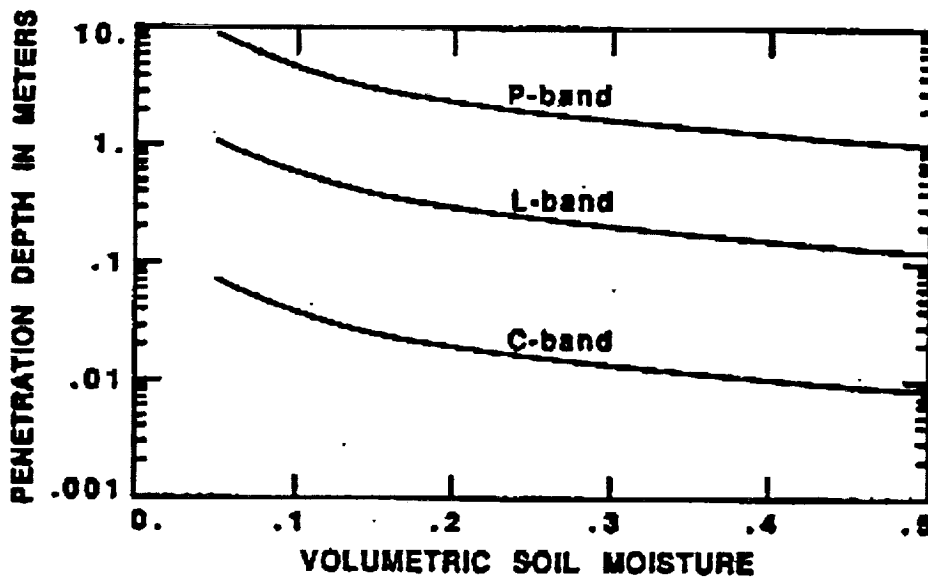


Figure 6.3.2.1 - 7 Penetration Depths Calculated as a Function of Volumetric Soil Moisture for C-, L-, and P-band [Ulaby et al, 1986, SPIRE, 1989]

3) Exposed soil / Soil moisture / Forest soil

The P-band SAR images will provide detailed soil moisture information at the sub-kilometer resolution. Estimates of soil moisture distribution will be most

desirable on a monthly basis for modelling purposes. In addition, the P-band will have the capability to penetrate the canopy providing information about the state of the surface boundary layer below the canopy.

4) Forest hydrological studies

The P-band signals penetrate deeper into the soil which increases the subsurface volume in which scattering occurs. The strong dependence of the signal attenuation on the water content of the target could be used for determining the canopy water content as well as standing water under the canopy.

5) Terrain / Engineering mapping

The P-band SAR images could provide information about the terrain roughness, which is a controlling factor for the defraction of ecophysical classes.

The determination of the woody biomass is based on the ability to isolate the scattering pathway which interacts mostly with tree trunks and stems. The development of radar backscatter models and model inversion algorithms could be used in conversion of the radar parameters to biophysical parameters.

The optimization of P-band SAR parameters has to address the following basic problems:

- 1) How much of the backscattered energy can be attributed to volume scatter, direct backscatter, or to multiple scattering?
- 2) What are the roles of branches, trunks, and foliage in scattering, reflecting, or absorbing microwave energy?
- 3) How do answers to these questions vary with incidence angle, frequency, polarization of the radar, and with dielectric and other physical properties of the forest and ground cover?

Deforestation Specifications

Important specifications for radar-based assessment of deforestation are:

- Spatial resolution;
- Temporal resolution;
- Incident angle; and
- Transmitted and received polarization.

The determination of spatial resolution is required in order to detect and accurately map the forest. For this purpose study could be carried out in two modes : (a) single date mode, and (b) two date mode. The following cases should be considered:

- Using single date P-band SAR data;
- Using single date P-band data along with data from other SAR and electro-optical instruments;
- Using two dates of P-band SAR data; and
- Using two dates of P-band SAR data along with other SAR and electro-optical instruments

Temporal resolution is another parameter required for satisfactorily detection and mapping of the forest. The selection of the radar incident angle and the send/receive polarization is of particular importance for maximizing the forest information sought.

Once the above parameters are determined, some possible approaches should be considered for interpretation of the obtained image data. Quantitative evaluations about the spatial resolution could be made by determining the size of the most widespread canopy openings in various kinds of forests. Some statistical techniques could also be applied for more accurate estimation of the utility of the clearcut patches detected on the images. After appropriate calibration, the compatibility of the IPEO P-band SAR data could be evaluated with respect to available image data from other sources (AVHRR, LANDSAT, SPOT, etc.). Figure 6.3.2.1 - 8 illustrates the type of relationships that could be studied.

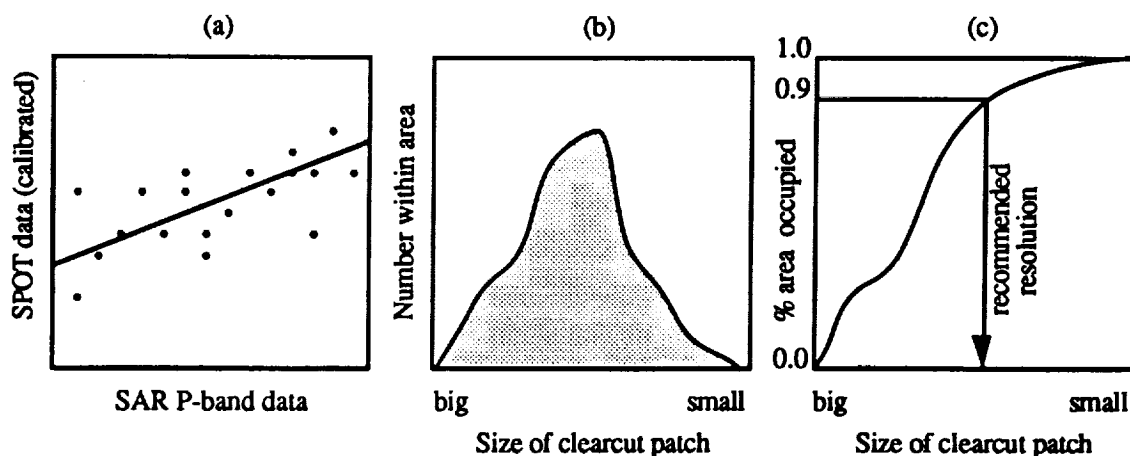


Figure 6.3.2.1 - 8 The Estimation of Clearcut Areas by Statistical Models: (a) Determining the Correlation between the SAR P-band Data Obtained and other Image Data; (b) Size Distribution of the Clearcut Areas; (c) Cumulative Diagram of the Clearcut Areas.

Figure 6.3.2.1 - 8a shows a hypothetical relationship developed by fitting a regression line through matched SPOT and P-band SAR observations of forest area. This relationship can be used to estimate Spot-derived forest removal, given area-wide P-band results. If SPOT clear cut area results are assumed (by experimental work for example) to be more accurate than corresponding figures derived from P-band SAR (e.g. because of spatial resolution differences), then a sampling method can be used to "correct" P-band results to a higher accuracy standard.

Figure 6.3.2.1 - 8b shows a histogram of forest clear cut patch dimension. Figure 6.3.2.1 - 8c is created by summing over the histogram in Figure 6.3.2.1 - 8b. This simple method can be used to select an initial spatial resolution size for pixels of the P-band. The example shown in Figure 6.3.2.1 - 8c indicates the average P-band pixel dimension required to detect 90percent of the clear cut area.

A relationship of the kind shown in Figure 6.3.2.1 - 8a could then be established for each P-band pixel dimension chosen. One rule for choosing a final nominal satellite pixel size might then be to select the P-band pixel dimension producing an estimated SPOT-derived error just meeting user requirements. Thus simple example shows that selection of radar parameters can be influenced by the kind of data used in conjunction with it and by the estimation procedure selected.

Another approach for estimation of deforestation could be the application of econometric models analyzing the relation between the growth of the human population and the degree of deforestation in a sample frame of provinces and countries. These models require as input additional economical data and have been applied for quantitative estimations in some countries in South East Asia (e.g. Thailand, Viet Nam). The results, however may be significantly improved using one or more levels of remote sensing data, for example in manner just described. [R. Thomas, 1990].

With extension of the clearcut areas of 1-2 percent per year the temporal resolution described should be about 6 months on average in order to provide information for decision making. Improvement in results is possible not only in area estimate accuracy, but perhaps even more importantly, in the frequency with which these estimations can be produced. For monitoring of specific regions, time resolution of one to three months would be appropriate, where change is occurring rapidly. For monitoring the global change, one to three years estimates may be sufficient.

Very extensive deforestation is due to burning the rain forest. Monitoring the forest decline would require temporal resolution less than a month (every three days). Optical data are the most appropriate for this type of observation.

From the considerations above, it may be seen that different characteristics require observations at intervals of three days, one month, six months and one year. If we abandon the detailed monitoring of rain forest burning, we conclude that the time resolution should be better than one month.

For the choice of incident angle, it is recommended that canopy penetration be maximized through the choice of the smallest possible incident angle.

Development of Data Analysis Methodology

Following are examples of tasks necessary for the development of a data analysis function:

- Develop Manual and Image Processing Techniques for the interpretation of the P - band data. In doing this it should consider that there are a number of image processing and GIS techniques applicable to other radar bands (e.g. X, C) which could also apply to P-band.
- Develop GIS / multisensor techniques to aid P-band data analysis.
- Advance the use of GIS - based modeling using remote sensing and other data for forest management by investigating the use of forest growth and ecosystem models to derive forest management information from combined remote sensing and ancillary information.
- Develop, verify and apply models of vegetation succession based on observed or postulated changes in the total phytomass, with optimum use of the remotely sensed P-band data.

Application Development Tasks

Following are examples of tasks necessary for the development of applications development:

- User-oriented application case studies: (training and guidebooks)
- Research and development of new applications using the latest sensor / scanner and data (image) processing and GIS technologies to satisfy user needs, in cooperation with interested parties.
- Stimulate the commercial development of useful application systems and services for domestic and international markets.

Airborne Program

The IPEOSAT experiment would provide a measurement capability that is different from previous spaceborne imaging radars. For this reason, airborne experiments using an IPEO SAR prototype sensor should be carried out. This preliminary study should be performed during the definition phase of the IPEOSAT experiment.

Objective: To develop, establish, and demonstrate P-band SAR for forest resource management and environmental monitoring. Prepare for advent of IPEOSAT P-band SAR through applied studies of airborne P-band data, namely:

- Initial evaluation of P-band SAR data for clear cut mapping;
- Establishment of the relationship between forest regeneration and P-band backscatter (depression angle, polarization, seasonal conditions); and
- Establishment of radar parameters for species determination (canopy composition) and density.

Plan: The IPEO airborne program could be carried out by the existing facilities of the JPL - DC 8 and the aircraft involved in the Canada Center for Remote Sensing (CCRS). This could be done either by the renting of these facilities by IPEO for the time of the pre-launch period or by contract between IPEO and JPL (or CCRS) for measurements and research of the P-band characteristics of IPEOSAT SAR, along with a CCD camera for aerial photos. Research should be concentrated on the interpretation of microwave measurements using this sensor. First order radiometric calibration of the SAR should be done to permit underflight experiments for IPEOSAT and more complex calibration such as phase integrity and spatial calibration.

Important target parameters affecting the P-band SAR response in forestry are:

- Dielectric constant of vegetation material;
- Size, shape and orientation of scatterers within the canopy (foliage, branches, etc.);
- Roughness and dielectric constant of ground surface; and
- Forest canopy, geometry and structure.

As well as:

- The influence of the radar incident angle on the backscatter and attenuation of forestry target;
- The influence of radar look-direction; and
- The backscatter minima and maxima of clearcut and forested areas occurring at different polarizations.

Satellite Data Acquisition and Processing Research and Development

The development of a P-band quicklook imagery processor for IPEO satellite SAR data should be established in order to facilitate the management of satellite radar data

archiving and therefore the use of IPEO P-band radar data in conjunction with that obtained from EOS platforms, ERS-1, JERS-1 and RADARSAT .

Objectives: Develop reception, archiving, processing and distribution systems for the IPEO SAT P-band SAR data.

Plan: In support of the ground station system, background research into the new sensor characteristics, archive, quicklook media, storage media, image distribution and image processing techniques should be carried out.

6.3.2.2 Topographical Mapping

In 1968 the Cartographic Section of the United Nations undertook a survey of the status of the world topographic mapping that has been carried out since at regular six-year intervals. The information about the available map coverage has been classified according to the following four scale ranges:

- Range I: 1:1000-1:31680 (2 inches to 1 mile); category 1:25,000 and larger.
- Range II: 1:40,000-1:75,000 (1 inch to 1 mile); category 1:50,000.
- Range III: 1:100,000-1:126,720 (0.5 inch to 1 mile); category 1:100,000.
- Range IV: 1:140,000-1:253,440 (0.25 inch to 1 mile); category 1:250,000.

The results of these surveys show that by 1980 the progress in topographic mapping had seriously decreased in such economically important categories as 1:100,000 and 1:50,000. For these scales the annual revision progress rate was found to be only about 2 percent of the mapped area. A conclusion was made that such topographic maps were indeed revised per year for only about 1 percent of the world's land area, on average. [Brandenberger and Ghosh, 1985].

An assessment of the current condition of the topographic map coverage shows that the situation has not improved very much. (Table 6.3.2.2 - 1). The quality of the solid Earth studies is still highly dependent on the availability of high-resolution, high-precision topographic data.

Table 6.3.2.2 - 1 Topographic Maps - Worldwide Coverage

| Scale Region | < 1:25,000 | < 1:50,000 | < 1:100,000 | < 1:200,000 |
|-----------------|------------|------------|-------------|-------------|
| Africa | 1% | 25% | 25% | 95% |
| Australia | 19% | 35% | 35% | 100% |
| Asia | 15% | 50% | 85% | 90% |
| Europe | 75% | 100% | 100% | 100% |
| N. America | 40% | 55% | 55% | 90% |
| S. America | 10% | 20% | 30% | 30% |

Considering the importance of such high-resolution, high-precision topographic information [Brandenberger and Grosh, 1985], a small satellite topographic system was considered as a second option for observing the Earth from space or the IPEO program. The parameters that characterize the type and the quality of topographic information are:

- 1) Spatial resolution;
- 2) Spectral resolution;
- 3) Stereo capability; and
- 4) Temporal resolution.

To date the highest spatial resolution digital topographic information on a large regional scale is Defence Mapping Agency data on the order of 60 m spatial resolution with a vertical resolution of approximately 12.3m. For many parts of the world, particularly Asia, South America, and Antarctica, relative topography is known only to several hundred meters at a spatial resolution of about 10km. Therefore it is of great importance to have extended high spatial resolution topographic data in order to perform long-wavelength (1,000 to 10,000 km) biological and geophysical studies [NASA, 1987].

In an attempt to address these unmet needs, the recommended spatial resolution for the IPEO topographic system is less than 10m vertical resolution, covering the visible and near infrared spectral ranges. This will give the opportunity for complimentary measurements of the spectral characteristics of the surface and specifically for collecting additional information about deforestation. A detailed discussion of the topographic case study is provided in Chapter 8.

6.3.2.3 Conclusions

As a result of the requirements assessment that has been carried out the following characteristics of the IPEO deforestation satellite and topographic systems are recommended:

Table 6.3.2.3 - 1 Specifications for IPEOSAT

| | |
|---------------------|----------------|
| Altitude | |
| Coverage | 35 degrees N/S |
| Spatial Resolution | 30 m |
| Spectral band | P = 0.7 m |
| Temporal Resolution | 10 - 30 day |
| Incident angle | |

Table 6.3.2.3 - 2 Specifications for Topographic Mapping

| | spatial resolution [m] | spectral range | stereo | revisit period |
|--|------------------------|---------------------|--------|----------------|
| Agriculture | 5 - 30 | VIS/NIR | yes | week to month |
| Forestry | 5 - 30 | VIS/NIR | yes | quarter |
| Engineering construction/ mapping | 5 | VIS | yes | by exception |
| Energy and minerals | 10 - 80 | VIS/NIR SWIR/SAR | yes | seasonally |
| Federal land managers and other agencies | 5 - 80 | VIS/NIR | yes | month to year |

VIS = visible

SWIR = short wave infrared

NIR = near infrared

SAR = synthetic aperture radar

7.0 IPEOSAT

7.1 Introduction

7.1.1 Scope of the Study

The definition of the IPEO Satellite specifications resulted from a multi - disciplinary process involving users, engineers, economists, political scientist and managers. This process aimed at identifying niches occurring in the existing and planned systems in which new satellite(s) have to be designed in order to give IPEO the data necessary to reach its short term objectives. Such a process is not linear and several iterations are necessary in order to match the state of the practice in engineering design with the users requirements, namely deforestation survey and monitoring as well as a real time alarm system for improving the management of the forests. The conclusions of this analysis, presented in the preceding chapter, are reproduced in Table 7.2 - 1.

The payload of IPEOSAT will be a SAR in P - band. Since there exists no such satellite, the design proposed in this section made use of some new technologies, some of them presently under development and having not yet been actually tested in space. This is a challenge, and the first results of this pre - project have to be confirmed by more elaborate studies.

The few weeks allocated for this project did not give enough time to achieve a complete design of IPEOSAT. What is presented in this chapter is therefore the first step in the design of the satellite and a necessary start for the integration process needed for any satellite design.

7.1.2 IPEOSAT Design Process

The process of designing a satellite follows a logical flow of actions which implies several iterations. The logic of this process for a SAR is presented in Figure 7.1 - 1.

Starting from user requirements, a first estimation of the design parameters of the SAR, its antenna and the orbit of the spacecraft is performed. These results lead to a first estimation of the specifications for the components of the platform which has to be integrated. This integration requires feedback on the payload and the components themselves, leading to an optimization procedure constrained by mass, size, reliability, cost, launching facilities, etc.

In this project, it was not possible to proceed through all these steps until the end of this optimization procedure to achieve a fully integrated and optimized satellite design. In fact, after the requirements were identified, first judgment assumptions were made concerning the antenna and the payload in order to pursue the design of all the parts of the satellite. These first judgments have been improved after a first iteration, leading to the

definition of the orbit, the design of the payload, the antenna and several components as well as a first approach to the structure itself.

Since it was not possible to perform this second iteration for all the elements of the platform, a fully integrated design with coherent inputs for these components will be needed. This is, for instance, the case for the thermal control. This lack is easily understood, because it is necessary to have a design of the structure and of the implementation of the various others components to obtain thermal design parameters.

This chapter presents the status of the design at the level at which it has been reached during the time allocated to the project. A system analysis of IPEOSAT with a brief description of the criteria and constraints sustaining the design will be presented in the following section which describes also the main characteristics of IPEOSAT.

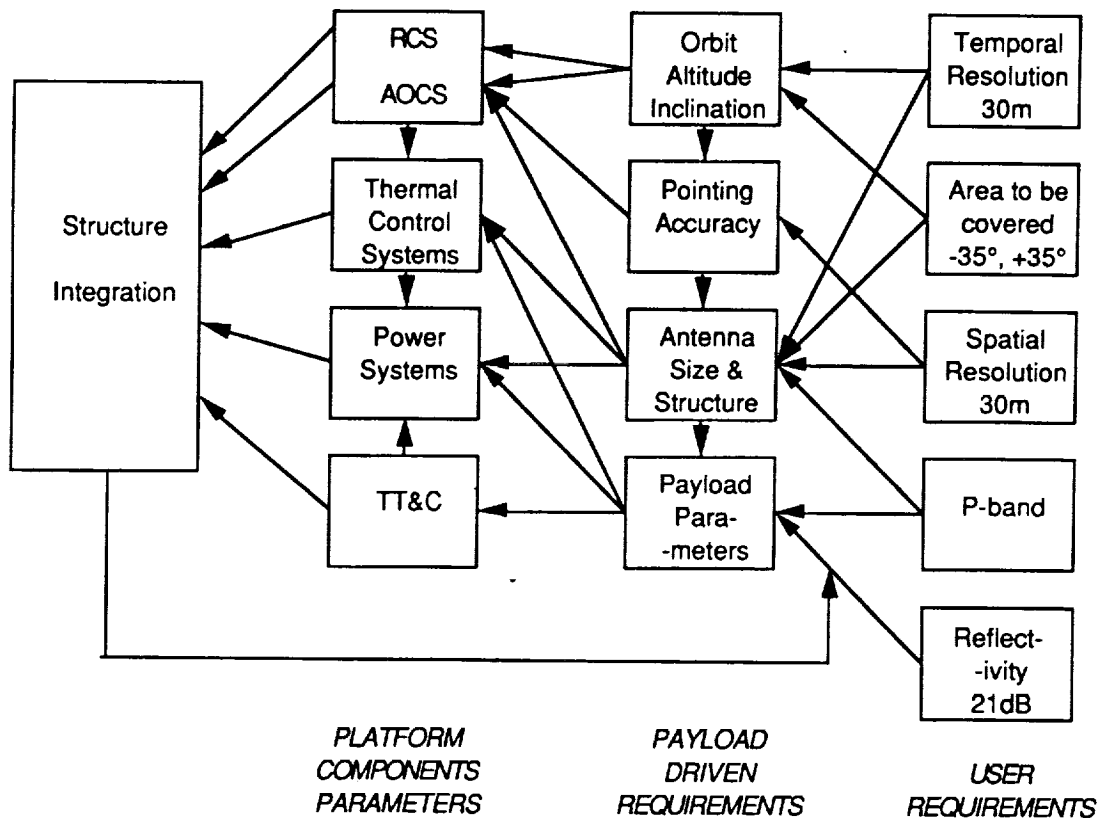


Figure 7.1 - 1 Design Process

7.2 Systems Analysis

7.2.1 Summary of Requirements

The requirements specified by the Users are shown in Table 7.2 - 1 and described within Section 6.

Table 7.2 - 1 Summary of Requirements

| FACTOR | REQUIREMENT | COMMENTS |
|------------------------|---------------------|-----------------------|
| Payload : | | |
| Temporal Resolution | 10 - 30 days | the smallest possible |
| Coverage | +/- 35° | |
| Spatial Resolution | 30m | |
| Frequency of operation | P - band (428MHz) | |
| (wavelength) | 0.7m | |
| | | |
| Mission : | | |
| Mission Lifetime | As long as possible | 2.5 years assumed |
| | | |

The driving requirements which are identified from the above parameters are the selection of P - band for the deforestation sensor which has a major impact on the antenna and spacecraft size. The temporal resolution requirement is the major factor for identification of the orbit parameters and has direct ramifications on the power and thermal subsystem.

7.2.2 System and Subsystem Evaluation Criteria

The overall objective of this study has been to develop a spacecraft for deforestation monitoring. In order to support this objective the main criteria which have been considered within the subsystems design have been as follows :

- Satisfaction of performance requirements;
- Mass and size;
- Use of existing technology and qualified equipment;
- Complexity;
- Reliability;
- Power/thermal control;
- Modularity;
- Ease of integration;

- Cleanliness;
- Launch vehicle accommodation; and
- Payload accommodation.

These criteria are not listed in a strict order of preference. For each subsystem the criteria will have a different importance and impact. In many cases the criteria are interrelated e.g., complexity and reliability.

The following sections describe the systems analysis of the study including configuration, launch vehicle selection and interfaces, mission analysis and finally the estimated budgets.

7.2.3 Spacecraft Configuration and Payload Engineering

The subsystems of the proposed spacecraft must be configured so as to optimize the whole spacecraft design taking into account the impact of one subsystem on any other subsystem, on the overall spacecraft and on the payload. The factors which must be addressed for this analysis are primarily:

- Launch vehicle accommodation;
- Payload performance and interface characteristics;
- Center of mass/centre of pressure constraints;
- Thermal and power constraints;
- Cleanliness - impingement of thruster plumes on sensitive surfaces and Electromagnetic cleanliness; and
- Modularity

This configuration assessment is an iterative process which occurs throughout the design and definition of the spacecraft subsystems. Due to the undefined nature of the subsystems it is not possible at this time to perform a satisfactory mass properties assessment, however due to the fundamental nature of this parameter on configuration design this factor is considered qualitatively in the following assessments.

A primary configuration assessment is presented within this section based upon the following driving accommodation requirements:

- Three axis stabilized spacecraft;
- 43m² parabolic synthetic aperture radar (SAR) antenna; and
- 19m² solar array area.

7.2.3.1 Primary Configuration - Antenna / Spacecraft Mounting

It is necessary for the SAR antenna to have a viewing direction of 30° to the nadir. The SAR antenna selected for study is a parabolic inflatable structure which has the flexibility of design to be either a centrally mounted symmetrical antenna or an asymmetrical offset feed antenna. Three main options were identified for mounting this antenna on the spacecraft body with relation to its principle axis whilst maintaining optimum performance. The spacecraft principle axis is the principle axis of inertia. Additionally one configuration option has been identified which may have system advantages but provides a reduced performance of the SAR antenna. These options are described below :

- a) Spacecraft body principle axis aligned to nadir with asymmetrical SAR mounted centrally on the S/C Earth face as shown in Figure 7.2 - 2 (a);
- b) Spacecraft body principle axis aligned to nadir with symmetrical SAR mounted on the side of the spacecraft as shown in Figure 7.2 - 2 (b);
- c) Spacecraft body principle axis aligned at 30° to nadir with a symmetrical SAR mounted centrally on the face perpendicular to principle axis as shown in Figure 7.2 - 2 (c); and
- d) Spacecraft body principle axis aligned to nadir with symmetrical SAR antenna mounted centrally on the S/C Earth face 7.2 - 2 (c).

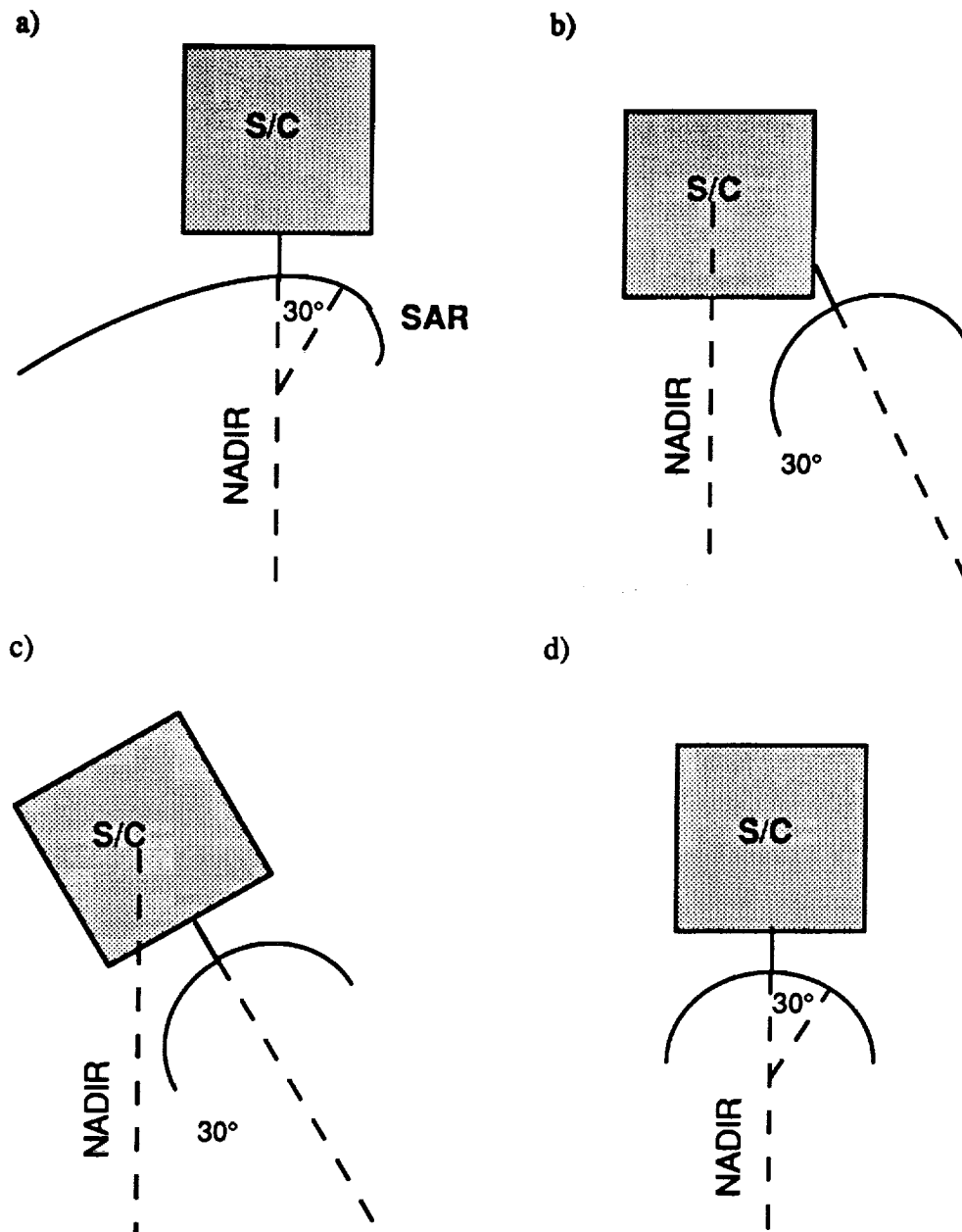


Figure 7.2 - 2 Antenna Mounting Configurations Options

Each of the above options has advantages and disadvantages and these are presented in Table 7.2 - 3. Each option is evaluated according to a set of factors and the relative weighting has been subjectively assigned to each of these factors on a scale of 1 to 3. Each of the options is ranked on a scale of 1 to 3 (in the left of the column) according to the satisfaction of these factors and the resulting multiplication with the weighting factor entered in the right of each column.

Table 7.2 - 3 Primary Configuration Trade - offs

| Factor | Relative weighting | Option a | | Option b | | Option c | | Option d | |
|---------------------|--------------------|----------|---|----------|---|----------|---|----------|---|
| | | | | | | | | | |
| Mass Properties | 3 | 2 | 6 | 1 | 3 | 1 | 3 | 3 | 9 |
| Stowage | 1 | 1 | 1 | 1 | 1 | 3 | 3 | 3 | 3 |
| Structure | 2 | 1 | 2 | 1 | 2 | 3 | 6 | 3 | 6 |
| Aerodynamic drag | 1 | 2 | 2 | 1 | 1 | 1 | 1 | 3 | 3 |
| Disturbance torques | 2 | 2 | 4 | 1 | 2 | 1 | 2 | 3 | 6 |
| Shadowing | 1 | 3 | 3 | 1 | 1 | 2 | 2 | 3 | 3 |
| SAR Performance | 2 | 3 | 6 | 3 | 6 | 3 | 6 | 2 | 4 |
| Total | ---- | 24 | | 16 | | 23 | | 34 | |

This trade - off is a very preliminary estimate as the effects of each of the options on the factors is remains ill - defined. The immediate conclusion presented by this table is that assuming the antenna performance degradation is not as significant (or can be compensated for by design) then Option (d) is the preferred solution. This was chosen as the configuration to be studied. However it should be noted that if the weighting factors are shown to be different on further analysis the impact on the configuration of using options (a) or (c) are minimal whereas option (b) would impact severely on many of the subsystem designs.

7.2.3.2 Solar Array Mounting

As a result of this configuration option there are limitations on the possible solar array positions. A solar array area of approximately 19m² has been identified. The arrays are to be orientated North - South with the capability for 360° of revolution in one axis to obtain maximum solar illumination.

With consideration of mass balance about the principle axis of the spacecraft it is necessary that the solar arrays are configured symmetrically about this axis. In order to provide the necessary degree of rotation the array must be split into two array panels and mounted on a yoke and drive mechanism for each.

The large inflatable SAR antenna presents potential problems of array shadowing. This effect of shadowing can be reduced by either extending the arrays out past the shadowed area or using extra solar array area which becomes redundant when the SAR obscures the arrays from the sun. Either way a central boom is needed to support the yoke and drive mechanisms.

The advantages of the former option are that the nominal area required for power generation is used and hence minimum array mass obtained. Also the thermal radiator

panels would be less obstructed the further the arrays from the spacecraft body, although the importance of this factor is not obvious without a full thermal assessment. The disadvantages of this option are primarily associated with the boom required to support the array away from the spacecraft. It would need to be structurally rigid and the complexity of the deployment would be increased.

The latter option has the advantage that the mounting boom would be shorter and therefore the rigidity requirements less constraining. However an amount of solar array area would necessarily be redundant over part of the orbit such that more than the nominal area would be required with implications on the array mass and hence cost - even though very small. The available radiator area field of view for the spacecraft body would be restricted but once again the importance of this factor cannot be determined at this level of the spacecraft design.

The qualitative arguments for either of these array configuration options have been highlighted above. As no fixed quantitative analysis can be performed at this level of design and since essentially the concepts are similar, it is assumed that the arrays are mounted on a central boom out from the 'anti - earth' face of the spacecraft with the the final optimization, of length of the boom and yokes, being a refinement of the design. An assessment of the effect on shadowing of the array due to the antenna and spacecraft body was made with the conclusion that minimal shadowing of approximately 1m^2 is an acceptable value.

7.2.3.3 Further Considerations

Further considerations are accommodation of the required attitude sensors. It is identified within the AOCS section 7.5 that Earth sensors are required. These must have a unobstructed field of view of the Earth. The SAR accommodation has a direct impact as there is no area on the spacecraft which is now visible to the Earth. It is therefore necessary for the Earth sensors to be mounted on booms extended out beyond the SAR masking area i.e., approximately 5 meters in length. These booms would need to be deployable for accommodation within the selected launcher fairing as detailed in the next section. The same is true of the TTC and data downlink antenna. It is also necessary for the magnetometers to be located away from the satellite body in a magnetically clean environment and so they could be mounted on these booms.

The structural design of the spacecraft body is discussed in section 7.8. Each subsystem is defined in sections 7.3 to 7.10. Within the bus it is necessary to accommodate all the spacecraft subsystems e.g., power, AOCS, propulsion with respect to the factors identified at the beginning of this section.

The propulsion subsystem consists of two propellant tanks which are a main component of the bus design and are best accommodated around the principle axis of the spacecraft to provide even mass distribution. Likewise the two batteries identified in the power section 7.4 are to be accommodated such that both mass balance and thermal control

is achieved. This is true of all the subsystems to the extent that grouping of electronics boxes, momentum wheels etc will be to provide optimum correlation of centre of mass along the launcher axis in this case defined as the principal axis of the spacecraft.

7.2.3.4 Preliminary Spacecraft Configuration Layout

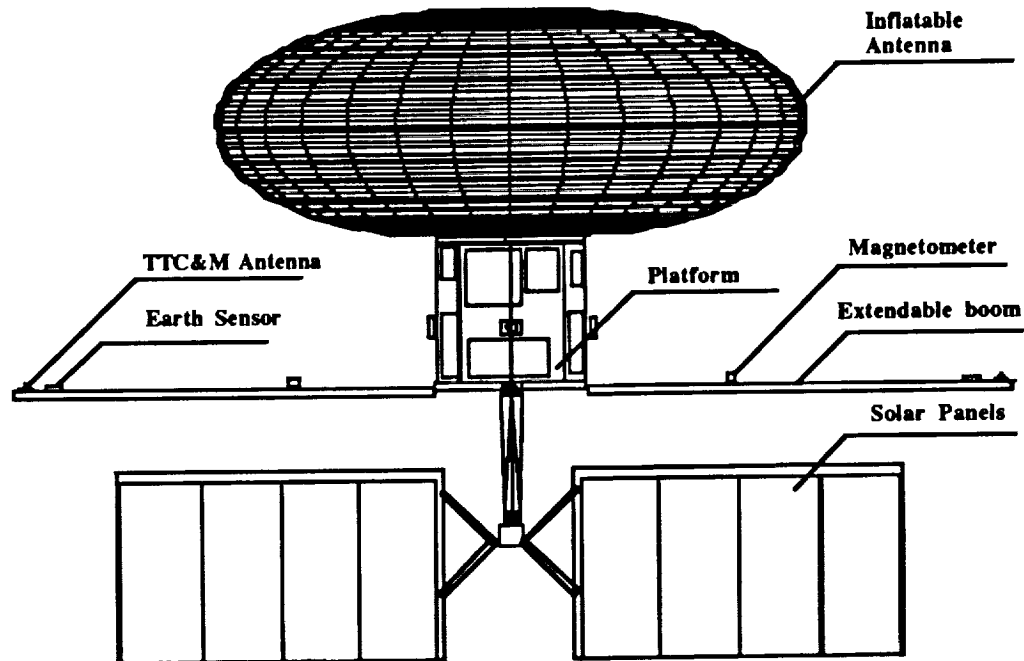


Figure 7.2 - 4 Spacecraft Configuration

7.2.4 Launch Vehicle Selection and Interfaces

Launch vehicles impose several constraints on spacecraft design. The most obvious and often most critical constraints are related to the mass and volume available to the spacecraft. Other parameters affecting the design of the satellite which are related to launch vehicle are the mechanical and electrical interfaces required, the launch vibration and thermal environment, the tip - off rate and the orbital injection precision given by the launcher.

The main parameter used for the selection of the launcher was the performance characteristics (payload mass vs. altitude). Other parameters such as the cost, the reliability

of the launcher system, the launch site, the ground base support and the availability or frequency of launch were considered in the selection.

The Chinese launcher Long March 2C was selected to launch the IPEO Satellite. It is a low cost and very efficient launcher. The main specifications of this launcher are given in Table 7.2 - 5.

Table 7.2 - 5 Launcher Specifications

| | |
|--------------------|--------------------------|
| Name | Long March 2C |
| Country | China |
| Launch Site | Xichang (Latitude 27.6°) |
| Performance | 2500 kg to LEO |
| Success Rate | 100% (12 launches) |
| Cost | \$30 M |
| Number of Stages | 2 |
| Overall Length | 38.4 m |
| Principal Diameter | 3.35 m |

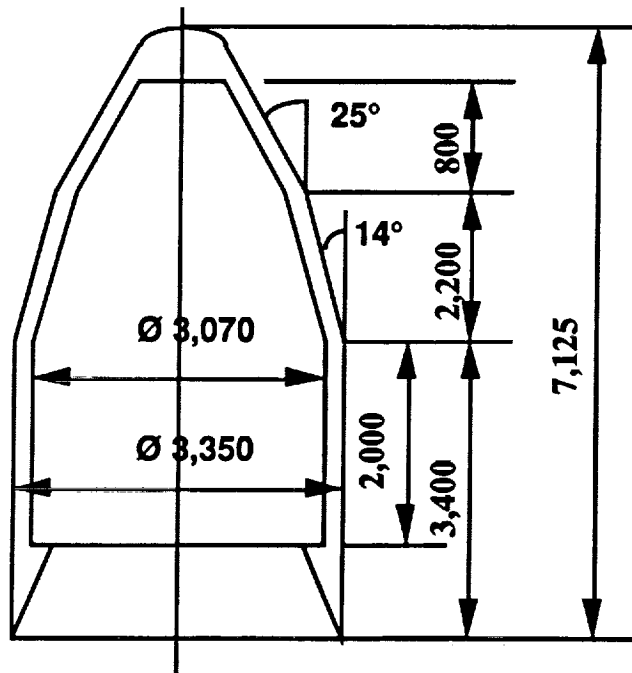


Figure 7.2 - 6 Long March 2C Launcher Fairing Payload Envelope.

To meet the requirements of the launcher the payload should be tested for 150 dB acoustic for 120 sec, 11g longitudinal acceleration, 2g lateral acceleration, and 70g shock

for 6 - 10 milliseconds and the volume should be small enough to fit into the payload dynamic envelope as shown in Figure 7.2 - 6.

7.2.5 Mission Definition and Orbit Selection

This section describes the main criteria used to select the orbit for the IPEO deforestation satellite. Two orbits were considered for this satellite: a polar sun synchronous and a low inclination orbit.

The selection of the satellite's orbit characteristics (altitude, inclination, etc.) results from a trade - off between mission objectives and constraints specific to engineering considerations. The constraints imposed on the engineers are as follows: the orbit should allow the satellite to cover $\pm 35^\circ$ of the Earth's latitude with a temporal resolution resolution of less than thirty days and a spatial resolution of 30 m. Since the payload uses a synthetic aperture radar it penetrates darkness and clouds so no ground illumination constraints need be considered. Finally the satellite should have a lifetime of about 2.5 years.

Table 7.2 - 7 Orbit Selection Criteria

| Criteria | Low inclination | Polar |
|---------------------|-----------------|-------|
| power | - | + |
| mass | - | - |
| thermal control | - | + |
| temporal resolution | + | - |
| launch cost (\$/kg) | + | - |
| ground stations | - | - |

The criteria used by the engineering group to select the best possible orbit are presented in Table 7.2 - 7. As seen in this table the advantage of polar sun synchronous orbit is that the solar angle is constant with respect to the orbit plane. This allows the power and thermal control systems to be simpler and more efficient than for ones used on a low inclination orbit. On the other hand, the low inclination orbit offers better temporal resolution and a lower launching costs. Parameters such as mass of the satellite and the necessary number of ground stations viewed by the satellite on its orbit were not found to have a major influence on the orbit selection.

Another important parameter to consider is the altitude at which the satellite operates. The higher the platform the larger is the energy necessary to operate the synthetic aperture radar. On the other hand, the lower the platform the larger the drag and the energy necessary to maintain a given altitude. From these considerations and taking into account the 30 meter spatial resolution required, an altitude of 600 km was chosen.

As shown in Figure 7.2 - 8, the temporal resolution, at 600 km altitude, is about 32 days for the polar sun synchronous orbit while a thirty eight degree inclination orbit could cover the Tropical belt in approximately 20 days. The temporal resolution was calculated by a computer program that took into account the off - nadir looking angle of $\alpha=30^\circ$ and a view angle $\beta=6^\circ$. These last values are specified by payload characteristics.

Temporal Resolution vs. Altitude

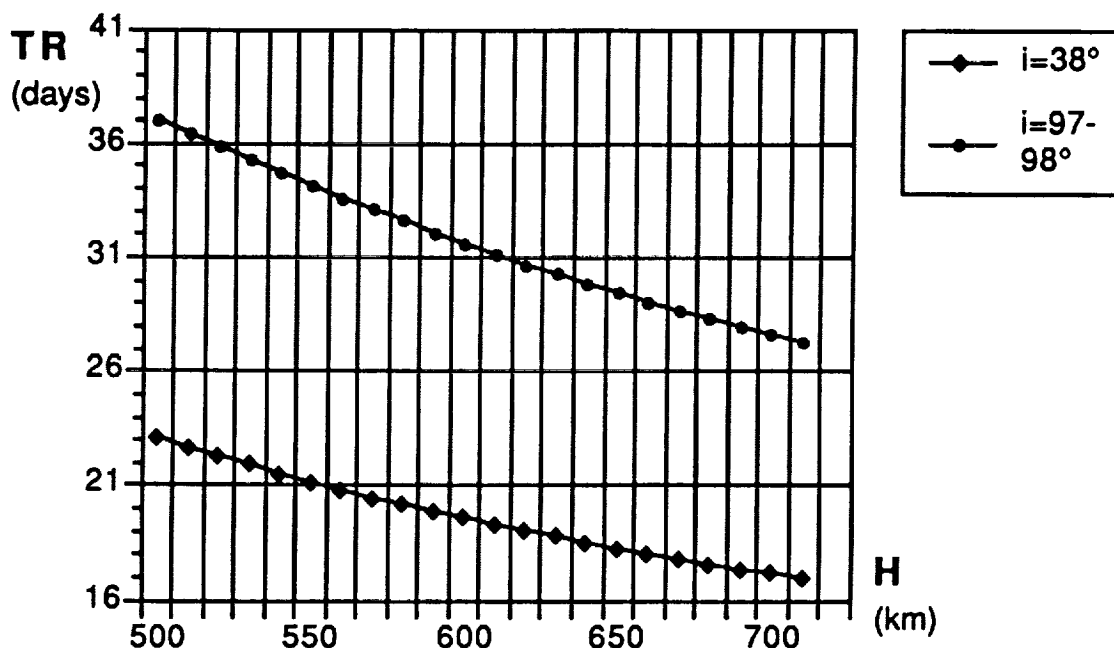


Figure 7.2 - 8 Temporal resolution as a function of orbit altitude

With these last considerations the polar sun synchronous orbit was rejected as a solution since it did not meet the specified temporal resolution requirements. The reason for using a low inclination orbit is to allow the satellite to cover the entire $\pm 35^\circ$ latitude belt with the minimum temporal resolution. An inclination of 38° was calculated from simple geometric relationships taking into account the fact that the payload looks off nadir at angle $\alpha=30^\circ$. To minimize the temporal resolution the orbit inclination should be as low as possible. The main parameters describing the orbit selected for the satellite are summarized in Table 7.2 - 9.

Table 7.2 - 9 The Main Orbit Parameters

| | |
|------------------------------|------------|
| Altitude | 600 km |
| Inclination | 38° |
| Temporal Resolution | ≈ 20 days |
| Swath Width | 83 km |
| Orbital Period | 5790 s |
| Orbital Velocity | 7.562 km/s |
| Average Shadow over 1 period | ≈ 37% |

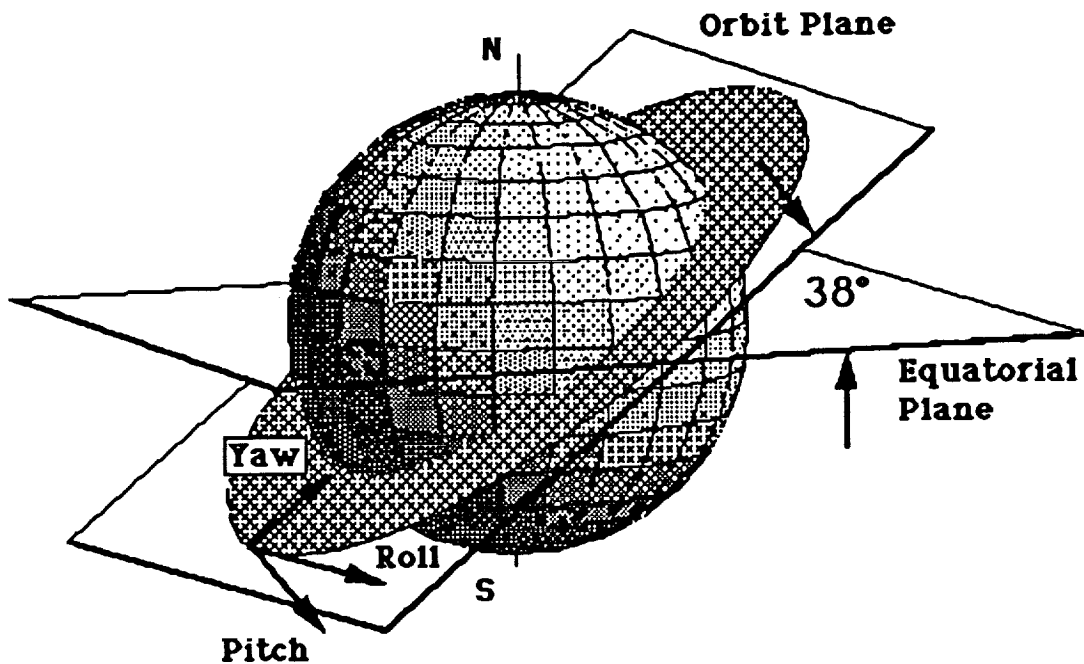


Figure 7.2 - 10 38° Low Inclination Orbit.

7.2.6 Spacecraft System Budgets

This section summarizes the spacecraft system budgets for the IPEO satellite.

7.2.6.1 Spacecraft Mass Budgets

The following table gives a mass budget breakdown for each of the spacecraft subsystems:

Table 7.2.6.1 - 1 Spacecraft Mass Budgets

| Subsystem | Mass (kg) |
|----------------------------|------------------|
| Payload | 100 |
| Reaction Control Subsystem | 84 |
| Thermal | 70 |
| Solar Array | 130 |
| Batteries | 65 |
| Data Handling | 28 |
| Propellant | 60 |
| Propulsion (tanks etc) | Undefined |

7.2.6.2 Spacecraft Power Budgets

The following table gives a power budget break down for each of the spacecraft subsystems:

Table 7.2.6.2 - 1 Spacecraft Power Budgets

| Subsystems | Power (W) |
|-------------------|------------------|
| Payload | 100 |
| Thermal | 150 |
| RCS | 68 |
| Solar Array | 1200 |
| Data Handling | 182 |

7.2.6.3 Spacecraft Propellant Budget

The propellant required for station keeping is 60kg.

7.3 Payload of the IPEO Satellite

7.3.1 Introduction

The use of radar for the payload was driven principally by the need to observe tropical forests. The Synthetic Aperture Radar, SAR, was selected for the following reasons :

- Smaller and hence feasible antenna aperture;
- Potentially higher along track resolution; and
- Fixed antenna scan instead of raster beam scanning.

The main constraint for the design has been the user requirement for spatial coverage and resolution as well as the need to keep the total mass of the system as low as possible. The payload also includes a Global Positioning System (GPS) receiver to provide the satellite altitude and time data necessary to process the SAR data to image format.

This section describes the preliminary design of a space-based Synthetic Aperture Radar (SAR) with the relevant theory. Figure 7.3.1 - 1 illustrates the different components of a space based. Each component will be described in this section.

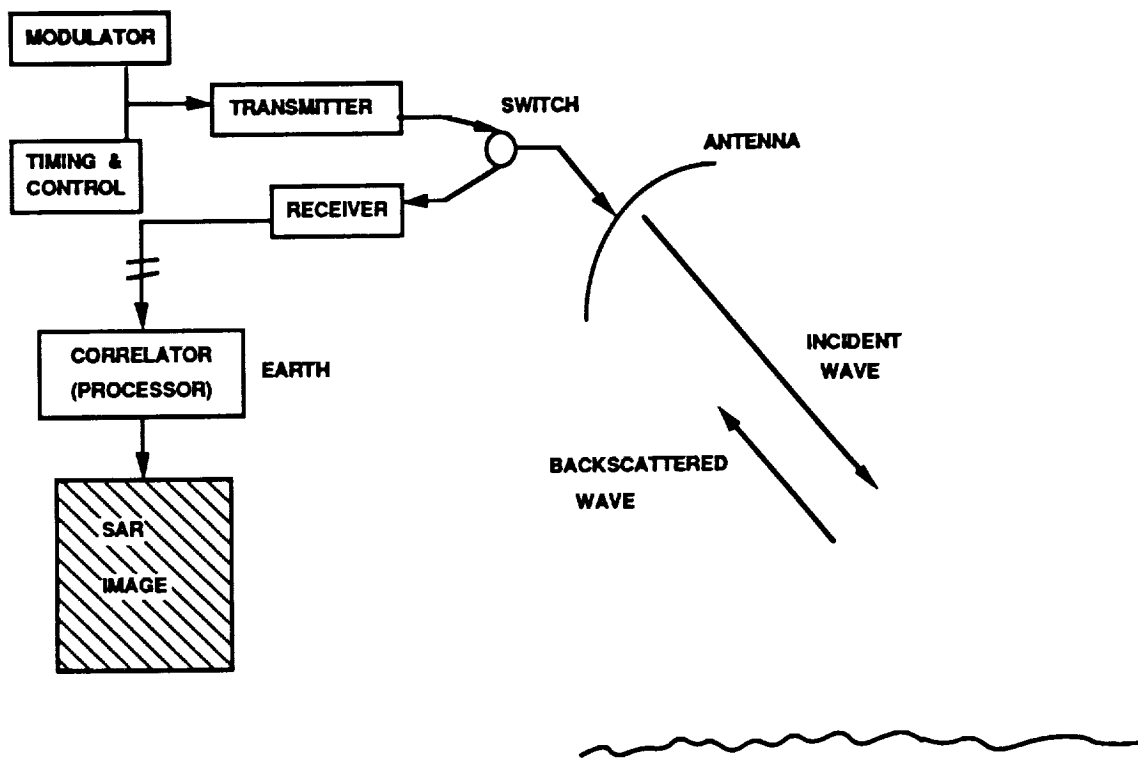


Figure 7.3.1 - 1 Block diagram of SAR

7.3.2 The General Principles of SAR

The general principles of the SAR are described in Appendix F. Details are given on the operational geometry, geometric resolution, image quality and system parameters.

7.3.3 Radar System Design Parameters

The design procedure followed is schematically illustrated in Figure 7.1.1. The starting point is user requirements which influence the SAR parameters such as the antenna area and power. The list of the different parameters needed for the radar system design is

shown in Table 7.3.1 - 1. The results of the study iteration and the ways used to calculate them will now be described.

Table 7.3.1 - 1 Design Parameters for the SAR

| Parameter | Symbol | Value |
|----------------------------|------------|-------------|
| Transmitter Frequency | f | 428 MHz |
| Wavelength | λ | 7 m |
| Pulse Repetition Frequency | PRF | 2 kHz |
| Pulse Repetition Interval | PRI | 500 μ s |
| Spacecraft Velocity | V | 7.56 km/s |
| Ground S/C velocity | V_g | 6.8 km/sec |
| Altitude | h | 600 km |
| Incident Angle | θ_i | 30° |
| Range | R | 690 km |
| Antenna Width | D_e | 6.9m |
| Range Beamwidth | β | ϕ |
| Swath Width (Range) | SW | 84 km |
| Range Pulsewidth | τ | 25 μ s |
| Range Bandwidth | B_d | 10 MHz |
| Antenna length | D_a | 8 m |
| Swath Length (Azimuth) | SL | 69 km |
| Azimuth Resolution | r_a | 30 m |
| Slant Range Resolution | r_{sr} | 26 m |
| Range Resolution | r_g | 30 m |
| Number of looks | N_a | 4 |

7.3.4 User Requirements

The choice of the transmitted frequency (428 MHz) was a compromise between the initial user requirement and the system design. Forest clear cut areas are better observed at longer wavelengths. For SAR, a longer wavelength improves the Signal to Noise Ratio (SNR), but on the other hand the antenna area increases with λ . Also, the hardware for this frequency exists and is more efficient as demonstrated in the proposal made by Spire, 1989.

The ultimate need of the user is to obtain a good quality image. From a system point of view, SAR image quality can be described by five parameters (Gram, 1986): number of looks (N_a), spatial resolution, amplitude resolution, signal to noise ratio (SNR), and incidence angle. Looks are independent azimuth observations which reduce by image

averaging the coherent noise or speckle, and spatial resolution. An optimum number of looks is about four. The ground range and azimuthal spatial resolution were set to 30 meters. The amplitude resolution is the number of bits per sample and is related to the dynamic range of the system. For this system, each word is 8 bits (4 In - phase and 4 Quadrature) but by using a block adaptive quantizer it could be reduced to four bits. The system SNR, which includes the sum of all noise contributors, is usually around 3 dB for the output image.

The incidence angle (θ_i) is another important parameter in image interpretation. The useful range of incidence angle is usually between 20° and 50°. If the angle is too shallow (<20°) the images suffer from foldover and there is corruption of the data due to nadir return of the pulse. If the angle is too high (>50°) portion of the images are shadowed by areas closer to the radar and the backscatter is smaller. For an optimization of the incidence angle (θ_i), the variation of the backscatter coefficient (σ_0) with θ_i for the tropical forest, will be needed but has not yet been investigated. The optimum θ_i varies between SAR designs from 23° (ERS - 1, C - Band) to 36° (X - Eos, X - Band). We have selected an angle of incidence of 30° to allow the use of the data for geologic purposes as well.

7.3.5 Pulse Timing

An imaging radar transmits a continuous sequence of pulses, which has been illustrated elsewhere [EOS - SAR], 1988]. For the requirement of P - band the carrier frequency is 428 MHz. The pulse width is determined by the resolution across - track ($r_g=30m$) and is given by

$$\tau_c = \frac{2 r_g \sin(\theta_i)}{c} = 100 \text{ ns}$$

This requires a bandwidth at the detector of 10 MHz ($1/\tau_c$).

The pulse repetition frequency (PRF) is another important factor for the SAR and is chosen to maximize the swath width and minimize unwanted overlap or ambiguity. The PRF has a lower limit that insures that the ground return will not interfere with the transmitted frequency and an upper limit to make sure that the returned pulse should come within the interpulse period. By combining the two inequalities, we obtain [Hovanessian, 1980]:

$$\frac{2V}{D_a} < \text{PRF} < \frac{c}{2R_{\max}}$$

where R_{\max} is the maximum mapping range. A PRF of 2 kHz was selected for this system.

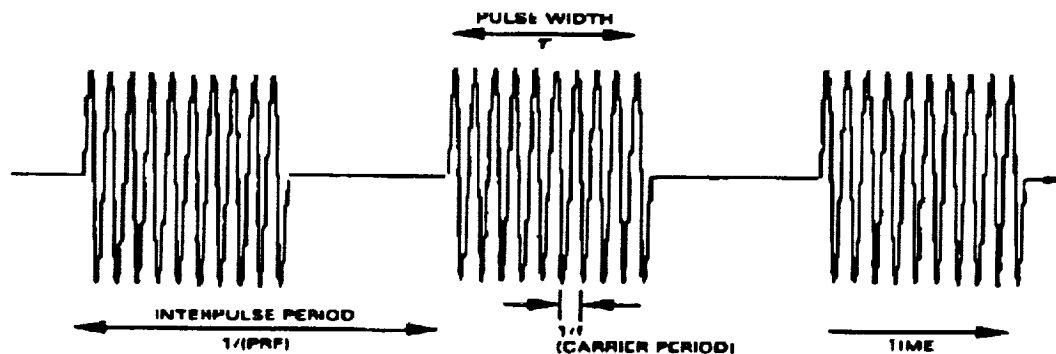


Figure 7.3.5 - 1 Time sequence of radar pulses

To raise the transmitter power it is common in SAR to linearly modulate (“chirp”) the frequency (chirp) of the pulse. This technique called pulse expansion allows the transmission of longer pulses without affecting the ground resolution and reduces the peak power by the same ratio. The elongated pulse is equal to the duty cycle of 5 percent divided by the PRF. In our case the new pulse length is 25 μsec.

7.3.6 Antenna Area

To minimize undesired radar echoes which contaminate the desired signal, it is necessary to provide a minimum aperture area of the antenna given approximately by:

$$\text{Area} > A_f \left(4 \frac{V R \lambda}{c} \text{tg}\theta_i \right)$$

[Cantafio, 1989] where A_f is an antenna illumination factor taken here as 1.5. For this system, the minimum area is 42 m². As will be shown latter, the effective area of the IPEO antenna is 43 m² ($D_e = 6.9$ m; $D_a = 8$ m) which satisfies this criteria.

7.3.7 Power

For the integration of the SAR with the satellite it is necessary to calculate its power requirement. An estimate of the power requirements of the radar was based upon the following assumptions :

- Minimum backscatter coefficient of (-21dB)
- Required signal to noise ratio (SNR) = 3 dB.

The formula to calculate the power (\bar{P}) equation is (Hovaressian, 1980):

$$\bar{P} = \frac{(4\pi)^3 R^3 (kT)L}{G^2 \lambda^2 (r_g) \sigma_o \lambda \frac{2V}{N} \sin \theta}$$

Power was evaluated by adding the logarithm of each factor of the equation. This technique facilitates the trade - off between each of the parameters. The result is displayed in Table 7.3.7 - 1. The average power is 20 W. For this value, the peak power requirement will be

$$P_{pk} = \frac{\bar{P}}{\tau PRF} = 400 \text{ W}$$

Table 7.3.7 - 1 Example of Mean Power Calculation

| Parameter | Definition | dB |
|--------------|--|-------|
| $(4\pi)^3$ | Constant | 33 |
| R^3 | Slant range(695 km) | 175 |
| kT | Temperature(400K) | - 203 |
| L | Losses | 10 |
| $2V/\lambda$ | Space velocity | 43 |
| S/N | SNR | 3 |
| G^2 | Gain of antenna | - 57 |
| λ^2 | Wavelength ($\lambda = 0.7 \text{ m}$) | - 3 |
| r_g | Ground resolution | - 15 |
| σ_o | Minimum backscatter | 21 |
| N_a | Number of looks | 6 |
| \bar{P} | Mean Power | 13 |

7.3.8 Image Calculation

The backscattered signal will need to be digitized before sending it to the Earth for processing. The proposed quantization(b) is 8 bits divided into 4 bits In - phase (I) and 4 bits in Quadrature (Q). To calculate the data rate (DR), the following formula was used:

$$DR = \left(\frac{V_g}{r_a} \right) N_a b \left(\frac{SW}{r_g} \right) O_s$$

where N_a is the number of azimuth looks, b is the number of bits (8) and O_s the oversampling rate (2). The total data rate is then 18 Mbits / sec. The storage necessary for a complete image is given by the product of the data rate with the time to take one image ($T=SL / V$) and this yields a file of 200 Mbit.

7.3.9 Antenna

The antenna is the mechanism by which electromagnetic energy is radiated and received. For radar, it is essential that the antenna enhance the performance of the system. A radar antenna has three roles: a major contributor to the radar's sensitivity, to provide the required surveillance, and to allow measurements of angle of sufficient accuracy and precision. The classical shape for focusing the electromagnetic energy is the parabolic reflector. Phased array antennas are the standard type for SAR, but the parabolic reflector type antenna has been used, for example, in the Magellan mission (Gram, 1986).

For large space structures, the antenna is the dominant element of concern, mainly because of the weight, size and deployment process. The SAR requirement is to have a large aperture antenna. For this application the minimum effective antenna area is 42 square meters as given in section 7.3.9 - 1.

A survey of large space antenna literature [Cantafio, 1989], [Bernasconi], 1984] and [Bernasconi, 1986] showed that in order to reduce weight, the deployment process, and drag, an inflatable space - rigidized structure antenna was the preferred choice. The selection criteria in Table 7.3 - 3 were used to decide which antenna to choose. The use of a reflector allows the polarization to be changed more easily than with a phased array. This also gives the ability to study the HH and VV polarizations.

Table 7.3.9 - 1 The Selection Criteria of the Antenna

| | Subjective Weighting Factor | Rectangular Phased Array | Inflatable Reflector | Mesh Reflector |
|----------------------|-----------------------------|--------------------------|----------------------|----------------|
| weight | 3 | - 1 : - 3 | 1 : 3 | - 1 : - 3 |
| Distortion | 2 | 0 : 0 | - 1 : - 2 | 0 : 0 |
| Stowed configuration | 3 | 0 : 0 | 1 : 3 | 0 : 0 |
| stiffness | 1 | 1 : 1 | 0 : 0 | 1 : 1 |
| TOTAL | | - 2 | 4 | - 2 |

Inflatable structures, which acquire their final mechanical characteristics after a chemical rigidization procedure in the orbital environment, can advantageously be used to

support a wide range of functions [Bernasconi, 1986]. Typically, they are deployed from their stowed configuration by inflation, then cured by solar heating.

The overall configuration of the inflatable antenna is shown in Figure 7.3.9 - 1. The antenna consists basically of four parts:

- 1) The paraboloid - shaped reflector membrane;
- 2) The radome membrane, with the same size and shape as the reflector membrane;
- 3) The stabilization torus; and
- 4) The central cylinder.

The central feed tower is exploited as a fixed support for the other attachment ring. The reflector has a thin wall of RF - transparent Inflatable Space - Rigidized Structure (ISRS) composite. This forms the main inflatable chamber. A second inflatable element is the stabilization torus, needed to keep the balloon's region free of deformation during pressurization. The torus is not rigid and is manufactured from plastic foil elements. It lies completely outside the nominal antenna aperture [Bernasconi, 1984].

The main chamber is delimited by the reflector shell (incorporating the RF - reflecting layer), the paraboloid radome shell and an equatorial toroidal element [Bernasconi, 1984]. Its wall is a laminated structure consisting of:

- The ISRS composite, a light weight KEVLAR cloth impregnated with the space - curing resin;
- A plastic foil as gas barrier; and
- A VDA layer, on the outside surface of the reflector's sealing foil.

The structure is assembled and launched with the material in its flexible precured state, so that it can be folded for stowage in the container. Once in orbit, the antenna is deployed by inflation with nitrogen, and then cured by maintaining it at a temperature of about 110 degrees for 6 hours by pointing the radome - side of the antenna towards the sun. After curing is complete, the nitrogen is evacuated.

Various kinds of reflector antenna have been put into practical use. Though their types, applications and characteristics are different, the reflector antennas can be roughly classified into two types according to their geometrical structure: symmetrical type and asymmetrical type (offset type). Alternatively, they can be classified into another two types according to the number of reflectors: single - reflector type and dual - reflector type (Cassegrain and Gregorian type). For this wavelength ($\lambda=0.7\text{m}$), the subreflector of a Cassegrain mirror will need to be around 6 meters for efficient use of the mount and to avoid large diffraction. Since the main reflector is around 8 meters, this option was ruled out. Because the looking angle of the SAR is 30° , a centrally fed reflector will require a tilt

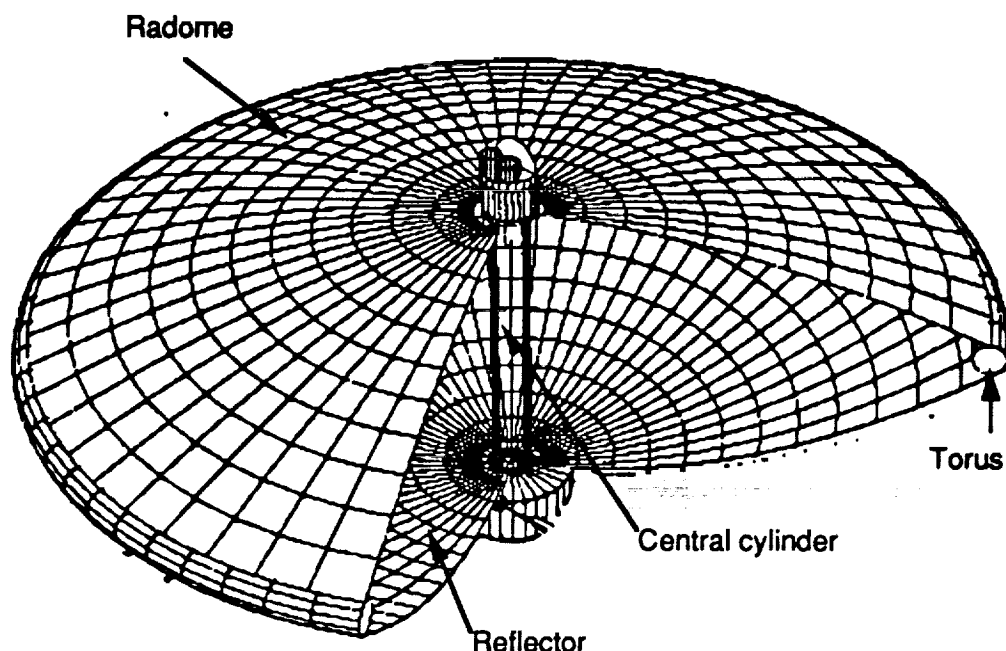


Figure 7.3 .9 - 1 The Inflatable Antenna

of the whole satellite which was rejected from the point of view of orbit control. The selected geometry is an offset horn which illuminates a circular antenna of 8 meter in diameter. The area of the antenna along its line of sight will be elliptical with semimajor axis of 8m and semi - minor axis of 6.9m. The total area is then 43m². The total mass of the inflatable antenna is approximately 100 kg. With a wavelength of 70 cm, the half power beamwidth θ_{3dB} is 6 degrees. The gain of the antenna is given by Hovanessian as:

$$G = 4 \pi \eta \frac{\text{Area}}{\lambda^2} = 4 * 3.14 * 0.6 * 43 / 0.7 / 0.7 = 661.3 = 56.4 \text{ dB}$$

where η is the antenna efficiency, taken to be a standard value of 60 percent.

7.3.10 RF Electronic Subsystem

The block diagram of the SAR is shown in Figure 7.3 - 1 and in this subsection we will describe the main components of each of the blocks. The 4 RF electronic subsystems are: modulator, transmitter, receiver and the timing and control subsystem [Ferguson, 1988].

Timing and Control

This subsystem has three main components. The first one comprises the master clock and the local oscillator for the radar. The second is the timing signal generation circuitry which produces trigger and synchronization signals for the PRF signals, the signal path switching and other functions. The SAR processor controls the instrument configuration.

Modulator

The modulator includes the low power transmitter subsystem. The chirp generator produces the pulse waveform at an intermediate frequency with a bandwidth of 10 MHz. The signal is then up - converted to the RF frequency of 428 MHz. Finally, the RF signal is then amplified to a level suitable for the transmitter subsystem (approximately 1Watt).

Transmitter

The transmitter converts DC electrical power to RF electrical signals at the carrier frequency and in the waveform desired. The transmitter consists of a high - power amplifier coupled to a horn via a coaxial cable. This is the preferred option since at this frequency the size of a waveguide will be too large.

Sources of transmitters can be either thermionic or solid state devices. Early versions include magnetrons, TWT (Travelling Wave Tubes), klystrons, EIKO (Extended Interaction Klystron Oscillators), EIKA (Extended Interaction Klystron Amplifiers), BWO (Backward Wave Oscillators) and gyrotrons. TWT and EIKA are the principal sources for high - power, coherent microwave radar systems and they usually have high efficiency. The other ones are usually heavier and bulkier than the TWT.

The solid state devices are IMPATT (Impact Ionization Avalanche Transit Time) diodes, Gunn - effect devices, and FET (Field - Effect Transistors). The advantages of IMPATT diodes as well as other solid - state devices are low cost, reliability, simplicity in operation, and long lifetimes. The disadvantages are usually the low power provided. Gunn effect devices and FETs have lower level of noise in comparison with IMPATT and their efficiency for different types are 5 - 20 percent. All the technologies listed were principally developed for higher frequencies than for this application. A recent report [SPIRE, 1990] suggested that an amplifier with peak power of 800 W is available. Dr. E. Caro stated that the present technology solid state amplifier can produce the 400 W peak power needed for our application with an efficiency greater than 40 percent. This will be the selected option for the study design.

Receiver

The receiver subsystem includes several steps of signal processing. The signal arrives at the antenna and is applied to the receiver through the transmit - receiver (TR) switch. Its function is to direct the transmitter energy to the antenna and the receiver energy to the receiver and to protect the receiver from the effects of the relatively high - power

transmitted signal. In the case of high power transmitters, the switch may be implemented using a hybrid and gas - fired TR tube. In the case of low - power transmitters, the TR device may be a circulator, which is three - port ferromagnetic device.

For most radar systems, after the TR, the received frequency (RF) signal is converted to an equivalent signal at an Intermediate Frequency (IF), where the subsequent functions (i.e. amplification, gain control, filtering, and detection) are more easily performed than they would at RF. The down - conversion to IF is performed by the frequency subtracting action of a mixer. The two inputs to the mixer are the received signal, which is nominally at the transmitted frequency, and a local oscillator frequency (near RF) but at some designed offset value. The output of such a mixer has components resulting from the sum, the difference and each of the input frequencies. The sum and the two original frequencies are suppressed by the low - pass filtering action of the IF amplifier circuits. The difference frequency is the desired signal. Common IF frequencies for microwave radar systems are 30 and 60 MHz or 45 and 70 MHz.

The following step is amplification, which is performed at IF using either wide band amplifiers or tuned ones. Tuned amplifiers can usually provide more gain but the use of wide band amplifiers provides the designer with more flexibility in the subsequent processing and filtering.

The final step is the detection of the in - phase (I) and the quadrature (Q) part of the IF frequency. This detection must be maintained between channels over a wide frequency range.

7.3.11 Interfaces

The following table summarizes the major characteristics of the payload which affect other subsystems:

Table 7.3.11 - 1 Payload Main Characteristics

| Characteristic | Value |
|-------------------------|------------------------------|
| Mass of Payload | 100kg |
| Power of Payload | 400W |
| Area of Antenna | 6.9m x 8m = 43m ² |
| Data rate | 18 Mbit/sec |
| Storage capacity | 200 Mbit |
| Across track resolution | 30m |
| Incidence angle | 30 degrees |
| Maximum noise | 3dB |
| Pulse repetition rate | 2kHz |
| Pulse length | 25usec |
| Number of looks | 4 |
| Frequency | 428MHz |

7.4 Power Subsystem

7.4.1 Introduction

The power system of the satellite will supply power to each subsystem of the satellite. In order to achieve this function, the power system will generate, distribute and store the required power (see Figure 7.4.1 - 1).

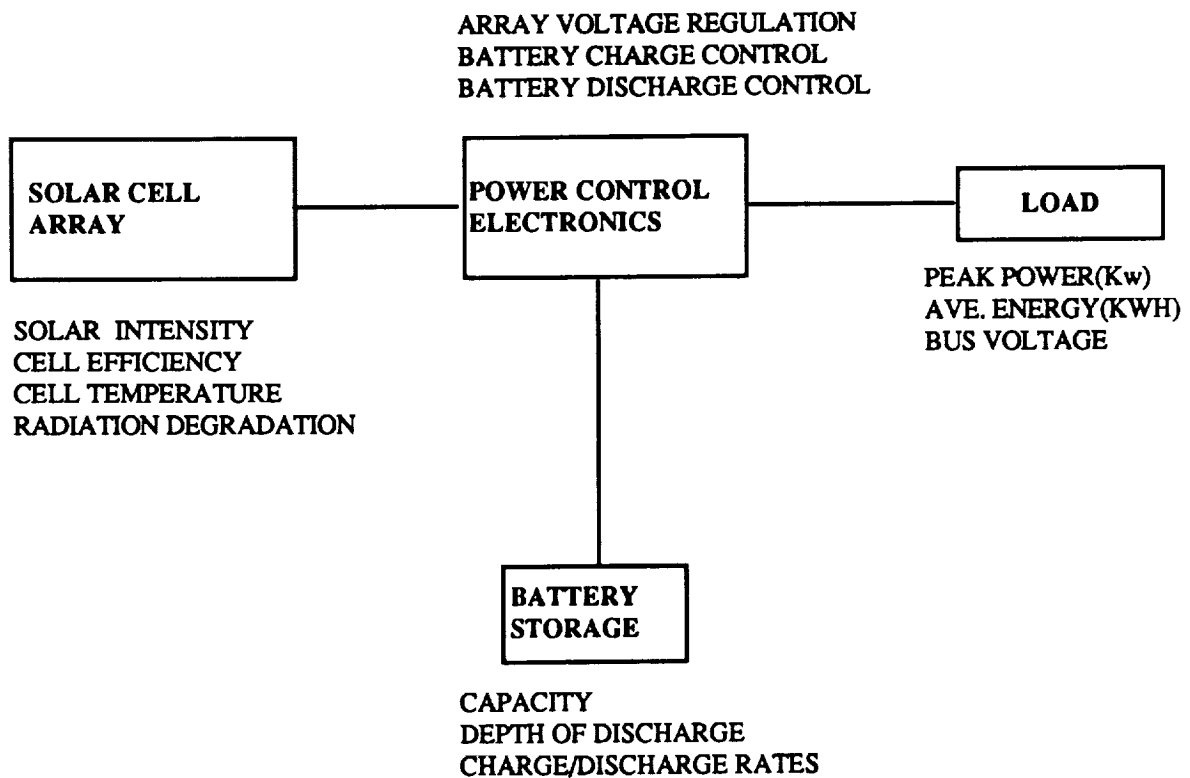


Figure 7.4.1 - 1 Power System Overview

The aim of this section is to identify the power requirements of the satellite as a prerequisite to the definition of the characteristics of the power generation system (solar arrays) and of the storage system (batteries). Then the general power distribution and management will be discussed and elaborated.

The main parameters which drive the design of the power system are the characteristics of the orbit of the satellite and the power requirements of the bus and of the payload. Table 7.4.1 - 1 gives the power requirements of the IPEO satellite payload and bus support

systems. Except for the SAR and the payload Communication and Data Handling, all other elements require almost constant power.

Table 7.4.1 - 1 IPEOSAT Power Requirements

| SUBSYSTEM | POWER (W) |
|-----------------------|--------------------------------|
| <u>Payload</u> | |
| - SAR | 120 (15min/orbit) |
| - C&DH | Recording 150 (15min/orbit) |
| | Playback 170 (5 min/orbit) |
| - Thermal | 20 |
| <u>Bus</u> | |
| - Power | 50 |
| - C&DH | 100 |
| - AOCS/PROP | 120 |
| - Thermal | 100 |

Some of the array power will be stored in batteries to supply power to the payload during orbital eclipse.

In order to start the evaluation of the batteries and the solar array characteristics, the regulation and voltage of the power distribution system have to be defined. An unregulated supply has been chosen because it is simple as far as power subsystem design is concerned. However it makes life more difficult for the payload and other subsystem equipment which must be designed to operate across a range of voltages. The bus voltage has been assumed to remain within the range 22 - 35 VDC with an average voltage of 28 VDC.

7.4.2 Mission Power Requirements

Four cases have been investigated corresponding to the various ways that the SAR can be operated. These four different payload power profiles correspond to the following combinations between the operating time (day or eclipse) and the numbers of pieces of

equipment that are involved: the SAR and its associated recorder can be operated during either the orbital day or the eclipse, while the recorded data will be dumped according to the availability of a ground station along the track, this can occur during either orbital day or eclipse.

The four possible power profiles are illustrated in Figures 7.4.2 - 1 through 7.4.2 - 4. In the following, they will be referred as case A,B,C and D respectively which correspond to:

- Case A: [(SAR + RECORDER) + PLAYBACK] during eclipse
- Case B: [(SAR + RECORDER) + PLAYBACK] during sunlight
- Case C: [(SAR + RECORDER)] during eclipse + PLAYBACK during eclipse
- Case D: [(SAR + RECORDER)] during sunlight + PLAYBACK during eclipse

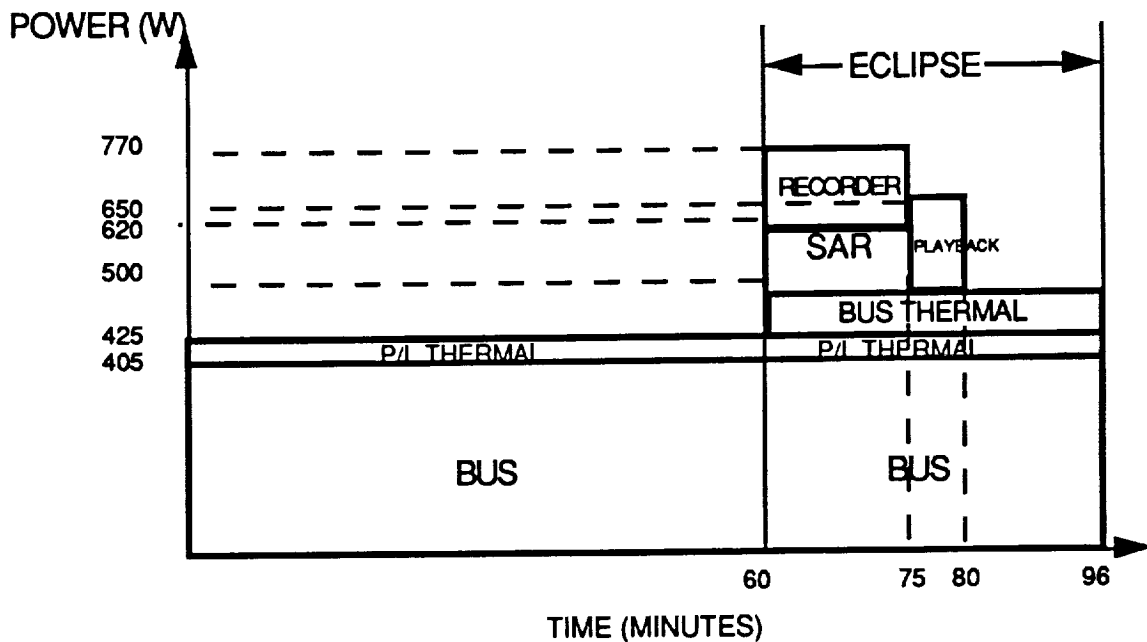


Figure 7.4.2 - 1 IPEOSAT Power Profiles - Case A

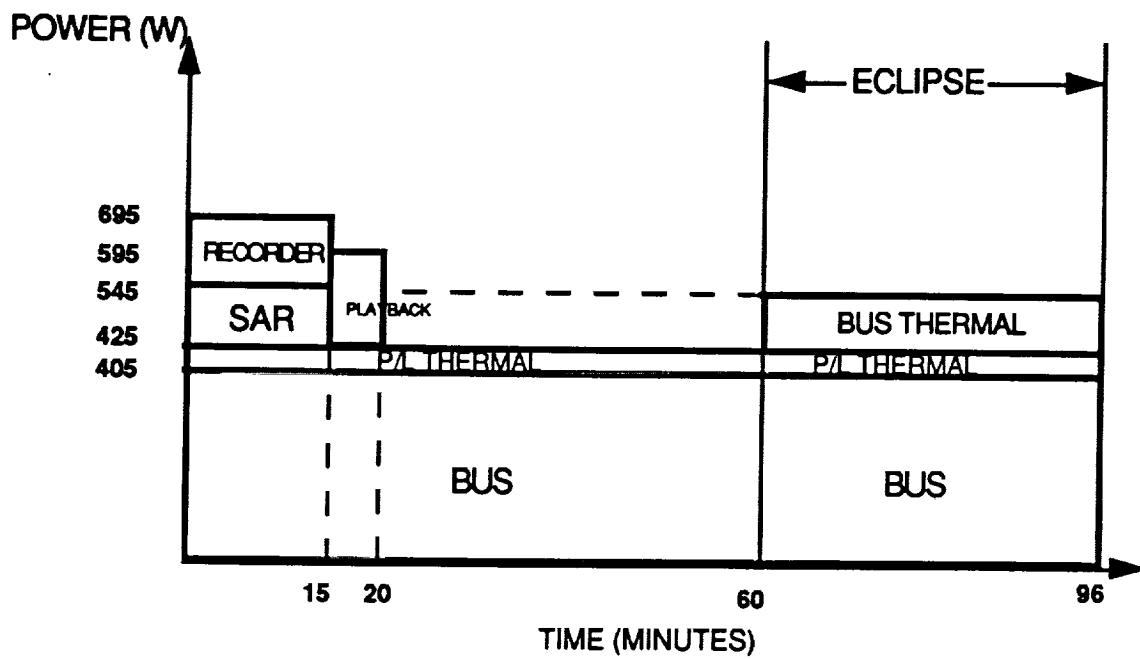


Figure 7.4.2 - 2 IPEOSAT Power Profiles - Case B

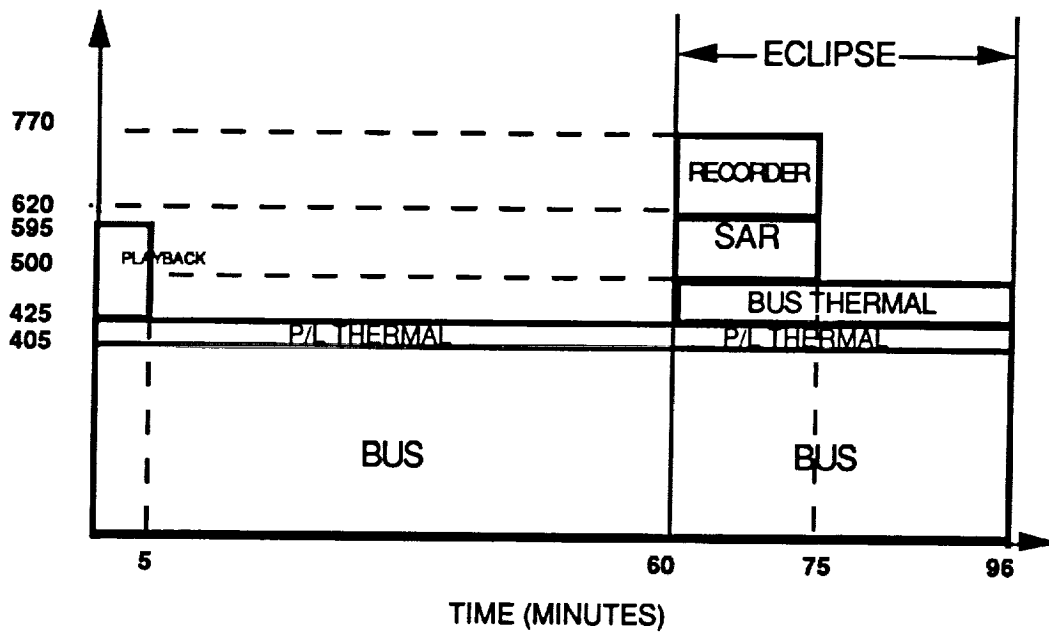


Figure 7.4.2 - 3 IPEOSAT Power Profiles - Case C

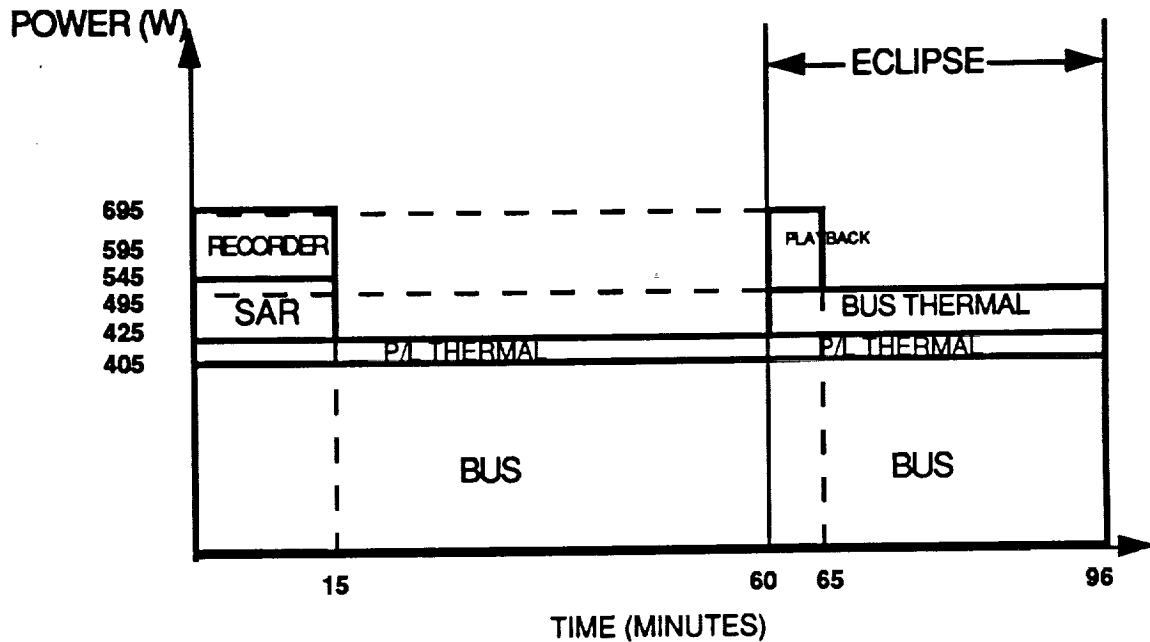


Figure 7.4.2 - 4 IPEOSAT Power Profiles - Case D

7.4.3 Power Generation Design

7.4.3.1 Introduction

There are many power systems and power sources. Solar cells are especially suited for space application because they consume no fuel, do not exhaust themselves, and do not emit exhaust products or radiation. Most satellites and space vehicles launched today have utilized solar cell energy to operate their internal equipment as well as to generate the power for their communications equipment.

The estimations of the mass and size of the solar arrays can only be initiated once the following information is available:

- The required output power;
- The power bus voltage;
- The equilibrium temperature of the solar cells; and
- The sun tracking mechanism characteristics.

7.4.3.2 Solar Array Output Power Estimation

Required solar power is calculated employing the following relationship which integrates the different factors that affect the different equipment of a power system. In addition, a built-in 10 percent margin in the power requirements has been included (factor 1.1). The

power required from the solar arrays at the input of the power control electronics, P_{sa} , is given by:

$$\text{req.}P_{sa} = \frac{P(\text{Day Ave.})}{(n \text{ OFF}) \times (n \text{ PRU})} + \frac{P(\text{Eclipse Ave.})}{(n \text{ OFF}) \times (n \text{ PRU})} \frac{TN}{TD} \frac{BCV}{BDV} (n \text{ RCH})$$

| | |
|-------------------------|---|
| where , req. P_{sa} : | Required Solar Array Power |
| P(Day Ave.): | Consumption Average Power during Sunlit period |
| P(Eclipse Ave.): | Consumption Average Power during Eclipse period |
| n OFF: | Maximum Power Tracking Factor : 95% |
| n PRU: | Efficiency of Power Regulator Unit : 90% |
| TN: | Maximum Eclipse Duration : 36 min |
| TD: | Minimum Sunlit Period : 60 min |
| BCV: | Battery End of Charge Voltage : 1.48V |
| BDV: | Battery End of Discharge Voltage : 1.15V |
| n RCH: | Battery Recharge factor : 1.06 |

Taking into account the 10% margin the Solar Array Power, P_{sa} , is given by

$$P_{sa} = \text{req.}P_{sa} \times 1.1$$

7.4.3.3 Temperature of Solar Panel

Operating temperature is one of the important factors which affects the design of the solar arrays since the power generation of a cell decreases as the temperature increases. However, the temperature of the solar arrays can be considered as constant for the major part of the sunlit part of the orbit thanks to the emittance characteristics of the solar cells surface. This equilibrium temperature tends to increase as the altitude of the orbit decreases, and it depends also on the material of cells. The estimated operating temperature is 50°C for Si and 60°C for GaAs according to the following relationship:

$$T(K) = \sqrt[4]{\frac{SA - SC}{B(Ef + Ea)}}$$

where

| | |
|-------|---|
| T(K): | Cell Temperature |
| S: | Solar Irradiation Power: 1350W/m ² |
| A: | Sunlight Absorbance of Cell Surface: 0.73 (Si), 0.86 (GaAs) |
| C: | Conversion Efficiency of Cell: 11.3% (Si), 17.5% (GaAs) |
| B: | Stefan - Boltzmann Constant: 5.67 x 10 ⁻⁸ W/m ² K |
| Ef: | Surface Emittance of Solar Cell Panel: 0.74 |
| Ea: | Back Surface Emittance of Solar Cell Array: 0.67 |

7.4.3.4 N by M Array Construction

Solar Array's electrical circuit is constructed by series and parallel as illustrated in the figure 7.4.3.4 - 1. The output power voltage is related to the Bus voltage.

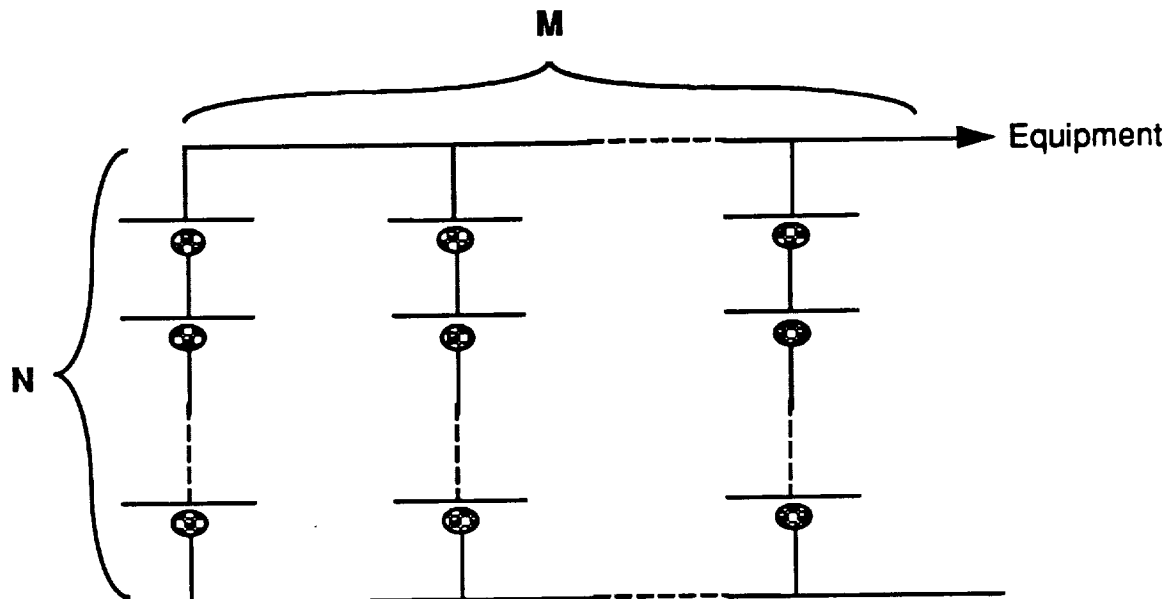


Figure 7.4.3.4 - 1 NxM array construction

N: The Number of Cells in series

$$N = \frac{\text{Bus Voltage} + \text{Diode Drop} + \text{Wire Harness Drop}}{V_m}$$

$$V_m = \text{Load Voltage} \times \text{Voltage Concentration Ratio} \times \text{Voltage Temperature Coefficient}$$

M: The Number of Cells in parallel

$$M = \frac{\text{Power Output from Array}}{\text{Bus Voltage} \times I_m} \times \frac{1}{\text{Incident Angle of Sunlight} \times \text{Solar Intensity}} \times \frac{1}{\text{Degradation of Heat Cycle} \times \text{Assembly Loss} \times \text{Degradation of Radiation}}$$

$$I_m = \text{Load Current Conservation Rate} \times \text{Current Temperature Coefficient}$$

L: The Total Number of Cells

$$L = M \times N$$

- 1) Cells Mass = The Total Number of Cells x Unit Cell Mass
- 2) Wire Harness Mass = $0.2 \times 10^{-3} \text{ kg} \times \text{The Total Number of Cells}$ (kg)
- 3) Total Cells Mass = (1) + (2) (kg)

7.4.3.5 Solar Array Mass Estimation

The main elements of a solar array are the panels, cells, deployment system, keeping system and motors for orientation. The control of the orientation of the solar arrays is supposed to be done around one axis; a 2 - axis would be more efficient but it is mechanically much more complex. The specific efficiency of Si and GaAs are $90\text{W}/\text{m}^2$ and $160\text{W}/\text{m}^2$ respectively. Specific mass efficiency of Si and GaAs are $45 \text{ W}/\text{kg}$ and $60\text{W}/\text{kg}$ respectively. Adoption of Semi - Rigid Type technology based on CFRP has been taken for the Paddle materials with a specific mass of $2.1 \text{ kg}/\text{m}^2$.

The following relationships are based on the assumption that the solar arrays will be driven around one axis only, consequently the cosine of the incident angle of sunlight has been introduced in the formula to take this assumption into account.

- (1) Total Cells Area

$$= \frac{\text{Solar Cell Power (W)}}{\text{Specific Area (W / m}^2) \times \cos(\text{Incident Angle of Sunlight})} \text{ (m}^2)$$

- (2) Paddle Area = $\frac{\text{Total Cells Area}}{0.9}$ (m²)

(If Total Cells Area is given by the relationship developed in chapter 7.4.3.4:

$$\text{Paddle Area} = \frac{\text{Total Cells Area}}{0.8} \text{ (m}^2 \text{)}$$

- (3) The Number of Panels = $\frac{\text{Paddle Area}}{\text{Panel Area}}$ ---> An Even Number

(If the Result is not an Integer number, the result equals the next Integer number ,e.g.: 5.4---> 6)

- (4) Deployment System/solar array = $(0.4 \text{ kg} \times \text{Number of Panels of one side} + 2.6 \text{ kg})$

- (5) Paddle Keeping System $\approx 9 \text{ kg} / 1 \text{ system}$ (kg)

- (6) Paddle Structure Mass $\approx 2.1 \text{ kg}/\text{m}^2 \times (\text{Panel Area} \times \text{The Number of Panels})$ (kg)

- (7) Paddle Mass $\approx (4) + (5) + (6)$ (kg)

- (8) Total Cells Mass = $\frac{\text{Solar Cell Power (W)}}{\text{Specific Mass (W / kg)}} \text{ (kg)}$

(9) Motor of Orientation Control = 10 kg / 1 motor (kg)

(10) Total Mass of Solar Array = (7) + (8) + (9) (kg)

7.4.3.6 Results

The results concerning the required output power and the associated solar array area are gathered in the following Tables 7.4.3.6 - 1 and 7.4.3.6 - 2.

Table 7.4.3.6 - 1 Solar Array Output Power

| | Case A | Case B | Case C | Case D |
|-------|--------|--------|--------|--------|
| Power | 1212 W | 1261 W | 1206 W | 1180 W |

Table 7.4.3.6 - 2 Solar Array Characteristics

| | Case A | Case B | Case C | Case D |
|-----------|-------------------|-------------------|-------------------|-------------------|
| Si Area | 32 m ² | 33 m ² | 32 m ² | 32 m ² |
| Si Mass | 170 kg | 179 kg | 170 kg | 167 kg |
| GaAs Area | 18 m ² | 19 m ² | 18 m ² | 18 m ² |
| GaAs Mass | 126 kg | 127 kg | 126 kg | 125 kg |

Here, the maximum power which must be considered to adequately size the solar arrays is Case B. If we use a Ga - As technology, 19 m² of solar cells will be enough providing that there is no solar cells under shadow. Unfortunately, the antenna and the bus induce some shadow on about 1m². Consequently the power generation system will be composed of two solar arrays of 10 m² each.

7.4.4 Power Storage Definition

7.4.4.1 Battery Subsystem Design Concept

For a spacecraft, rechargeable batteries are used during the periods when the electric power from the solar array is not available or is not large enough. In many spacecraft missions the solar array will deliver power only intermittently during the transfer orbit, thus requiring batteries to supplement it during eclipses or power load peaks.

An attempt was made to estimate the mass and size of two kinds of the most popular batteries, Ni - Cd battery and Ni - H₂ battery for the satellite orbiting in low Earth orbit. In order to perform these estimations the required energy during the eclipse must be known. The battery discharge efficiency must also be taken into account. The depth of discharge (DOD) must be controlled to achieve the required lifetime. Finally, one must assess if it is possible for the battery to discharge the maximum power during eclipse. To do that, an indicator named C rate (the rate of charge and discharge) is used.

For the IPEO satellite the following formulas have been considered:

- C rate of cell = Maximum discharge ampere(A) / Cell capacity(Ah) (1)
- Battery capacity = Charging energy / (Bus voltage * DOD) (2)
- Charging energy = Needed energy / Efficiency of battery discharge (3)

7.4.4.2 Battery Characteristics

The main characteristics of the batteries are gathered in the following table 7.4.4.2 - 1

Table 7.4.4.2 - 1 Capacity, Mass, Size of Cell

| Cell | Capacity(Ah) | Mass(kg) | Size(liter) |
|---------------------|--------------|----------|-------------|
| Ni - Cd | 70 | 1.83 | 0.53 |
| | 45 | 1.29 | 0.34 |
| | 40 | 1.17 | 0.30 |
| | 35 | 1.05 | 0.27 |
| | 30 | 0.93 | 0.23 |
| | 20 | 0.67 | 0.15 |
| Ni - H ₂ | 45 | 1.20 | 2.00 |
| | 40 | 1.15 | 2.00 |
| | 35 | 1.05 | 2.00 |
| | 25 | 1.00 | 1.28 |

(The size of battery includes the assembly structure.)

N.B.: Discharge voltage of battery: 28V(assumption)
 DOD(Depth Of Discharge) of Ni - Cd battery cell is 20%.(assumption)
 DOD(Depth Of Discharge) of Ni - H₂ battery cell is 40%.(assumption)
 The efficiency of battery discharge is 80%(assumption)

7.4.4.3 Battery Sizing

The energy in each case which a battery discharges during the eclipse :

- Case A: Bus control + Bus thermal control + P/L thermal control + SAR + recorder + Playback = 509W
- Case B: Bus control + Bus thermal control + P/L thermal control + Playback = 389W
- Case C: Bus control + Bus thermal control + P/L thermal control + SAR + recorder = 456W
- Case D: Bus control + Bus thermal control + P/L thermal control = 372W

• Capacity and C rate of batteries in each case:

• Case A:

the capacity of batteries is,

$$509 / (28 * 0.20) = 91.0\text{Ah (Ni - Cd)}$$

$$509 / (28 * 0.40) = 45.5\text{Ah(Ni - H}_2\text{)}$$

C rate is,

$$(405 + 70 + 20 + 120 + 150) / 28 / 91.0 = 0.30\text{C}$$

(Ni - Cd: discharge of 15min) -> reasonable

$$(405 + 70 + 20 + 120 + 150) / 28 / 45.5 = 0.60\text{C}$$

(Ni - H₂: discharge of 15min) -> reasonable

• Case B:

the capacity of batteries is,

$$389 / (28 * 0.20) = 69.5\text{Ah (Ni - Cd)}$$

$$389 / (28 * 0.40) = 34.8\text{Ah (Ni - H}_2\text{)}$$

C rate is,

$$(405 + 70 + 20 + 170) / 28 / 69.5 = 0.34\text{C}$$

(Ni - Cd: discharge of 5min) -> reasonable

$$(405 + 70 + 20 + 170) / 28 / 34.8 = 0.68\text{C}$$

(Ni - H₂: discharge of 5min) -> reasonable

- **Case C:**

the capacity of batteries is,

$$456 / (28 * 0.20) = 81.5\text{Ah (Ni - Cd)}$$

$$456 / (28 * 0.40) = 40.8\text{Ah (Ni - H2)}$$

C rate is,

$$(405 + 70 + 20 + 120 + 150) / 28 / 81.5 = 0.37\text{C}$$

(Ni - Cd: discharge of 15min) -> reasonable

$$(405 + 70 + 20 + 120 + 150) / 28 / 40.8 = 0.68\text{C}$$

(Ni - H2: discharge of 15min) -> reasonable

- **Case D:**

the capacity of batteries is,

$$372 / (28 * 0.20) = 66.5\text{Ah (Ni - Cd)}$$

$$372 / (28 * 0.40) = 33.3\text{Ah (Ni - H2)}$$

C rate is:

$$(405 + 70 + 20) / 28 / 66.5 = 0.27\text{C}$$

(Ni - Cd: discharge of 36min) -> reasonable

$$(405 + 70 + 20) / 28 / 33.3 = 0.54\text{C}$$

(Ni - H2: discharge of 36min) -> reasonable

Whatever the kind of batteries that will be selected, each of them can sustain the rate of discharge corresponding to the peak power demand.

7.4.4.4 Conclusion

The main characteristics of the possible combination of batteries are gathered in the Table 7.4.4.4 - 1:

Table 7.4.4.4 - 1 Power Storage Batteries Alternatives

| | Battery | Capacity of Cell(Ah) | Number of Parallel | Number of Serial | Total Mass(kg) | Total Size(liter) |
|-------|---------------------|----------------------|--------------------|------------------|----------------|-------------------|
| CaseA | Ni - Cd | 45 | 25 | 2 | 83.9 | 22.1 |
| | | 30 | 25 | 3 | 90.7 | 22.5 |
| | | 20 | 25 | 5 | 109 | 24.4 |
| | Ni - H ₂ | 45 | 25 | 1 | 39.0 | 65.0 |
| | | 25 | 25 | 2 | 65.0 | 83.2 |
| CaseB | Ni - Cd | 70 | 25 | 1 | 59.5 | 17.3 |
| | | 35 | 25 | 2 | 68.3 | 17.6 |
| | | 20 | 25 | 4 | 87.1 | 19.5 |
| | Ni - H ₂ | 40 | 25 | 1 | 37.4 | 65.0 |
| | | | | | | |
| CaseC | Ni - Cd | 40 | 25 | 2 | 76.0 | 19.5 |
| | | 20 | 25 | 4 | 88.4 | 19.5 |
| | Ni - H ₂ | 40 | 25 | 1 | 37.4 | 65.0 |
| CaseD | Ni - Cd | 70 | 25 | 1 | 59.5 | 17.3 |
| | | 35 | 25 | 2 | 68.3 | 17.6 |
| | | 20 | 25 | 4 | 87.1 | 19.5 |
| | Ni - H ₂ | 35 | 25 | 1 | 34.2 | 65.0 |

(Data includes 30percent of margin for mass and size of heater and structure.)

One of the preliminary conclusions which can be drawn from these results is that the utilization of Ni - H₂ batteries tends to save the mass to the prejudice of the volume when the opposite conclusions apply for the Ni - Cd batteries. Another point is that it is preferable to have more than one battery to reduce the consequences of a battery failure. Two 25 Ah Ni - H₂ batteries will provide enough energy for operating the SAR and the playback during the eclipse.

7.4.5 Power Distribution and Management

As mentioned in the introduction, an unregulated power bus voltage has been deliberately chosen to simplify the power subsystem. This unregulated system feeds the array or battery output, with an inherently by wide range of voltages, directly to the power bus. The average voltage will be around 28 VDC.

In order to avoid dissipation of the unused power, in the case where the spacecraft accepts the power from the total area, an array shunt regulator will be used to switch sections of the array on and off in accordance with demand.

A block diagram of the power distribution system is illustrated on Figure 7.4.5 - 1. In this diagram the main power bus is redundant in order to improve the reliability of the system.

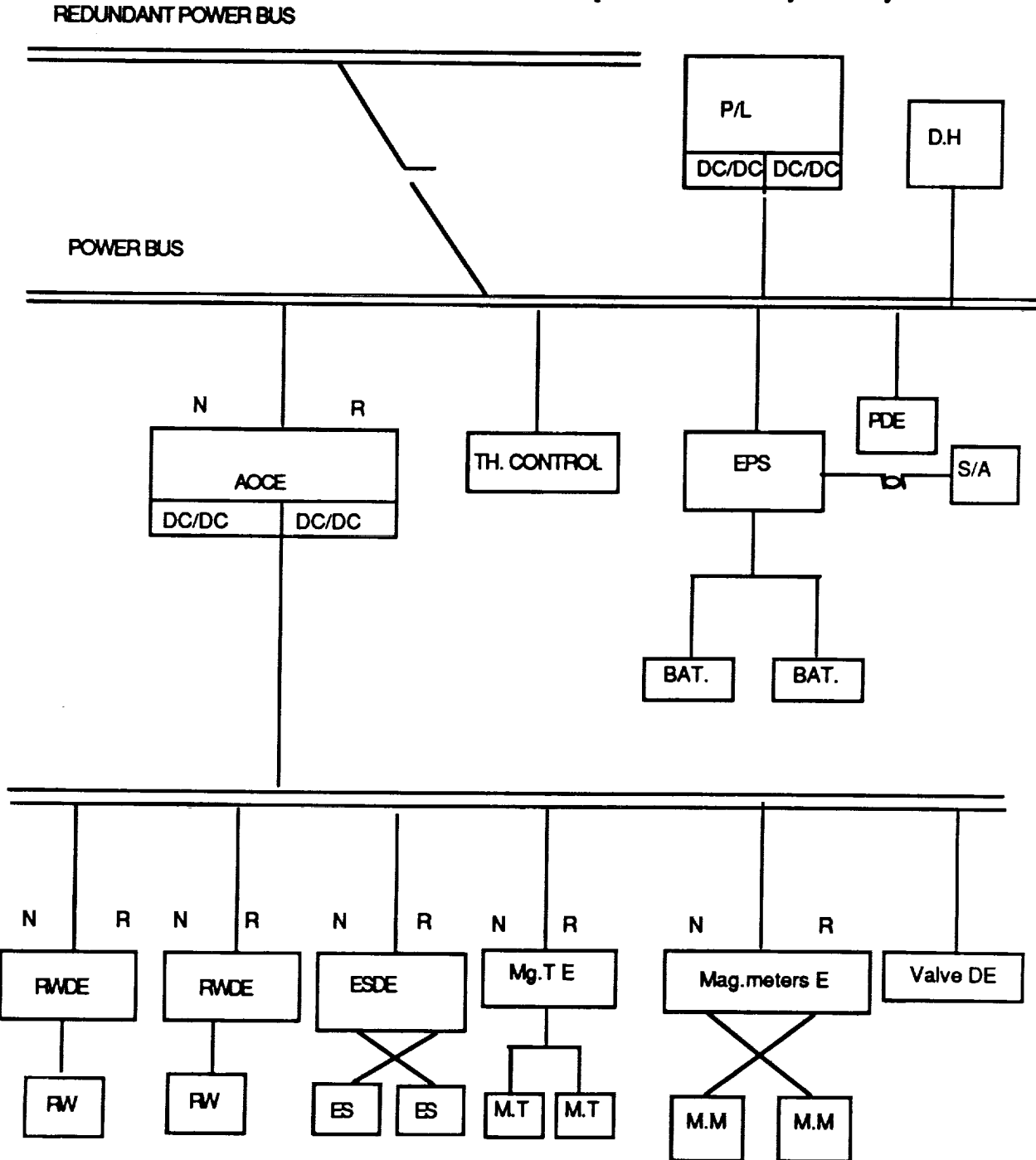


Figure 7.4.5 - 1 Power Distribution System

Legend : AOCE: Attitude Orbit Control Electronics; ESDE: Earth Sensor Drive Electronics; Mg.TE: Magneto Torque Electronics; M.M: Magnetometer; RWDE: Momentum wheel Drive Electronics.

7.4.6 Power System Design

The power system has been sized to allow the utilization of the payload to the maximum extent. The most constraining case has been taken to design the two main equipments of the power system (solar arrays and batteries).

Amongst the four possible power payload profiles investigated, the most constraining case for the sizing of the storage batteries is case A, when the SAR and the playback are operated during the eclipse. For the solar arrays, the maximum power output must be supplied when both the SAR and the playback are activated during the orbital day (Case A). But it should be mentioned that the array output power range is very small for all these four cases and varies from 1180 W to 1260 W. Taking into account the margins which have been taken to design the solar arrays, the power system can provide the required power for each of these cases.

The IPEO satellite is intended to be launched toward the end of the decade. At that time one can assume that both Ni - H₂ and Ga - As technologies will be available for batteries and solar arrays respectively. Because the most important criteria for a spacecraft are the mass and the propellant consumption, the Ni - H₂ technology will be adopted for the batteries because of its better efficiency and its lower mass with respect to the Ni - Cd. In order to increase the reliability of the satellite, power storage will be assured by two 25 Ah Ni - H₂ batteries assembled in parallel, in such a way that the satellite could still be operated in a degraded mode in case of a battery failure. On the other hand, the reduction of the propellant mass consumption can be also obtained by the reduction of the drag of the spacecraft. Solar arrays contribute for a part to this drag. Thanks to the better efficiency of the Ga - As technology with respect to Si, the required solar array area can be minimized and reduced by a factor of about 2 (18 m² for Ga - As versus 33 m² for Si). That is why this technology is selected. Even if Ga - As is a relatively new technology, one can reasonably foresee that by the end of the decade it will become a well proven technology. Another advantage of the Ga - As technology is the mass saving of the solar arrays (about 40 percent).

The last point to be discussed is the solar array orientation capability. In order to keep the power system as simple as possible and to increase its robustness, the solar arrays will be driven to track the sun along one axis only, which leads to an increase in the total area of the arrays by 100 percent compared to a two axes approach. With a two axis driving mechanism it would have been possible to track the Sun with a constant optimum angle of illumination, thus minimizing the area of the solar arrays. However in the selected solution the effect of the Sun inclination has been introduced as a cosine factor in the design of the solar arrays. Nevertheless the one axis approach will avoid the introduction of a complex and bulky driving mechanism which has not been used to date.

7.4.6.1 Sun Tracking Approach

In order to guarantee good tracking of the Sun, the intensity of the electrical current will be measured and analyzed by the on board computer and the solar arrays will be reoriented accordingly.

7.4.6.2 Synthesis

Because of its design simplicity, its higher robustness and its easier accommodation on the satellite the one - axis double wing solar array has been selected. Of course a two axis system would have compensated for the cosine effect of the Sun angle illumination but would prejudice both the reliability (increased moving parts) and the simplicity (driving mechanism) of the system.

In summary, the power system will be based on an unregulated power bus (28 VDC on average), two 25 Ah Ni - H₂ batteries mounted in parallel and a one axis double wing solar array of 10 m² each. The total estimated mass budget for the power system is detailed in Table 7.4.6 - 1.

Table 7.4.6 - 1 Power System Mass Budget

| | |
|-------------------|-----|
| SOLAR ARRAYS (kg) | 130 |
| BATTERIES (kg) | 65 |
| TOTAL (kg) | 195 |

7.5 Attitude and Orbit Control Subsystem (AOCS)

This section describes the attitude and orbit control subsystem to be used on the IPEO satellite.

7.5.1 Description of AOCS Options

The spacecraft and subsystem designs are strongly influenced by the stabilization technique selected, which is influenced by the pointing requirements of spacecraft antennas. The pointing requirements for the IPEO satellite are 0.5° on the roll axis and 1° on the yaw and pitch axes.

There are three types of spacecraft attitude stabilization: gravity gradient stabilization, spin stabilization and 3 - axis stabilization. Table 7.5.1 - 1 summarizes the advantages and limitations of each technique. Since the IPEO deforestation satellite uses a very large antenna constantly pointing at the Earth, with a pointing accuracy of 0.5° on the roll axis, a three - axis stabilization system has been selected as the optimum choice.

Table 7.5.1 - 1 Satellite Stabilization

| Type of stabilization | Pointing accuracy | Power of solar cell | Thermal control | Loading big antenna |
|-----------------------|---------------------|------------------------|-------------------------|---------------------|
| Gravity gradient | low ($1^\circ >$) | high power is possible | complex | easy |
| 3 - axis | very high | high power is possible | complex | easy |
| Spin | high | lower than above types | easier than above types | complex |

7.5.2 AOCS for the IPEO Satellite

There are several types of three - axis stabilization systems: bias momentum systems and zero momentum systems. Basically the bias momentum system provides an angular momentum along the pitch axis which gives gyroscopic stiffness to the satellite. A zero momentum system uses reaction wheels to control all three axis independently. Table 7.5.2 - 1 outlines the major characteristics of each system. Because the zero momentum systems are generally expensive and more complex to handle, a controlled Bias momentum system for the stabilization of the IPEO's satellite has been selected. The pointing accuracy of this system is moderate, but good enough to meet the specified requirements for the IPEO satellite.

Table 7.5.2 - 1 Attitude Control of Satellite

| Type | System | Pointing accuracy | Existing Satellites |
|--------------------------|---------------------|----------------------------|-------------------------------|
| Bias Momentum | simple | low | INTELSAT - V RCS SATCOM |
| Controlled Bias Momentum | moderate | moderate ($0.4^\circ <$) | MOS - 1, INSAT |
| Zero Momentum | complex (expensive) | high ($< 0.3^\circ$) | SPOT - 1, ERS - 1 JERS - 1 |

The major features of the attitude system are described here. The torques along the pitch and roll axes are controlled by varying the speed of the momentum wheels. These momentum wheels have their axis of rotation making an angle of 10° with the pitch axis in the roll/pitch plane. The total effective angular momentum therefore lies along the pitch axis

giving gyroscopic stiffness to the satellite. Since the yaw and roll motion are coupled it is possible to control the yaw by measuring and controlling the roll. Yaw error is controlled and monitored indirectly due to the interchange of yaw and roll error every quarter of the orbital period. Earth sensors will be used to detect changes in roll or pitch. In order to ensure that the buildup of yaw errors on the quarter of the orbit are within the pointing requirements for the satellite an estimation of the torques acting on the spacecraft must be done.

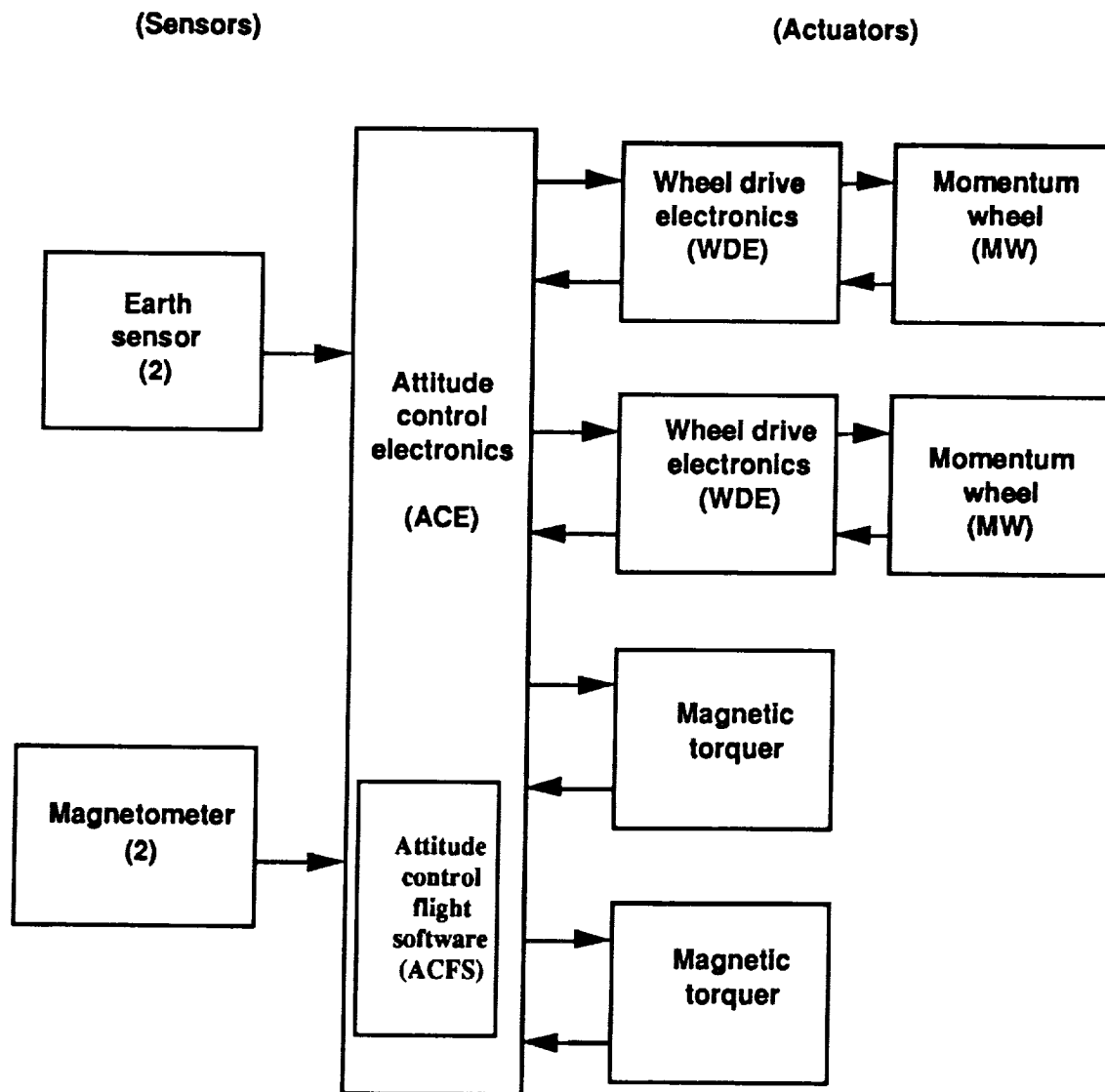


Figure 7.5.2 - 2 Block Diagram of Attitude Control System (ACS).

The dominant disturbance torques acting on the spacecraft at 600 km altitude are the aerodynamic torques, the gravity torques due to the oblateness of the Earth and magnetic torques. Solar pressure torques can be neglected for these calculations since there are one

order of magnitude smaller than the other disturbances. After estimating the principal moments of inertia of the spacecraft and the major cross section area of the different elements, calculations led to magnetic and gravity torques of the order of 10^{-4} N*m while the aerodynamic torque was of the order of 10^{-5} N*m. It was found that the gyro compassing techniques proposed here would satisfy the pointing requirements of the spacecraft. In other words, the cumulative errors on the yaw axis for one quarter of the orbit were low enough to provide the specified pointing accuracy.

Because momentum accumulates in the momentum wheels, two magnetic torquers (one placed along the pitch axis, the other along the roll axis) are used to lock the satellite while unloading the wheels. Magnetometers placed in a magnetically clean environment on the spacecraft will allow a precise measurement of the surrounding magnetic field, giving better control on use of the magnetic torquers. Table 7.5.2 - 3 gives the characteristics of attitude control system components.

Table 7.5.2 - 3 Characteristics of ACS Components

| | Earth sensor | Magneto - meter | Attitude control electronics | Momentum Wheel and Electronics | Magnetic torquer |
|--------------------|--------------|-----------------|------------------------------|--------------------------------|------------------|
| Number | 2 | 2 | 1 | 2 | 2 |
| Weight * (kg) | 1.5 | 0.5 | 6.5 | 10 | 3.2 |
| Power * (W) | 4 | 0.7 | 38 | 20 | 1.3 |
| Total Mass | | | 36.8 kg | | |
| Total Power | | | 90 W | | |

* the value for one component

For a satellite configuration to be stable the moment of inertia about the yaw axis has to be as small as possible with respect to the moments of inertia about the two other axes. The distribution of the mass of the elements composing the different subsystems in the bus has to be done taking into account this effect. Also, because of the aerodynamic drag, the satellite shape should be as symmetrical as possible. Table 7.5.2 - 4 is a summary of the different acquisition phases of attitude control system from the injection phase to the true operating mode of the satellite.

Table 7.5.2 - 4 Attitude Control System Acquisition Phases

| Acquisition Phase | Characteristics |
|--------------------------------|---|
| 1) Launcher Injection | <ul style="list-style-type: none"> - Possible errors in altitude, orbital velocity, etc. - tip off rate approx. 0.5°/s |
| 2) "ON" | <ul style="list-style-type: none"> - Attitude Control Power Acquisition |
| 3) Rate Reduction | <ul style="list-style-type: none"> - deploy solar panels and TTC&M booms - Use Magnetometers and Magnetic Torquers to reduce angular rate |
| 4) Earth Acquisition Phase | <ul style="list-style-type: none"> - Search Sequence using Earth Sensor - Spin up momentum wheels using magnetic torquers to lock satellite |
| 5) Orbital Altitude Correction | <ul style="list-style-type: none"> - use thrusters to correct altitude |
| 6) Antenna Deployment | <ul style="list-style-type: none"> - Wait period for antenna solidification |
| 7) Operating Mode | <ul style="list-style-type: none"> - Earth Sensor to measure Pitch and Roll - Magnetometers and Magnetic Torquers used to unload wheels - Momentum Wheels for Pitch, Roll/ Yaw control |

7.6 AOC, Launchers, Mass Budgets, Orbits

7.6.1 Reaction Control Subsystem (RCS).

This section describes the reaction control subsystem (RCS) of the IPEO satellite. The purpose of the RCS is to maintain the orbit of the satellite during its 2.5 year lifetime. The RCS design presented considers the main objective of orbit correction but can also be used to desaturate the reaction wheels of the bias momentum attitude control system. This Attitude Control System uses magnetic torquers instead of thrusters because of simplicity and cost, as presented in the previous section.

The need for orbit corrections is a consequence of two different sets of errors or perturbations: those given by the launching system, basically inaccuracies in altitude (ΔH), orbit inclination (Δi), velocity (ΔV) and position in the orbit ($\Delta \Omega$); and those originated by orbit perturbations such as the aerodynamic drag, solar pressure forces, electromagnetic forces, the imperfect gravity field of the Earth and the influence of the Sun and the Moon.

7.6.2 Launching System

The corrections to be done at the injection point are strongly dependent on the launcher, the type of propellant and navigation system, and on the mission requirement. The possible errors at injection can be split in two groups: Δi , orbit inclination, $\Delta \Omega$ or

position on time; and ΔH or errors in altitude and ΔV or velocity error for the correct orbit. The influence of the first group on the mission is negligible. $\Delta\Omega$ does not give influence on the mission and small values of Δi are expected, $\Delta i \approx 0.2^\circ$, so its correction does not practically affect the mission and does not compensate from the increase of satellite mass. Only altitude and velocity errors will be corrected. Referring to altitude and velocity, the following errors are expected:

$$\begin{aligned}\Delta H &\approx \pm 50 \text{ km} \\ \Delta V &\approx 0.005 V_{co} \approx 38 \text{ m/s}\end{aligned}$$

7.6.3 Orbit Perturbation

The evaluation of the effect of the perturbations on the orbit is not an easy task when looking for a high accuracy estimation. In this section the effect of the aerodynamic drag and the influence of the sun and moon are considered. The solar activity has been taken into account by a correction factor applied to the aerodynamic drag while the influence of earth's oblateness has been considered negligible because it has no influence on the mission requirements.

For a circular orbit, the altitude decay rate can be estimated as $\Delta r/\Delta t = -2Bp\sqrt{\mu}r$, where $B=C_D A/(2m)$, C_D = drag coefficient, m = mass of the satellite, A = cross - section area or equivalent area, r = radius of the orbit and p = atmospheric density. At that altitude the drag coefficient is independent of the shape of the satellite and can be assumed to be equal to $C_D=2$. Now assuming an ARDC 1959 atmosphere model, the previous expression leads to a decay rate of 25 m/day. Finally a factor of 2 is applied for solar activity and possible atmosphere model influences. This, taking into account the lifetime requirements, $t = 2.5$ years, leads to the final estimation of

$$\begin{aligned}\Delta r/\Delta t &= - 50 \text{ m/day} \\ \Delta H(\tau = 2.5 \text{ years}) &= - 54 \text{ km}\end{aligned}$$

Other perturbations that could be important are due to the influence of the sun and the moon. These perturbations would mostly influence the orbit inclination. For geosynchronous satellite the combined sun and moon rate of change of inclination is between $0.943^\circ/\text{year}$ and $0.747^\circ/\text{year}$. For low inclination orbits, the rate of change of inclination is proportional to the square radius of the orbit in a first approximation. This means, using geosynchronous satellite data, the rate of change of inclination for our satellite will be about $0.02^\circ/\text{year}$ or about 0.05° for 2.5 years lifetime. This influence is therefore negligible and a change of orbit inclination will not be corrected.

Summarizing and referring to orbit corrections during the satellite's lifetime, the only variable to be corrected is the altitude of the orbit. Assuming corrections every month or two months, the estimate of the total altitude to be corrected in 2.5 years is 54 km.

7.6.4 ΔV Budget and Mass of Propellant

Previous sections show the corrections to be carried out as well as an estimate of the different variables to be corrected. Table 7.6.4 - 1 presents those variables and the ΔV needed to correct them. All manoeuvres are reduced to the simplest case of increasing or reducing the velocity in the orbit plane, so the thrust needed will always be applied in the orbit plane and tangentially to the orbit.

Table 7.6.4 - 1 ΔV Budget for the RCS.

| | |
|---|--|
| Altitude error: 50 km | 25 m/s |
| $\Delta V = 0.005 V_{CO}$ ($V_{CO} = 7.56$ km/s) | 38 m/s |
| Altitude correction (50 m/day; correction every 30 days; 3years): 54 km | 29 m/s |
| Contingency (10% subtotal) | 10 m/s |
| TOTAL BUDGET | $\Delta V = 102$ m/s |

The budget presented in Table 7.6.4 - 1 allows computation of the total mass of propellant as $M_p = M_{sp}[1 - \exp(-\Delta V/Ig)]$, where M_p = mass of propellant and M_{sp} = mass of the satellite, including the propellant mass. For the propulsion system (RCS) monopropellant (hydrazine) has been selected, $I = 220$ s, which means that the ratio M_s/M_{sp} will be equal to 0.046. Based on a 1200 kg satellite, 60 kg of propellant will be allocated for the RCS.

The use of bipropellant has been considered since it offers higher specific impulse, therefore reduces the propellant mass. However, bipropellant has the distinct disadvantage of increasing of the mass of the propellant tanks and feed system. Furthermore, bipropellant adds complexity to the system, so for small systems the propellant mass reduction does not compensate for complexity and reliability. The most logical choice is therefore to use monopropellant hydrazine as the fuel.

7.6.5 RCS Scheme

Figure 7.6.5 - 1 shows the drawing scheme for the RCS system. Four thrusters (22.2 N each) are located in pair, firing in either the positive or negative direction of the roll axis of the satellite. All thrusters work at blow - down condition. Their position is such that they can be used to create a torque about the pitch axis and therefore be used as a redundant system to unload the momentum wheels when they are saturated.

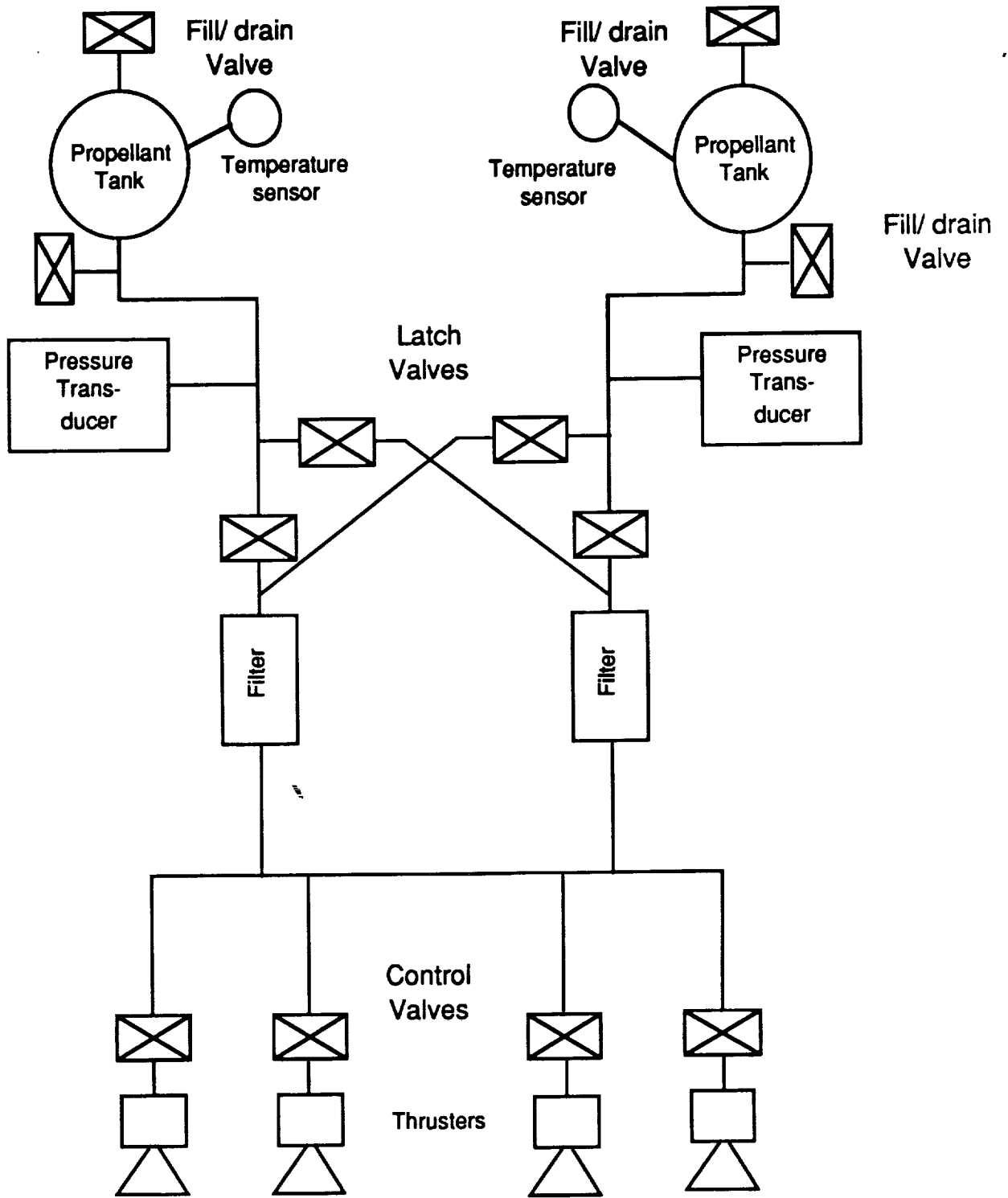


Figure 7.6.5 - 1 Reaction Control System Scheme

The 60 kg mass of propellant has been allocated in two fuel tanks, for redundancy and also to allow the position of the center of mass to be practically fixed. Each tank is provided with a temperature sensor to measure the temperature of the pressurant (Helium) and a pressure transducer, that will allow thruster performance prediction before maneuver.

The type of thrusters have been selected considering the ΔV required for the different orbital manoeuvres. Assuming the worst possible case, with an orbit correction every 30 days, the thruster pulse width will vary between 10 s and 30 s approximately, depending on propellant mass in the tanks. It was verified that the pulse width is much higher than the minimum pulse width allowed by the thruster.

Table 7.6.5 - 2 MR - 50L Engine Performance (PRC)

| Design Characteristics | |
|----------------------------------|---|
| Propellant | Hydrazine |
| Catalyst | Shell 405 |
| Thrust, Steady State (lbf) | 5.0 - 2.2 |
| Feed Pressure (psia) | 245 - 85 |
| Chamber Pressure (psia) | 106 - 43 |
| Expansion Ratio | 40:1 |
| Flow Rate (lbm/sec) | 0.0216 - 0.0103 |
| Valve | Wright Components Dual Seat/Moog Single Seat |
| Valve Power | 14 watts/coil @ 18vdc & 45°F/29 watts max @ 33 vdc & 35°F |
| Weight (lbm) | 1.50 |
| Engine | 0.90 |
| Valve | 0.60 |
| Demonstrated Performance | |
| Specific Impulse (lbf - sec/lbm) | 225 - 215 |
| Total Impulse (lbf - sec) | 11,394 |
| Total Pulses | 12,300 |
| Minimum Impulse Bit (lbf - sec) | 0.075 @ 245 psia & 22 ms ON |
| Steady - State Firing (sec) | 600 |

The total mass of the RCS or propulsion system is 83.9 kg divided as follows:

Table 7.6.5 - 3 Total Mass of the RCS or propulsion system

| | |
|---------------------|----------------|
| 4 Thrusters | 2.7 kg |
| 4 Latch Valves | 1.1 kg |
| 4 Fill/Drain Valves | 1.1 kg |
| Tubes + Filter | 2 kg |
| 2 Propellant Tanks | 17 kg |
| Propellant | 60 kg |
| Total Mass | 83.9 kg |

The minimum electric power required, when the system is operating, is 68 watts as shown below:

Table 7.6.5 - 4 Minimum Electric Power Required

| | |
|--------------------|-----------------|
| 1 Latch Valve | 10 watts |
| 2 Control Valves | 58 watts |
| Total Power | 68 watts |

7.7 Thermal Control Subsystem (Method Example)

This section discusses the methodology used to define a thermal control subsystem for the satellite. The thermal control subsystem (TCS) keeps the temperature of the spacecraft subsystems within the specified thermal operating limits. The main constraints for these limits are set by the payload requirements. At the time this study was written the payload of the IPEO Satellite had not been decided. It was necessary therefore to make a number of initial assumptions which were subsequently used when demonstrating the methodology.

7.7.1 Initial Assumptions

The altitude of the orbit will be 600km with an inclination of 38 degrees, with an angle between the satellite orbit and the ecliptic plane having a minimum value of 15 degrees. The antenna is assumed to be rectangular in shape with an area of 50 square meters and a mass of 100kg. The antenna will consist of 65 percent aluminized Kapton and 35 percent silver paint. The material of the antenna is the same on both sides, having equal emittance properties. The thermal limits for the payload are assumed to be 273 Kelvin minimum and 313 Kelvin maximum both in operating and non - operating phases.

7.7.2 Factors Affecting Thermal Control

The heat flux received by the spacecraft will change drastically during the orbit due to the relative position of the sun and the spacecraft.

Four heat sources have to be considered:

- Sun Radiation: The sun is considered as a black body. The amount of energy for a low Earth orbit is about 1353 W/m^2 ;
- Heat emitted by the subsystems: when operating, each subsystem produces a certain amount of energy that has to be taken into account in the thermal budget of the satellite;
- Earth Radiation: The Earth is considered as a black body at 254 Kelvin and produces its own radiation. The intensity of energy emitted by the Earth is a function of altitude. Following [NASA,1968], we choose 300 W/m^2 for our situation; and
- Earth albedo: This energy is reflected by the Earth coming from the sun. The albedo of the Earth is about 0.3. This energy is a function of the altitude of the orbit and of the angle between sun, Earth and satellite. [NASA, 1968] has lead us to the following values for the altitude of the satellite. (Table 7.7.2 - 1)

Table 7.7.2 - 1 Heat from Earth Albedo (θ) at an Altitude of 600 km, Function of Earth, Sun, Satellite Angle

| θ | 0 | 30 | 45 | 60 | 75 | 90 | 94 |
|----------|-----|-----|-----|-----|-----|----|----|
| Ea | 480 | 410 | 340 | 240 | 120 | 20 | 0 |

The heat sinks can be produced by radiation, following the Stephan - Boltzmann Law. The Thermal Equilibrium between heat source and radiation leads to the temperature of the system. In the case where this temperature does not meet the thermal requirements of the subsystem, active systems are necessary to heat the satellite with electric heaters, or to cool it more efficiently with heat pipes, liquid droplets radiators, moving belts, etc.

The main parameters of the orbit have been determined. For a circular orbit of 600 km altitude, the period of orbit is 5780 sec, split into 2120 sec of eclipse and 3660 sec of sunlight.

The determination of the eclipse angle $\theta = 114^\circ$ is provided by simple geometrical relations, using the following values for the distance between Earth and sun as $1.44 \cdot 10^8$ km, the radius of the Earth $r = 6400$ km and the one of the circular orbit $a = 7000$ km.

The inclination of the orbit is 38° , but due to the seasonal variation of the angle between the eclipse plane and the equatorial plane, the angle between the satellite orbit and the ecliptic plane has a minimum value of 15° . For this condition, at the solstice, the sunlight will illuminate the spacecraft almost perpendicularly. This condition, which is the most severe for the thermal control has been kept for our calculations. (Figure 7.7.2 - 1)

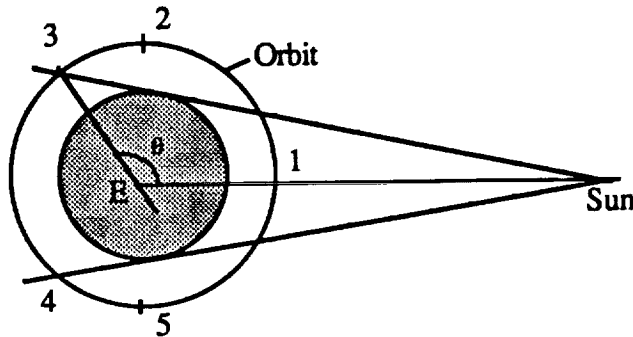


Figure 7.7.2 - 1 Sketch of the orbit . The eclipse area extends from point 3 to point 4.

For further calculations a mathematical model, which describes different points of the whole satellite is necessary. This model should take into account all changes of parameters including the evolution of the angles of view of the satellite from the Earth and the Sun, and all changes of heat from the payload itself. In fact this is a very complex problem and many situations have to be approximated. The transformation of this mathematic model into a computer code should then be developed to generate more precise and faster calculations. Thermal effects on large space structures have been studied by [Mella et al., 1988] who developed a specific computer code for this purpose.

In the next subchapter we present calculations related to the radar antenna. Due to the time - scale of this study, the heat fluxes were calculated for fixed satellite positions.

7.7.3 Thermal Control of Satellite Components

7.7.3.1 Thermal Control of the Antenna

Due to its unusual size, about 50 m^2 , attention was focused on the problem of the thermal control of the radar - antenna. The radar - antenna must be kept Earth pointing. In such a case, the rear side of the antenna will face the sun between points 5 and 2, with a maximum illumination at point 1 and the front side will be illuminated between the points 2, 3 and 4, 5 (see Figure 7.7.3 - 1).

One of the major issues for the design of a thermal control subsystem is the choice of the coating of the subsystems, leading to given values for the absorbance factor α , and the emittance ϵ .

Once again, the use of a computer may allow to check easily different coatings to find the optimal one. In this study, it was assumed both sides were the same coating as for the ERS 1 - antenna, which consists of 65percent aluminized Kapton and 35percent of silver paint.

For such a coating, using the emittance, (which here refers to the thermal infrared), and the absorbance, (which refers to that of the solar spectrum), of aluminum and silver, we obtain $\alpha = 0.07$ and $\epsilon = 0.02$.

The evolution of the temperature of the antenna as a function of time is described from the following relations:

$$M C (dT/ dt) = Q_{in} (t) - Q_{out} (t), \quad (7.7.3.1 - 1)$$

where M is the mass of the structure, assumed to 100 kg, C is the specific heat capacity of the material, assumed to be aluminium ($C = 0.215 \text{ cal/ g K}$).

$$Q_{out} = \epsilon \sigma A T^4, \quad (7.7.3.1 - 2)$$

where A is equal to the total surface of the antenna, 100 m^2 .

It was assumed in the calculation that the temperature of the antenna was homogeneous, so that both sides of the antenna have the same radiative properties.

The total heat input is

$$Q_{in} = Q_s + Q_a + Q_{er}, \quad (7.7.3.1 - 3)$$

where $Q_s = G \alpha A \cos \theta$, comes from the sun and is equal to 0 during the eclipse, and $G = 1353 \text{ W/ m}^2$, Q_a is the Earth albedo and Q_{er} represents the Earth radiation.

For this calculation we also considered that no heat coming from subsystems was convected or radiated towards the antenna.

The calculation was achieved for a whole orbit, beginning at point 4, the spacecraft coming out of the eclipse area, with the lowest temperature, assumed to be 273 K. Then the thermal budget was calculated at the points 5, 1, 2, 3 and finally again 4.

The equation (7.7.3.1 - 1) is integrated with averaged values of Q_{in} and Q_{out} , during the time of transfer of the spacecraft from one point to the other.

We get :

$$T_j = T_i + 1/ M C * (av (Q_{in}) - av (Q_{out})) * t_{ij}, \quad j = i + 1 \quad (7.7.3.1 - 4)$$

Where

- $t_{ij} = t(\theta_j - \theta_i) / 2 \pi$,
- $av (Q_{in}) = av (Q_s - in) + av (Q_a - in) + av (Q_{er} - in)$,
- $av (Q_s - in) = av (\cos \theta) A \alpha G$,
- $av (\cos \theta) = (\sin \theta_j - \sin \theta_i) / (\theta_j - \theta_i)$,

- $av(Q_{out}) = \epsilon \sigma A av(T_{ij}^4)$,
- $av(T_{ij}^4) = (T_j^5 - T_i^5) / (T_j - T_i) / 5$.
- t is the period of the orbit

We can see that the equation (7.7.3.1 - 1) is not linear in temperature and has to be solved iteratively by a "predictor - corrector" scheme.

First Calculation

We assume the antenna to be thermally "disconnected" from the rest of the satellite.

The mass taken into account in equation (7.7.3.1 - 1) is then 100 kg. The initial temperature, at point 4, is 273 K, the minimum required temperature. It is actually obvious that the point 4, at the exit of the eclipse area will be the coldest of the whole orbit, since the antenna will be basically heated during the sunlight phase, and radiating its heat while being in the shadow.

Equation (7.7.3.1 - 1) is used successively to obtain the temperature at the points 5, 1, 2, 3 and 4.

The results are summarized in the next table.

Table 7.7.3.1 - 1 Evolution of the Temperature Along the Orbit (First Calculation)

| Point | t_{ij} | $av(Q_{in})$ | $av(Q_{out})$ | $d T$ | T |
|-------|----------|--------------|---------------|-------|-----|
| 4 | | | | | 273 |
| 5 | 385 | 2050 | 660 | 6 | 279 |
| 1 | 1445 | 5170 | 1090 | 65 | 344 |
| 2 | 1445 | 5170 | 2060 | 50 | 394 |
| 3 | 385 | 2050 | 2730 | - 3 | 391 |
| 4 | 2120 | 1050 | 2310 | - 30 | 361 |

The temperature at the second time the satellite reaches the point 4 has increased to 361 K, which means that the antenna has not reached its thermal equilibrium over one period of orbit. The amount of energy that is produced by the radiation has not been completely evacuated; and the temperature of the satellite will raise during the next orbits, till a level at which thermal equilibrium will be achieved.

This will be observed, because the input energy will remain constant while the output energy will raise at the fourth power of the temperature. The calculation has been iterated for the two next orbits, and the following temperatures are the result at point 4: 273 K, 361 K, 374 K, 381 K. The convergence of that process is slow, and once again, a computer

code would have helped to find the equilibrium temperature at the exit of the eclipse phase. We can assume that it would be about 420 K.

This leads us to an incompatibility with the thermal requirements for the antenna. On the other hand, the maximum temperature difference between the hottest and the coldest point of the orbit is probably too high: it reaches 88 K for the first orbit, and 64 K for the third one.

Next Calculations

To modify the thermal balance between input and output energy, we can act on several parameters: the absorbance and emittance factors of the materials, change the thermal capacity of the antenna, or modify the mass of the system. The first solution leads mainly to use radiators to increase the rejected energy, while the other ones can be said in other words "modifying the thermal inertia" of the system.

Several calculations have been made: we will only present the last one. We always kept the value of the thermal capacity, that means that we did not change the materials of the antenna.

We tried to add radiators on the surface of the antenna, by a black coating, to modify the balance between absorbed and emitted radiation, but the results were unsatisfying. Finally the best results were obtained in changing the mass of the system, that means by setting a thermal bridge between the antenna and a part of the bus, and by adding radiators on the bus. Those radiators should be located on the North - South sides of the bus, so that they are hit by a minimum radiation from the sun, and they are also not affected by the Earth radiation, because of the "shielding effect" provided by the antenna facing the Earth.

The equation (7.7.3.1 - 1) remains valid, but with a different mass and a different emittance factor.

We get:

$$A \epsilon = A_{ant} \epsilon_{ant} + A_{rad} \epsilon_{rad}, \quad (7.7.3.1 - 5)$$

A_{rad} being the area of the radiator, and we chose $\epsilon_{rad} = 0.87$ for its emittance, which is a typical value for black painting. The final result was an area of 7 m² for the radiator, and a mass of 250 kg for the system.

For these values, the emittance factor is strongly increased: we get $A \epsilon = 8.09$, instead of 2.0 for the finest calculation.

The results are summarized in the next table:

Table 7.7.3.1 - 2 Evolution of the Temperature Along the Orbit (Final Calculation)

| Points | 4 | 5 | 1 | 2 | 3 | 4 |
|---------------|----------|----------|----------|----------|----------|----------|
| T | 273 | 272 | 287 | 299 | 297 | 277 |

Once again, the thermal equilibrium is not achieved, but the difference in temperature is low for the two successive orbits at the point 4 and the maximum value for the temperature at the point 2 is far away from the limitations of the requirements.

Conclusion

This study shows the importance of a precise thermal control of the antenna, which is subject to very severe heat fluxes.

With the initial assumptions, the estimation of the mass of the thermal control system of the antenna is 50 kg. However, several parameters can have a great influence on the result, mainly the coating and the material of the antenna, or the possibility to set the antenna in thermal bridge with the bus.

This initial work should be completed by a more extensive trade - off of these parameters and finally a thermo - mechanical calculation of the antenna should be achieved by a finite element modelling to describe the deformation in various nodes of the antenna due to thermal stresses.

7.7.3.2 Thermal Control for the Bus

The goal of this section is to check the possible problems posed by the thermal control of the bus. As in the case of the antenna, there are several parameters which can have a great influence on the result, but the technology of thermal control of satellite platforms is much more usual than for big size antennas.

In order to calculate the area of the radiator for the bus , we considered a temperature range between 273 K and 313 K as a limitation for the payload and instruments. The heat coming from the payload has an average level of 400 W and raised for several minutes a value of 700 W. The surface of the bus exposed to the radiations is assumed to be 4 m². This assumption corresponds probably to maximum working conditions.

The parameters of this problem are the absorbance and emittance factors of the surface materials. This can be improved by special coatings on the surface. The next table from [NASA, 1968] provides several typical values.

Table 7.7.3.2 - 1 Absorbance and Emittance Factors for Different Coatings.

| Material | α | ϵ |
|-----------|----------|------------|
| Vapor. Al | 0.08 | 0.024 |
| Gold | 0.19 | 0.020 |
| Silver | 0.05 | 0.013 |

The total amount of received energy is described by the the equation:

$$Q_r = A (\alpha (Q_s + Q_a + Q_{er})) + Q_p, \quad (7.7.3.2 - 1)$$

where Q_r is the total heat amount, Q_s the heat coming from the sun, Q_a the heat from the Earth albedo, Q_{er} the Earth radiation , α the absorbance factor.

From this value, we can calculate the area of the radiator, assuming the thermal equilibrium of the system. This leads to:

$$Q_r = A * \sigma * \epsilon * T^4 \quad (7.7.3.2 - 2)$$

The first table presented shows the results obtained for different coatings and different heat fluxes coming from the payload. This thermal budget provides us the different amounts of heat to be evacuated by the radiator system. The next figure shows the required area for radiators with given emittance, to achieve the thermal equilibrium at 313 K, which is the highest tolerated temperature.

Table 7.7.3.2 - 2 Received Energy for Different Absorbances and Emittances

| α | ϵ | Q_p (W) | Q_r (W) |
|----------|------------|-----------|-----------|
| 0.2 | 0.7 | 400 | 1920 |
| 0.1 | 0.7 | 400 | 1300 |
| 0.2 | 0.7 | 700 | 2220 |
| 0.1 | 0.7 | 700 | 1600 |
| 0.08 | 0.024 | 400 | 910 |
| 0.08 | 0.024 | 700 | 1200 |

Table 7.7.3.2 - 3 Surface of Radiators for Thermal Equilibrium at 40° Celsius

| Qr (W) | ϵ | A(m ²) |
|--------|------------|--------------------|
| 2000 | 0.8 | 4.6 |
| 1700 | 0.8 | 3.9 |
| 1400 | 0.8 | 3.2 |
| 1100 | 0.8 | 2.5 |
| 1700 | 0.7 | 4.9 |
| 1400 | 0.7 | 3.7 |

The results obtained give values close to 4 m² for the surface of the radiator. If we consider the biggest radiator, sized for two kilowatts, and with a surface of 4.6 m², we can calculate its temperature of equilibrium to be 270 K for a heat flux of 1100 W. With these conditions, we reach a value of 150 W for the heating devices to provide a temperature of 273 K during the eclipse.

As an estimation for the mass of the thermal control system, we chose as an area for the radiator of 4 m² with a thickness of 2 mm consisting of Titanium (4700kg/ m³) and got about 38 kg for the mass of the radiator. Including the mass for supporting structure, thermal blankets, boost heaters, painting of the surface and a 10percent margin, the result for the total mass is about 70 kg.

This brief feasibility study shows that the achievement of an efficient thermal control of the bus is probably not a major difficulty. The results which are given may be improved, and lead to a reduction of the power required for the heating devices.

7.7.4 Technical Issues

The antenna appears to be the major technical issue for the design of the satellite. The required size, about 50 m², leads us to the concept of an inflatable antenna, for reasons of weight and accommodations under the fairing of the launcher.

According to [Reibaldi, 1986], the following statements can be given. The technology of inflatable antennas has been tested on Earth, by the company, from Switzerland, with a diameter of 3.5 meters. This company foresees the development of a bigger antenna, with a diameter of 10 meters. The project QUASAT of ESA is based on a 18 meter diameter antenna with the same kind of deployable structure inside the reflector to stiffen it.

This technology requires proof under space working conditions, because of the vibrations which may be induced by thermal stresses, when the spacecraft comes from sunlight to shadow, or during orbit control operations. These vibrations might be inconsistent with the requirements for the surface accuracy of the antenna.

The thermal control of this antenna appears also must be specifically considered. Its inflatable nature probably precludes the use of devices such as heat pipes to achieve thermal control.

7.7.5 Review of Assumptions

The purpose of this section has been to describe the methodology to be used for the final design of the thermal control subsystem of a satellite. It is recognized that the configuration of the antenna has changed from our initial assumptions and further studies are required to develop the specific thermal design for the IPEO satellite using the methodology described above. The assumptions which are anticipated to change are the payload heat dissipation, thermal limits, antenna shape and size, and materials used.

7.8 Structure Subsystem

The requirements identified for the structure subsystem are as follows :

Support of :

- Inflatable SAR - including deployment mechanism;
- Payload electronics;
- Solar arrays;
- Propulsion tanks and propulsion subsystem;
- ACS (2 momentum wheels/2 magnetorquers) and 4 RCS thrusters;
- Two sensors (Earth sensors, magnetometers); and
- Communications equipment - TTC/X band antenna and S - band omni directional antenna.

compliance with launcher environment in the following areas (as identified in section 7.2.4):

- Launcher interface;
- Center of mass on principle launcher axis;
- Bending moments;
- Lateral and longitudinal accelerations; and
- Acoustic vibrations.

The first consideration, which is related to the configuration assessment of section 7.2.3, is the philosophy of the bus structure. The spacecraft has been identified as a 3 - axis stabilized momentum bias system which conventionally has a basic rectangular box shaped main bus structure. Essentially any bus geometry can be used with examples being

cylindrical, hexagonal cross section or octagonal cross section. The main bus shape is chosen for the following reasons :

- The necessity to stow solar arrays on a flat surface with sufficient hold down points for rigidity during launch;
- Provide distinct radiator surfaces for thermal control;
- Optimize accommodation area within the spacecraft body;
- Maximize area for mounting of payload and communications; and
- Support of main deployable structures.

The choices between any of these options relating to these criteria is not yet fixed. As a first estimate, so that configuration layouts could be assessed, a cylindrical main body was chosen. However with the need for stowage of large solar arrays at launch it is noted that the requirement of flat stowage sides may be preferable.

The choice of material for the main structural body has not been addressed at this level, but possible examples are aluminium, carbon composites, carbon fiber laminate, and Kevlar. It should be noted that careful selection of materials is required to satisfy deformation constraints and cleanliness constraints (from outgassing). The following part of the section identifies some of the options which fulfill the above requirements without making a selection of preferred solutions.

The configuration options and trade - offs for the inflatable SAR antenna show that the antenna is to be mounted in the center of the Earth face of the spacecraft body. Within the antenna itself there is the requirement for a rigid connection between the antenna shells. This stiffening function is provided by a conical truss of composite materials. On the top of this truss there is the need for a horn feed for the antenna. This horn is orientated at 30° to the nadir of the spacecraft which provides the 30° incidence angle required for the SAR operation.

The main bus is required to support the above subsystem items primarily with structural floors providing support for opposing ends of the propellant tanks. A central load bearing member is needed to provide a primary load path during launch to the launcher itself via the launcher interface.

The electronics units are typically bolted to a base plate which is mounted on the outer panels of the main body.

The solar array panel structure will be determined by the choice of solar array technology. Rigidity can either be a feature of the solar cell substrate such as Advanced Rigid Array technology used on the Eurostar satellites or a deployable structural member will be required to support a flexible array, such as the Hubble Space Telescope solar array. The solar arrays are mounted via yokes in a symmetric configuration on a main boom deployed in an anti - Earth direction. The boom is required to be structurally rigid enough to accommodate any loading induced when attitude and orbit control manoeuvres

are performed. The solar arrays require a mechanical hold down system in the stowed configuration an example being Kevlar wires cut by heat knife latches for deployment.

As identified earlier, the Earth sensors, magnetometers and antennas must be deployed away from the spacecraft body on deployable booms. Possible options for these are a pop-up stacer type (telescopic), hinged boom etc. These booms are over 3m in length and will therefore need to be very rigid considering the spatial measurement accuracy required from the sensors.

Due to the chosen launcher which subjects the structure to a launch stress of 11g as opposed to 6 to 9g for Ariane the structure will need to be designed to a greater design specification than for the more widely used launcher systems. Based on the level of the study undertaken to date and on satellites of similar size and type, for example, ECS, the structure mass is estimated to be approximately 180kg.

7.9 Communication Links

7.9.1 Introduction

The requirements for onboard satellite data communications are handling data for the SAR (Synthetic Aperture Radar) and TT&C (Tracking Telemetry and Command) systems.

A Digital Data Handling Assembly (DDHA) is provided to interface the SAR with the onboard data recorders and the X - band (8.2 GHz) transmitter. The data recorders are provided to record the 20 Mbps data stream from the SAR over areas of the Earth's surface where no ground station is in sight of the satellite.

An X - band transmitter is used to transmit the data stored on the recorders or to transmit in real time the data from the SAR to a ground station in sight of the satellite. This is achieved through the data steering interface facility. The real time data from the satellite is sent to the ground at the same rate as that of the SAR, i.e., 20 Mbps. However, since the time that a ground station is in sight of a satellite is limited, a higher data rate of 100 Mbps is used to dump the stored data to the ground. In addition, the data steering interface facility interfaces the 1 kbps TT&C data to the X - band transmitter for transmission to the ground.

During launch and under emergency operations, telemetry data is transmitted to the ground through an omni - directional S - band (2.1 GHz) transmitter. However, under normal operation this data is transmitted through the X - band transmitter along with SAR data. The reason for this dual transmission system is that the S - band is shared by many terrestrial microwave radio systems. Therefore, it is used only when necessary. All these functions are controlled through redundant on - board computers.

Frequency Modulated (FM) tracking signals are demodulated in the command receiver and retransmitted to the ground through the S - band transmitter in the form of a Phase Modulated (PM) signal. The Onboard Communication Data Handling facilities block diagram is given in Figure 7.9.1 - 1 below.

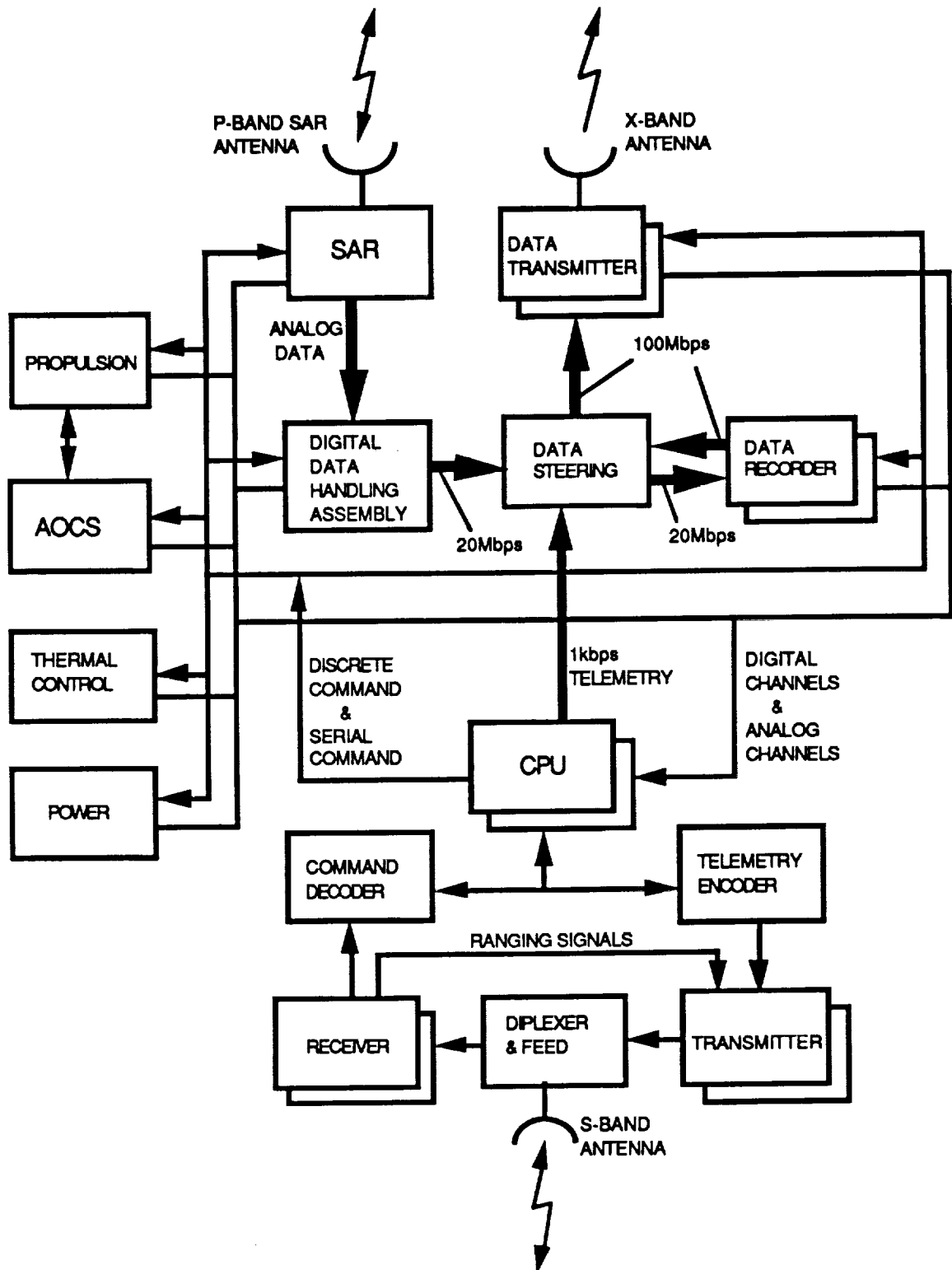


Figure 7.9.1 - 1 On Board Communication Block Diagram

7.9.2 SAR Onboard Data Handling Requirement

The data handling requirements for onboard SAR communications systems are as follows: Maximum data recording rate - 20 Mbps; Play back rate 100 Mbps; Recording time - 15 minutes; Memory capacity 18 Gbits.

7.9.3 Onboard Data Handling Specifications

The onboard data handling facilities follow.

7.9.3.1 Digital Data Handling Assembly

The main task of this assembly is to convert the analog signals from the SAR receiver to a digital data stream. Additional information such as the satellite position from a Global Positioning System (GPS) receiver, satellite altitude, and time are also added to the data stream. This additional data is necessary in order to convert the SAR data into pictures suitable for viewing. The total data rate from the DDHA is 20 Mbps. This 20 Mbps data stream is sent to the Data Steering Facility for recording or direct transmission to ground.

7.9.3.2 Digital Data Recording System

There are two main functions of this system, either recording data or playing back the data. The system that is used is a high density magnetic tape digital recorder. The data from the SAR is recorded at 20 Mbps. The playback rate is 100 Mbps for real time transmission to ground. Thus, 15 minutes of recorded data can be sent to the ground in only three minutes. This allows more information to be obtained, since all the recorded data can be sent to the ground even when the satellite is in sight for only a few minutes (the maximum viewing time of the satellite is 11 minutes 20 seconds). Since data recorders are not known for their high reliability, the design incorporates two data recorders. Each data recorder should be able to meet the required specifications.

Table 7.9.3 - 1 Onboard Data Recorder Specifications

| | |
|------------------------|-----------------|
| Recording rate | 1 - 100 Mbps |
| Average recording rate | 20 Mbps |
| Playback rate | 100 Mbps |
| Memory capacity | < 45 Gbits |
| Recording time | 750/7.5 min |
| Recording power | 144/117 W |
| Playback power | 178/182 W |
| Mass | 28.1 kg |
| Size | 28 x 34 x 28 cm |
| Expected lifetime | 34 Months |

7.9.4 Data Transmission System - Satellite to Ground

An important input to the design of this system is the altitude of the satellite (600 km). This determines how long the satellite is in view from the ground station as the satellite passes overhead. In order to view the satellite at all times when it is not blocked by the Earth, a ground station will have to look very close to the horizon. Unfortunately, an antenna pointing at the horizon has many problems.

At the horizon, the signal from the satellite will be at its weakest. There are two reasons for this. First, by the satellite will be at its furthest distance from the ground station (signal strength is inversely proportional to the distance squared). Secondly, the satellite signal is passing through more atmosphere, thus increasing signal attenuation. Also, the noise at the antenna will be greatest looking along the horizon. With the antenna perpendicular to the ground, noise from the ground is greatest and the attenuation from the atmosphere, cloud, and rain, generates even more noise. Thus, we have the lowest signal to noise ratio along the horizon.

With these signal to noise ratios along the horizon, the ground station antenna size and transmitted powers would become too large to be practical. Increasing the minimum inclination of the antenna (0 degrees is pointing to the horizon and 90 degrees is pointing straight up), increases the signal to noise ratio at the satellite, thus allowing a practical design.

The remote sensing ground station in Alice Springs, Australia is able to see Landsat satellites (at a height of 908 km) for up to 15 minutes. This implies a minimum inclination of 2.86 degrees. Thus, in the design of our ground station we have chosen a minimum inclination of 3 degrees. For this inclination, a ground station is able to see the IPEO satellite (at an altitude of 600 km) for a maximum of 11 minutes and 20 seconds.

An important parameter for the satellite is the EIRP (Effective Isotropically Radiated Power) of the communications system. This was calculated to be about 7 dB(W) or 5 Watts. In calculating the required EIRP as detailed below, a frequency of 8.2 GHz in the X - Band was used. All calculations are for the chosen 3 degree inclination, since the worst case signal to noise ratio occurs at the smallest inclination of the antenna.

At a 3 degree inclination, the distance from the satellite to the ground station is 2,517 km. This results in a free space loss of 178.7 dB. At this low inclination communications must also take into account the attenuation of the signal due to the atmosphere and rain. From Maral, 1990, the atmospheric attenuation is 0.95 dB.

The determination of the loss due to rain is much more complicated because of the random nature of rainfall. The main requirement is to determine what loss can be tolerated for some percentage of time. To do this correctly requires a determination of the rain statistics in the area of the ground station. The area we have chosen is that of the remote sensing ground station in Cuiaba, Brazil. This station experiences fairly heavy rainfall and is in a region that is of vital interest to the IPEOSAT mission (i.e., deforestation). We have

used the Rice and Holmberg [Miya, 1985] empirical formula for the determination of the rain statistics. To use this formula, one needs to know the yearly average rainfall (M) and the thunderstorm rain depth to yearly rain depth ratio (B). An average for the whole of South America of 1350 mm/yr was used for M (as rainfall information for Cuiaba is sparse). From [Miya, 1985], the value of B is 0.7. Using the formula, it is then determined that the rain rate will exceed 39 mm/hr for 0.1 percent of the year and 1.7 mm/hr for 1 percent of the year. These rain rates will produce an attenuation of 12.96 dB and 0.66 dB respectively [Miya, 1985]. Reduced performance for 1 percent of the time was considered to be acceptable.

The total loss due to space, atmosphere and rain is therefore 180.30 dB. The next step is to consider the ground station. The ground station antenna diameters in Australia and Japan are 9.14 m and 10 m, respectively. The smaller 9.14 m diameter (with reduced performance) antenna was selected to perform calculations. Taking into consideration all the losses and noise at the station, a G/T of 33 dB(K) and a noise temperature of 185.7 K was obtained. The assumptions and calculations used are as follows:

Table 7.9.4 - 1 Satellite to Ground X - band Transmission System

| | |
|--|---------|
| Antenna pointing loss (assuming a 0.1 degree pointing accuracy) | 1.53 dB |
| Sky noise temperature [Maral, 1990] | 46.4 K |
| Ground noise temperature (derived from a 4 GHz system [Miya, 1985]) | 25 K |
| Rain temperature (assumed) | 300 K |
| Antenna feed loss (obtained from a real system [Miya, 1985]) | 0.24 dB |
| Antenna feed temperature (assumed) | 300 K |
| Receiver noise temperature (assuming FET low noise amplifiers [Miya, 1985]) | 70 K |

In first calculations, it was assumed that the industry standard rate half convolutional code is used to reduce the required signal to ratio. Normally, for uncoded BPSK (Binary Phase Shift Keying) or QPSK (Quaternary Phase Shift Keying) modulation with differential encoding (to remove 90 or 180 degree phase ambiguities in the received signal) an E_b/N_0 (energy per bit per noise power density) of 9.9 dB is required to obtain a BEP (Bit Error Probability) of 10^{-5} . With rate half coding, the E_b/N_0 can be reduced by 5.2 dB to 4.7 dB for the same BEP of 10^{-5} .

Assuming all the above, a bit rate of 100 Mbit/s an EIRP of 4.93 dB(W) was obtained. To this 2 dB was added as extra margin for losses and noise that cannot be predicted. This gives an EIRP of 6.93 dB(W) or roughly 7 dB(W). Without coding the EIRP would be 12.1 dB(W) or 16.3 W (more than three times the coded case). At the lower data rate of 20 Mbit/s, the EIRP can be reduced by 6.99 dB to - 0.06 dB(W) or 0.99 W. Decoders for this code operate up to 25 Mbps. Paralleling up 4 or 5 of these decoders will allow the required decoding speed.

The choice of modulation can be either BPSK or QPSK. QPSK has the advantage that it requires 120 MHz of bandwidth (assuming a bandwidth expansion factor of 1.2) compared to 240 MHz of bandwidth for BPSK. Also, the demodulator for QPSK would operate at half the speed of BPSK, i.e., 100 Msymbol/s versus 200 Msymbol/s (requiring more sophisticated and expensive technologies). The disadvantage is that twice as much hardware is required on the satellite. QPSK was chosen since it can be constructed more easily than the BPSK system.

An important design consideration was in meeting ITU (International Telecommunications Union) emission restrictions. For regions outside of North and South America, there is a restriction on the flux density in X - Band [ITU, 1983]. The flux density restriction depends on the angle of arrival of the signal. Since the maximum flux density occurs when the satellite is directly above, calculations were based on this angle. The restriction is that the power flux density shall not exceed (for 90 degrees above the horizontal plane) - 140 dB(W/m²) in any 4 kHz band. The figure obtained is - 163.6 dB(W/m²) in any 4 kHz band, 23.6 dB below the required figure.

The design of the on - board antenna for X - Band has not been made in this report. Redundant RF X - band transmitters and QPSK modulators are implemented for greater system reliability.

A summary of the X - band Transmission System follows:

- X - Band (8.2 GHz) RF Transmitter - Receiver System. EIRP of 5 Watts with 2 dB margin.
- Ground station antenna diameter of 9.14 m and 3 deg minimum elevation angle.
- 100 Mbps QPSK modulation modulation with rate 1/2 convolution coding and 120 MHz of bandwidth.

7.9.5 Tracking Telemetry and Command (TT&C)

TT&C are key service functions for satellites. Telemetry is necessary to monitor and evaluate the satellite. Telecommand is necessary to control satellite functions. Finally, tracking is used for ranging. The ranging data is necessary for determining the satellite orbit which is used for orbit control and services to users.

7.9.5.1 Telemetry

Telemetry includes Pulse Coded Modulation (PCM) and real time FM signals as well as PCM dwell mode data in which specific words are selectable by command from the

ground. One main frame consisting of both analog and digital subframes can be formatted to 1 kbps digital bit streams. The modulation and format of the telemetry should be compatible with existing Earth station specifications.

The engineering and telemetry data are Reed - Solomon encoded for forward error correction and then down linked at bit rates up to 1 kbps.

7.9.5.2 Command

Two possible forms of command messages that could be sent to the spacecraft are:

- Discrete commands used for equipment on/off operation; and
- Proportional commands (analog signals) for orbit control, solar array extension, and antenna deployment.

Before commands are executed the contents of each command are retransmitted to the ground through the telemetry channel for verification. The spacecraft must be protected against miscommanding by using well protected command sequences. Real time and stored command sequences are processed at rates up to 1 kbps.

7.9.5.3 Ranging

There is a provision for FM ranging signals to be demodulated in the command receiver and immediately retransmitted to the ground through the telemetry transmitter in the form of a PM signal .

7.9.6 TT&C Specifications

- Up link transmission frequency band 2025 - 2110 MHz (Earth - to - Space).
- Down link transmission frequency band 2200 - 2290 MHz (Space - to - Earth).
- The power flux density at the Earths surface produced by emission from the satellite for all conditions and for all methods of modulation shall not exceed - 154 dB (W/m²) in any 4 kHz band for angles of arrival below 5 degrees above the horizontal plane.

This specification is in accordance with ITU RR8 Provisions 747/750 and further in compliance with Radio Regulations Provision No.s 2557 through 2560. A common transmit and receive antenna system for all TT&C functions has been considered in this design.

Since it is critical to maintain satellite - Earth TT&C links at varying satellite attitudes and positions, it is desirable that maximum angular coverage is provided by this antenna so

that normal operation and recovery actions are at all times feasible. On the other hand antenna design complexity and transmitter power requirements increases noticeably with the widening of coverage angle.

At satellite altitudes in the range of 600 km the use of an omnidirectional antenna is feasible. Therefore a 0 dBi omni - directional antenna of size and diameter in the order of 80 mm should be used.

7.9.7 Power and Mass Estimates for the Onboard Systems

The power and mass estimates for the required onboard communications systems are given in Table 7.9.7 - 1.

Table 7.9.7 - 1 Power and Mass Estimates

| Subsystems | Power (watts) | Mass (kg) |
|--|---------------|------------|
| 1. Data Recorder (x 2) | 180 | 56 |
| 2. Data Steering Subsystem | 5 | 20 |
| 3. Data Handling Assembly | 3 | 5 |
| 4. X - band Transmitters (x 2) including Antenna Subsystem | 15 | 18 |
| 5. Computer subsystem | 4 | 36 |
| 6. TT&C subsystems including RF Receivers/Transmitters, Telemetry - Command Encoder/Decoder, and Antenna Subsystems | 10 | 15 |
| Total | 217 | 150 |

7.9.8 Conclusions

The technology required to design and implement the Onboard Communications System for the IPEO satellite appears to be mature and of already proven status. Therefore, it is possible to meet the sub - system requirements without many constraints. No constraints for physical reliability of the sub - systems is foreseeable at this stage.

Use of low power Radio Frequency (RF) transmitters for both SAR data and TT&C ground communications transmission allows the use of solid state power amplifiers. This results in a simpler thermal control system for the communications sub - systems and a reduction in total power consumption requirements.

The use of large beamwidth and low gain antennas with modern antenna design techniques should produce small size antennas of low mass. With feedback from antenna

manufacturers, it may be possible to reduce some of the design margins and obtain mass and power savings.

The recommended Onboard Data Recorders have memory capacity more than twice the initial requirement, giving room for future expansion capabilities. The onboard computer is to be of proven hardware. Redundant unit design has been considered to promote higher instrument reliability, improve instrument performance and lower schedule A and cost risk.

The IPEO communications payload is designed to match the wide variety of existing ground stations that could be used during the implementation of the IPEO Project.

7.10 Acquisition Network

7.10.1 Introduction

A final design of the IPEOSAT acquisition network was derived from the various aspects and systems discussed in section 6.1.6. The chosen strategy follows.

7.10.1.1 Data Acquisition

IPEO ground segment will be based on four Earth stations, one of them also being the control station. The functions of these Earth stations are :

- To receive and store the IPEOSAT data; and
- To send these data to the IPEO Central Facility.

7.10.1.2 Data Processing and Archiving

Each Earth station is in charge of archiving the data which is received in this station. At the same time, this data is also sent to the IPEO Central Facility and therefore the IPEO Central Facility will store all data received from all the Earth stations.

7.10.2 Earth Stations

7.10.2.1 Functions

Figure 7.10.2.1 - 1 describes an IPEOSAT Earth station facility. The main function of the Earth station is data acquisition, local archiving and data transmission to the IPEO Central Facility.

On - board recorded data is sent from the satellite to the Earth stations at a data rate of 100 Mbps in X - Band. The total amount of data produced during an orbit is 2.25 GBytes.

Received data (level 0) is archived onto optical disks. The average amount of raw data archived per day in an Earth station is 9 GBytes. It is kept as on - line data for two days

during which time it is easy and fast to retrieve. After this, it is stored off - line in the long - term archive.

Each Earth station has a control interface to the IPEO Central Facility. It receives low data rate control commands and parameters from the Operation Control Center, and these commands are used for example for antenna pointing control (satellite coordinates) to prepare for data reception.

The operational nature of the IPEO program leads to requirements in terms of availability of the satellite data at the Central Facility. The chosen approach is to send the received data from the station to the center within one orbit (90 min). This necessitates a throughput of 2 to 4 Mbps in order to be able to send more than 2 GBytes within that period. The data is still level 0 data and it will be processed and archived in IPEO Central facility. This process is described in more detailed in the following sections.

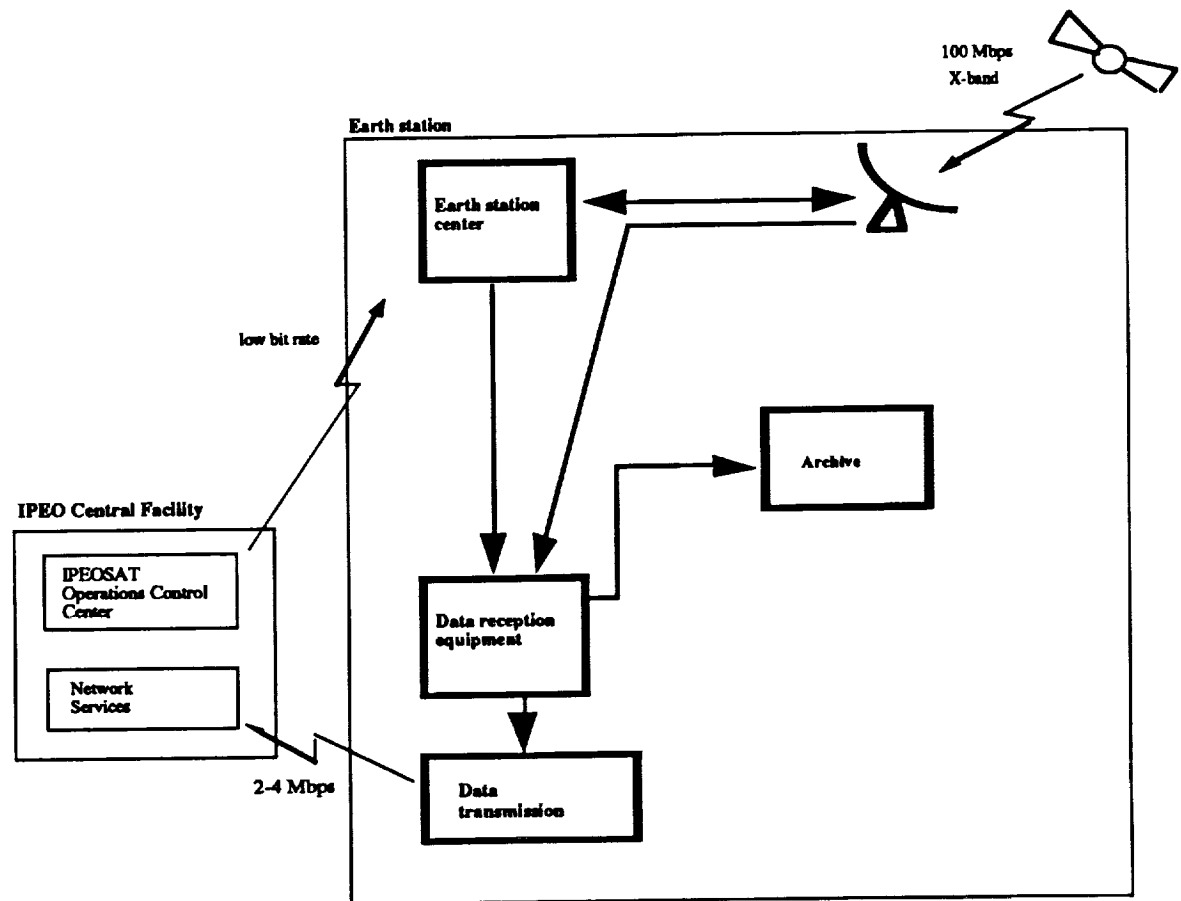


Figure 7.10.2.1 - 1 Data Acquisition Earth Station Facility

7.10.2.2 Locations of the Earth Stations

The locations of the IPEO Earth stations are chosen on the basis of existing realities and constraints. These include:

- Several existing Earth stations which currently, or after upgrading, could be suitable for IPEO purposes; and
- Visibility period per orbit (38° inclination).

Trade-offs taking these aspects into account resulted in the following locations of the Earth stations (figure 7.10.2-2) : A - Cuiaba (Brazil), B - Maspalomas (Canary Islands), C - Bangkok (Thailand) and D - Alice Springs (Australia). Brief computer simulations were performed indicating that this seems to be a reasonable choice which fulfills the mission requirements.

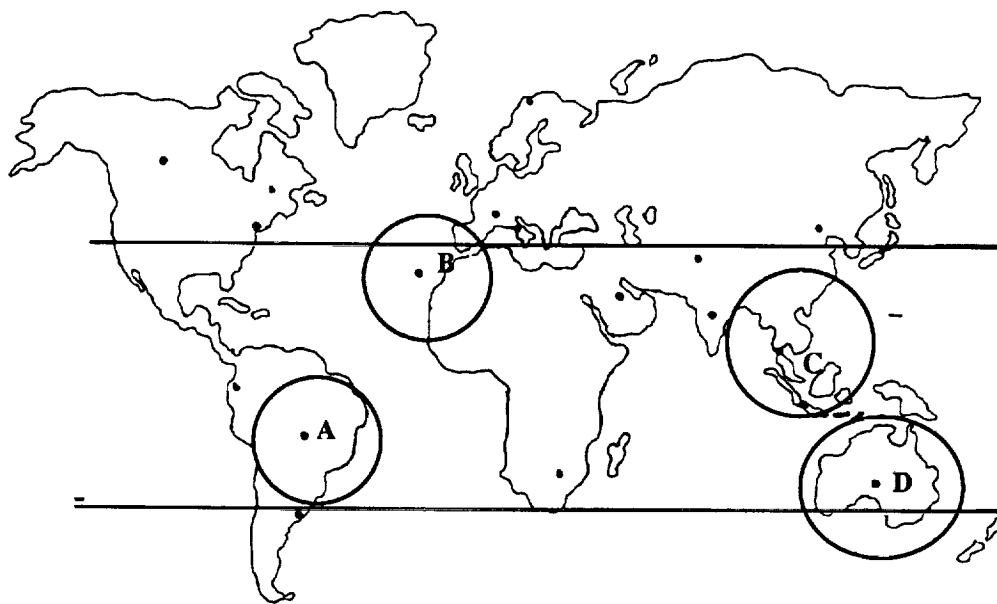


Figure 7.10.2.2-1 Location and Coverage of Earth Stations

7.10.3 Tracking, Telemetry, Command & Monitoring (TTC&M)

7.10.3.1 Launch Control

Control during launch will be driven from the launch center of Xichang (China) using S-band telemetry. Characteristics of this Up and Down link are given in chapter 7.7.

7.10.3.2 Operational Control

Orbital adjustment manoeuvres, instruments and subsystems switch on and off and parameter settings will be carried out during the lifetime of the mission from the Maspalomas (Spain) Earth station using X-band telemetry.

The satellite design permits the storage of a command program to cover 15 consecutive orbits or more than 24 hours, with a single uplink during the contact period with the Maspalomas station. This link is available every 5 to 6 orbits, i.e. a safety factor of 3.

The TTC&M ground station is directly connected to the Mission Control Center in the Central Facility, from where it receives all the commands to control the satellite.

7.10.3.3 Maspalomas Characteristics

The main reasons for the choice of the Maspalomas (Spain) as both the IPEOSAT TTC&M station and one of the four IPEOSAT data acquisition stations are described.

- It has a large storage room, a photographic laboratory, stores, a screened room, an equipment repair room.
- It is a national facility on the territory of an ESA Member State.
- It is being used to receive signals from Earth resources satellites (e.g. Landsat, SPOT) via a 10 m S - band antenna.
- It is free from harmful radio - frequency interference.
- It is located at a latitude of 27.8° N.
- It has a 15 m antenna which compared with commercially available S/X - band antennas has the following characteristics :
 - A higher gain at S - band, by about 1.3 dB
 - A higher gain at X - band, by about 1.7 dB
 - A higher figure of merit at S - band, by about 2.5 dB
 - A higher figure of merit at X - band, by nearly 3 dB

In conclusion, the equipment installed at the Maspalomas station generally represents 'state of the art' technology. The extensive use of digital signal - processing techniques results in negligible losses in the space - to - ground links. The use of the X - 25 data communications standard in the ground network ensures worldwide reliable communications.

7.10.4 Data Processing and Archiving

The SAR processing of the data will take place in the IPEO Central Facility, whereas archiving will be done both locally at the Earth stations (level 0 data) and in the Central Facility (level 0 and level 1 data). The procedures for this are described below.

7.10.4.1 SAR Processing

SAR systems employ signal processing to convert stored radar signals into fine - resolved radar images. Once an image or a family of images has been generated in this manner, it may be subjected to further processing to achieve image enhancement, shape

recognition, or other analogous results, in much the same manner as may the output of a conventional photographic system or a multispectral scanner.

Raw SAR data is processed by specialized SAR processors. In the SAR processor parallelism and pipelining are combined to achieve a programmable processor for computationally heavy vector - oriented applications. Parallel processing is more effective and faster compared to serial or sequential data processing.

The processing of SAR data is done by the range - Doppler algorithm, a two - dimensional matched filtering which is implemented by using one - dimensional Fast Fourier Transforms. The first dimension is used for range compression and the second dimension for azimuth compression, i.e. the actual synthesis of the synthetic aperture.

The SAR processor main memory is used for storage of intermediate results from the SAR range compression. When range compressed data are read back for azimuth compression, the data have to be addressed orthogonal to the way the data was stored. This operation is called corner - turning.

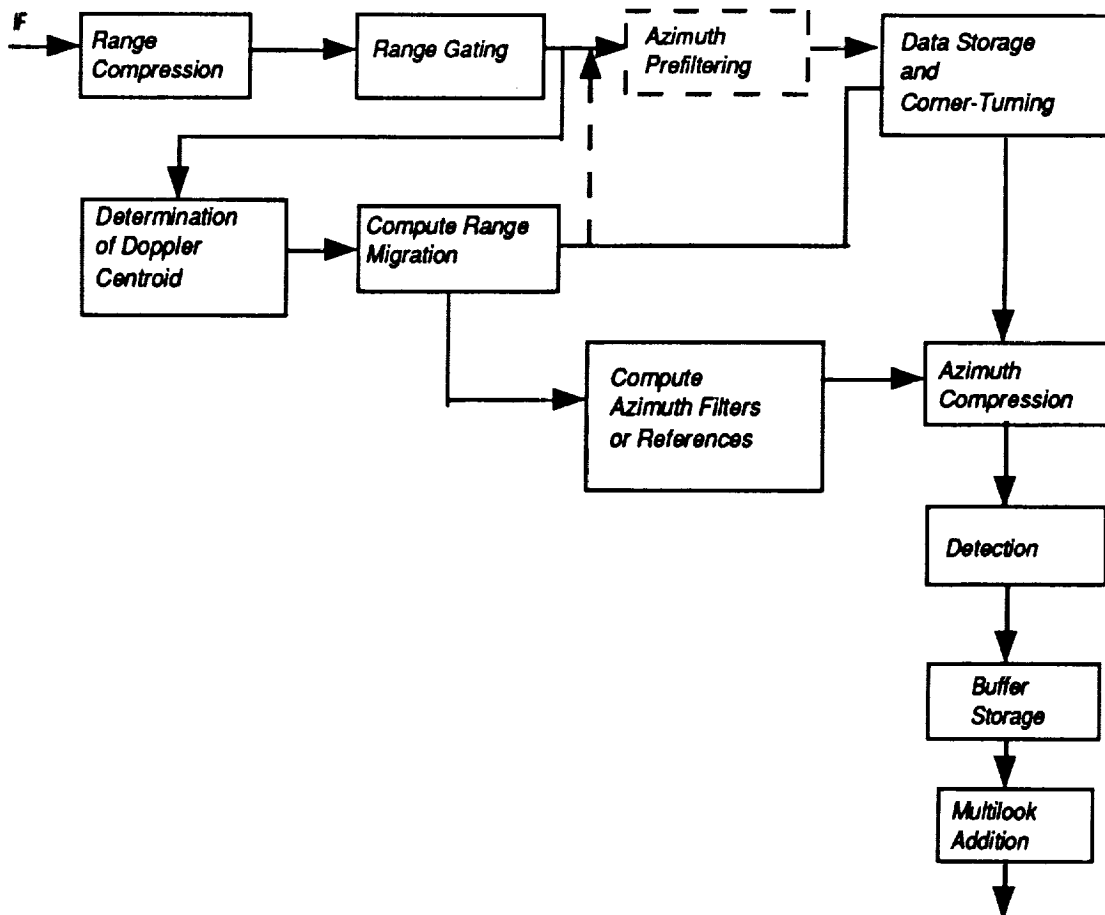


Figure 7.10.4.1 - 1 Principal Block Diagram for SAR Processor

In general the SAR processor brings the data from level 0 (i.e. level 1A which is considered as level 0 data) to level 1. The level 0 data leaving the SAR instrument is identical to the the level 0 data entering the SAR processor.

For the IPEO satellite the raw data downlinked from the satellite will be processed in the IPEO Central Facility, so only one SAR processor is needed. As the data received at an Earth station is recorded data, it might be from any geographical location and there is no explicit need for processing the data at the station. In any case the data have to be sent to the Central Facility for archiving.

The amount of data per orbit can be calculated based on the following information and assumptions :

- The swath width is 74 km so one scene is 74 by 74 km
- The resolution is 30 m
- The pixel size is 8 bits
- The satellite speed projected on the ground is about 7 km/sec
- The SAR on - time per orbit is 900 sec

This leads to the following conclusions :

- The distance the satellite overfly during SAR on - time is 6300 km per orbit
- This gives 85 scenes per orbit
- Each pixel represents 30 m, so one scene is 2500*2500 pixels or 6.25 Mpixels
- This gives 6.25 MBytes per scene or 530 MBytes per orbit

The data should be processed in real - time, that is, the data received from one orbit should be processed before data is received from the next orbit. Each orbit is about 90 min. Taking into account the time needed for initialization and rewinding of tape recorders, and time needed for producing quick - looks and other products, it is assumed that all data from one orbit, or 2.25 GBytes, should be processed in 60 min resulting in 530 MBytes of processed data.

This is comparable to the ERS - 1 SAR processing requirements for the Tromso ERS - 1 Receiving Station (TERS) in Norway. The throughput requirement is 10 scenes represented by 1.8 GBytes of data in about 80 min, resulting in 600 MBytes of processed data.

A high performance SAR processing facility for data from the ERS - 1 satellite consistent with the above requirements for TERS has been designed and is described by [Holm et.al., 1990] and [Maoy et.al., 1990]. This processor, called CESAR (Computer for Experimental SAR), combines parallelism and pipelining to achieve a programmable computer for heavy vector - oriented applications. The processing power is obtained from

four computing units or MALU's (Microprogrammable Arithmetic Logic Units) working in parallel in a SIMD (Single Instruction Multiple Data) structure. The architecture of the CESAR processor is shown in Figure 7.10.4.1 - 2.

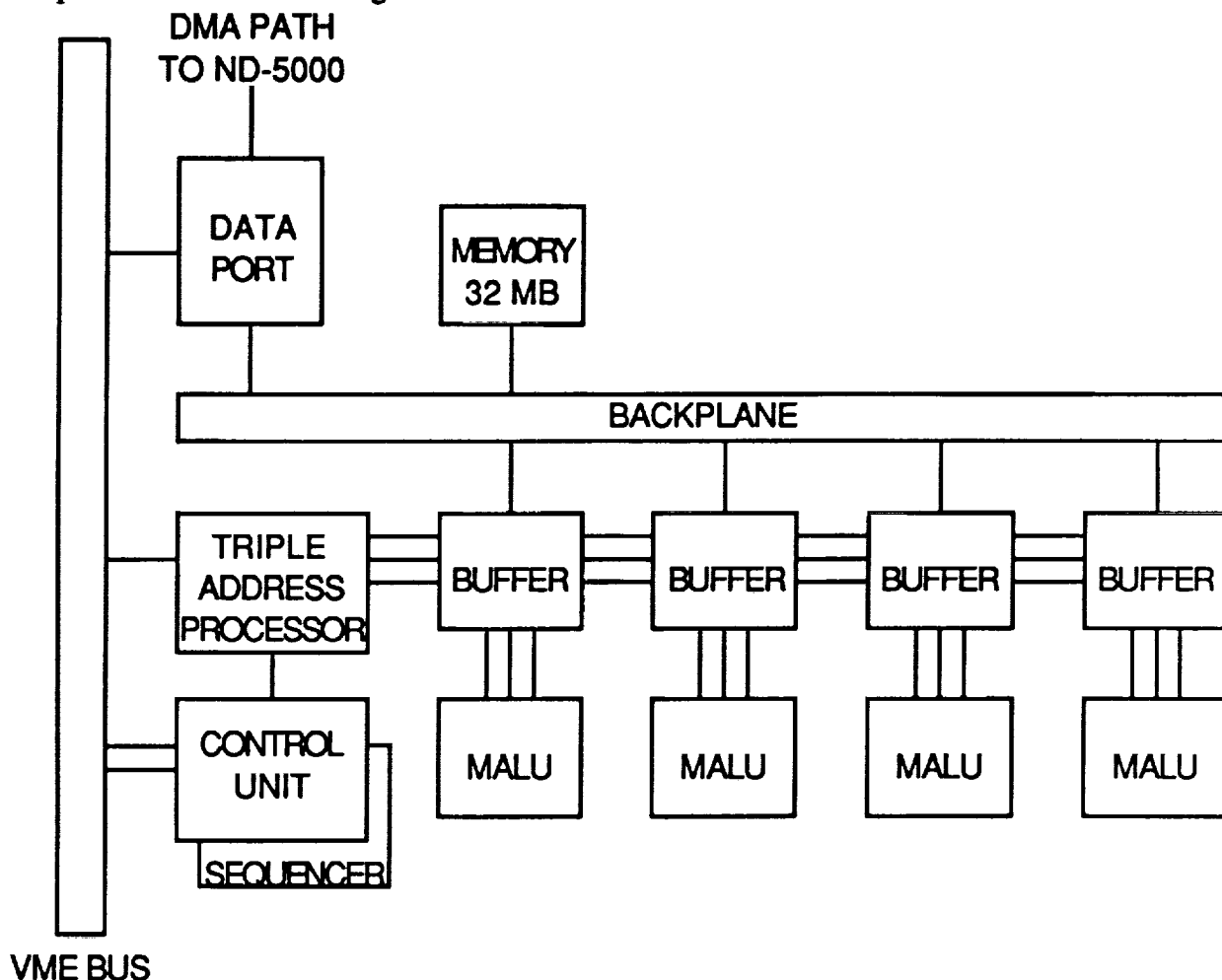


Figure 7.10.4.1 - 2 Main Components of the CESAR Parallel Processor

7.10.4.2 Archiving

For IPEOSAT the amount of data that needs to be handled are :

- Raw data (level 0) :
 - Per orbit (900 sec) : 2.25 GBytes
 - Per day (16 orbits) : 36 GBytes
- Processed data (level 1) :
 - Per orbit : 530 MBytes
 - Per day : 8.5 GBytes
- Quick looks :
 - Per day, assuming 300*300 m resolution : 85 MBytes

Local Archive

From section 7.10.2. it is known that the raw SAR data received from IPEOSAT will be stored immediately at the Earth station where it is received. Referring to section 6.1.6 where some general properties of an archive was listed, the local archives take care of preserving the data as soon as they are acquired.

Assuming that the data from the satellite is equally divided between the 4 Earth stations, this means that 9 GBytes per day needs to be stored in each of these local archives. The data will be kept on - line for 2 days.

Central Archive

The Data Archive in the IPEO Central Facility takes care of the long - term archiving. In this archive the level 0 raw data and the level 1 SAR processed data will be stored.

The level 0 data volume from all 4 Earth stations is 36 GBytes per day. About one month of data, or 1 TByte, should be kept in an on - line archive for easy retrieval. After one month the data is moved to an off - line long - term archive, still easily accessible for further use.

The level 1 data, which is the output from the SAR processor is 8.5 GBytes per day. These data will be kept on - line for 4 months, requiring another 1 TByte archive.

The IPEO Central Facility will also offer low resolution quick - look products. All quick - looks generated will be kept on - line, corresponding to 30 GBytes per year.

Storage Media

The volume of the data that needs to be stored seems large, but developments in the field of data storage capacity are rapid. One reason is that this is non - space qualified technology.

Even using today's technology, the archiving of the IPEO satellite data is not a major problem. It is proposed to use non - erasable optical disks (WORM - Write Once Read Many) for IPEO long - term archiving. This type of storage medium has a capacity of up to 6.4 GBytes per disk.

One optical library unit (or 'juke - box' of optical disks) can house up to 50 of these disks. To keep the necessary data for IPEO on - line (level 0, level 1 and higher levels), it is estimated that 10 of these units (3 TBytes) will be used.

The most difficult problem might be degradation of data due to age. One should learn from the case of the SEASAT SAR data sets which were archived on HDDT's. Due to the degradation of the tapes, portions of valuable data sets were lost. Optical disks should last up to 30 years, according to the manufacturers technical data sheets. In general, secure

and controlled storage for Earth observation data sets is required, and improvement of the technology is important.

7.11 Summary of the IPEO Satellite

This chapter has given a preliminary design of the IPEO satellite for deforestation. The main design considerations will now be summarized and spacecraft feasibility discussed.

The following table gives a summary of the main spacecraft parameters which were developed during this study.

| | |
|-----------------------|---|
| Lifetime | 2.5 years |
| Mass | 1200 kg |
| Power | 445 W |
| Orbit | 600 km/38° |
| Data rates | 20 Mbps to recorder 100 Mbps to Earth |
| TT&C + Emergencies | 2025 - 2110 Mhz uplink 2200 - 2290 Mhz downlink |
| Payload | <ul style="list-style-type: none"> • P - band ($\lambda = 0.70$ m) • 30 x 30 m @ 4 looks • 84 km swath width • 30° incidence angle • antenna diameter 8 m |
| Launcher | Long March 2C launched from XICHANG (27,6°N) |
| Ground Stations | Brazil, Canary Islands, Thailand, Australia |
| AOCS | Controlled bias momentum & Magnetic torquers |
| RCS | monopropellant - hdyrazine |
| Data Storage | 3 TBytes |
| SAR Processor | CESAR (Computer Experimental SAR) |

There are two key areas of technology which play a role in the feasibility of this design and have not been fully studied. These areas are the inflatable antenna and on - board processing, storage and transmission of terra bytes of data.

As stated in section 7.3, an inflatable antenna having a diameter of 3.5m has been tested and proven to work on the Earth and studies are underway on antennas of 10 and 18m. Given the lengthy tests required for a new product to be flight qualified, the year 1997 may not be an unreasonable date for OPEO use. Data processing and handling has experienced exponential growth over the last 15 years and assuming that it continues a terrabyte of data by the year 1997 will be as easy to handle as a gigabyte is now. Thus, all of the key technologies may be available by the year 1997.

Assuming these two key technologies are available, it is safe to state that the time for a P - band SAR has come and with further study the design for the IPEO satellite which has been presented is feasible.



8.0 TOPOGRAPHICAL MAPPING FEASIBILITY STUDY

8.1 Introduction

One of the priorities of IPEO is to cover topographical mapping. Initial investigations on technical and economic possibilities revealed some promising ideas. The goal of this study is to look at the feasibility, both technically and economically, of a small satellite performing topographical mapping. A case study for a potential IPEO topographical mapping data supplier is contained in Appendix E.

Although the design needs more study, we think in general this idea could be feasible and provides a low cost option for IPEO.

The Chapter is structured as follows:

- 8.1.1 The concept, which presents the way the small satellite can develop.
- 8.2 The payload design, which describes a sophisticated design of a stereo-optical camera. As result of the limited time during the summer session, an existing design is employed with only minor changes. Future study has to show that it can compete, technically, with bigger satellites.
- 8.3 The platform design, which describes a slightly modified existing design and a detailed trajectory analysis. Again, this section aims only to prove that the general idea is feasible.

8.1.1 General Small Satellite Concept

The following concept should be the basis for future small satellites.

Platform

The platform provides a standard interface with the payload. It defines power available, the electrical interface, the thermal interface, the communications bus and protocol, the mechanical interface, and so on.

Payload

The payload is the only item that is specifically designed to fulfill the mission requirements and is designed within the limits of the platform.

It is foreseen that technical developments will take place in the payload industry. A sophisticated payload that match standard platforms is likely.

Why use this concept? First, the time seems ripe. The more sophisticated and expensive large satellites become, the more they provide an opportunity for small satellites at the cheaper end of the market.

Second, this concept may provide new economies. The technology involved in platforms is mature enough to allow for economies of production scale. For sensor manufacturers, the possibility to sell their design to different buyers without changes can also reduce cost.

One thing shown in this feasibility study is the possibility to have a low cost platform, combined with a sophisticated payload.

8.2 Payload for Topographic Mapping Satellite

8.2.1 User Specifications

For many parts of the world, and particularly in Asia, South America, and Antarctica, relative topography is known only to several hundred meters at a spatial resolution of about 10 km [NASA, 1987]. Only about half of the land area of the world has topographic coverage in the economically important scale 1:100,000/1:50,000 and only 2 percent of this area is revised each year [Brandenberg and Ghosh, 1985].

This was the starting point of the IPEO requirements group to propose as one of the short term goals of IPEO, satellite system to provide topographic information.

The next step was to specify the user needs in terms of spatial and spectral resolution, stereo capability and the coverage of the Earth. Driven by these needs the IPEO Application and User Development group specified the requirements as follows :

- Stereo capability;
- Spatial resolution: less than 10 m (if technically feasible);
- Spectral range: VIS (Visible) and NIR (Near Infra-Red); and
- Polar, sun-synchronous orbit.

With this information a small group began to work on a system concept to fulfill the above requirements by using small satellites.

8.2.2 Small Satellite Constraints

To fulfill user requirements the payload options are:

- An altimeter;
- An altimeter in conjunction with an electro-optical instrument; and
- A stereoscopic electro-optical instrument.

The first option has the advantage of the best vertical resolution with the disadvantage of only providing a trace and not giving an image of the sensed area. The second option has the great disadvantage of being very heavy and inability to fly on a small satellite. These two options were discarded in the following design process and only the remaining third option has been considered. This third option can provide height information as well as information on the land cover of the sensed area.

The next constraints to be considered in the design process of the small satellite are the following conditions:

- Low mass;
- Small volume;
- Low power consumption; and
- Flexibility in operation.

These four points forced a look at adequate systems and concentration on cameras which accommodated the constraints. This led to a search for instruments which have been flown or are proposed to fly on planetary exploration missions, where constraints are very severe.

The following table gives some examples of the optical instruments used in planetary missions.

Table 8.2.2 - 1 Optical Instruments

| | MOMS | HMC | HRV | MEOSS | HRSC | MOC | SBC |
|------------------------|------------------------|----------------------|--------------------------|----------------|-------------------------------|---------------------|-----------------------------|
| Spacecraft | STS 7/11 | GIOTTO | SPOT | IRS | MARS94 | Mars Observer | tbd |
| Stereo | yes | no | yes | yes | yes | no | no |
| Spatial resolution [m] | 20 | ~100 pan ~200 col | 10 pan 20 col | 80 | 10 pan 20 stereo 80 col | 1.5 | 7 |
| Altitude [km] | 300 | 1700 | 832 | 450 | 250 | 360 | 100 |
| Swath-width[km] | 93 | na | 60 | 256 | 52 | 3 | 13 |
| Mass [kg] | 141 | 13.5 | 242 | na | 35 | 12.3 | 1 - 2 |
| Power [W] | 350 | 12 | 260 | na | 41 | 16 | ~5 |
| Launch | 1983/84 | 1985 | 1986 | 1991 | 1994 | 1992 | tbd |
| Comment | | spin-stabilized | | | | narrow angle camera | narrow angle camera |
| Reference | Bodechtel et al., 1984 | Keller et al., 1986 | Courtois and Weill, 1985 | Drescher, 1990 | Neukum, 1990 | Danielson, 1989 | Ravine and Soulanille, 1985 |

na = not available tbd = to be determined pan = panchromatic col = color

MOMS = Modular Optoelectronic Multispectral Scanner

HMC = Halley Multicolor Camera

HRV = High Resolution Visible (instrument)

MEOSS = Monocular Opto-Electronic Stereo Scanner

HRSC = High Resolution Stereo Camera

MOC = Mars Observer Camera

SBC = Small Body Camera

IRS = Indian Remote sensing Satellite

8.2.3 Stereography

In this section the basic concept of stereoscopic viewing and height determination is described.

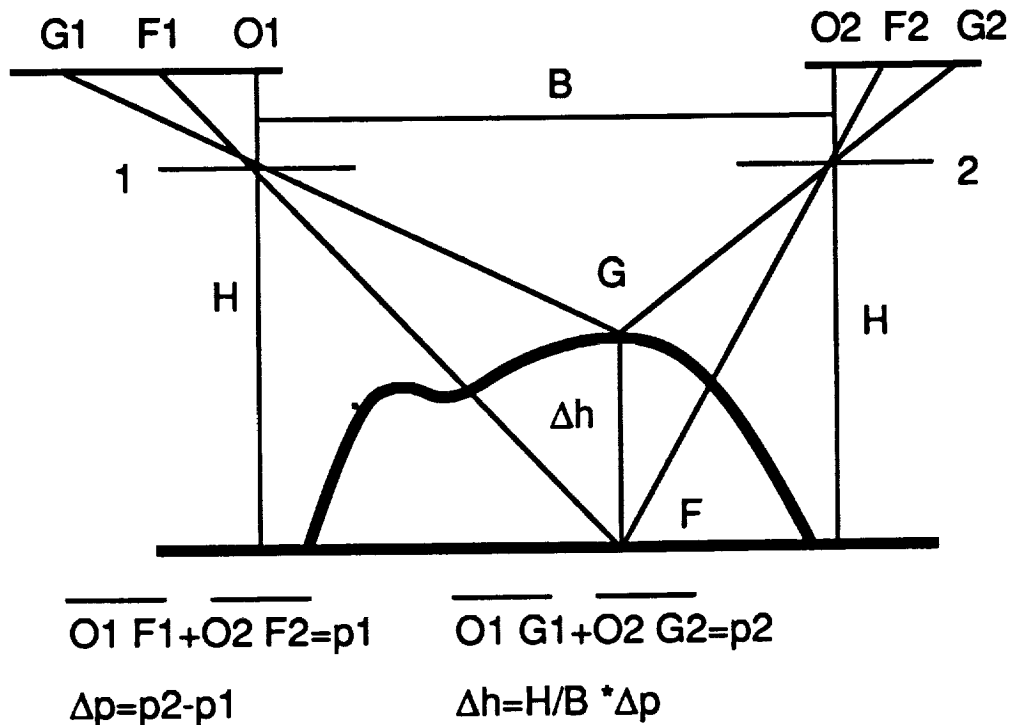


Figure 8.2.3 - 1 Stereoscopic Viewing Geometry and Important Geometrical Relationships

All rays of the projection have the same picture center and only the central ray is perpendicular to the ground. That is why in general the projection of a mountain peak G and its footpoint F are not the same except when the satellite is exactly overhead. The displacement in the projection plane is called parallax.

If there are two pictures of the same area the displacement of the mountain peak in these two pictures is different. The difference of the displacement Δp is responsible for the stereoscopic perception. The horizontal pixel resolution is the measurement threshold for Δp .

The vertical resolution Δh is directly proportional to the ratio of the height H to the base B and the parallax difference Δp . The Δh values when added to the known Z-coordinate for a control point or reference point in a screen-sized area, yield elevation (Z) referenced to mean sea level. For details see Welch, 1989

For Base to Height ($B/H=1$) the horizontal and the vertical resolution are equal, for smaller B/H ratios the resolution of the vertical is less than that of the horizontal. The former ratio is favorable for relatively flat terrain, whereas the latter is applicable for moderate-to steep terrain.

For further details on stereoscopy the interested reader is referred to Colwell, 1983 and Wolf, 1974.

8.2.3.1 Cross-track Stereoscopy

The High Resolution Visible (HRV) instrument on the French SPOT-platform allows modification of the look direction, making a variable across-track angle with the vertical through an adjustable mirror in front of the instrument. The maximum angle is ± 27 degrees.

It is thus possible to take images of the same area on ground from different subsequent orbits at different look angles. The main constraint with this technique is that it takes approximately 20 days to get the best achievable base to height ratio of 1, and it takes even 10 days to achieve a ratio of 0.5. The main problem is the change in the atmospheric conditions with time [Rodriguez et al., 1988]. This constraint is particularly strong over tropical areas where the probability to have two clear days to acquire useful stereo images is very small.

8.2.3.2 Along-track Stereoscopy

Parallax differences for stereoscopic perception of the topography can also be achieved with two pictures made in the forward and aft direction with respect to the flight direction. This concept was introduced first for satellite use in 1975 for a moon mission [cf. Drescher, 1990]. For Earth-remote sensing this concept was proposed later on for STEREOSAT [Welch and Marko, 1981] and MAPSAT [Colvocoresses, 1979, 1982]

The two projects had different optics for the forward-, nadir- and aft-looking capability. A similar concept using different cameras for the different viewing angles as well as for the different spectral bands has been studied and realized in the MOMS-camera [Bodechtel et al., 1984].

This arrangement of sensors leads to high accuracy of picture sharpness and good radiometric and spectral quality. However this requires high thermo-mechanical stability of the camera-ensemble and leads to great volume and mass of the instrument.

Another concept for a stereoscopic camera has been studied by DLR (German Aeronautics and Space Research Institute) which uses one set of optics for all different viewing angles and spectral bands. The first version of this kind of camera (MEOSS) was to fly on the Indian satellite SROSS in 1988. Unfortunately the payload was destroyed due to a malfunction of the rocket booster [Drescher, 1990].

The newest development of the DLR is the High Resolution Stereo Camera (HRSC) proposed for the Mars 94 mission of the Soviet Union (Principal investigator, Professor Neukum). This instrument is an improvement of the MEOSS-instrument concept and will be described in the next section.

8.2.4 High Resolution Stereo Camera (HRSC)

The HRSC combines the advantages of the MEOSS-system (one optical set, operational flexibility) with the constraints of low mass, small volume, low power consumption and high resolution [Neukum, 1990a]. These were the reasons this instrument was selected as a payload for the small satellite study.

The camera consists primarily of three parts; the camera optics, the electronic box, and the buffered mass memory.

The mechanical parameters of the camera and the mass memory are as follows:

Table 8.2 4 - 1 Parameters of the HRSC

| | camera optics and electronics | mass memory |
|------------------------|--------------------------------------|--------------------|
| Weight in kg | 20 | 15 |
| Size (l * h * w) in mm | 460 * 250 * 280 | 430 * 275 * 180 |
| Power consumption in W | 24.5 | 16 |

The optical system has the following specification at the present stage of development:

- 175 mm focal length, leading to a 10 m ground pixel from 250 km orbit altitude;
- Aperture 1: 5.6;
- Total field of view (TFOV) of ± 20 degree for stereo observation;
- Length less than 290 mm (first lens to focal plane);
- Maximum lens diameter including housing 130 mm;
- 9 Thompson THX31516 line sensors, with $7\mu\text{m} \times 7\mu\text{m}$ pixel size and 5184 signal pixels;
- Broad spectral range (395 to 925 nm) for multispectral imaging;
- Plan parallel glass plate of 8 mm thickness representing spectral filters between optics and focal plane; and
- Thermal infrared protection window

The following figure gives a sketch of the focal plane and the arrangement of the nine CCD's. Arrays 1,2,3 are (panchromatic) stereo channels, 4 and 5 are photometric channels and the remaining four channels are color channels in the blue, green, purple and infrared.

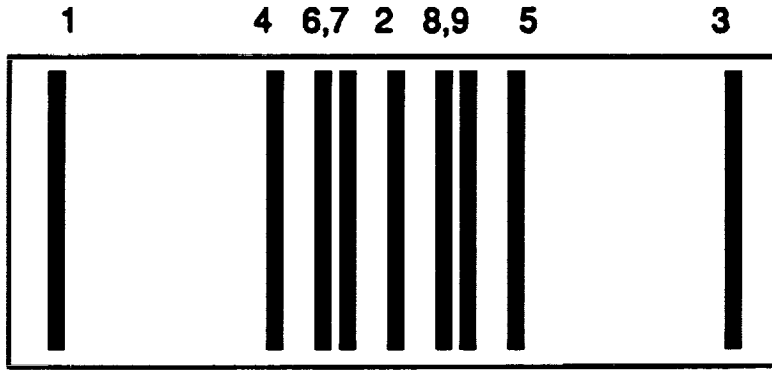


Figure 8.2.4 - 1 Sketch of the Focal Plane and Linear CCDs. Arrangement (not scaled): Number 1 is the forward looking, number 3 the aft looking stereo channel. Number 2 is the nadir looking channel and number 4,5 are photometric channels, numbers 6,7,8,9 are spectral channels (after Neukum, 1990a).

8.2.5 Adopting the HRSC for Earth Observation

To fly the HRSC on an Earth observing satellite one has to remember that the HRSC in its current specifications is designed to fly on a Mars orbiting platform. Nevertheless there exist plans to fly this camera on Earth observing platforms [Neukum, 1990b]. One should be aware of the fact that the incident solar irradiance on Earth is approximately 2.3 times higher than on Mars. Mars average albedo is 1.5 times lower than on Earth. This leads to a factor of 3.4 (average) in the amount of light which is collected by the instrument. This will have an effect on the integration time and therefore on the resolution along-track.

8.2.5.1 Data Rates

Assuming 10 meter resolution on the ground, a velocity of approximately 8 km/s and 8 bit radiometric resolution each one of the nine linear CCD-arrays produces a maximal output data rate of 33.18 Mbits/s. Ground pixel sizes of 20 and 40 meters lead to a decrease in the data stream by a factor of 4 and 16, respectively.

8.2.5.2 Spatial Resolutions

If the optics of the instrument are not changed considerably, the decrease of the spatial resolution per 50 km orbital height increase, is approximately 2m. The 250km orbit was chosen to ensure the nominal resolution of 10 m.

The ratio B/H for the HRSC with its fixed ± 20 degrees forward and aft looking CCDs is 0.73 which is not optimal. Further research and development with the aim of increasing the look angle is needed.

8.2.5.3 Spectral Bands

For an Earth observing payload the spectral bands have to be determined according to the mission objectives.

The following spectral bands have been chosen for this payload:

- 790nm - 1000nm : for the forward, aft and nadir looking stereo channels
(optional: upper limit 930 nm, dependent on CCD)
- 680nm - 700nm and 710nm - 760nm : for two spectral channels
(optional: 680nm - 730nm)
- 540nm - 590nm : for another spectral channel

The decision to use the near infrared band for the stereoscopic channels was driven by the need of high resolution and the effect of high reflectance in the near infrared. This band is sensitive to foliage biomass and is necessary for vegetation mapping. The nadir-looking stereo channel is dedicated to provide this information.

The first red channel (680nm - 700nm) is sensitive to the chlorophyll concentration and it is possible to detect vegetation stress (Singhroy, 1987; and references therein), whereas the second red band provides information relating to senescence and/or stress of vegetation. The channel in the green is of specific interest for detailed studies of water in streams, lakes and coastal zones, and may provide indications of plant disease symptoms as well. For the final selection of these spectral bands, further investigation and research is needed. Figure 8.2.5.3 - 1 shows the different locations of the spectral bands on the ground track.

To estimate the data stream to be accommodated, a mission scenario with the three stereo channels (10m resolution) and all 3 color channels (20m resolution) working was assumed. This leads to a maximum data stream of 124.4 Mbits/s.

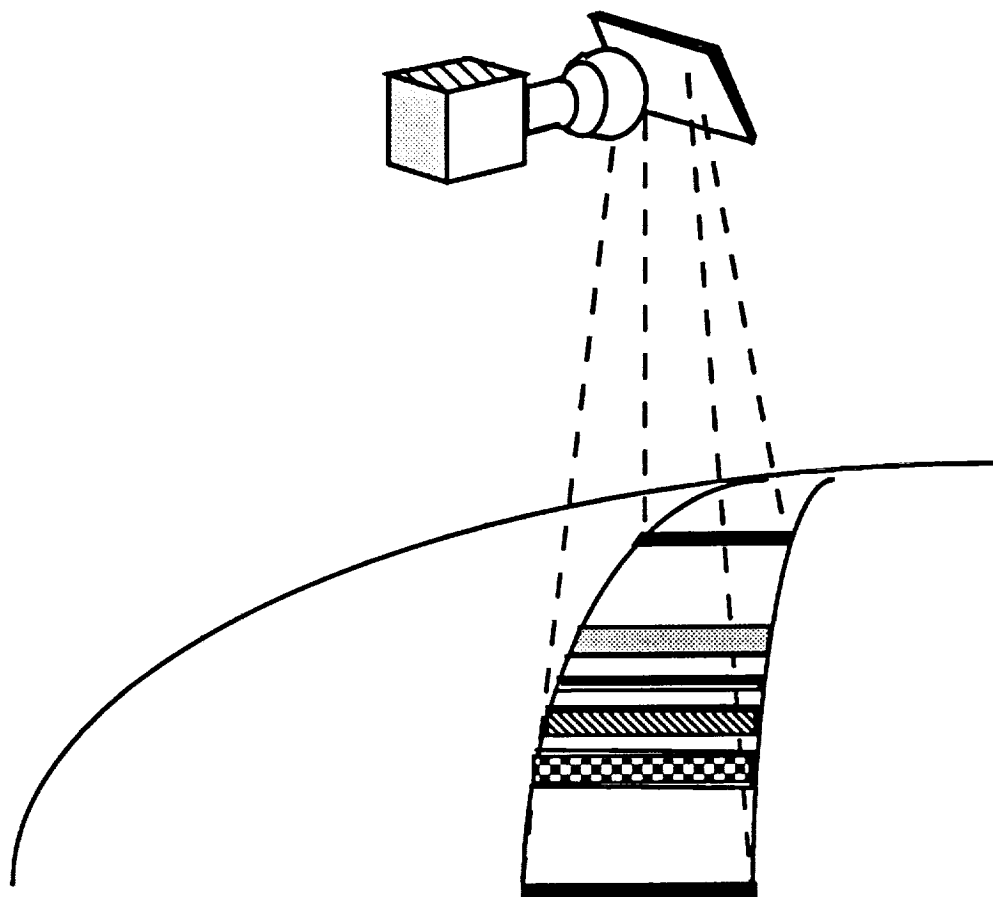


Figure 8.2.5.3 - 1 Location of the Spectral Bands on the Ground Track

8.2.5.4 Pointing Accuracy Mechanism

The small satellite can not provide high pointing accuracy needed for the camera. A way to overcome this problem is the installation of a mirror in front of the camera which can be adjusted to compensate for the perturbation in the satellites motion. This mirror also provides the opportunity to acquire pictures across the track like the system on the SPOT-satellite, which can shorten the revisit time.

An alternative possibility to correct for the distortions of the sensed areas, is to accurately monitor them and make the corrections on the ground.

Figure 8.2.5.4 - 1 shows the scheme for the mirror mounting in front of the camera.

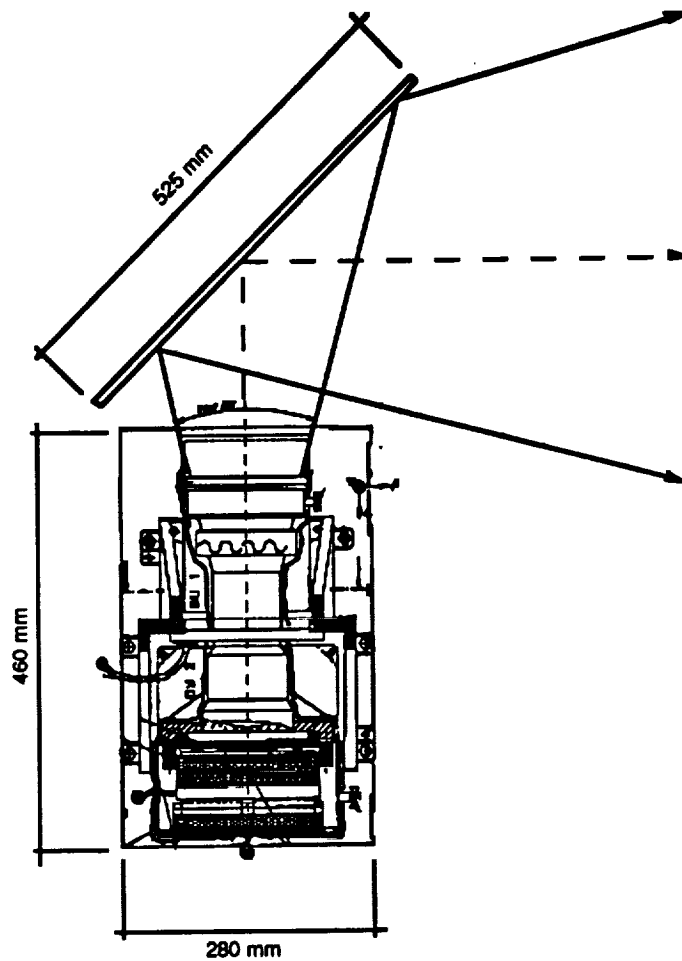


Figure 8.2.5.4 - 1 Mirror in Front of the Camera.

8.2.6 Conclusions for Payload

The HRSC seems to be quite applicable to fly on a small spacecraft, although changes in the spectral bands due to the mission objectives have to be made. The points which need further investigation are as follows :

- Pointing accuracy mechanism (including across track looking mechanism);
- Larger forward and aft looking angle for stereo;
- Use of linear CCD arrays with higher number of pixels and different spectral responsivity (option: aligning more than one CCD array in the focal plane); and
- Choice of spectral bands

The main parameters of the payload are summarized in Table 8.2.6 - 1.

Table 8.2.6 - 1 Payload Parameters

| | |
|------------------------|---|
| Weight | 35 kg |
| Power consumption | 30.5 W |
| Resolution (in 250 km) | 10 m (nadir-looking channel) |
| Swathwidth | 52 km |
| Spectral bands | 540 - 590 nm 680 - 700 nm 710 - 760 nm 790 - 1000 nm |
| Data rate | 33.18 Mbit/s |

This feasibility study investigated the possibility of flying a payload for topographical mapping on a small spacecraft. There is no doubt that payloads, other than optical cameras, can be flown on small spacecraft to investigate other scientific questions.

8.3 Technical Feasibility of Topographic Mapping Satellite

8.3.1 Introduction

In this section, the technical feasibility of the Topographic Mapping Satellite (TMS), carrying the HRSC payload, will be discussed. The concept of TMS is shown in figure 8.3.1 - 1.

8.3.2 Design Flow of TMS

Generally, an Earth Observation system consists of four parts :

- User requirements;
- User interface;
- Payload; and
- Satellite & launcher.

The user requirements and payload have already been discussed in the previous section. This section examines the satellite & launcher and data relay & user interface issues. To clarify the procedure, the flow of the study is shown in Figure 8.3.2 - 1.

The satellite design is based on the requirements and interface conditions of the payload. Subsystem design and examination of critical problems must be conducted in parallel in accordance with the general concept of the TMS. Volume, weight and structural integrity of the satellite determine the potential launch vehicle.

The interface between the TMS and the user is discussed in chapter 5.2 and complements our feasibility study.

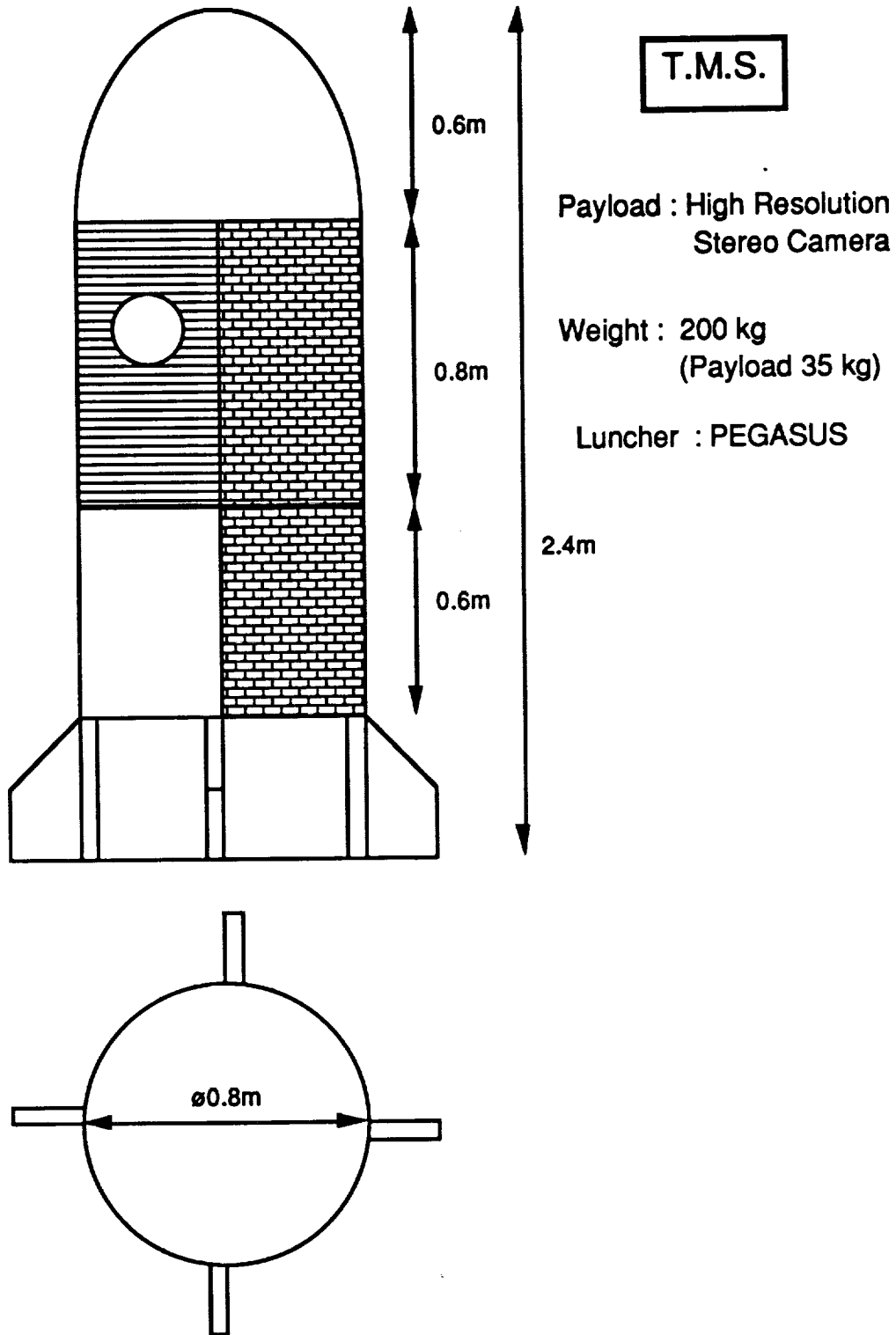


Figure 8.3.1 - 1 TMS Concept

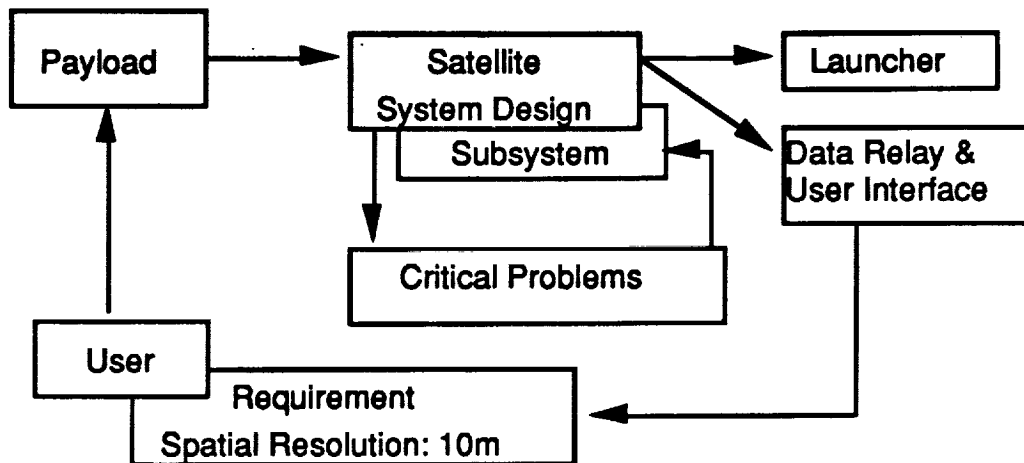


Figure 8.3.2 - 1 Design flow of TMS

8.3.3 General concept of the TMS

A small satellite for topographic mapping was chosen as one of the IPEO short term study priorities. When designing this satellite, one of the most important factors is the cost of the TMS. This will be addressed in Appendix E "Strategic Approach". Some factors in cost and flexibility are given below.

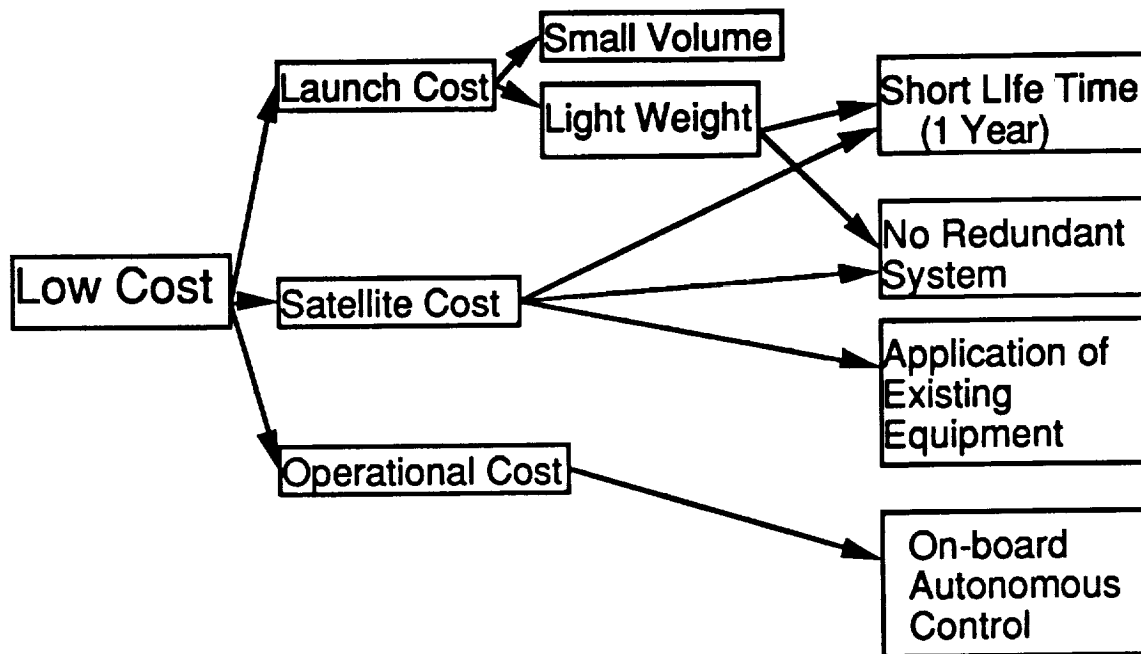
- Programs for land mapping satellites already exist (SPOT, LANDSAT). They are very expensive and inflexible to changes in the requirements of the user.
- TMS is a small satellite which has only one payload for topographic mapping with some possibilities for land mapping.

Based on these factors, a general concept for the TMS is examined. There are three kinds of costs related to the TMS-design: launch costs; satellite costs; and operational costs.

In order to save launch costs, volume and weight are constrained to be small. For this first estimation, the use of a PEGASUS launcher is assumed.

To minimize TMS satellite costs three assumptions were made: short life time of one year; essentially no redundant systems; and application of existing equipments.

To accomplish low operational costs, on-board autonomous control is essential and has been investigated. The summary of this general concept is shown in Figure 8.3.3 - 1.



8.3.3 - 1 General Concept for the Satellite Design

8.3.4 Design of the TMS

8.3.4.1 Orbit Selection

As described in section 8.2, the altitude is determined by the resolution capability of the payload and was selected as 250 km. In order to achieve world wide coverage a polar orbit has been chosen. For reasons of thermal control, solar power utilization, and attitude control a sun-synchronous orbit is selected.

The next parameter to be determined was the passing time at the equator. Existing land mapping satellites select it between 9:30 AM and 11:00 AM. We decided to choose 10:00 AM because of the atmospheric conditions in the tropics.

In this case, inclination, i , and period, T_p , are calculated as follows :

$$i = \arccos\left[\frac{2\pi}{T_0 \cdot e \cdot \sqrt{\frac{a}{\mu}}}\right] = 96.48 \text{ deg.}$$

$$T_p = 2\pi a \sqrt{\frac{a}{\mu}} = 5361.6 \text{ sec}$$

$$a = R_e + h$$

h : Altitude

R_e : Earth Radius 6371 km

T_0 : Earth Year $3.1536 \times 10^7 \text{ sec}$

μ : Gravitation Constant $398600 \text{ km}^3/\text{sec}^2$

e : Constant, estimating that the Earth is not real sphere $6.607 \times 10^4 \text{ km}^2$

The revisit time of this orbit has been estimated to be about 40 days, based on the 52 km swath width of the HRSC at 250 km.

8.3.4.2 Configuration

The factors which influence the configuration of the TMS are shown in Figure 8.3.4.2-1. The most important factor is the orbit altitude of 250 kilometers which is relatively low compared to most existing satellites. At this altitude the air density is high and this causes a large aerodynamic drag force, which decreases the altitude of the satellite. It is very important therefore for the configuration of the satellite to estimate accurately the propellant mass and volume for orbit maintenance.

The power requirements determine the solar cell area needed. To reduce aerodynamic drag, body mounted solar cells are desirable.

To achieve high pointing accuracy of less than 0.1 degree, an adequate attitude control system must be chosen. Aerodynamic drag will cause some disturbances, especially if the satellite structure has a complicated configuration.

In order to overcome this problem, an aerodynamic stabilization fin was chosen [Barberis et al., 1987]. This solution has two advantages. First, it will be able to trim in the airstream without using any active control and therefore saves weight and power. Second, it will have a tolerance against the airflow disturbance. The application of aerodynamic stabilization dominates the configuration of the TMS.

The satellite configuration is also directly affected by the volume of the payload.

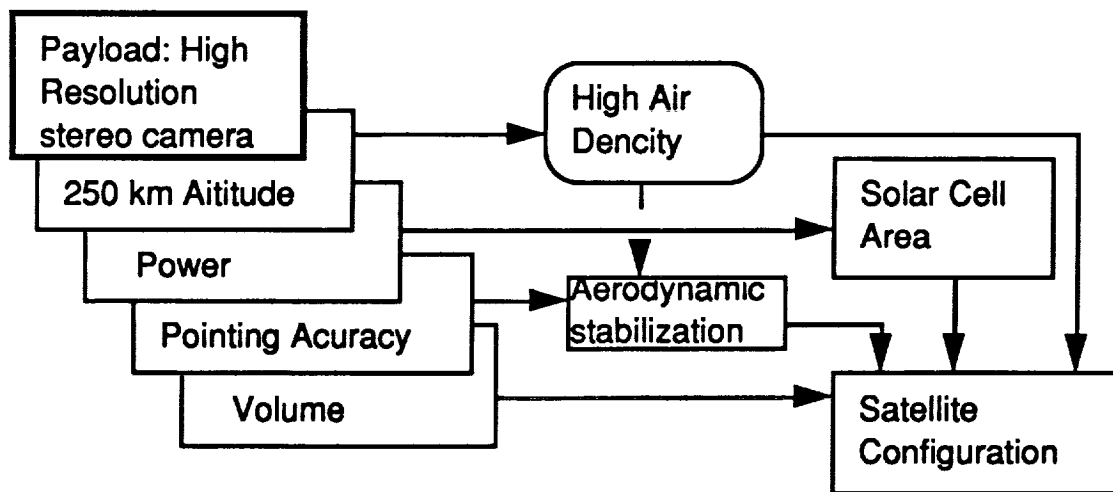


Figure 8.3.4.2 - 1 Configuration Definition

8.3.4.3 System Break Down

The system break down of the satellite is shown in figure 8.3.4.3 - 1. It is based on existing satellite concepts. Each subsystem is discussed in the following section.

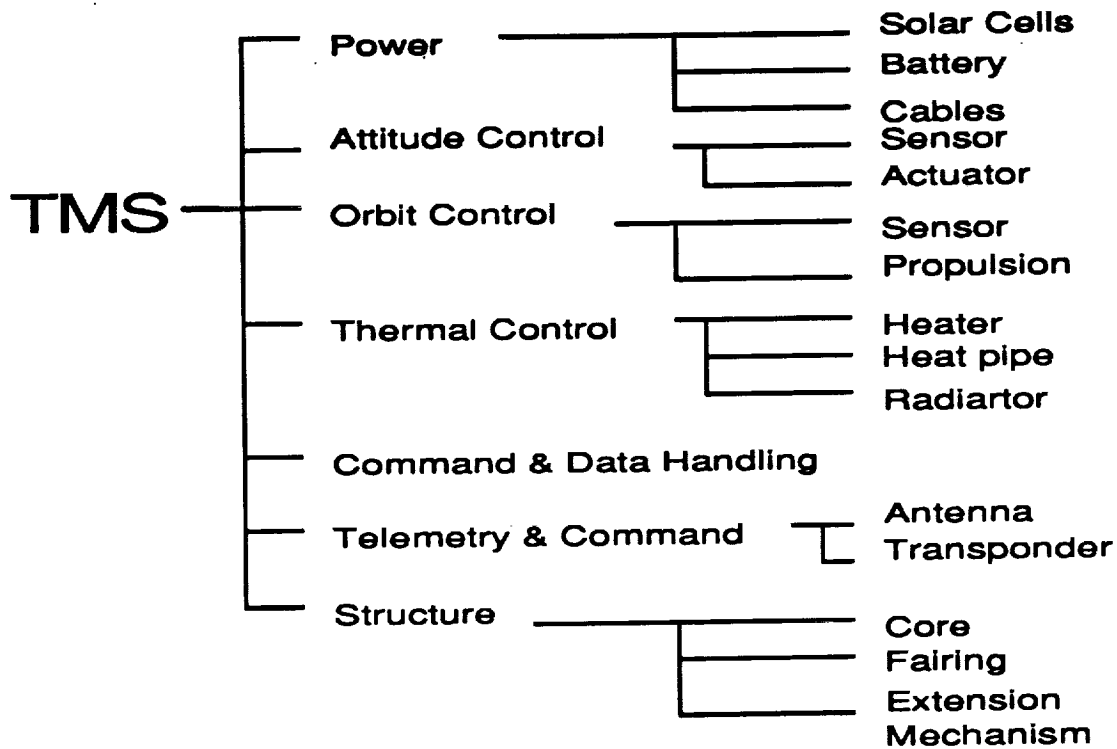


Figure 8.3.4.3 -1 System Break Down of the TMS

8.3.4.4 Subsystem Design

Power Subsystem

Requirement: Initially, the power requirement of the TMS has to be examined. As a first estimation, it is supposed that the power for the satellite bus power is the same as the power for the payload. Based on the calculations made for a similar satellite design [Stuart, 1987], the power requirement of the bus system is estimated to be 50 W, (shown in Table 8.3.4.4-1). If a mismatching of the power requirement during the calculation occurs, this value has to be changed and the next stage of the iteration process for the design starts.

Design: For the selected orbit the eclipse time must be considered. According to a chart by Barberis et al., 1987, the ratio of sunshine time to orbital period is about 0.6. The orbital period is approximately 90 minutes. The satellite is 54 minutes in sunshine and 34 minutes in eclipse. Under the assumption that the payload is operating in sunshine the power consumption profile can be drawn and is shown in figure 8.3.4.4-1. The total requirement of power can be summarized as follows:

91 W : 54 minutes

68 W : 36 minutes (discharge).

9 W is set as a design margin of the power system.

The amount of discharge per period, WdH , is

$$WdH = 68 \text{ W} \times 36 / 60 = 40.8 \text{ Wh.}$$

Assuming a battery efficiency of 0.8, the power to be generated for sunshine conditions, Wg , is

$$Wg = WdH / 0.8 \times 60 / 54 + 91 \text{ W} + 9 \text{ W (margin)} = 156.7 \text{ W.}$$

Specific values of existing GaAs solar power cells are summarized as follows,

efficiency : 18 % ••• 150 W/m²

specific weight : 120 W/kg (with 2mm cover).

Using these values, the area, As , and the weight, Ws , of solar cells can be estimated.

$$As = Wg / 150 = 1.0 \text{ m}^2.$$

$$Ws = Wg / 120 = 1.3 \text{ kg.}$$

As described before, batteries are required for the operation. For low Earth orbit the depth of discharge (DD) is usually 20 percent in order to ensure a minimum life time. The life time of batteries varies according to its DD and the number of discharges.

A voltage of 28 VDC will be supplied, as usual in existing satellites. The capacity of the battery cells, Cb , can therefore be estimated :

$$Cb = WdH / 28 \text{ v} / DD = 7.3 \text{ Ah.}$$

To provide 28 V to the satellite, 24 battery cells are necessary (the voltage of one battery cell is 1.2 V, in general). The mass of a 7.3 Ah-class battery cell is very small, 250g ~ 300g for Ni-Cd, so the weight of the Ni-Cd batteries is about 6 kg ~ 7.2 kg. We selected Ni-Cd batteries instead of Ni-H batteries, because of the lower costs, even though the Ni-H batteries weigh 3 kg less.

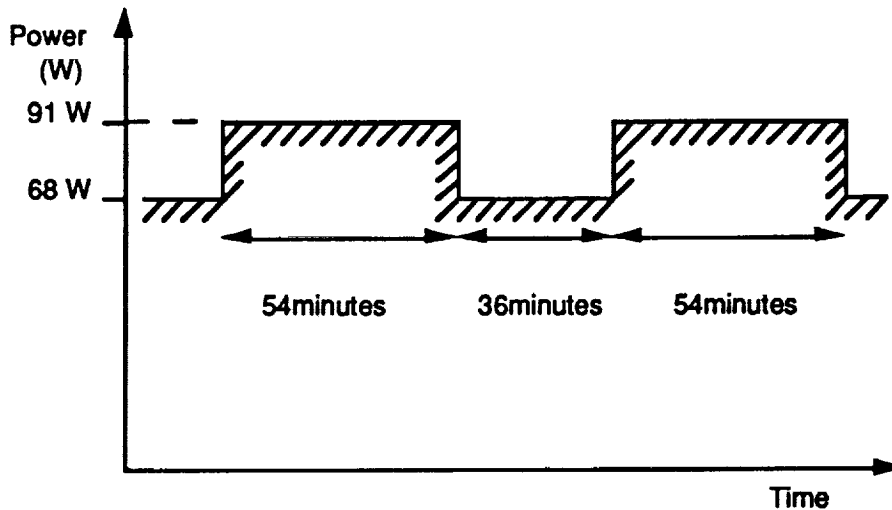


Figure 8.3.4.4 - 1 Power Consumption Profile

Table 8.3.4.4-1 Power Requirement

| ITEMS | Power(W) |
|------------------|----------|
| Power | 4.0 |
| Thermal Cont. | 6.0 |
| Attitude Cont. | 5.6 |
| Orbit Cont. | 5.6 |
| Teleme.&Comm. | 5.7 |
| Comm.&D.Handling | 15.3 |
| Contingency(20%) | 8 |
| Total | 50.2 W |

Thermal Control

Requirement : As a first estimation, the heat rejection requirement is supposed to be equal to the power requirement. The heat rejection requirement profile is also shown in Figure 8.3.4.4 - 1. The temperature requirement of the electrical equipment is $0\text{ }^{\circ}\text{C} < T_e < 40\text{ }^{\circ}\text{C}$.

Design : As a first estimation; thermal balanced or static conditions were assumed. The radiator surface temperature is given by the Stefan-Boltzmann's Law :

$$Q = \sigma * \epsilon * A_s * (T^4 - T_s^4)$$

Q : heat from equipment (W)

σ : Stefan-Boltzmann constant $5.67 \times 10^{-8} \text{ W/m}^2/\text{K}^4$

ϵ : emissivity of the radiator surface, 0.8 is reasonable for radiator surface

A_s : area of the radiator surface (m^2)

T : radiator surface temperature (K)

T_s : heat sink temperature of space

The results of the calculation are shown in Table 8.3.4.4-2. The temperature gradient between the radiator surface and the electrical equipment, about $10\text{ }^{\circ}\text{C}$, must be considered. So, an adequate radiator surface area is $0.5 \sim 0.6 \text{ m}^2$.

Table 8.3.4.4-2 Temperature and Area of Radiator

| | Q = 68 W | Q = 91 W | |
|----------------------|-----------------|----------------|--------------------------|
| A = 1 m ² | T = -1.9 C deg. | T = 4.3 C deg. | A : Radiator Area |
| 0.8 m ² | 2.7 C deg. | 10.0 C deg. | T : Radiator Temperature |
| 0.7 m ² | 5.9 C deg. | 13.9 C deg. | |
| 0.6 m ² | 9.9 C deg. | 18.8 C deg. | Q : Heat from Equipment |
| 0.5 m ² | 15.3 C deg. | 25.3 C deg. | |
| 0.4 m ² | 22.8 C deg. | 34.3 C deg. | |

Attitude Control

Aerodynamic stabilization fins, in general, only give rough accuracy (5 degrees), so another control system is needed to accomplish the high pointing accuracy required by the payload. Following Barberis et al., passive dampers for yaw and pitch, and cold gas reaction control for roll can easily provide 1 ~ 2 degrees accuracy. It is obvious that using reaction wheels and cold gas control will provide better pointing accuracy. A mechanism of a correcting mirror may achieve the high pointing accuracy requirements, which are less than 0.1 degrees. The attitude control system can be summarized as follows: attitude control accuracy of bus system is less than 1 degree; and according to the requirement of the payload, some compensation mechanism will be adopted.

Structure

In order to achieve small volume, the idea of a deployable body and deployable fins seemed to be applicable for the TMS. The concept is shown in Figure 8.3.4.4 - 2

The main structure consists of carbon fiber composites to save weight. Glass fiber composite is applied for the antenna covering area (fairing port). The detailed structure concept is not yet available, but it is obvious that these structures are based on the current technology, which is already used for the deployable body of large spin satellite and rocket fairings.

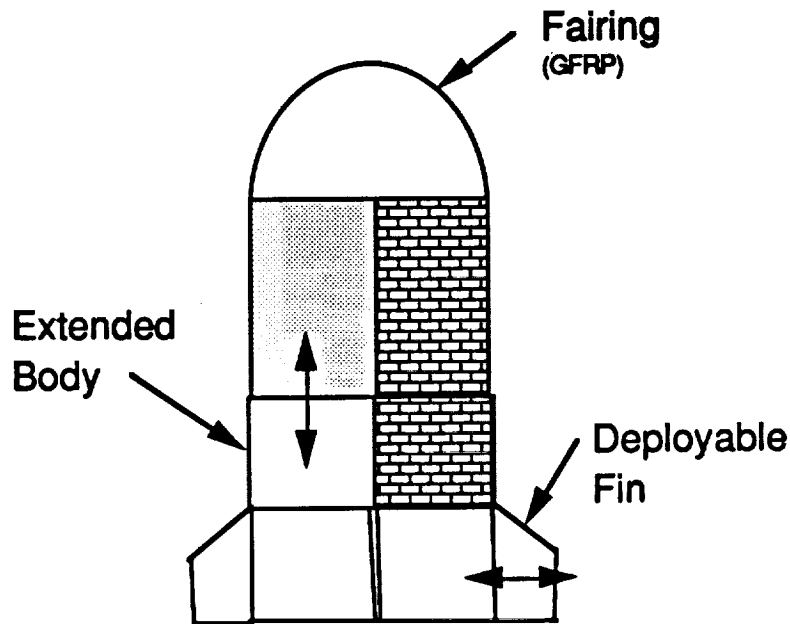


Figure 8.3.4.4 - 2 Basic Concept of the TMS

Data Handling / Telemetry & Command

The details of the electrical and electronic equipment were not defined in detail, as this is highly dependent on the specifications of the payload. Only the feasibility is presented of data communications. The downlink to the ground station is very important for the user interface and the antenna configuration. Only the on-board antenna and the ground station antenna. The data transfer capacity is supposed to be in the 100 Mbit/sec-class (payload requirement).

$$\left(\frac{G_e}{T_e}\right) = \frac{E}{N_o} + B + L + k - (P_s * G_s)$$

$$\frac{E}{N_o} = 10^{+)} \text{ dB}$$

$$B = 80^{+)} \text{ dBHz}$$

$$L = \left(\frac{4 * \pi * h * f}{c}\right)^2$$

$$c = 3 \times 10^2 \text{ m/s}, f = 2 \times 10^{9+)} \text{ Hz}$$

The loss of the free space L is

$$L = 146.4 \text{ dB.}$$

We furthermore assume that the diameter of the satellite antenna is 0.3 m and the transmitting power on the satellite is 1W.

$$k = -230 \text{ dB+),}$$

$$G_s = 0.5 \times \left(\frac{\pi * D * f}{c}\right)^2 = 13 \text{ dB}$$

$$\frac{G_e}{T_e} = 10 + 80 + 146.4 - 230 - 13 = - 6.6 \text{ dB}$$

$T_e = 300 \text{ K}$,

The antenna gain of the Earth receiving station G_e is

$$G_e = -6.6 \text{ dB} + 10 \log(300) = 18 \text{ dB}$$

$$D_e = \frac{c}{\pi f} \sqrt{2 G_e} = \underline{0.54 \text{ m}}$$

The diameter of the ground station antenna would need to be 0.54 m. This therefore proves the technical feasibility of the antenna system of the TMS sufficiently.

Orbit Control Subsystem

The orbit control system may be the most important and delicate problem. The weight and the volume of the propellant to keep the orbit should not exceed the capabilities of the small satellite. We realized that the orbit control issue is one of the most critical problems for the TMS and it is addressed in the following section.

8.3.4.5 Study of Critical Problems

Orbit Control Problem Induced by Air Drag

(1) The drag estimation

The air drag is determined by the following formula :

$$D = 1/2 * r * S * C_d * V^2 \quad (8.3.4.5-1)$$

D : drag

r : air density (kg/m^3)

S : cross section perpendicular to the velocity vector

C_d : drag coefficient

V : velocity (m/sec)

The air density of at 250 km altitude is $r = 1.149 \times 10^{-10} \text{ (kg/m}^3\text{)}$, but is highly variable [Vinh et al., 1980].

We assumed a configuration of the TMS to achieve an initial value for S. Based on the discussion of section 8.3.2 the cross section is assumed to be a circle. To contain the payload, as described in section 8.2, the satellite diameter is assumed to be 0.8 m as shown in Figure 8.3.4.5-1. This is only an initial assumption to start the study and not a rigorous assessment.

The drag coefficient depends on the configuration, on the Mach number and the Reynolds number. A drag coefficient $C_d = 0.018$ is assumed (CNES, 1988) in our study. Unfortunately, we could not gather enough information about flight in an orbit of 250 km height. We assumed this value as being applicable and made a first order calculation. This issue has to be addressed later.

$$S = \pi \times 0.4 \times 0.4 = 5.027 \times 10^{-1} \text{ m}^2 \quad (8.3.4.5-2)$$

$$V = \sqrt{(\mu / a)} \quad (8.3.4.5-3)$$

$$\mu = 3.986 \times 10^{14} \text{ m}^3/\text{sec}^2$$

$$a = 6371 \text{ km} + 250 \text{ km} = 6.621 \times 10^6 \text{ m} \quad (8.3.4.5-4)$$

The drag is

$$\begin{aligned} D &= 1/2 * \rho * S * C_d * (\mu / a) \\ &= 1/2 \times 1.149 \times 10^{-10} \times 5.027 \times 10^{-1} \times 0.018 \times 3.986 \times 10^{14} / (6.621 \times 10^6) \\ &= 3.129 \times 10^{-5} \text{ kgm/s}^2 \end{aligned} \quad (8.3.4.5-5)$$

(2) The orbit (altitude) change estimation

The energy of the satellite in a circular orbit of the radius R is

$$E = 1/2 * m * V^2 - \mu * m / R = - m * \mu / (2 * R) \quad (8.3.4.5-6)$$

m : Mass of the satellite.

If the altitude changes by Δh , the energy change of the satellite, ΔE , is

$$\begin{aligned} \Delta E &= - m * \mu / (2 * R) + m * \mu / (2 * (R - \Delta h)) \\ &= m * \mu * (\Delta h / R / (R - \Delta h)) / 2. \end{aligned} \quad (8.3.4.5-7)$$

The energy loss of the satellite per one period which is suffering the air drag in this circular orbit is

$$\Delta E_p = D * 2 * \pi * R. \quad (8.3.4.5-8)$$

If the energy change is linear, the altitude change per one period, Δh_p , is

$$\Delta h_p = \Delta E_p * \Delta h / \Delta E = 4 * \pi * R^2 * (R - \Delta h) * D / (m * \mu). \quad (8.3.4.5 - 9)$$

This method assumes a small altitude change and is only applicable in this case.

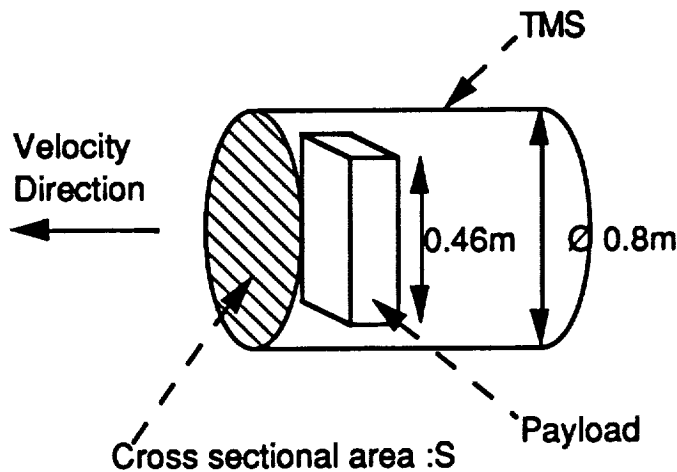


Figure 8.3.4.5 - 1 Initial Assumption of TMS-Configuration

(3) The orbit change and the maneuver

To consider the case of an orbit maneuver which changes the radius from the original altitude R to $R+\Delta h$ (Figure 8.3.3.5-2) the necessary Δv_1 and Δv_2 are

$$\Delta v_1 = \sqrt{(2*\mu*R / (R+R') / R')} - \sqrt{(\mu / R')} \quad (8.3.4.5-10)$$

$$\Delta v_2 = \sqrt{(\mu / R)} - \sqrt{(2*\mu*R' / R / (R+R'))} \quad (8.3.4.5-11)$$

$$R' = R - \Delta h \quad (8.3.4.5-12)$$

(4) Mass estimation of the propellant

The necessary propellant mass, Δm , for a Δv maneuver can be calculated by the next equation.

$$\Delta m = M_{\text{initial}} * \left(1 - \frac{1}{\text{EXP}\left(\frac{\Delta v}{I_{\text{sp}} * g_0}\right)}\right) \quad (8.3.4.5-13)$$

M_{initial} : satellite mass before maneuver

I_{sp} : specific impulse of the engine

g_0 : Earth gravity ; 9.1 m/s²

By the iterative calculations for 365 days, the total propellant mass per one year can be estimated.

N₂H₄ was chosen for the orbit maneuvering engines because of the high specific impulse, the high density which implies good volume efficiency, the well proven technology and the low cost compared with two-liquid engines. The specific impulse can be assumed to be 225 sec.

To calculate the propellant mass, the initial mass of the satellite has to be chosen and Δh_p can be calculated. After the decision of the maneuvering timing (once per day or twice per day...) one can calculate the necessary orbit maneuvering velocity impulse Δv . Then the iteration of (8.3.4.5 - 13) leads to the total mass of the satellite. Comparing the initial mass of the satellite and the total mass of the propellant, the feasibility of the case must be considered.

After some repetition of this process, a reasonable result was obtained.

The initial satellite mass is 200 kg. Using $\Delta h = 1$ km, the altitude change within one period is

$$\begin{aligned} \Delta h_p &= \frac{\Delta E_p}{\Delta E * \Delta h} = 4 * \pi * (6.621 * 10^6 \text{ m})^2 * 6.62 * 10^6 \text{ m} * 3.129 * 10^{-5} \text{ kg m} / \text{sec}^2 \\ & \quad / 200 \text{ kg} / (3.986 * 10^{14} \text{ m}^3 / \text{sec}^2) \\ & = 1.43137 \text{ m} . \end{aligned}$$

Assuming maneuver once a day , this leads to an orbit change within one day (16 orbits) of

$$\Delta h_d = \Delta h_p * 16 = 22.9 \text{ m} .$$

With $\Delta h_o = \Delta h_d$ the necessary Δv are

$$\Delta v_1 = 0.9144707 \text{ m} / \text{sec}$$

$$\Delta v_2 = 0.9144525 \text{ m} / \text{sec} .$$

The total propellant mass, m_p , for one year is

$$m_p = \underline{52.2 \text{ kg}} .$$

In this case the satellite mass without the propellant is 147.8 kg and the volume of N_2H_4 , V_p , is

$$V_p = 5.22 \times 10^4 \text{ cm}^3.$$

These calculations are based on the SPOT-1 drag coefficient, $C_d = 0.018$. C_d is basically a function of the configuration. In this case, the TMS has a very simple and aerodynamical shape, and one can expect a very small C_d -value. The air drag coefficient depends also on the Mach number, Ma , and the Reynolds number, Re . The orbits of SPOT and TMS are quite different and Ma and Re are different as well. In the limited time frame, enough data was not available about the 250 km altitude orbit. Aerodynamic texts recommend the use $C_d = 2$ for arbitrary shaped bodies, but if this value used the necessary propellant mass increases proportionally, one hundred times. With this value the TMS will not be feasible. A re-entry-body with drag skirt has a drag coefficient of about 0.02. The issue of atmospheric drag requires careful consideration and it is recommended that great effort be put into this question.

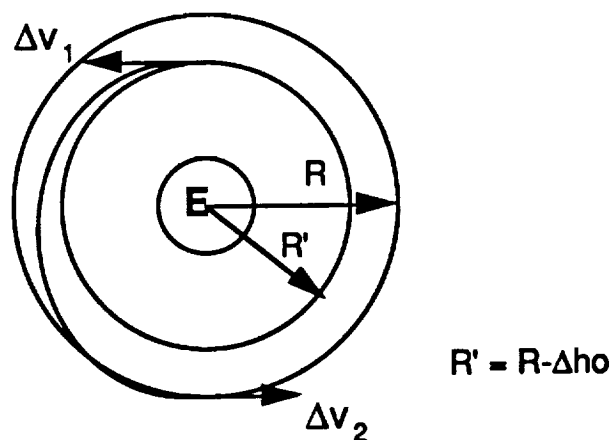


Figure 8.3.4.5 - 2 Orbit Maneuver

8.3.4.6 TMS Design Summary

Through the study of the previous sections the concepts of the satellite become clearer. The configuration of the TMS is shown in Figure 8.3.4.6 - 1 and the rigging image is shown in Figure 8.3.4.6 - 2. The main factors of the configuration are as follows:

- The cross section area is small and the volume contains the N_2H_4 tanks of $5.22 \times 10^4 \text{ cm}^3$. The satellite has 4 tanks with 30 cm diameter each;
- The launch configuration is mainly determined by the PEGASUS payload envelope;
- The required radiator surface is 0.64 m^2 ; and
- The extended body size is selected for accomplishing the required area of 1.0 m^2 . The actual design provides 1.12 m^2 .

The weight and the power summary are shown in Table 8.3.5 - 1.

a) LAUNCH CONFIGURATION

b) ON-ORBIT CONFIGURATION

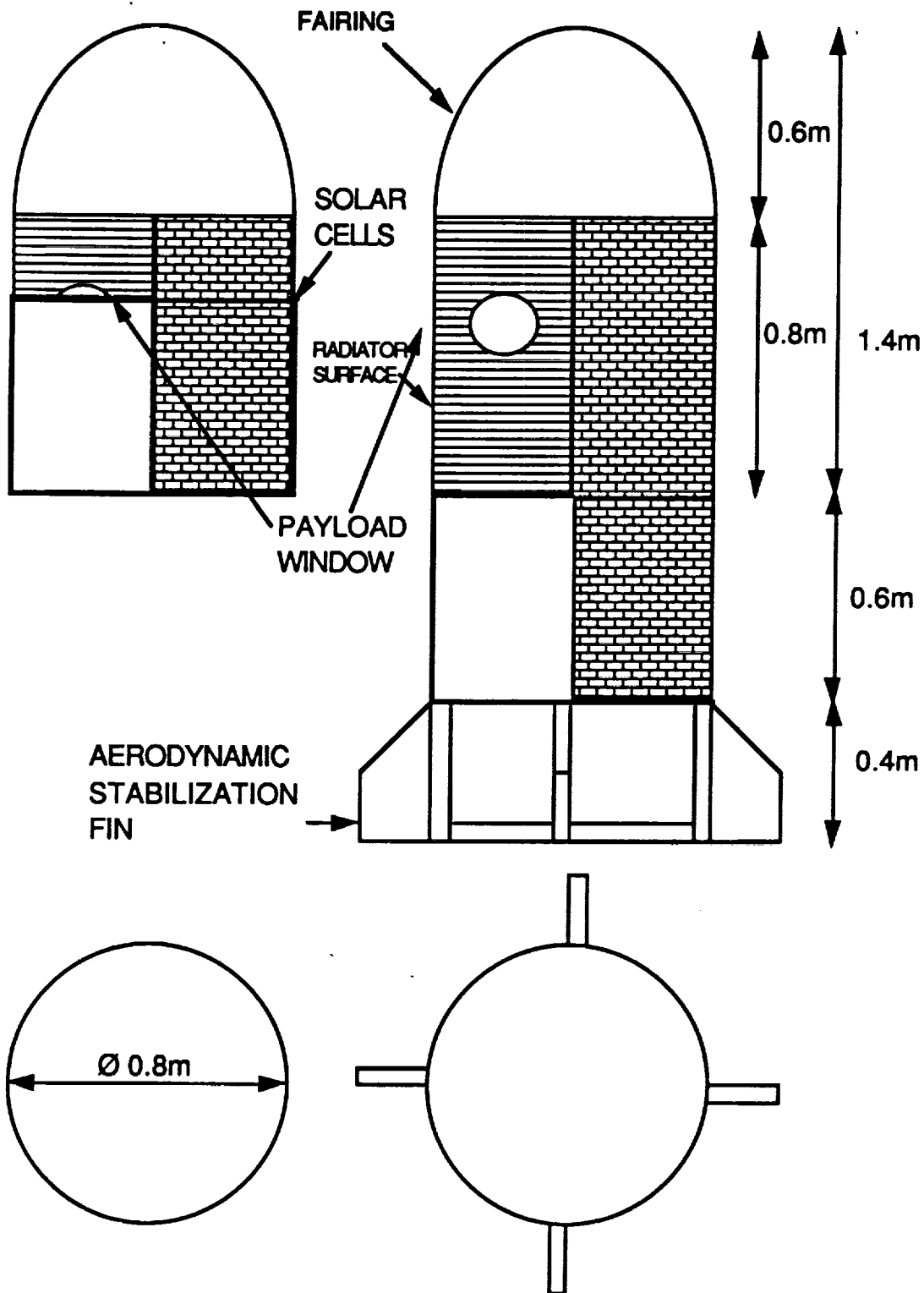


Figure 8.3.4.6 - 1 Configuration of TMS

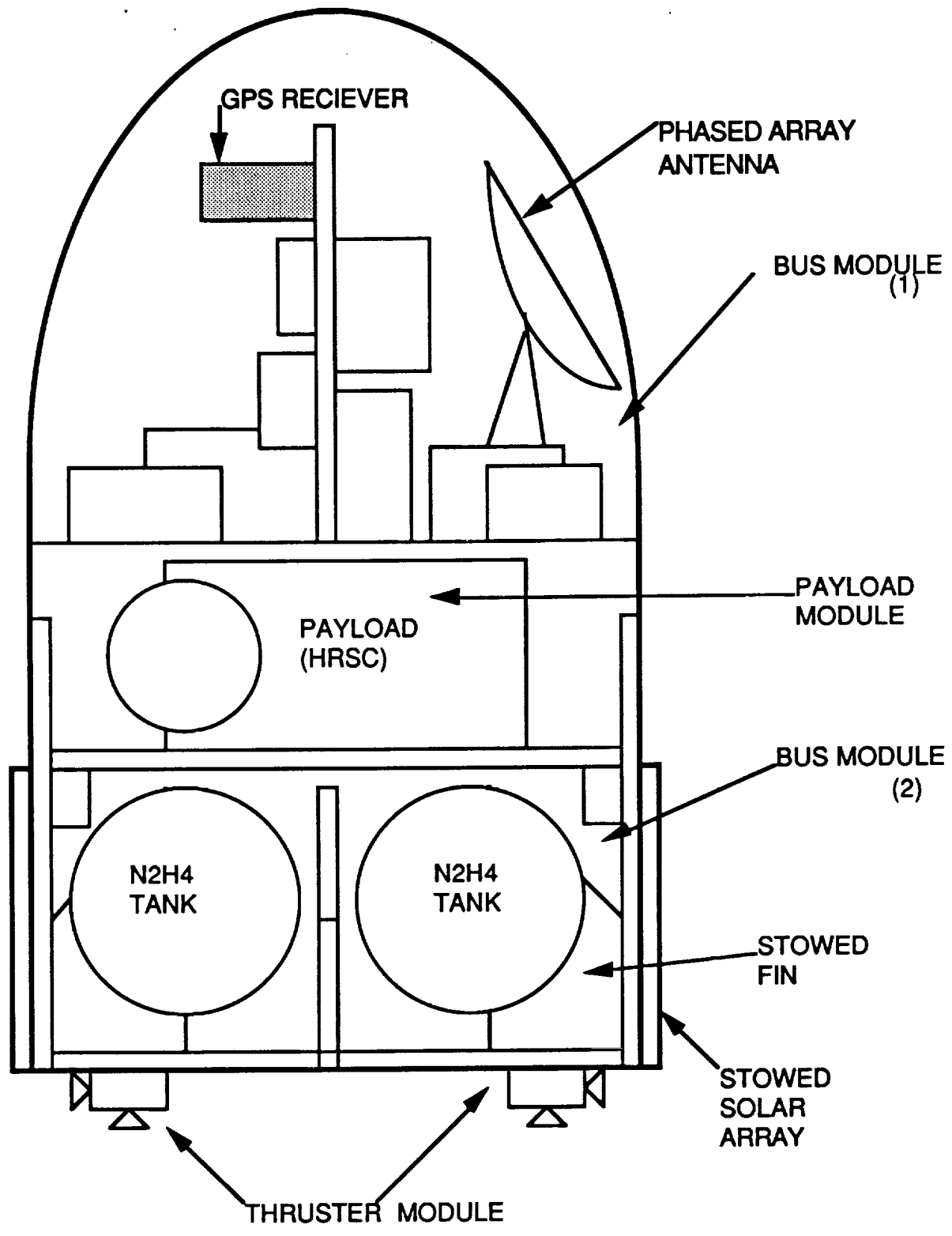


Figure 8.3.4.6 - 2 Rigging Image of TMS

8.3.4.7 Launcher Selection

At the beginning of this study we selected the PEGASUS launcher as a basic option. The result shows that the TMS is compatible with the PEGASUS launcher.

8.3.5 Conclusions

The TMS System using the small satellite concept has been examined. The main challenge was to fly a high resolution camera in a low orbit to achieve high resolution. The study was based on some basic assumptions and it turns out that the satellite does not violate them. There are still some open questions, as described in chapter 8.3.4.5., which have to be investigated in further detail. Not enough information was at hand about air density data of 250 km height and the drag coefficient of the satellite. Calculations used the averaged value of the density, not taking into account the large variations. Therefore the satellite life time will have large deviations. Solving these issues before the launch of the TMS seems possible.

The following Tables and Figures summarizes the TMS concept.

Table 8.3.5 - 1 Weight Summary

| ITEM | Weight(kg) |
|------------------|--|
| Power | SolarCell 1.3kg Battery 6.8kg Cabling 3 kg |
| Thermal Cont. | 4 kg |
| Attitude Cont. | 15 kg |
| Orbit Cont. | Propellant 57.4kg Tank etc.10kg |
| Teleme&Comm. | 9 kg |
| Comm.&D.Handling | 23kg |
| Structure | 35.5kg |
| TOTAL | 165 kg |

Table 8.3.5 - 2 TMS Main Parameters

| ITEMS | Figures | Remarks |
|---------------------|---|---|
| Weight | 165 kg Including 58 kg propellant | Pay load :35 kg |
| Power (Supply) | 91 W(Daytime) 68 W(Eclipse) | Solar cells :1.2m ² Battery: Ni-Cd (DOD 20%) |
| Power (Required) | Bus:50.2W Payload : 41W / 18 W | |
| Thermal Control | Effective Radiative Area :0.6 m ² | Required Temperature: 273~313K |
| Attitude Control | <0.1 deg(Aerodynamic Stabilization+ Reaction Wheel) | |



9.0 FINANCIAL OPERATIONS OF IPEO

9.1 Introduction

This chapter discusses the financial and economic aspects of IPEO. This will include an IPEO cost analysis, the marketing aspects of the body, financing methods and sources. Following these descriptions, a ten-year forecast of IPEO operations will be described. Finally, the ending section will describe the economical benefits IPEO has for society.

9.2 IPEO Cost Analysis

This section deals with the overall IPEO cost estimation and cash flow. The whole program was broken into cost items which can be associated either to capital cost, operating cost or both. For this purpose a capital cost is the amount of investment necessary to implement the facilities (hardware, software, building, etc.) which will be used to carry on the activities of IPEO, while the operating cost is related to the activities themselves (personnel, maintenance, etc.).

The cost breakdown structure is related to the performing units in the IPEO organizational chart and the cost estimates for all cost items are presented by appropriate topics. A special topic [9.2.1] is addressed to approach the estimation of the satellite development cost, since that cost is the most relevant.

For the estimations presented herein, the following assumptions or conventions were assumed:

- Currency used : US \$ (1990 constant dollars);
- Satellite development time : 7 years;
- Ground stations : 2 IPEO-owned and 2 rented ground stations;
- Buildings to accommodate IPEO personnel and equipment were supposed to be rented and the cost allocated in the finance/administration cost item;
- Maintenance cost : 10 percent of the capital cost;
- Personnel cost : \$150,000 / year per IPEO employee; \$170,000 / year per contracted person; and
- Electronic data processing equipment : replacement necessary each 5 years.

9.2.1 Space Segment Cost Estimation Approach

Space segment cost was estimated based on the parametric approach presented by D.Koelle (1990). The results are:

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| | |
|-----------------------|---|
| First unit cost (PFM) | 300 M\$ (US) including development cost |
| Launch cost | 30 M\$ (US) |
| Insurance cost | 34 M\$ (US) |
| Second unit cost | 170 M\$ (US) |

9.2.1.1 Satellite Cost Estimation

The following approach has been used in order to evaluate the cost of the IPEO deforestation satellite:

The first unit cost is derived from the satellite's dry mass (i.e. without propellant) using the empirical curves in figure 9.2.1.1-1. These curves show the relationship between the first unit cost in man-years MY (where 1 MY is equivalent to 170.000 \$ - 1990 value) and the spacecraft dry mass for existing communication satellites. Koelle uses a man-year as a tool to express the costs of a satellite. A man-year does not only include salaries, but also all other costs. It can be assumed that these curves can also be applied to remote sensing satellites, provided that the specificities of the foreseen spacecraft are taken into account. In the case of the IPEO satellite with its advanced technological features (inflatable antenna, ...) curve A, advanced technology spacecraft, has been chosen.

A protoflight development plan for the satellite has been assumed. This means that instead of separate qualification and flight models only one protoflight model will be built and launched as the first flight unit. This approach assumes that the satellite development costs include the cost of the first flight unit.

For the protoflight approach the development costs including the protoflight model can be expressed according to K. Kondo (1986) by 1.5 to 2.0 times the first unit cost taken from Figure 9.2.1.1-1.

The foreseen dry mass of the IPEO satellite is approximately 1000 kg (1200 kg total launch mass). This results in a first unit cost of 170 M\$ (1000 MY) and a total development cost ranging from 255 M\$ to 340 M\$. The mean value, 300 M\$, has been chosen as a conservative estimation. For the follow-on units the estimated cost equals the 170 M\$ of the first flight unit.

COMMUNICATION SATELLITES

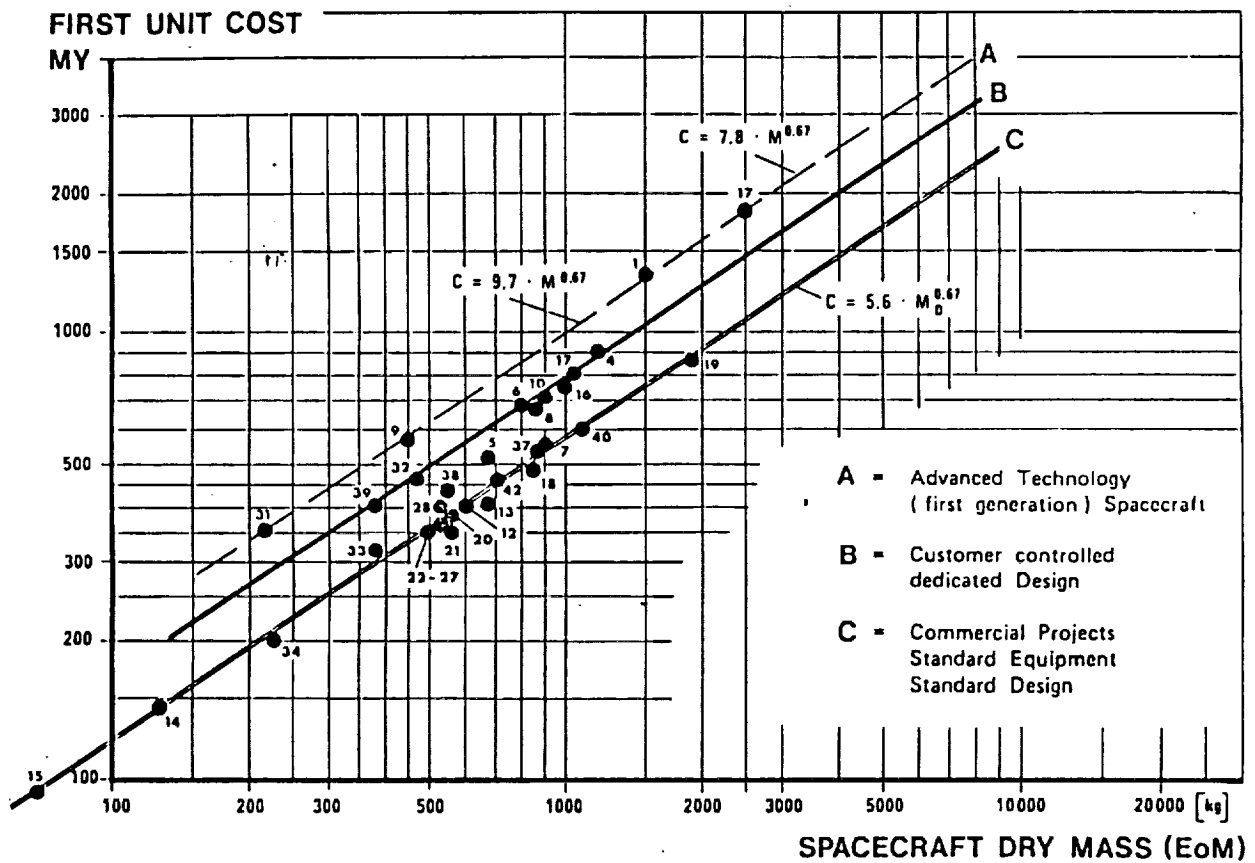


Figure 9.2.1.1 - 1 First Unit Cost vs. Satellite Mass (Koelle, 1990)

Other remote-sensing satellite costs compared to IPEO satellite costs are as follows:

| | MASS | LIFE | SAT. COST* |
|--------------------|----------|---------------|--------------|
| MOS-1 (JAPAN)** | 1.4 tons | 2 years | 250 M\$ (US) |
| JERS-1 (JAPAN)** | 1.4 tons | 2 years | 250 M\$ (US) |
| IPEO-SAT | 1.2 tons | 2.5 - 3 years | 300 M\$ (US) |

(*) Including development cost (**) from NASDA 1989

From the table it appears that the estimated value of the IPEO satellite cost could be too conservative. However, we are confident that this figure should be used taking into consideration the present phase of the IPEO study.

9.2.1.2 Launch Cost Estimation

Launch cost was estimated based on the cost of existing launchers, shown in Figure 9.2.1.2-1. In case of IPEO deforestation satellite, the payload mass will be 1.2 tons approximately. Thus, the launch cost is predicted as 30 M\$.

LONG-MARCH launcher (CZ-2C, China) was traded-off from the engineering point of view, and the cost is nominally 25 - 30 M\$.

9.2.1.3 Insurance Cost Estimation

Insurance premium rates depend considerably on the actual effectiveness of the launching industry (success/failure rate). Following space segment disasters such as the launch failure of SUPERBIRD-B the insurance rates temporarily increased to about 30%. However they also tend to recover quite soon to below 20percent (17percent at the moment) after a series of successful launches. A value of 20percent has been chosen for the IPEO cost estimation. The resulting insurance cost has been obtained by applying this rate on the replacement cost of the spacecraft, i.e the estimated 170 M\$ of the IPEO satellite follow-on unit.

SPECIFIC TRANSPORTATION COST

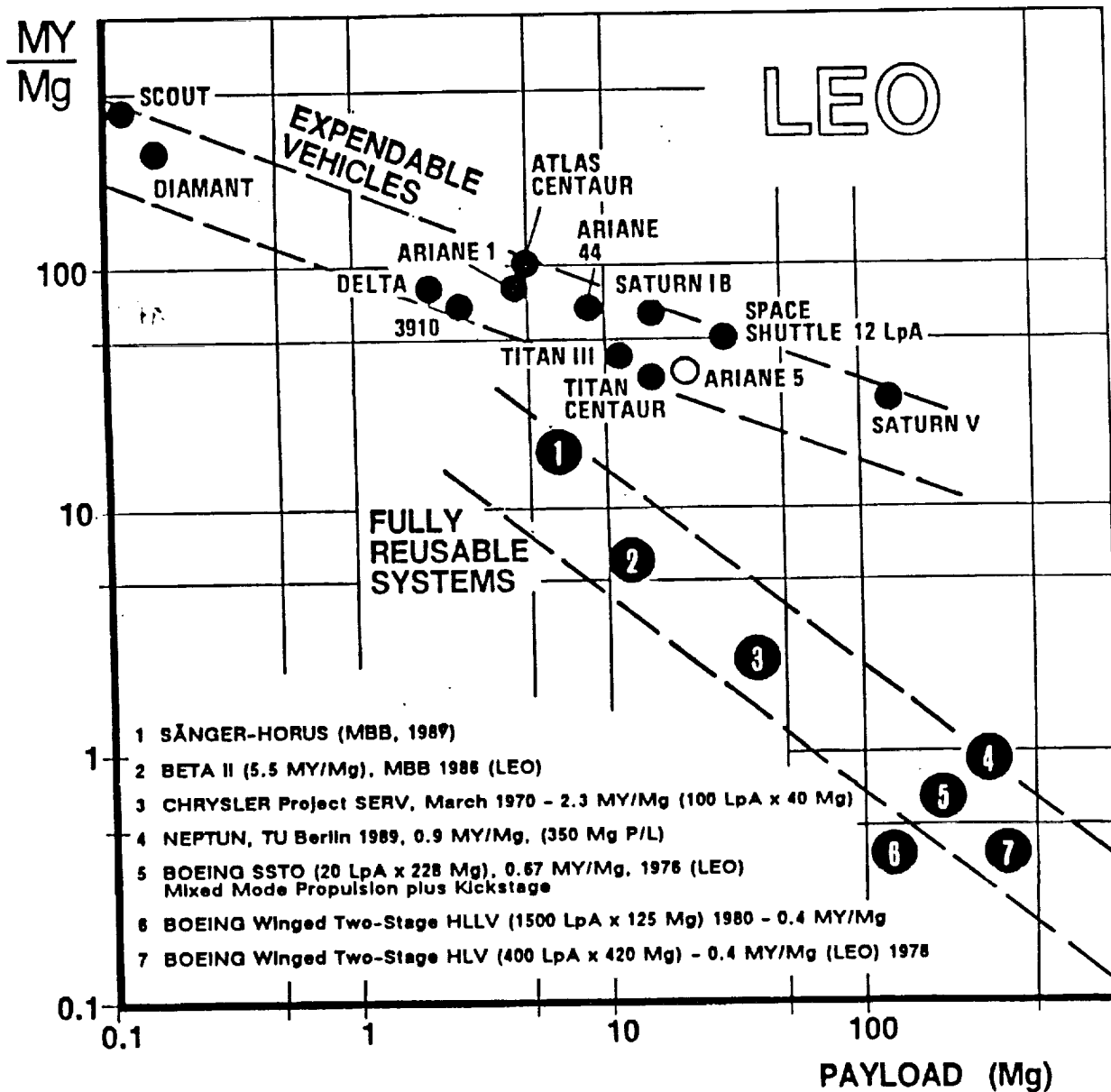


Figure 9.2.1.2 - 1 Specific Transportation Cost vs. Payload Mass (Koelle, 1990)

9.2.2 IPEO Cost Estimation

9.2.2.1 Operational Programs

A) IPEO SATELLITE DEVELOPMENT & OPERATIONS

• IPEO Satellite Operations

Data Acquisition

IPEO ground stations (2):

equipment

| | |
|-----------------------------|----------------------------|
| antennas | 2@ \$ 3.5 M |
| workstations | 2@ \$ 0.03 M every 5 years |
| archiving | 2@ \$ 0.2 M every 5 years |
| building | 2@ \$ 0.5 M |
| maintenance & storage disks | 2@ \$ 0.7 M / year |

staff

| | |
|----------------------------------|------------------|
| 1 person for the first 3 years | \$ 0.15 M / year |
| 4 persons after the 3rd year | \$ 0.6 M / year |
| 10 contracted after the 4th year | \$ 1.7 M / year |

rented ground stations (2):

| | |
|-----------------------------|---------------------------|
| archiving | 2@ \$ 0.2 M every 5 years |
| maintenance & storage disks | 2@ \$ 0.3 M / year |
| rental costs | 2@ \$ 0.6 M / year |

Data Calibration & Processing

equipment

| | |
|---------------|----------------------|
| SAR processor | \$ 5 M every 5 years |
| maintenance | \$ 0.5 M / year |

staff

| | |
|---------------------------------|------------------|
| 1 person for the first 4 years | \$ 0.15 M / year |
| 2 persons after the 4th year | \$ 0.3 M / year |
| 3 contracted after the 4th year | \$ 0.51 M / year |

Mission Control Center

equipment

| | |
|-----------------|-------------------------|
| 2 workstations | \$ 0.03 M every 5 years |
| 2 minicomputers | \$ 0.5 M every 5 years |
| software | \$ 1.5 M every 5 years |
| maintenance | \$ 0.2 M / year |

staff

| | |
|---------------------------------|------------------|
| 1 person for the first 3 years | \$ 0.15 M / year |
| 2 persons for the 4th year | \$ 0.3 M / year |
| 3 persons after the 4th year | \$ 0.45 M / year |
| 5 contracted after the 4th year | \$ 0.85 M / year |

Operations Control Center

operations center:

equipment

| | |
|-----------------|-------------------------|
| 2 workstations | \$ 0.03 M every 5 years |
| 2 minicomputers | \$ 0.5 M every 5 years |
| software | \$ 1.5 M every 5 years |
| maintenance | \$ 0.2 M / year |

staff

| | |
|---------------------------------|------------------|
| 1 person for the first 3 years | \$ 0.15 M / year |
| 3 persons for the 4th year | \$ 0.45 M / year |
| 5 persons after the 4th year | \$ 0.75 M / year |
| 5 contracted after the 4th year | \$ 0.85 M / year |

TTC&M station

| | |
|--------------|-----------------|
| rental costs | \$ 0.6 M / year |
|--------------|-----------------|

• IPEO Satellite Development

satellite

| | |
|----------------|--|
| first unit | \$ 300 M over 7 years development period |
| follow-on unit | \$ 170 M every 3 years |

launch

| | |
|---------------|----------------------|
| Long March II | \$ 30 M every launch |
|---------------|----------------------|

| | | |
|-----------|----------|----------------------|
| insurance | | |
| | premium | \$ 34 M every launch |
| staff | | |
| | 1 person | \$ 0.15 M / year |

B) NETWORK & COMPUTER SERVICES

• Computer & Archiving Services

| | | |
|-----------------------------|----------------------------------|------------------------|
| equipment | | |
| | 1 supercomputer | \$ 10 M every 5 years |
| | workstations & interfaces | \$ 1.5 M every 5 years |
| central archive | | |
| | pre IPEOSAT | \$ 1.0 M every 5 years |
| | post IPEOSAT | \$ 2.8 M every 5 years |
| maintenance & storage disks | | |
| | pre IPEOSAT | \$ 1.3 M / year |
| | post IPEOSAT | \$ 2.9 M / year |
| staff | | |
| | 3 persons for the first 2 years | \$ 0.45 M / year |
| | 10 persons after the 2nd year | \$ 1.5 M / year |
| | 20 contracted after the 2nd year | \$ 3.4 M / year |

• Network Services

| | | |
|------------------------------------|----------------------------------|----------------------|
| equipment | | |
| | hardware & software | \$ 2 M every 5 years |
| | maintenance | \$ 0.2 M / year |
| acquisition & distribution network | | |
| | pre IPEOSAT | \$ 6.0 M / year |
| | post IPEOSAT | \$ 22.5 M / year |
| staff | | |
| | 2 persons for the first 2 years | \$ 0.3 M / year |
| | 5 persons after the 2nd year | \$ 0.75 M / year |
| | 15 contracted after the 2nd year | \$ 2.55 M / year |

C) USER SUPPORT

• GEOD

equipment

| | |
|---------------------|----------------------|
| hardware & software | \$ 5 M every 5 years |
| maintenance | \$ 0.5 M / year |

staff

| | |
|---------------------------------|------------------|
| 5 persons for the first 2 years | \$ 0.75 M / year |
| 65 contracted for the 2nd year | \$ 11.05 M |
| 25 persons after the 2nd year | \$ 3.75 M / year |

• Applications & Emergency Programs

equipment shared with Advanced Programs & Research (see 9.2.2.4)

| | |
|----------------------------------|-------------------------|
| 1 minicomputer | \$ 0.25 M every 5 years |
| 10 workstations | \$ 0.15 M every 5 years |
| computer peripherals | \$ 0.05 M every 5 years |
| AVHRR receiver | \$ 0.06 M every 5 years |
| maintenance | \$ 0.05 M / year |
| data from existing organizations | \$ 1 M / year |

staff

| | |
|-------------------------------|------------------|
| 5 persons for the 1st year | \$ 0.75 M / year |
| 10 persons for the 2nd year | \$ 1.5 M / year |
| 20 persons after the 2nd year | \$ 3.0 M / year |

D) REGIONAL CENTER OFFICE

regional centers (5):*

equipment

| | |
|---------------------|---------------------------|
| hardware & software | 5@ \$ 0.2 M every 5 years |
| maintenance | 5@ \$ 0.02 M / year |

staff

| | |
|----------------------------------|------------------|
| 1 person for the first 2 years | \$ 0.15 M / year |
| 35 persons after the 2nd year | \$ 5.25 M / year |
| 25 contracted after the 2nd year | \$ 4.25 M / year |

* (Number of regional centers subject to change in final evaluation)

9.2.2.2 Marketing

staff

| | |
|------------------------------------|------------------|
| 2 persons for the 1st year | \$ 0.3 M / year |
| 3 persons for the 2nd year | \$ 0.45 M / year |
| 5 persons after the 2nd year | \$ 0.75 M / year |
| 1 contracted for the first 3 years | \$ 0.17 M / year |

9.2.2.3 Finance / Administration

| | |
|---------------|---|
| office rental | \$ 0.15 M / year for the first 2 years \$ 0.42 M / year after the 2nd year |
|---------------|---|

staff

| | |
|-------------------------------|------------------|
| 6 persons for the 1st year | \$ 0.9 M / year |
| 8 persons for the 2nd year | \$ 1.2 M / year |
| 13 persons after the 2nd year | \$ 1.95 M / year |

9.2.2.4 Advanced Programs & Research

| | |
|------------------|-------------------------------------|
| airborne program | \$ 5 M / year for the first 2 years |
|------------------|-------------------------------------|

data processing equipment shared with "Applications & Emergency Programs"

staff

| | |
|-------------------------------|-----------------|
| 4 persons for the 1st year | \$ 0.6 M / year |
| 8 persons for the 2nd year | \$ 1.2 M / year |
| 16 persons after the 2nd year | \$ 2.4 M / year |

9.2.2.5 Education & Training

regional centers (4):

equipment

| | |
|----------------|-----------------------------|
| 5 workstations | 4@ \$ 0.075 M every 5 years |
| maintenance | 4@ \$ 0.0075 M / year |

staff

| | |
|---------------------------------|-----------------|
| 4 persons for the first 2 years | \$ 0.6 M / year |
| 8 persons after the 2nd year | \$ 1.2 M / year |

9.2.2.6 IPEO Management

staff

| | |
|------------------------------|------------------|
| 3 persons for the 1st year | \$ 0.45 M / year |
| 4 persons for the 2nd year | \$ 0.6 M / year |
| 7 persons after the 2nd year | \$ 1.05 M /year |

9.2.3 IPEO Cash Flow

Tables 9.2.3-1 and 9.2.3-2 show the IPEO cash flow for a 10 year horizon, respectively, in 1990 US\$ and nominal US\$. The entries in those tables are related to the cost estimates presented above, and consider the following additional assumptions:

- The investments concerning the ground segment facilities (data acquisition and mission control) were split in the 2 years immediately before satellite launch;
- Inflation rate is 6 percent per year (used in table 9.2.3-2 only);
- Maintenance cost applies from the first year after capital cost is incurred;
- and
- Network operating cost increases at a rate of 2 M \$ / year until the satellite is operational.

Table 9.2.3-1 IPEO Cash Flow ['90 US M\$]

| COST ITEMS: | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | TOTAL |
|---------------------------------------|-------|-------|--------|--------|--------|--------|--------|--------|--------|--------|---------|
| OPERATIONAL PROGRAMS | | | | | | | | | | | |
| Data Acquisition (C) | | | | | 3.00 | 5.90 | | | | | 8.90 |
| Data Calibration & Processing (C) | 0.15 | 0.15 | 0.15 | 0.60 | 2.30 | 4.70 | 5.50 | 5.50 | 5.50 | 5.50 | 30.05 |
| Mission Control (C) | 0.15 | 0.15 | 0.15 | 0.15 | 0.81 | 1.31 | 1.31 | 1.31 | 1.31 | 1.31 | 10.00 |
| Center (C) | 0.15 | 0.15 | 0.15 | 0.30 | 2.03 | 1.50 | 1.50 | 2.03 | 2.03 | 2.03 | 7.96 |
| Operations Control Center (C) | | | | | 2.03 | 1.50 | 1.50 | 1.50 | 1.50 | 1.50 | 4.06 |
| IPEO Satellite Development (C) | 10.00 | 20.00 | 50.00 | 80.00 | 80.00 | 40.00 | 50.00 | 102.00 | 102.00 | 64.00 | 14.50 |
| Computer & Archiving Services (C) | 0.45 | 0.45 | 12.50 | 0.15 | 0.15 | 0.15 | 34.15 | 0.15 | 0.15 | 34.15 | 50.00 |
| Network Services (C) | 0.30 | 0.30 | 5.10 | 6.20 | 6.20 | 6.20 | 7.80 | 7.80 | 7.80 | 7.80 | 26.80 |
| GED (C) | 0.75 | 5.00 | 9.30 | 11.50 | 13.50 | 15.50 | 17.50 | 26.50 | 26.50 | 26.50 | 54.20 |
| Applications & Emergency Programs (C) | 0.75 | 11.80 | 4.25 | 4.25 | 4.25 | 4.25 | 4.25 | 4.25 | 4.25 | 4.25 | 4.00 |
| Regional Center Office (C) | 0.75 | 2.50 | 4.05 | 4.05 | 4.05 | 4.05 | 4.05 | 4.05 | 4.05 | 4.05 | 10.00 |
| SUB TOTAL (A) | 10.00 | 28.51 | 84.50 | 80.00 | 92.08 | 45.90 | 56.51 | 50.30 | 102.00 | 73.06 | 800.84 |
| MARKETING (B) | 3.15 | 15.95 | 33.05 | 37.25 | 43.76 | 49.86 | 86.46 | 63.06 | 63.06 | 97.06 | 492.46 |
| FINANCE/ADMIN (C) | 13.15 | 42.46 | 97.55 | 117.25 | 135.82 | 95.56 | 142.97 | 113.36 | 165.06 | 170.12 | 1093.30 |
| MARKETING (B) | 0.47 | 0.82 | 0.92 | 0.75 | 0.75 | 0.75 | 0.75 | 0.75 | 0.75 | 0.75 | 0.00 |
| FINANCE/ADMIN (C) | 0.47 | 0.92 | 0.92 | 0.75 | 0.75 | 0.75 | 0.75 | 0.75 | 0.75 | 0.75 | 7.26 |
| ADVANCED PROGRAMS & RESEARCH (D) | 1.05 | 1.35 | 2.37 | 2.37 | 2.37 | 2.37 | 2.37 | 2.37 | 2.37 | 2.37 | 21.36 |
| EDUCATION & TRAINING (E) | 1.05 | 1.35 | 2.37 | 2.37 | 2.37 | 2.37 | 2.37 | 2.37 | 2.37 | 2.37 | 21.36 |
| EDUCATION & TRAINING (E) | 5.60 | 6.20 | 2.40 | 2.40 | 2.40 | 2.40 | 2.40 | 2.40 | 2.40 | 2.40 | 0.00 |
| EDUCATION & TRAINING (E) | 5.60 | 6.20 | 2.40 | 2.40 | 2.40 | 2.40 | 2.40 | 2.40 | 2.40 | 2.40 | 31.00 |
| EDUCATION & TRAINING (E) | 0.60 | 0.60 | 1.23 | 1.23 | 1.23 | 1.23 | 1.23 | 1.23 | 1.23 | 1.23 | 0.60 |
| EDUCATION & TRAINING (E) | 0.60 | 0.90 | 1.23 | 1.23 | 1.23 | 1.23 | 1.53 | 1.23 | 1.23 | 1.23 | 11.84 |
| IPEO MANAGEMENT (F) | 0.45 | 0.60 | 1.05 | 1.05 | 1.05 | 1.05 | 1.05 | 1.05 | 1.05 | 1.05 | 0.00 |
| IPEO MANAGEMENT (F) | 0.45 | 0.60 | 1.05 | 1.05 | 1.05 | 1.05 | 1.05 | 1.05 | 1.05 | 1.05 | 9.45 |
| TOTAL (A+B+C+D+E) | 21.32 | 52.13 | 105.52 | 125.05 | 143.62 | 103.36 | 151.07 | 121.16 | 172.86 | 177.92 | 1174.01 |

Table 9.2.3-2 IPEO Cash Flow [nominal US M\$]

| COST ITEMS: | FISCAL YEAR: | | | | | | | | | | | | TOTAL | | | | | | | | | | |
|---------------------------------------|--------------|-------|--------|--------|--------|--------|--------|--------|--------|--------|---------|--------|--------|--------|--------|---------|--------|--------|--------|--------|---------|--------|---------|
| | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | | | | | | | | | | | | | |
| OPERATIONAL PROGRAMS | | | | | | | | | | | | | | | | | | | | | | | |
| Data Acquisition (C) | | | | | 4.28 | | | | | | | | | | | | | | | | | | 13.13 |
| Data Calibration & Processing (C) | 0.17 | 0.18 | 0.19 | 0.80 | 3.26 | 7.07 | 8.87 | | | | | 6.77 | 9.29 | 9.85 | | | | | | | | 10.44 | 50.02 |
| Mission Control Center (C) | 0.17 | 0.18 | 0.19 | 0.20 | 1.15 | 1.97 | 2.09 | 2.21 | 2.25 | 2.53 | 2.85 | 2.99 | 2.53 | 2.69 | 2.85 | 3.05 | 3.05 | 3.05 | 3.05 | 3.05 | 3.05 | 3.05 | 16.58 |
| Operations Control Center (C) | 0.17 | 0.18 | 0.19 | 0.80 | 2.88 | 3.61 | 4.05 | 4.05 | 4.30 | 4.56 | 4.56 | 4.56 | 4.56 | 4.56 | 4.56 | 4.56 | 4.56 | 4.56 | 4.56 | 4.56 | 4.56 | 4.56 | 8.73 |
| IPEO Satellite Development (C) | 11.24 | 23.82 | 63.12 | 107.06 | 113.48 | 60.15 | 78.88 | 57.44 | 182.67 | 121.48 | 84.83 | 58.43 | 24.16 | 13.18 | 13.97 | 14.81 | 14.81 | 14.81 | 14.81 | 14.81 | 14.81 | 14.81 | 23.75 |
| Computer & Archiving Services (C) | 0.51 | 0.54 | 0.54 | 6.30 | 6.79 | 9.32 | 9.88 | 9.88 | 9.88 | 9.88 | 9.88 | 9.88 | 9.88 | 9.88 | 9.88 | 9.88 | 9.88 | 9.88 | 9.88 | 9.88 | 9.88 | 9.88 | 820.16 |
| Network Services (C) | 0.34 | 0.36 | 1.17 | 15.39 | 19.15 | 23.31 | 27.89 | 44.77 | 47.46 | 50.30 | 50.30 | 50.30 | 50.30 | 50.30 | 50.30 | 50.30 | 50.30 | 50.30 | 50.30 | 50.30 | 50.30 | 50.30 | 120.95 |
| CECD (C) | 0.84 | 1.17 | 1.42 | 5.89 | 6.03 | 6.39 | 6.77 | 7.18 | 7.61 | 8.07 | 8.54 | 8.97 | 9.40 | 9.83 | 10.26 | 10.69 | 11.12 | 11.55 | 11.98 | 12.41 | 12.84 | 13.27 | 5.90 |
| Applications & Emergency Programs (C) | 0.84 | 2.98 | 5.11 | 5.42 | 5.75 | 6.09 | 6.46 | 6.84 | 7.25 | 7.69 | 8.12 | 8.54 | 8.97 | 9.40 | 9.83 | 10.26 | 10.69 | 11.12 | 11.55 | 11.98 | 12.41 | 12.84 | 246.71 |
| Regional Center Office (C) | 0.17 | 0.18 | 12.12 | 12.85 | 13.62 | 14.43 | 15.30 | 16.22 | 17.19 | 18.22 | 19.30 | 20.43 | 21.61 | 22.84 | 24.12 | 25.50 | 26.98 | 28.56 | 30.24 | 32.01 | 33.84 | 35.73 | 13.82 |
| SUB TOTAL (A) | 11.24 | 31.57 | 81.43 | 107.06 | 130.59 | 89.02 | 90.07 | 84.98 | 182.67 | 138.69 | 827.31 | 90.07 | 84.98 | 182.67 | 138.69 | 827.31 | 90.07 | 84.98 | 182.67 | 138.69 | 827.31 | 90.07 | 827.31 |
| MARKETING (B) | 3.54 | 18.00 | 41.72 | 49.85 | 82.07 | 74.87 | 137.80 | 106.54 | 112.93 | 184.25 | 792.38 | 137.80 | 106.54 | 112.93 | 184.25 | 792.38 | 137.80 | 106.54 | 112.93 | 184.25 | 792.38 | 137.80 | 827.31 |
| FINANCE/ADMIN (C) | 14.78 | 50.57 | 123.15 | 156.91 | 192.86 | 143.89 | 227.87 | 191.52 | 295.60 | 322.94 | 1719.69 | 227.87 | 191.52 | 295.60 | 322.94 | 1719.69 | 227.87 | 191.52 | 295.60 | 322.94 | 1719.69 | 227.87 | 1719.69 |
| ADVANCED PROGRAMS & RESEARCH (D) | 0.53 | 0.74 | 1.16 | 1.00 | 1.06 | 1.13 | 1.20 | 1.27 | 1.34 | 1.42 | 0.00 | 1.20 | 1.27 | 1.34 | 1.42 | 0.00 | 1.20 | 1.27 | 1.34 | 1.42 | 0.00 | 1.42 | 0.00 |
| EDUCATION & TRAINING (E) | 0.53 | 0.74 | 1.16 | 1.00 | 1.06 | 1.13 | 1.20 | 1.27 | 1.34 | 1.42 | 0.00 | 1.20 | 1.27 | 1.34 | 1.42 | 0.00 | 1.20 | 1.27 | 1.34 | 1.42 | 0.00 | 1.42 | 0.00 |
| IPEO MANAGEMENT (F) | 0.51 | 0.71 | 1.33 | 1.41 | 1.49 | 1.58 | 1.67 | 1.77 | 1.88 | 1.99 | 0.00 | 1.67 | 1.77 | 1.88 | 1.99 | 0.00 | 1.67 | 1.77 | 1.88 | 1.99 | 0.00 | 1.99 | 0.00 |
| TOTAL (A+B+C+D+E) | 11.24 | 31.93 | 81.43 | 107.06 | 130.59 | 89.02 | 90.07 | 84.98 | 182.67 | 138.69 | 827.31 | 90.07 | 84.98 | 182.67 | 138.69 | 827.31 | 90.07 | 84.98 | 182.67 | 138.69 | 827.31 | 90.07 | 827.31 |
| | 12.22 | 30.16 | 51.78 | 60.29 | 73.14 | 86.40 | 150.24 | 119.72 | 126.90 | 199.06 | 910.39 | 150.24 | 119.72 | 126.90 | 199.06 | 910.39 | 150.24 | 119.72 | 126.90 | 199.06 | 910.39 | 150.24 | 910.39 |
| | 23.96 | 62.09 | 133.22 | 187.35 | 203.73 | 155.42 | 240.78 | 204.70 | 309.57 | 337.75 | 1838.54 | 240.78 | 204.70 | 309.57 | 337.75 | 1838.54 | 240.78 | 204.70 | 309.57 | 337.75 | 1838.54 | 240.78 | 1838.54 |

9.3. Marketing Analysis

9.3.1 The IPEO Marketing Function

The marketing in IPEO is determined by IPEO objectives. The primary objective of IPEO and thus its marketing group is to serve the international environmental interests of its members and the world community. The marketing function in IPEO, therefore, is oriented primarily to serve its Member States and the programs they adopt. However, it has been decided also that marketing will seek to develop additional sources of revenues, as long as these efforts are consistent with its primary objectives. Secondary market and revenue developments are described briefly in this section. These developments are considered as a possible complement to IPEO primary missions and the marketing support for them.

The following sub-sections describe the IPEO market problems, analyze the deforestation needs and the standard products to serve them, describe the marketing organization and staffing, and give an overview of potential commercial markets. The section concludes with a longer term view of IPEO market opportunities and possibilities for cost recovery.

The Deforestation Problem

Although IPEO marketing primarily serves public interests, it must take into account a number of marketing problems that face the use and commercial development of satellite remote sensing. A review of the marketing of remote sensing products and services was performed, and the highlights of this review are presented here.

It is clear that the forestry community needs products from remote sensing to make better decisions. The main area that marketing was asked to answer concerned the problems in the tropical forests. The importance of the deforestation of the tropical forests is high because their existence is endangered. In the case of the tropical forest in Latin America, the region contains more than 57 percent of all the tropical forests and has a very high rate of deforestation.

Brazil contains 30 percent of the world's tropical forest and in this case the rate of deforestation is very high. Costa Rica has the highest rate of deforestation in Central America, with 6 percent per year.

The reasons for deforestation are the increase of population, the increase of agricultural lands in a few hands, the expanding of the agricultural frontier, and the demand for high-value timber. Perhaps the most important reason is the nonexistence of government laws to protect and manage the forest.

The cost of this situation is very high in the long term. Most of the developing countries are dependent directly on their forest products. Deforestation of the watersheds has led to high sedimentation rates which affects water resources. Changes are affecting

the ecosystems, and reduction in the bio-diversity may reduce invention of new foods and medicines.

The only solution in this kind of catastrophe is education to understand, respect and protect the natural resources. For an efficient monitoring of the forest, better information is needed, including the remote-sensing products.

This special market has very high barriers to service. The current economic problems show little possibility of developing countries to secure and provide the funds for this data. Apart from the difficulties of financing a remote sensing mission, even if they have the data they have inadequate information infrastructure that can analyze them and produce the information that they need. All this makes clear that the participation of the developed countries is recommended and necessary, but requires international financing and marketing.

The existence of IPEO will not radically change the commercial market because many of the services already exist. IPEO marketing must try to provide a kind of "public goods" that can respond to the needs of this special market.

Until now perhaps 30 percent of the existing needs are covered by aerial photography. The principal disadvantages of this method of data acquisition is the very high price and difficulty of post processing. The acquisition of imagery with satellite is \$0.18 per area unit instead of \$14.00 per unit cost (RADARSAT Reports). The multinational non-profit characteristics of IPEO can make possible the provision of the data to the nations that need them. At the same time, it must try to cover needs for funding by having an independent segment for selling the data to the non member nations and individual customers.

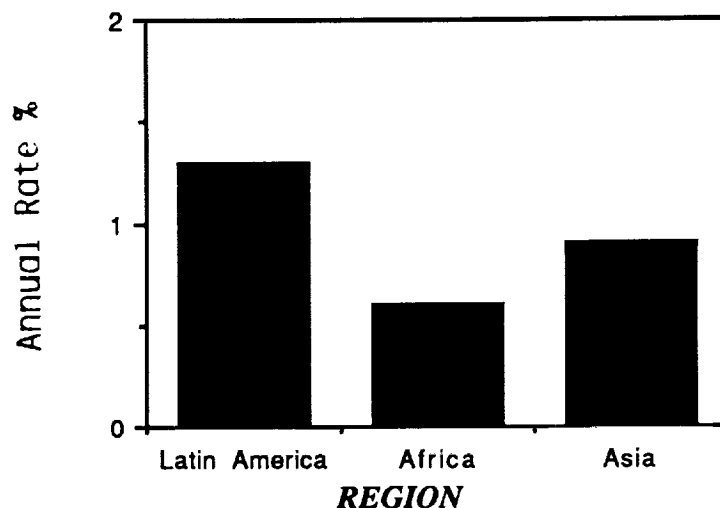


Figure 9.3.1-1 The Rate of Deforestation in the Tropical Forests.

9.3.2 The Deforestation Market

We have seen in Chapter 6 the area of coverage of the deforestation satellite. This geography covers almost 80 million square kilometers of land area. More than 40 percent of this area is covered by forests and wooded land (World Resources, 1987).

The satellite coverage will be available for the entire land areas of over 90 small and large countries. Partial land coverage will be possible over several others (The Times Atlas of the World, 1985). The areas within IPEO satellite coverage are the primary targets of IPEO marketing, the services needed to support these countries and to help manage the local, regional and global scale problems. It is important to point out that the developed countries (which are primarily outside of the IPEO satellite coverage area) are expected to be the most immediate focus of the marketing group. The developed countries have the resources and capabilities to immediately use the deforestation data, and through IPEO, to translate the means to use it to the countries, organizations and managers in deforestation areas.

A parallel marketing task, one which is likely to grow in importance, will be direct marketing with and response to developing countries.

The determination of priorities for acquisition of basic market products is a necessary first marketing step. The process to reach the general priorities for deforestation was described in detail in Chapter 6. Here the marketing team restates and adds several examples that help clarify the priorities of coverage for IPEO satellite data. These examples and priorities include:

- Rates of forest loss and decline are fastest in the tropical forests, the same areas thought to be the most critical areas are of the world's biomass. Experts indicate that the tropical forests need the most timely possible understanding, information and management. Priority 1 should acquire complete data of the tropical forests.
- The shrub and forest fallow areas of the tropics and subtropics are very often associated with deforestation and desertification. Wood resources per capita in Priority 1 and on related areas may be reduced 65 percent by the year 2000 (JRO Topic Map, May, 1986). These areas require immediate attention and acquiring data for shrub and forest areas should be Priority 2.
- The Developed Countries in the IPEO satellite coverage (e.g., parts of the United States and all of Australia) are likely Member States of IPEO and will require coverage data over their forest and related areas. These areas form Priority 3.

- The remainder of the IPEO land coverage would be Priority 4, with priority given to "hot spot" coverage needed anywhere in the monthly satellite coverage repeat cycle of the IPEO satellite.

Table 9.3.2-1 presents the basic product supply and coverage data for the IPEO satellite. The Table is a guide to the basic coverage areas of deforestation products and services for IPEO.

Table 9.3.2-1 Areas Covered by Deforestation Mission (millions of Km², 1985)

| DEVELOPING COUNTRIES | LAND AREA | ESTIMATED FOREST COVER | FOREST AREA | SHRUB, FOREST FALLOW |
|---------------------------------|------------------|-------------------------------|--------------------|-----------------------------|
| AFRICA | 29.7 | 24% | 7.1 | |
| LATIN AMERICA | 20.0 | 46% | 9.2 | |
| ASIA (-CHINA) | 16.4 | 26% | 4.3 | |
| CHINA (80%) | 7.4 | 15% | 1.1 | |
| FOREST SUB-TOTAL | 73.5 | 30% | 21.7 (1) | |
| ALL DEVELOPING COUNTRIES | | | | 10.81 (2) |
| UNITED STATES | 4.5 | 37% | 1.7 | |
| OTHER | 0.9 | 15% | 0.1 | |
| SUB-TOTAL | 5.4 | 33% | 1.8 (3) | |
| TOTAL AREAS | 78.9 | | 23.5 (1+3) | 32.5 (1+2) |

Sources: World Resources (1987), JRO Topic Map (1989), The Times Atlas Of The World (1985).

Table 9.3.2-1 shows some basic features of the IPEO satellite coverage and the size of key areas in need of forest related information. There are 22 million square kilometers of forested area in the Developing Countries covered. There are nearly 33 million square kilometers of forested and scrub-fallow areas in the developing countries covered. A total of about 80 million square kilometers of data will be available from the IPEO satellite, including an increasing number of repeat coverages after Year 1.

The marketing group calculated estimates of IPEO products from Table 9.3.2-1. The method for estimating the basic IPEO product database used the satellite design requirements, which called for the equivalent of one complete coverage of tropical forest area each month of satellite operation. Each IPEO satellite image product is expected to cover an area of about 6100 square kilometers (78x78 kilometers). When compared to the marketing priority areas, the following initial product list results.

| Initial Product Acquisition Priorities | Products |
|--|---------------|
| • Priority 1: Forested Areas of Developing Countries, | 3,600 |
| • Priority 2: Shrub-Forest Fallow Developing Countries | 1,800 |
| • Priority 3: Forested Areas of Developed Countries | 330 |
| • Priority 4: Remaining Land Areas | 7,200 |
| Total | 12,930 |

The marketing group estimates that the IPEO satellite and ground support systems can produce the following marketable products in the first two years of operation.

- During Year 1, IPEO will be able to produce an archive and standard products of all priority deforestation areas and also be able to acquire "hot spot" data .
- By the end of Year 2, IPEO will be able to provide standard products for the entire IPEO satellite coverage area. IPEO should be able to acquire repeat coverages of critical areas, perform special mission acquisitions and begin to offer products and services to non IPEO members and to commercial customers.

9.3.3 Components of the Market

The product that IPEO will provide in the first period of its existence will be the same format as used by commercial companies. The difference will be in the availability of the

data and the zone that will be specially covered by the IPEO satellite . The format of the data is as follows:

- **Computer Compatible Tapes (CCTs) in standard data densities of the raw P-band data. This standard product will serve primarily the scientific and highly advanced users.**
- **CCTs containing IPEO SAR data that is radiometrically and geometrically corrected. This product will serve a broader group of users, since applications data processing and interpretation of the data can proceed without pre-processing the IPEO data.**
- **A CCT time series (i.e., month-to-month, season-to-season) standard product which allows generation of color photo comparisons.**
- **Standard black and white photographic products produced from radiometrically and geometrically corrected CCTs. Marketing will be involved in identifying the initial photo product scales, but believes that the minimum standard photo products should include a small scale "reconnaissance" picture at 1: 400,000 scale and a larger scale photo product at 1: 100,000 scale.**

The only way to obtain a larger part of the market is to create new demands and to provide new services and products to it. A first review of the needs and the information needs makes evident that the existing market can accept a high extension. The area of growth is in the value added services that can transform our data into useful information for our customers (analysis, adding information, interpreting the data received from the spacecraft). To provide the attractive products to members and non-members, IPEO must understand the fundamental needs of the members, trends in related technologies, and future competition. Generally, the IPEO marketing group must determine the needs of the market using an understanding of market-demand and the "competitors".

9.3.4 Marketing Support

A critical marketing function during IPEO start-up will be to verify the user requirements for standard products, to quantify the demand for such products and to see whether the standard products of IPEO should be expanded. User verification will be important because CCT products can be made into "diskettes" for sub-scene areas (and lower cost), and a number of other formats. Similarly, photographic products can be produced at scales ranging from 1:50,000 to 1: 500, 000. The range of "value adding", such as map projections and mergers with other data, is very large. Marketing must work with GIS, GEOD, Operations and other groups to explore the value added potentials of the IPEO data base.

The marketing support for deforestation will reflect political decisions of the members. These decisions are difficult to predict but direct support of member needs will be one of them. The marketing philosophy will be to consider Member States as primary consumers. This philosophy will be borrowed from successful commercial service industries. An example of such a service model would be the IBM customer representative.

The marketing group also must establish close relationships within key developing country research, environmental and development organizations. An important source of knowledge about these contacts will be GEOD. In turn, marketing will be a source of new data for GEOD.

Marketing will reach out to IPEO customers rather than waiting for problems or opportunities to come to IPEO. The early years of IPEO will require especially heavy work on learning new applications in the field. It will also require marketers to coordinate with member commercial remote sensing industries. Overlap or duplication with competitors will be avoided.

It is believed that some areas of forest applications may be valuable not only to IPEO members and recipients but also to commercial users. An example of such a possibility is in management information to support reforestation plantations. The literature (JRO Topic Map, May, 1986) indicates that more than 100,000 square kilometers have been planted in reforestation in tropical areas. Intensive plantation management may benefit from special IPEO services. Marketing must identify such opportunities as part of its activities.

The potential user needs the information for the existence or non existence of the forest (forest off, forest on) . That means that the first need is the monitoring of the deforestation rates and the reforestation monitoring. At the same time IPEO will obtain information concerning the growth of the trees. In the long term IPEO data will help solve the general problems of forest management. Examples of forest management applications follow.

- **Forest Management of the trees: health ; fires ; illness ; and planting**
- **Forest Inventory updating: the road location surveys; the forest site evaluation; reforestation; planting; forest health; soil moisture; and cleaning;**
- **Information needs for monitoring: tree growth; soil composition; effect of natural disasters; and reforestation and deforestation.**

9.3.5 Characteristics of the Market

A preliminary characterization of the market drawn from existing practice reveals the following preliminary findings:

- In this kind of market, IPEO must overcome some important barriers including the economic, the political and the technological aspects.
- The forestry industries and the developed countries are not interested in the processing of the information. They are interested in information ready to use.
- The forestry market is very conservative. They resist paying for new information but they are ready to pay at the moment that data can be proved beneficial.
- The continuous efforts for the education of the market is perhaps the most critical function.
- The sensitivity of the market to the changes of prices is very important. (i.e. price elasticity) Demand decreases when the price increases, especially if there are less costly alternative ways to acquire the data.
- New products and technologies tend to displace current products. This presents an IPEO opportunity. But often, budgets aren't increased to include the expenses for these new products. Surveys show that the non USA market have interest in higher resolution (-10 m panchromatic-SAR and stereo imaging) but be unwilling to pay more for remote sensing overall.

Availability of the data plays an important role in its value. The time that the data are available to users is critically important to some industries. The existing situation is that the current systems often delay the data collection. They do not revisit the same place on Earth more often than approximately every two weeks. A market advantage of IPEO is its capacity to have access to the data without taking in consideration the clouds and the sun.

That means the capacity to provide data without weather problems. In many tropical areas, one or two relatively cloud free images exist after fifteen years of LANDSAT operation.

9.3.6 The IPEO Marketing Group

The marketing group consists of two segments, the Product and Services Distribution Group and the Market Analysis Group, as shown in Figures 9.3.6-1 and 9.3.6-2.

9.3.6.1 Product and Services Distribution

In this department one manager is needed who, with the cooperation of four persons will be responsible for the distribution of the product and the services. Their task is to advise customers and the members as to location and provide the services to them. All of them will be employees of IPEO .

9.3.6.2 Market Analysis

In this department one person will be the contact with a consulting and management office that will be responsible for the analysis of the market for the first three years. After these years the market analysis will pass to IPEO control. The economic agreement between the IPEO organization and the Consulting And Management Office will be a yearly renewable contract.

We consider that this will cost \$250,000 for each year for the market analysis. After three years the IPEO will have the possibility to continue the market analysis to develop new needs of the market.

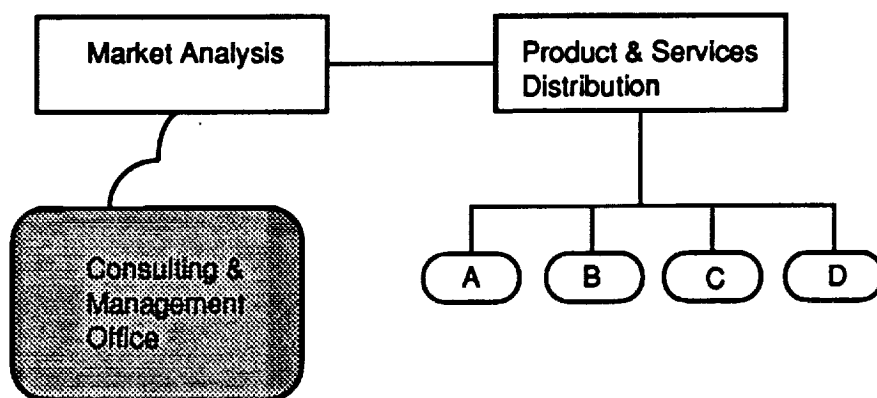


Figure 9.3.6-1. Consulting and Management Office.

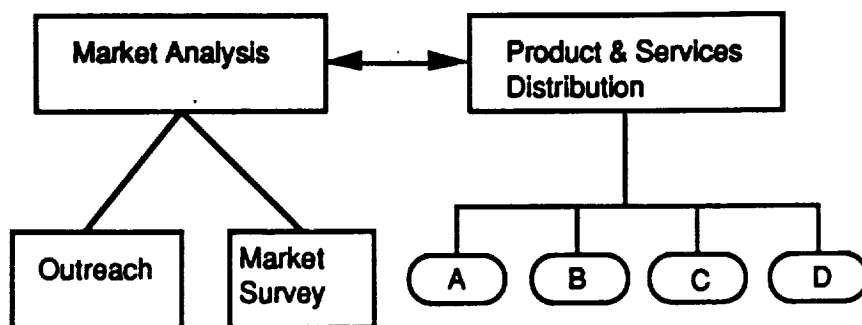


Figure 9.3.6-2. Functions of the Market Analysis Group.

9.3.7 Commercial Markets

9.3.7.1 A Structure of Markets

This subsection analyzes the market problem from several theoretical and practical perspectives : structure, competition, segmentation and forecasting.

Generally speaking, it is important to analyze the competitive sources of the industry when thinking about the new entrance to an industry. Formulating competitive strategy is one of the most important keys to success. Fig 9.3.7-1 shows the general state of competition in a remote sensing industry.

The arrow from [Suppliers] shows bargaining power of suppliers who may threaten to raise prices or reduce the quality of the products. The arrow from [Users] shows bargaining power of buyers which may force down the prices or require higher quality. The arrow from [Substitutions] shows pressure from substitute products.

There is one more arrow from [Potential Entrants] which shows the threat of new entrants. These threats are not critically important for IPEO because it is an intergovernmental organization. However, market planning by IPEO may benefit from a market estimate of existing and planned commercial systems.

From this general approach (Fig 9.3.7-1), LANDSAT, SPOT, JERS-1, etc. are listed as competitors with IPEO. This is true if the short term goal of IPEO is considered - deforestation. In this case IPEO has only its own satellite as its data sources.

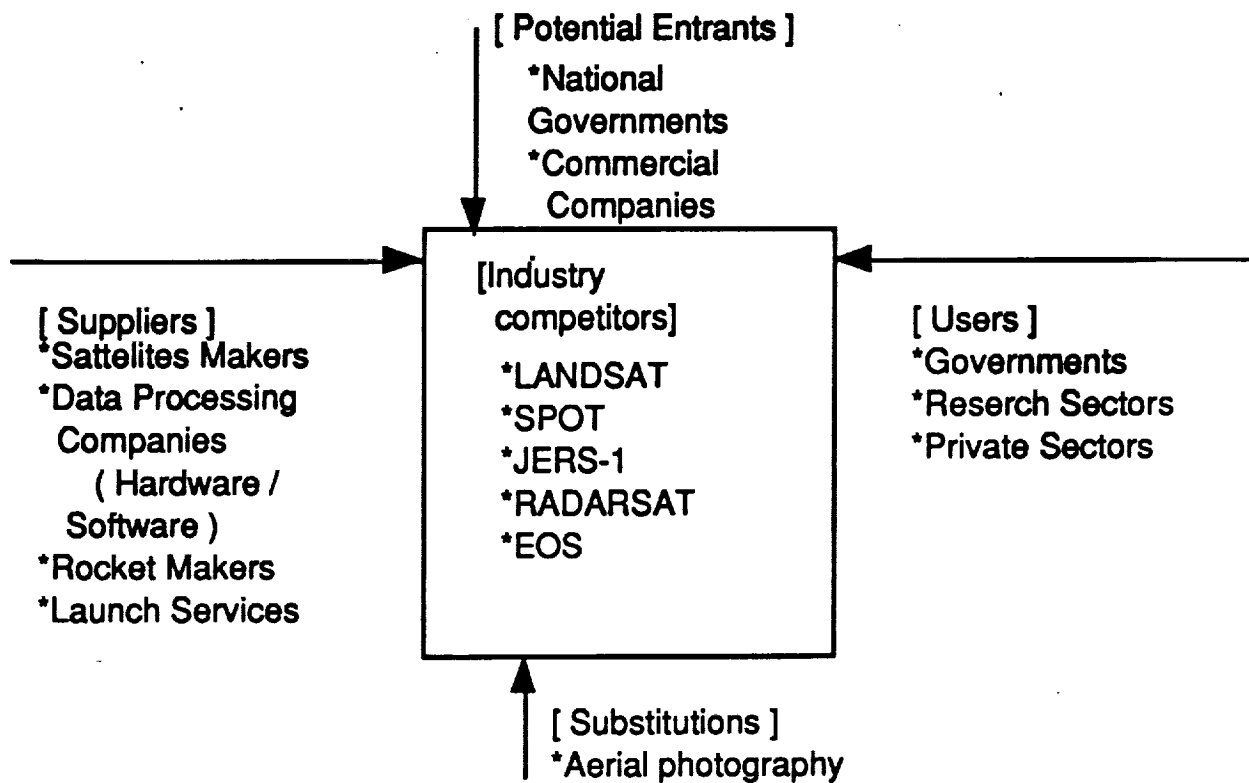


Figure 9.3.7-1 Earth Observation Industry Model

To analyze the whole IPEO, analysis focuses on the data processing and distribution function of IPEO. From this point of view, one describes the value system of the whole IPEO as Fig 9.3.7-2. In this figure, two things are emphasized.

- 1) LANDSAT, SPOT, etc. are no longer the competitors, but the data suppliers which are parallel to IPEO satellite data.
- 2) Governments which invested in IPEO can be one of the data distribution channels. Thus, many governments can get the data as a result of IPEO membership.

This analysis suggests that the idea of a no competition approach is one of the important keys to success of IPEO.

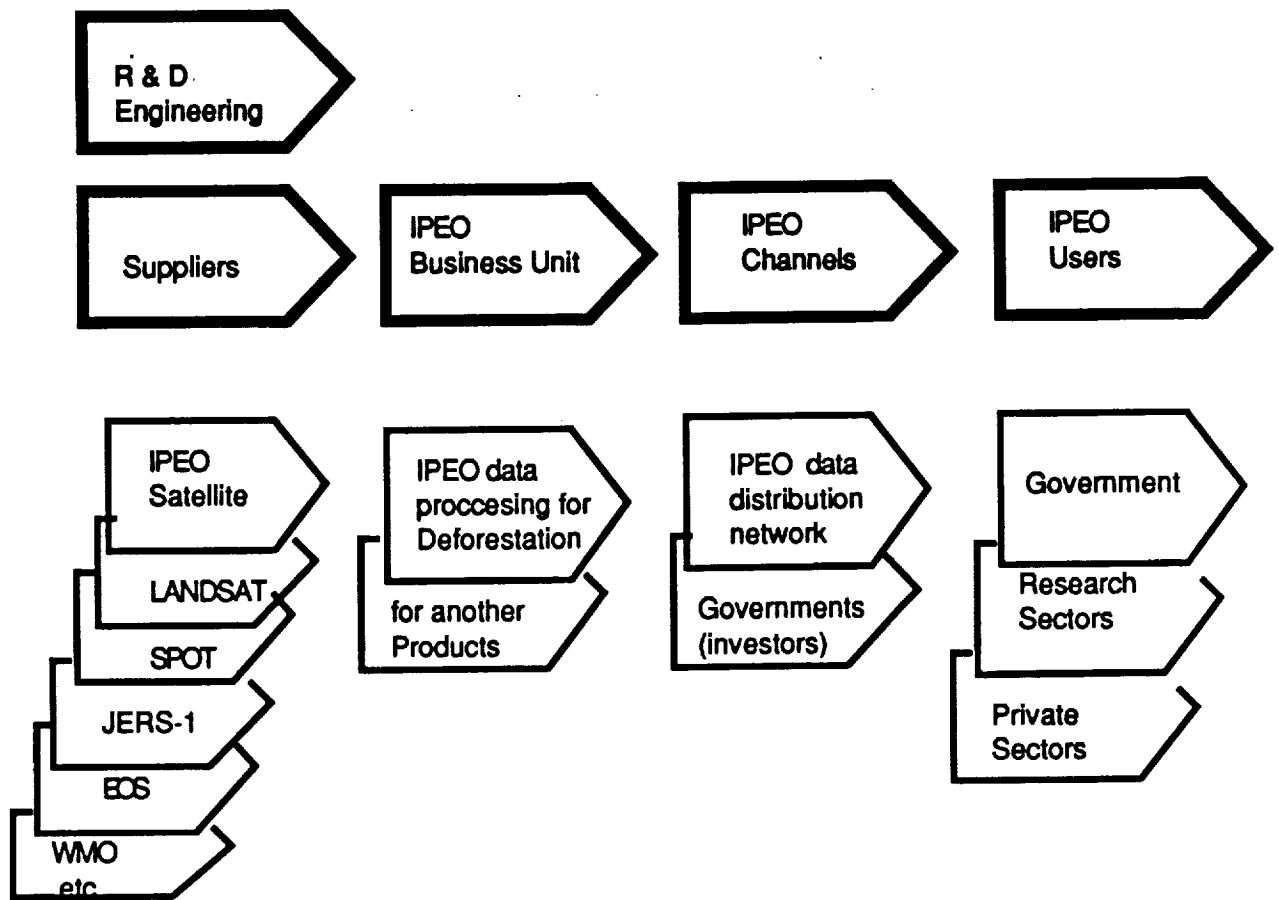


Figure.9.3.7-2 The Value System of IPEO

9.3.7.2 Segmentation of Products

It is very important to determine the products of IPEO, politically and commercially. In order to encourage every nation in the world to participate in IPEO, it is better that every nation become the user and get benefit from IPEO products. Here is introduced a concept of segmentation of products as one of the approaches to determine the IPEO strategy.

For example, we showed the area of IPEO deforestation products in section 9.3.4. This is a geographical segmentation of the products. We know that users are specialized in the countries within 38 degrees of the equator.

Listed are examples of other parameters of segmentation that should be undertaken by the IPEO market analysis function.

- a) Geographical
- b) Developed / developing
- c) Governmental / private
- d) Delivered by existing organization /or not
- e) Sources of information
- f) Type of data (analyzed / processed / raw)
- g) Frequency of request
- h) Commercial / non-profit

Parameter d) is discussed in the chapter on policy, and parameters e, f, g, h are discussed in the chapter on GIS applications.

9.3.7.3 A Composite Forecast

Kodak estimated a market profile for a LANDSAT follow-on from 1988 to 2000 in its 1987 report to the U.S. Department of Commerce. Based on this report, an attempt is made to estimate the growth of the overall data market. From this estimate, a very rough idea of IPEO market potential can be made.

In order to estimate the whole market, the amount of SPOT sales, which are approximately the same as LANDSAT, are added to the LANDSAT total. These combined amounts are listed on the left side of Figure.9.3.9-3. Conservative estimates were made of the market growth induced by JERS-1 ('92 Japan), RADARSAT ('94 Canada), ADEOS ('95 Japan), TRMM ('96 USA & Japan), and EOS ('97 USA). The total amounts of each year are listed on the right side of Figure.9.3.9-3.

It is difficult to estimate the share of data markets made by new satellites. But the data listed in Figure.9.3.9-3 is evaluated based on the following ideas.

JERS-1 will be launched in 1992. The share of the first year will not be high (5 percent). The next year it will grow rapidly (15 percent). The life time of JERS-1 is 2 years, but after 1993, sales from the archived data will still get the same share (15 percent). In 1994, ADEOS will start its sales (5 percent). Then the amount of share by new (except LANDSAT & SPOT) satellites is accumulated to 20 percent. Each ratio in Fig.9.3.9-3 is estimated in this way.

IPEO will begin its sales in 1999. If the market share of IPEO is supposed as listed in Figure.9.3.9-4, we could project the amount of IPEO market opportunity for data products only.

LANDSAT
& SPOT (M\$)

THE WHOLE
MARKET (M\$)

| YEAR | L. & S. | NEW SAT. | Ratio | TOTAL |
|------|---------|----------|-------|-------|
| 1988 | 182 | | | 182 |
| 1989 | 197 | | | 197 |
| 1990 | 216 | | | 216 |
| 1991 | 228 | | | 228 |
| 1992 | 246 | JERS-1 | 5% | 267 |
| 1993 | 259 | | 15% | 297 |
| 1994 | 272 | RADARSAT | 20% | 327 |
| 1995 | 287 | ADEOS | 20% | 344 |
| 1996 | 301 | TRMM | 30% | 391 |
| 1997 | 315 | EOS/EOP | 40% | 441 |
| 1998 | 331 | JPOP | 40% | 463 |
| 1999 | 346 | IPEO | 45% | 502 |
| 2000 | 363 | | 50% | 544 |
| 2001 | 381 | | 50% | 572 |

Figure.9.3.7-3 Total market profile

IPEO

| YEAR | SHARE | MARKET |
|------|-------|--------|
| 1999 | 1% | 5 |
| 2000 | 4% | 11 |
| 2001 | 5% | 23 |

Fig.9.3.7-4 IPEO market profile

We plot the possible whole market for data in Figure 9.3.9-5. For the long term goal of IPEO, we estimate the amount in 2009 (10 years after IPEO first launch) by extending the line along the curve. But this approach is not so accurate, because this curve is based on many assumptions, beginning with the sales of LANDSAT & SPOT, and after 2000, the situation of the remote sensing industry is expected to be quite different from today.

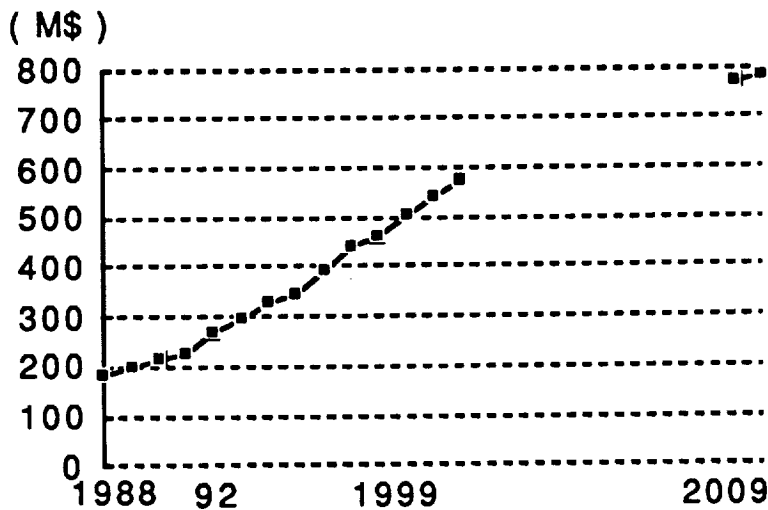


Figure 9.3.7-5 Total market profile

9.3.8 Discussion

The ability to finance IPEO will depend not only on political issues but also on the severity of the financial risks. In the remote sensing industry, there are many risks. For example, there is risk that the utility of remote sensing data for use in many applications is still unclear or unproven. But here is discussed the risks from the marketing point of view which relates only to the agenda in this section.

If IPEO tries to compete with other existing remote sensing organizations, the risk would be losing market share to competitors. However as mentioned above in market structure, IPEO should take the no competition approach. In this case we have to consider the risk that a market will not exist for the service provided by IPEO. The effort of user education is one of the strategies to avoid this risk.

The products of IPEO are segmented by various parameters. But IPEO has to provide the products for world wide use. In the case of IPEO, therefore, the costs of the following are assumed as risks.

- R & D for new products;
- Production of various products;
- User promotion; and
- User education.

9.3.9 Conclusions

This section has set forth the problems and preliminary directions of the IPEO marketing function. It has developed some further quantification of the scope and nature of the deforestation issue, and defined the buildup of a standard product archive. From the perspective of IPEO advanced planning the marketing task has been defined and warrants several conclusions.

- Marketing is a legitimate and necessary component of IPEO. It has yet to be fully defined, but at first will give priority to sponsoring member services.
- Regardless of the eventual IPEO structure and funding, its members are likely to look at marketing to, at least, reduce the annual operating costs of the organization. The marketing function may shift only from assuring member services and development of standard products, to advanced product and service development. The diversification (segmentation) of markets is likely to become more important.
- Marketing in IPEO in its first years may be similar to the earlier operation of the Earth Resources Observation System (EROS) Data Center, a U.S. government facility that sold Landsat products. The EROS Data Center was able to recover less than 20 percent of its annual

operating costs through the sale of data products. A lecturer estimated that SPOT Image returns something of the order of 10 percent of the total costs of the SPOT system. The marketing approach recommended here, as with SPOT, takes an active stance toward treating Member States as true customers, aggressively reaching out to the commercial community and seeking to create new demand.

Reliable estimates of market opportunity for IPEO are not possible today because of internal and external uncertainties. Although heavily burdened with assumptions, the analysis of 9.3.9 indicates that such opportunity may be important. By extrapolating from Landsat forecasts by Kodak, adding SPOT and planned satellite data systems, and making conservative estimations, world data markets are projected to exceed \$500 million by 1999. One to two percent of this estimate results in \$5 to \$8 million. Can IPEO marketing achieve a 5 or 10 percent (~\$25-\$45 million) share? Such a marketing objective is feasible.

Thus, marketing also concludes that IPEO introduces severe constraints to revenue recovery strategies, but that the further development of such strategies, whether based on past government or commercial models, is money well spent.

9.4 Financial Structure of IPEO and Sources of Financing

This section outlines an approach to the financial structure of IPEO as an organization. Since the goals of the program are essentially environmental in nature, most of its funding will result from member nations. The proposed model allows for some private funding. The degree to which member governments will contribute to IPEO, as well as the involvement of the private sector in funding IPEO, will be described.

9.4.1 Review of Funding of Similar International Institutions

Similar international institutions were reviewed in order to provide a framework for describing the IPEO financial structure. The review included the Intelsat model, the model of the European Space Agency and Eumetsat.

9.4.1.1 Intelsat

Each signatory has an investment share equal to its percentage of all utilization of the Intelsat space segment by all signatories. No signatory shall have an investment share of less than 0.05 percent of the total investment shares. Each signatory makes contributions to the capital requirements of Intelsat in proportion to its investment share and receives capital repayment and compensation for use of capital if the revenues earned by Intelsat allow it. The revenues are distributed using the following order of priority:

- To meet operating, maintenance and administration costs;
- To provide such operating funds as the Board of Governors may determine to be necessary; and
- To pay to signatories.

It is interesting to note that, the shares are becoming less and less expensive; and Eutelsat and Inmarsat have the same financial structures.

9.4.1.2 European Space Agency (ESA)

ESA has two kinds of programs, mandatory programs and the optional programs. Mandatory programs include science, administration, the Guiana space center and technology and development. Optional programs include telecommunications, the space station, microgravity, space transportation, and operational satellites. Each of them has different funding methods.

The total average investment per member is 0.04 percent of the Gross National Product (GNP), but greater contributions are allowed (France invests 0.11 percent of GNP).

9.4.1.3 Eumetsat

The expenditures of Eumetsat are covered by the financial contributions of the Member States and by any other Eumetsat incomes. Each Member State pays to Eumetsat an annual contribution in convertible currency on the basis of the following scale.

| Member State | % |
|----------------|-------|
| Germany | 21.00 |
| Austria | * |
| Belgium | 4.00 |
| Denmark | * |
| Spain | 4.50 |
| Finland | 0.30 |
| France | 22.00 |
| Greece | * |
| Ireland | * |
| Italy | 11.00 |
| Norway | 0.50 |
| Netherlands | 3.00 |
| Portugal | 0.30 |
| United Kingdom | 14.40 |
| Sweden | 0.93 |
| Switzerland | 2.60 |
| Turkey | 0.50 |

*Figures not available

The World Meteorological Organization (WMO) has the same principles of funding as Eumetsat. The expenditures of the organization are apportioned among the members of the organization in the proportions determined by the World Meteorological Congress.

9.4.2 Funding Requirements

The IPEO organizational structure has been defined in Section 4.3. For each area of the organization, a projected cost has been described, as shown in section 9.2. In order to determine the sources of financing for the IPEO program it is necessary to highlight the different areas for which financing must be found. These are:

- **Space segment :**
 - satellite
 - launch
- **Ground segment :**
 - data distribution network
 - archiving facilities
- **Operational infrastructure :**
 - buildings
 - personnel
- **Services :**
 - research
 - education
- **Products :**
 - GIS
 - GEOD

Use of these facilities applies to both mandatory and optional programs and therefore constitutes the investment financing and financing for incurred interest repayments on the investments, operating costs and distribution costs.

9.4.3 Financial Structure Options for IPEO

This section describes the possible general financial structures envisaged for an international organization involved in large scale projects such as IPEO. The level of funding required for such a project necessitates consideration of the degree of government financing for IPEO. The following three options were considered:

- 1) Purely private funding with fully commercial activities, a corporation.
- 2) Hybrid structure - government funding with commercial activities that is, a state owned enterprise; to private funding without commercial activities, that is a non-profit, philanthropic organization.
- 3) Purely government funding with no commercial activities, for example, public welfare assistance.

These options are represented in Figure 9.4.3-1 below.

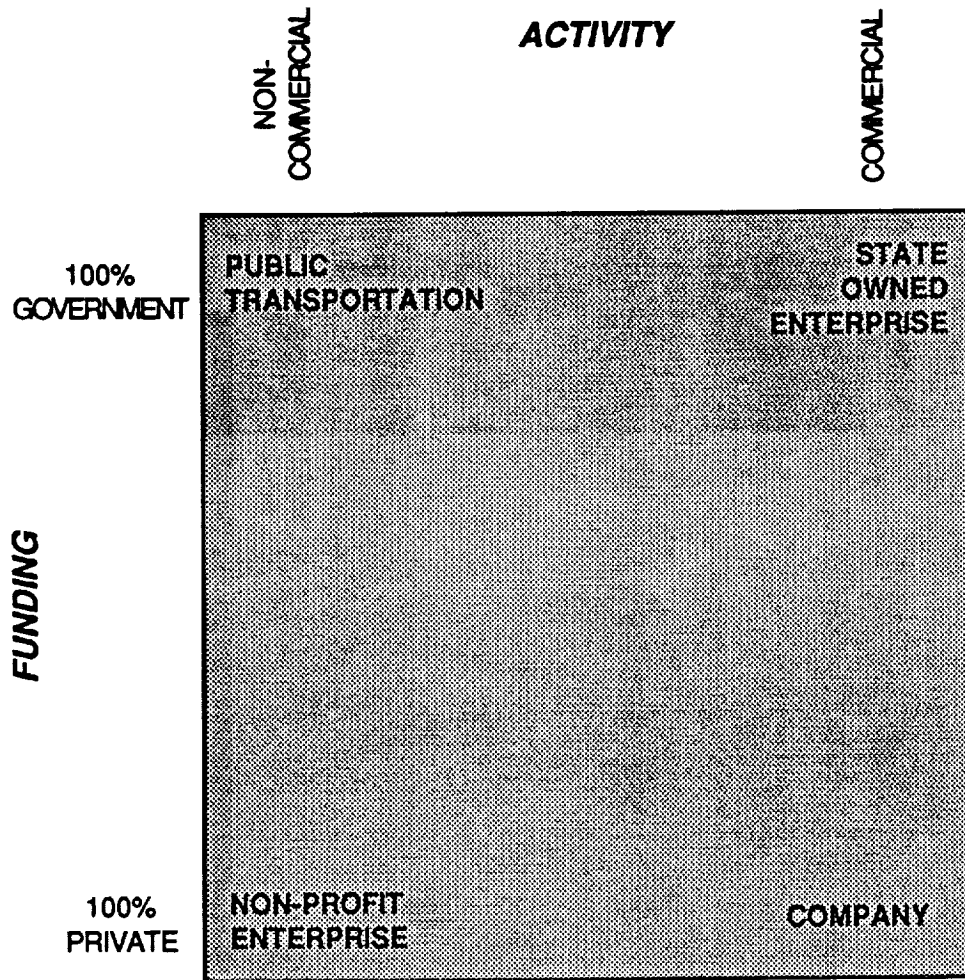


Figure 9.4.3-1. Funding and Activities of Typical Organizations.

The relevance of each of these scenarios to IPEO is governed financially by the potential private sourcing of space projects. Conventional space projects are often too high a risk and offer too little return on investment to be considered by financial institutions. It is considered that the IPEO program too would not provide sufficient return on investment in the early stages of the program. It is therefore not considered viable to begin with a purely privately financed institution, and will therefore not be considered in more detail in this document. Even a partially privately funded institution does not seem to be a relevant option at this stage. However, it is worth noting that as IPEO develops and increases its market over the next 20 plus years the potential for private financing may progress with more of the individual sub-sections of the IPEO program areas and products being able to run on a commercial basis. This assumption is based purely on financial considerations and does not integrate political and institutional ideals.

Between the two extreme scenarios for the financial structure, (a) and (c), there is a wide spectrum of possible hybrid financial structures based upon the percentage of government funding coupled with the percentage of commercial activities (or 'revenue enhancement' or 'sales'), as shown in Figure 9.4.3-1 above. It has already been identified that at the present time the likelihood of any private funding for the IPEO is insignificant and therefore the funding will be provided by governments as shown in Figure 9.4.3-2. In order for the IPEO organization to be as successful as possible, it is necessary to utilize to the fullest extent any revenue enhancing or commercial activities. However, this must not be to the detriment of the IPEO goals and therefore has a restricted horizon.

Over the the next 20 years the potential commercial market for IPEO products may develop, as shown by curves (1) and (2) on Figure 9.4.3-2. It is also possible that the potential for private funding will increase over the next 20 years and should the organizational philosophy of IPEO allow for this extra funding, the scenario of curve (2) may be more applicable.

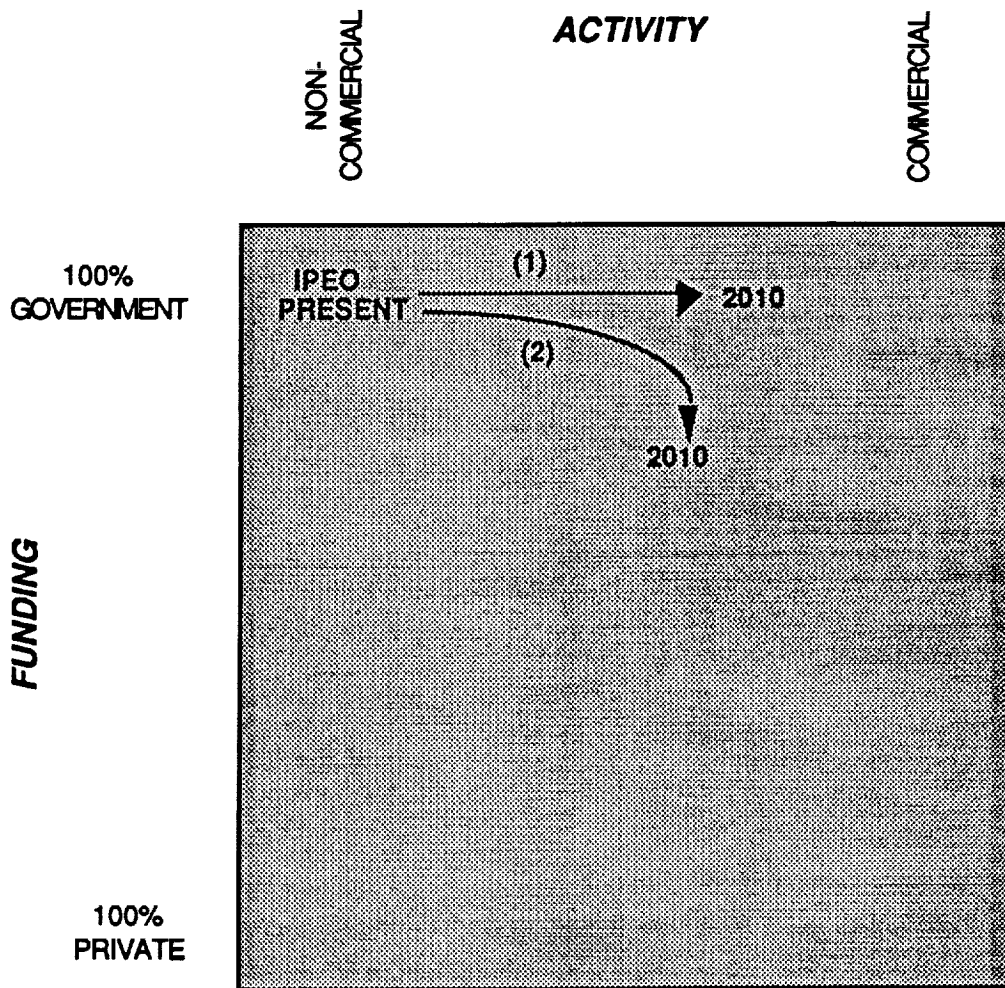


Figure 9.4.3-2. Funding and Activities of the IPEO Organization
 9.4.4 Selection of Financial Structure

The IPEO organization is selected to have a hybrid financial structure, that is, government funding with a small amount of revenue enhancing activities. The financing requirements for the organization in terms of operation and of individual programs is detailed in Section 9.4.5. The top level financial structure consists of the following two sections :

- a) The global primary program. This addresses the financial structure required for the IPEO long term goal, that is, the advancement of global environmental understanding.
- b) Revenue Enhancement Section. Examples within this section are:
 - Country specific requests, for example, a country which requires information about a particular area within its nation using the IPEO global primary program infrastructure but which needs additional processing; and
 - Requests from commercial bodies from both member and non-member nations.

Within this structure it is necessary to identify where the mandatory and optional programs of IPEO manifest themselves in financial implementation. This is based on legal, political and user requirements as well as financial considerations.

A mandatory program is primarily encompassed by (a.); the global primary program. Data from these primary programs are available to member nations. If a non-member nation wishes to benefit from IPEO using these data, then a price must be paid for the data. The price will not be too high, so IPEO can benefit from the analysis done in of non-member nations institutes using IPEO data, but will be such that it is attractive for non-member nations to become a member of the IPEO program. This essentially only applies to non-commercial entities. If a commercial body wishes to acquire data then this will be a revenue-enhancement item. Exceptions to this rule may occur if a commercial body requires IPEO data or services for a program which is in line with the IPEO primary goal. Thus, mandatory programs can be funded through both levels, (a) and (b), of the financial structure.

An optional program is funded by the member nations who are interested in that program. It is difficult to distinguish financially the mandatory and optional activities for the following reasons: free data access, non-funding members have the same rights and access; and optional activities use the same infrastructure, due to the problem of cost allocation.

Possible solutions to this are to set a high price for non-participating countries or consider optional programs donated to IPEO.

The way that optional programs are consolidated in IPEO has some financial consequences. These will be discussed in more detail in section 9.4.5.2.

There are essentially two areas of funding from member nations which are relevant to any program: investment and operating costs.

It is necessary to set a level of required funding for this total - investment and contribution. This level of funding is described in section 9.4.6 and the division of payment of these funds into investment and contribution is discussed in section 9.4.5.

Within the IPEO model, once the revenues flowing from commercial activities are determined then the total funding requirements are known.

9.4.5 Investment and Contributions

9.4.5.1 Financial Implementation Concept

This section develops a conceptual accounting mechanism for consideration by IPEO, which has the following outputs: Government funding requirements; and IPEO resource allocation.

The main idea behind the accounting mechanism is that IPEO has some scarce resources which have to be distributed amongst its investors with regard to investment and utilization of IPEO services and products.

The inputs needed for this accounting mechanism are:

- Cost of the IPEO programs split into Investment and Operating costs;
- Commercial revenues;
- Marginal costs to perform the commercial activities; and
- Interest rate.

We assume here that non-commercial sales will not generate extra financial revenues. Sales within the "non-commercial" sense must be defined more clearly. Such sales relate to the method in which IPEO handles non-commercial transactions. In the following description, we assume that the Member States want to use IPEO and that after the governments pay for IPEO, their research institutes are not required to pay for the IPEO products and services.

The Member States have a double role in this process. They are both owners and clients of IPEO. In the owner role they play the role as investor or banker, whose aim it is to have a return on this investment. At the same time, they want to promote the use of IPEO products and services by institutes and researchers within their country.

Member State contributions are broken into two distinct sections:

- **Capital investments.** In, for example, a network, satellite, infrastructure, or building. This is the bankers function.
- **Operational contributions,** for example, salaries, depreciation. This is a customer function.

An IPEO accounting unit could be adopted and called a **Global Accounting Unit (GAU)**. This is based on a basket of the currencies of the Member States, similar to the AU's used by ESA. The way the GAU is determined is not crucial for the accounting mechanism and will not be further discussed here.

9.4.5.2 A Step-By-Step Guide to The IPEO Accounting Mechanism

Using a simple, fictitious example, the following shows how the IPEO accounting mechanism could function. IPEO investments and operations are outlined for two years, Year 0 and Year 1. In this example, all investments are made in Year 0 and all operation costs are incurred in Year 1. In practice, the two operations may occur in the same year. It is assumed that IPEO will be an ongoing institution.

Step 1: Assess Investment

The first step within IPEO operations is to assess the required investments. In this example, the planned organization requires an initial investment of 100 in year 0. Three countries raise the money for IPEO, countries A, B and C. Their initial investments are as follows:

Country A = 50
 Country B = 30 => INV = 100
 Country C = 20

The amounts paid by the three countries here relates to their GDP, and will be discussed in more detail in section 9.4.5.

Interest rates are introduced:

$i = 10\%$

In year 1 the interest on the investments of the countries is:

Country A = 5
 Country B = 3 => INT = 100 x 10% = 10
 Country C = 2

Step 2: Assess Operating Costs

The second step is to assess the operating costs. In year 1 the operating costs are assumed to be:

$$OC = 50$$

Step 3: The Commercial Gross Margin

Estimates of non-contributed revenue gained by marketing, are then calculated. In year 1 the following revenues from commercial activities are forecast:

$$REV = 25.$$

The marginal costs incurred in order to perform these activities are:

$$MCC = 5$$

Thus:

$$GM = REV - MCC = 25 - 5 = 20$$

Step 4: Assess the Yearly Contribution

There is a gap between costs and revenues, which will lead to a need for a contribution of the Member States in the operating costs. The basic assumption here is that IPEO is a non-profit organization (that is, it has no aim to maximize shareholder return). Thus, the contributions plus the revenues must equal the total costs.

$$\text{Operating cost} = OC = 50$$

$$\text{Marginal costs commercial} = MCC = 5 \quad \Rightarrow \quad \text{Total Cost} = TC = 65$$

$$\text{Interest} = INT = 10$$

$$\text{Revenues} = REV = 25$$

Therefore:

$$REV - TC = 65 - 25 = -40$$

This means that after paying interest to countries IPEO shows a loss of 40 in year 1. However the aim of the initial investment in IPEO was not to get a financial return on the investment, but to contribute to the solution of environmental problems. Thus, at this stage

of the calculation one can determine the real financial contribution of the member nations in IPEO. (Thus far in the example, member nations have not given money to IPEO, but instead made an investment with a fixed return.) Member nations will contribute to IPEO in two ways. First, they will keep the interest on the money in IPEO, so IPEO does not have to pay the interest to the investing nations. Second, the member nations will contribute to IPEO operations. This contribution of the states will be "consumed" by IPEO in the year it receives the contribution. So:

$$\text{Participation} = \text{interest} + \text{operational contribution}; \quad \text{PART} = \text{INT} + \text{OPCONT}$$

$$40 = 10 + 30$$

So countries A, B and C must pay 30 in Year 1 for the IPEO operations. Now assume that this breakdown is different from the one used for the investment, but this assumption is not necessarily fixed. The origin of the amount of the contribution is again GDP related.

$$\begin{aligned} \text{Country A} &= 10 \\ \text{Country B} &= 10 \Rightarrow \text{OPCONT} = 30 \\ \text{Country C} &= 10Y \end{aligned}$$

Step 5: Breakdown of the Participation of Country A, B and C in Year 1

There is now a basis to calculate the participation of a country as a percentage of the total contribution in year 1. The total participation of a country is defined as the sum of the interest payment and the operational contribution.

$$\begin{aligned} \% \text{ PART A} &= (\text{OPCONT Country A} + \text{interest country A}) / (\text{Total part A, B, C}) \\ &= (10 + 5) / 40 = 15 / 40 \Rightarrow 15 / 40 = 37.5\% \\ \% \text{ PART B} &= (\text{OPCONT Country B} + \text{interest country B}) / (\text{Total part A, B, C}) \\ &= (10 + 3) / 40 = 13 / 40 \Rightarrow 13 / 40 = 32.5\% \\ \% \text{ PART C} &= (\text{OPCONT Country C} + \text{interest country C}) / (\text{Total part A, B, C}) \\ &= (10 + 2) / 40 = 12 / 40 \Rightarrow 12 / 40 = 30.0\% \end{aligned}$$

Now can be expressed the participation of the three countries in terms of percent of GDP. Suppose that:

$$\begin{aligned} \text{GDP country A} &= 300,000 \Rightarrow \text{IPEO} = 15 / 300,000 = 0.005 \text{ percent of the} \\ &\quad \text{GDP of country A} \\ \text{GDP country B} &= 130,000 \Rightarrow \text{IPEO} = 13 / 130,000 = 0.01 \text{ percent of the} \\ &\quad \text{GDP of country B} \\ \text{GDP country C} &= 150,000 \Rightarrow \text{IPEO} = 12 / 300,000 = 0.008 \text{ percent of the} \\ &\quad \text{GDP of country C} \end{aligned}$$

Here it should be noted that the determination of the contribution and the investment as a percentage of the country's GDP is a highly iterative and also political process. One can calculate the requirement for funding in terms of GDP, but the realization depends on many additional factors.

Step 6: Distribution of GAU's Amongst Member States

IPEO could use the accounting units to measure the usage (consumption) of IPEO products and services by the Member States. A Member State purchases these products and services with GAU's. The way GAU's are distributed amongst the Member States is a political decision, made by the Board. Considering the nature of the activities of IPEO, there may be no explicit relationship between Member States contribution and GAUs. However, there will be an implicit relationship between the two. This is because of two reasons. The first reason is that large countries have more capacities to use IPEO data. The other reason is that countries investing in IPEO already showed their commitment to IPEO, and therefore will also want to use the system they created. Here it should be noted that the non-commercial use of IPEO implies that Member States will incur more costs (that is, a university using IPEO data). This is because the research and analysis done with IPEO data will consume time and money at the universities and institutes using IPEO data.

The following are examples of how GAUs could be distributed. The choice of whether and how GAUs will be used will be made by the Board of IPEO:

- Equal for each member;
- Decided by the Council;
- On request of Member States;
- Fixed amount for categories (e.g. small, medium and large); and
- Related to contribution.

Before continuing it is important to know which of IPEO's resources may be scarce. Typical scarce resources are computer or CPU time, radar "on-time" from the deforestation satellite, CCT tape, and services. Some of IPEO's resources are not scarce (other than for practical technical reasons), such as access to a database.

The next step is to decide what the maximum capacity of IPEO is to provide for the scarce resource.

The final step is to determine a price (in GAUs) for each item. This again is a political decision, and allows for freedom in managing IPEO. Prices for GAUs could be set according to free market principles (supply and demand) but this seems unlikely in IPEO. Price can be regulated in order to stimulate the use of certain data. An innovative approach could even be to charge a negative price (that is, subsidize) for certain products. This for example is in the case of data which requires extensive research which is badly needed. The

drawback of any regulated pricing system is that it creates tensions. If some products are too cheap, everybody would want to buy this product with their GAUs. IPEO might run out of this product (for example the computer could be oversubscribed). Relatively costly products might then be underutilized. This system will signal the Board which products and services are 'scarce', and they then can try to increase the capacity.

In our conceptual example we have:

| Item | Capacity | Price (GAU) | Volume (GAU) |
|-----------------|------------|-------------|---------------|
| CPU time | 3000 h | 1 | 3000 |
| Radar-on time | 1000h | 6 | 6000 |
| Man Years | 50 years | 600 | 30,000 |
| CCT | 5000 tapes | 0.2 | 1000 |
| Database access | unlimited | free | 0 |
| TOTAL | | | 40,000 |

A total of GAUs, 40,000 , are available to allocate. Distribution amongst three example Member States is decided to be the following:

Country A: 14,000 GAU
 Country B: 13,000 GAU
 Country C: 13,000 GAU

We put in the limitation that a GAU can only be spent in the year it is issued, and will lose its value the next year.

9.4.5.3 Aspects of the IPEO Accounting Mechanism

The accounting mechanism concept provides two methods for Member State contribution: through investment and through operational contribution. This division of payment of funds from member nations is flexible. For example a nation (A) with a surplus of funds can put all money into IPEO as an investment with no extra contribution. However a nation (B) with no surplus of funds may simply pay a contribution towards operations equivalent to the interest of nation A's investment.

A possible problem with this flexible approach can occur if the total required investment for the IPEO mandatory programs is not obtained because all member nations decide to pay IPEO in the extreme by contributions. An active role of the Board of IPEO to avert this situation by a political resolution would need to be employed. It is necessary to

require a long term (say, five year) budget policy from member nations to provide consistency, although this would be very difficult to enforce.

With the interest rate used IPEO has a tool to appreciate investment. If it wants to favor and attract investors it can use a high percentage, say, the risk free rate plus 2 percent. If it wants to penalize investors it can use a lower percentage, say the risk free rate less 2 percent.

As described in the previous section, an optional program can be integrated fully into IPEO. This will dilute the percent participation of the non-funding, (for the optional program) other member nations. For example:

A total of 100 is provided by nations A and B for a mandatory program as follows:

A=50 => $50/100 = 50\%$ participation

B=50 => $50/100 = 50\%$ participation

If additionally B provides funding for an optional program of 100 then :

A has $50/200 = 25\%$ participation

B has $150/200 = 75\%$ participation

Another important aspect is that IPEO will create a situation where both user and supplier are aware of the value of the product offered. If IPEO were to give its products and services away, it would create a different relationship between both parties ('do not complain user, this is for free, so take it or leave it!'). The situation where a customer has to pay will result in a situation of 'customer king', and IPEO will try harder to match its products and services with demand. At the same time the client (user) will value the IPEO products, and thus use them more effectively.

As mentioned before, the accounting mechanism is used for the larger non-commercial activities of IPEO. The board must set the priorities for IPEO in accordance with its goal, that is, dedicating enough of its resources to its core activities. However, certain products and services offered by IPEO will also attract commercial interest. The revenue generated with these activities can very well be used to support the core activities. The Board will every year decide which of its products and services are in each category of product. For all products and services offered by IPEO there are in principle four different pricing classes possible.

1. Products and services for which one only can pay in GAUs; that is, explicitly non-commercial.
2. Products and services with a GAU and a dollar price (that is, it can be paid for either in GAUs or in dollars). This is useful in both a commercial and a non-commercial environment.

3. Products and services which are paid for in GAUs and dollars. This could be a computer-compatible tape, with dollars to cover the cost of the tape, and GAUs for the data.
4. Dollar only products and services. That is, purely commercial.

Another dimension is the pricing policy for non-Member States. They can only pay in dollars, but they might be charged a different price than Member States.

It should be noted here that for both users or clients, continuity of a certain product or service is very important. This should be an important guideline for the Council while allocating resources to either category. The advantage of this structure is that it is dynamic, that is, it can adapt in a changing environment, which is likely given IPEO's long term plans. In almost every study about the future of the remote sensing segment, it is foreseen that the commercial interest will grow. With this structure, IPEO will be able to serve both the commercial and the non-commercial user.

9.4.6 Financing of IPEO

The bulk of IPEO financing will result from yearly contributions by member nations of IPEO. Countries become members of IPEO with the aim of supporting the long-term goals of IPEO. Simply stated, they expect to benefit from international cooperation in the area of environmental issues. The amount of contribution required by these nations will now be outlined.

9.4.6.1 Publicly Funded Sources

Government funds can be acquired in three ways, as shown in table 9.4.6.1-1. The first method is based upon the utilization of the resources generated by the program, much like the Intelsat model previously described. A certain resource is chosen, and member countries pay in advance for a certain percentage of the use of the resource. They are then entitled to receive the percentage of the resource when the program is initiated. For example, say the mandatory program is the purchase of a computer processing system. A given country may contribute 5 percent of the cost of the computer, and expect to receive five percent of the computer time of the computer. Although this method is based upon utilization, it would discriminate against developing nations, who, within the context of IPEO, should be encouraged to use as much data as possible to manage their resources.

Table 9.4.6.1-1. Member Nation Contributions to IPEO for Mandatory Programs

| Method | Pluses | Minuses |
|--------|--------|---------|
|--------|--------|---------|

| | | |
|--|--|---|
| 1. Governments contribute based upon projected use. | Charges based upon data usage. | Does not encourage developing nations to use data. |
| 2. Governments contribute based upon % GDP. | Developing nations encouraged to use more data. | Developing nations may not be able to afford the premium. |
| 3. Governments contribute based upon a fixed percentage of GDP, but this percentage is lower for those nations with less of an ability to pay. | Developing nations encouraged to use more data. Developing nations may better be able to afford IPEO. | This is an additional burden on the developed countries which already contribute largest share of IPEO, based on GDP. |

The second method is based upon a fixed percentage of the nation's Gross National Product (GNP, the sum of the incomes of all factors of production), or Gross Domestic Product (GDP, the GNP less real-estate income derived abroad) similar to the funding of the mandatory programs by ESA. However, unlike ESA, it will not be possible to require that each country expect an equal payback in contracts, since not all countries are capable of producing the goods required. Thus, within IPEO, contract allocation is similar to that subscribed to by Intelsat, where there are no contractual obligations. Each nation decides the degree to which its contribution is a capital investment or a service contribution. Although this method is more equitable to developing nations, it still may represent too great a requirement of funds from these nations.

Countries will contribute an amount based upon a percentage of the Gross-Domestic Product (GDP). Intuitively, an equal share of GDP from each country is equitable. This formula may not be enough to support IPEO, in which case national aid monies may be used to enhance revenues in exchange for IPEO acting as a remote sensing clearinghouse. Another way in which shares could be calculated would have countries with a GDP of less than 100 billion dollars contribute 0.005 percent of their GDP to IPEO for their first two years of membership. Nations with a GDP greater than 100 billion dollars could contribute 0.01 percent (0.05 percent GDP contribution and 0.05 percent GDP for aid) of their GDP for each of their first two years of membership. Thus, as shown in table 9.5.3.1-2, enough of the developed nations are members to correspond to 80 percent of the total GDP requirement and enough of the developing nations are members to account for 20 percent of the total GDP requirement. These assumptions lead to a yearly contribution by member nations of a maximum of 820 million dollars for the first two years of operation and 410 million dollars per year in subsequent years.

Table 9.4.6.1-2. Contribution Analysis of Member Nations.

| Category | Millions of U.S. dollars | |
|---|--------------------------|-----------|
| GDP of developing Nations | \$2,000,000 | (i) |
| GDP of developed Nations | \$10,000,000 | (ii) |
| Total World GDP | \$12,000,000 | |
| Membership of developing Nations | 20% | (iii) |
| Membership of developed Nations | 80% | (iv) |
| Available GDP of developing Nations | \$400,000 | |
| Available GDP of developed Nations | \$8,000,000 | |
| % of GDP by developing Nations | 0.005% | (v) |
| % of GDP by developed Nations | 0.010% | (vi) |
| Maximum 1st year | \$820 | (vii) |
| Maximum 2nd year | \$820 | |
| Subsequent years | \$410 | (viii) |

Notes.

- (i) A developing nation has a GDP of less than \$100,000 million dollars
- (ii) A developed nation has a GDP of greater than \$100,000 million dollars
- (iii) This figure is based approximately upon those nations with a space program
- (iv) This figure based approximately upon those countries with an active remote sensing program
- (v) This figure is based upon a perceived ability to pay
- (vi) This figure is based upon Canada's contribution to remote sensing
- (vii) This figure is a maximum, since not all nations will initially be members
- (viii) After 2 years membership, the required GDP percentage is cut in half

The analysis of table 9.4.6.1-2 assumes that those nations with a remote sensing budget will approximately double their current budget, and contribute this increase to IPEO. As shown in table 9.4.6.1-3, various levels of lesser funding is possible, based upon fewer member nations and lesser contributions. For example, if membership is composed only of nations amounting to 50 percent of the originally expected GDP, and

they contribute 50 percent of their remote sensing budget to IPEO, then a first year contribution of only 205 million dollars will be made.

In the Table, the horizontal axis shows the degree to which countries increase their spending on remote sensing. For example, 10percent on the horizontal axis means that countries increase their current remote sensing budgets by 10percent and contribute this directly to IPEO. The vertical axis is percentage of projected countries to join IPEO. For example, 50percent means that a total of 50percent of the GDP from the projected nations actually join IPEO.

Table 9.4.6.1-3. Financing Scenarios (\$ Million)

| GDP | .001% | | | | .005% | | | | | .01% |
|------|-------|-----|-----|-----|-------|-----|-----|-----|-----|------|
| | 10% | 20% | 30% | 40% | 50% | 60% | 70% | 80% | 90% | 100% |
| 10% | 8 | 16 | 24 | 32 | 41 | 49 | 57 | 65 | 73 | 82 |
| 20% | 16 | 32 | 49 | 65 | 82 | 98 | 114 | 131 | 147 | 164 |
| 30% | 24 | 49 | 73 | 98 | 123 | 147 | 172 | 196 | 221 | 246 |
| 40% | 32 | 65 | 98 | 131 | 164 | 196 | 229 | 262 | 295 | 328 |
| 50% | 41 | 82 | 123 | 164 | 205 | 246 | 287 | 328 | 369 | 410 |
| 60% | 49 | 98 | 147 | 196 | 246 | 295 | 344 | 393 | 442 | 492 |
| 70% | 57 | 114 | 172 | 229 | 287 | 344 | 401 | 459 | 516 | 574 |
| 80% | 65 | 131 | 196 | 262 | 328 | 393 | 459 | 524 | 590 | 656 |
| 90% | 73 | 147 | 221 | 295 | 369 | 442 | 516 | 590 | 664 | 738 |
| 100% | 82 | 164 | 246 | 328 | 410 | 492 | 574 | 656 | 738 | 820 |

Note: this chart assumes equal contributions by both developed and developing nations, and is meant only for approximations.

The second type of funding, funding for optional IPEO programs, will be achieved via contributions by those nations interested in pursuing that program. These contributions will be above and beyond that of the determined percentage of GDP for the mandatory programs. This type of program allows member nations to take advantage of the IPEO infrastructure. It should be noted that by policy all member nations of IPEO will have access to the data produced by these optional projects.

9.4.6.2 Commercial (Revenue Enhancing) Activities

Commercial funding sources will now be described. This source of funding will not be significant in the first few years of operation. Nevertheless, it is a source of funding, and can be expected to increase with time as potential markets are developed.

As identified earlier the potential sources of revenue enhancement lie within the area of specific requests for data/information and sale to commercial entities of the following:

- Distribution of data;
- Sales of remote-sensing data;
- Sales of remote-sensing information;
- Educational services;
- Technology transfer; and
- Research contracts.

These areas with expected markets are covered in more depth within the marketing assessment section.

9.4.7 Potential Future Funding Sources

This section describes the possible sources of finance in the future for IPEO. Under each possible source, four issues will be discussed, where appropriate. These are :

- A description of the source and why it may be of interest to IPEO;
- The amount of resources it may contribute;
- Methods of convincing the source to contribute; and
- Who is competing for the funds.

9.4.7.1 Private Funding

The following international financial institutions have been identified as potential sources of debt financing:

- International Resources and Development Bank (IRDB, World Bank)

IRDB has a large interest in programs which are environmentally constructive, from two aspects : projects which ensure the preservation of the environment within their normal practices; and specific environmental enhancement projects.

There could be a conflict of interests between requests for funds from IPEO and from the member nations themselves as this bank is essentially part of the UN, whose member nations may be established as member nations of the IPEO.

Other similar organizations are:

- Arab Funds
- International Monetary Fund (IMF)
- Bank for International Settlements

9.4.7.2 Novel Methods of Funding

The potential sources of financing for international projects is becoming very stretched with the advent of new organizations, each addressing important global issues. Not least of these is the issue of environmental monitoring and management. This area is currently particularly interesting to governments of industrial nations realizing a political visibility about "green" issues.

In 1977 a study by E. Steinberg and J. Yager of the Brookings Institution discussed the potential for extra channels of financing obtained on an international scene for well needed international projects with particular reference to environmental issues. This study addressed a large number of possible financing options with the conclusion that the following selections are most easily implemented or provide the most funds :

- International Revenue Taxes;
- Taxes on Polluters of the Marine Environment (this is more for providing an incentive for polluters to reduce pollution by means of taxation and therefore the expected funds is small); and
- Revenue from Nonliving Ocean Resources - exploitation of these resources outside national jurisdiction.

There are many possible funding methods within each of these groups. It should be noted that each of these exists to enforce international laws, although some are not implemented. Each of these methods levies an international charge on a commodity or use of transportation of a potentially hazardous or risky commodity. The funds obtained are currently distributed according to the victim, whether that be an individual, a nation or society as a whole. The process, even though in place, is by no means perfect, and there is much room for improvement. In the process of this improvement, it would be possible that a responsible international, governmentally represented organization involved in the advancement of global environmental issues (such as IPEO) could solicit some of these funds.

9.4.7.3 Payment-in-Kind

Payment-in-kind is a very viable financing option for IPEO. In exercising this option, a poor nation who may not be able to contribute actual dollars may contribute instead either in-situ measurements, scientists, hardware or technology. In this way, loans or grants

could be obtained from regional development banks (World Bank, Arab Development Bank etc.) for use in developing the country where the measurements or sensors are to be developed. Another potential agreement in the payment-in-kind area could be the donation of a sensor to a given satellite project by a developed nation, in lieu of actual dollar contributions. A potential problem with this is the lack of continuity of funding for IPEO and thus this option is not considered in more depth for the initial IPEO financial structure.

9.5 Ten-Year Financial Outlook

Enough information exists to perform a high level estimated financial analysis of IPEO in the years 1992 - 2002. Here the method used is the same developed in section 9.4.1. The following inputs:

1. Costing data (source: section 9.2), broken down into:
 - Investment requirements. These include investments in hardware items like the satellite, buildings and computers. This includes the R&D effort for the development of the satellite.
 - Interest (cost of financing) of the above investments.
 - Operating costs. These include costs to operate the satellite and to run the organization.
 - Depreciation of the above investments. Note that this is a non-cash item, but nevertheless is a cost.

2. Commercial sales (that is, revenues)
 - Deforestation satellite
 - GEOD
 - GIS

We use a 8.5 percent interest rate (present rate on government bonds) and a 6 percent inflation over the period.

In this model, interest expenses are assumed throughout (assuming the investments are not paid back). This is a realistic approach, but might work on the balance sheet. It is realistic because it is like a government bond on which one receives annually the risk free interest rate (perpetuity). For example, if a country has a budget deficit, financing an additional program like IPEO will increase directly the budget deficit of this country, and it has to pay the interest on the bonds it has issued. The interest is used to assess the real participation of a member nation, and has no direct implication on the country GAUs.

A second point to consider is depreciation. This also is a real cost. There are two different possibilities to deal with depreciation:

1. In principle costs are recovered by revenues, and include money for the replacement of, for example, a satellite. This means that the cash contribution of the Member States would also include depreciation

2. Another approach is basically to ignore depreciation as a source for the yearly contribution requirements. This implies that the new satellite has to be financed from the ground up again.

The method to deal with depreciation has no impact on the costs of IPEO. The only impact it has is on when the payments will be made. This does influence the way IPEO operates. If option 2 is chosen, IPEO has to raise money for every major procurement performed. This makes IPEO very dependent on its financiers, and is unstable as such.

Therefore it is recommended to use the normal method to deal with depreciation, which will increase the contribution, but smooth investment requirements. An aspect here is that in this approach the depreciation can be higher than the additional investment, in which case we calculate as if IPEO would give back the surplus the year it appears. The accumulated investment will then remain, but decrease.

9.5.1 Financial Data

The following data is used:

Table 9.5.1-1. Input Data Financial Analysis

| Year: | Investm. | Interest | Op. Cost | Deprec. | Net Rev |
|-------|----------|----------|----------|---------|---------|
| 1992 | 11 | 1 | 13 | 0 | 0 |
| 1993 | 32 | 4 | 30 | 0 | 4 |
| 1994 | 81 | 10 | 52 | 2 | 6 |
| 1995 | 107 | 19 | 60 | 5 | 8 |
| 1996 | 131 | 30 | 73 | 5 | 10 |
| 1997 | 69 | 35 | 86 | 8 | 12 |
| 1998 | 91 | 116 | 150 | 10 | 15 |
| 1999 | 85 | 112 | 120 | 136 | 21 |
| 2000 | 183 | 157 | 127 | 138 | 30 |
| 2001 | 139 | 157 | 199 | 138 | 45 |

The costs items are the same as those in section 9.2 (Cost analysis). The depreciation is assumed to be linear. The cost recovered by the depreciation charges is reinvested in new IPEO satellites, as in deforestation satellite #2. The revenue forecast is a sum of the commercial revenues generated by the deforestation satellite, GEOD and GIS. These

figures are highly speculative, due to the long time horizon and the youth of the market (but are relatively low compared with the costs) .

The results are given in the following table:

Table 9.5.1-2. Condensed Financial Figures in the Period 1992-2002.

| Year: | NAI | NOCI | RTCI | CNI | OC | TOC |
|-------|-----|------|------|-----|-----|-----|
| 1992 | 11 | 13 | 24 | 11 | 13 | 14 |
| 1993 | 32 | 26 | 58 | 43 | 30 | 34 |
| 1994 | 79 | 48 | 127 | 122 | 52 | 64 |
| 1995 | 102 | 57 | 159 | 224 | 60 | 84 |
| 1996 | 126 | 68 | 194 | 350 | 73 | 108 |
| 1997 | 61 | 82 | 143 | 411 | 86 | 129 |
| 1998 | 81 | 145 | 226 | 492 | 150 | 276 |
| 1999 | -51 | 235 | 184 | 441 | 120 | 368 |
| 2000 | 45 | 235 | 280 | 486 | 127 | 422 |
| 2001 | 1 | 292 | 293 | 487 | 199 | 494 |

Where:

NAI = Net Additional Investments

The requirement for funding in a year.

NOCI = Net Operational Cash Inflow

The cash transferred to IPEO by its Member States per year for the cost of operations.

RTCI = Required Total Cash Inflow = NAI + NOCI

Total cash payments of IPEO Member States in a year

CNI = Cumulated Net Investment

The investments cumulated over the last years ('Sigma NAI')

OC = Operating Costs

Operating costs without interest and depreciation charges

TOC = Total Operating Costs

Operating costs including interest and depreciation

The NAI goes to near zero at the end of the period. This is logical, because there is no need to raise any additional investments for the second satellite, because these are already

covered by the depreciation payments. Consequently, the CNI is more or less constant then. Also the RTCI and the NOCI are more or less stable, and cover the gap (i.e. the difference between the total costs and the commercial revenues.), which has to be filled by the IPEO member nations. All these investment requirements are scenarios or 'perfect', assuming no excess cash, no delay in payments, etc. The negative figure for the NAI (Net additional Investments) comes from the fact that the depreciation charges are higher than the reinvestment requirements in this year. This is due to the fact that it takes longer time to build this satellite (7 years for the first one, and 5 years for the second) than to fly (three years). This implies that IPEO 'overinvested', and on the curve it shows IPEO paying back this 'overinvestment' to its members. This would not be the case in reality.

If IPEO would decide to fund a new mission, the investment requirements would go up, and a new financial cycle will start.

9.5.2 IPEO Costs as Percent GNP

Now it is possible to express the costs of IPEO in terms of percent GNP and use Table 9.4.6.1-3. Two figures are relevant here. First the RTCI, the total cash flow. This is what governments will have to pay directly. The second figure is the TOC, the total costs, which includes a hidden item, the interest (opportunity) costs.

Both costs distinguish between three periods. The first period (1992, 1993, 1994) is characterized by little investment, no satellite and low costs. The second period consists of the years 1995, 1996, 1997, 1998 during which the satellite is developed, built and tested. The third period consists of the years 1999, 2000, 2001, during which the satellite operates, is depreciated, and where the revenues do not cover these expenses.

Now a table can be constructed which gives the funds available in percent GDP. The table has two dimensions, and gives any combination of percent of countries increasing their budget in favour of IPEO, and the number of percentage points they do so. For example, if 30 percent of the countries join IPEO, and all increase their budget with 50 percent (assuming the increase will be spent on IPEO), this means a contribution of \$123 million per year.

Table 9.5.2-1. Financing Scenarios (Millions of 1988 U.S. Dollars)

(Table is identical to Table 9.4.6.1-3. see notes on this figure for explanation)

| GDP | .001% | | | | .005% | | | | | .01% |
|-----|-------|-----|-----|-----|-------|-----|-----|-----|-----|------|
| | 10% | 20% | 30% | 40% | 50% | 60% | 70% | 80% | 90% | 100% |
| 10% | 8 | 16 | 24 | 32 | 41 | 49 | 57 | 65 | 73 | 82 |

| | | | | | | | | | | |
|------|----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| 20% | 16 | 32 | 49 | 65 | 82 | 98 | 114 | 131 | 147 | 164 |
| 30% | 24 | 49 | 73 | 98 | 123 | 147 | 172 | 196 | 221 | 246 |
| 40% | 32 | 65 | 98 | 131 | 164 | 196 | 229 | 262 | 295 | 328 |
| 50% | 41 | 82 | 123 | 164 | 205 | 246 | 287 | 328 | 369 | 410 |
| 60% | 49 | 98 | 147 | 196 | 246 | 295 | 344 | 393 | 442 | 492 |
| 70% | 57 | 114 | 172 | 229 | 287 | 344 | 401 | 459 | 516 | 574 |
| 80% | 65 | 131 | 196 | 262 | 328 | 393 | 459 | 524 | 590 | 656 |
| 90% | 73 | 147 | 221 | 295 | 369 | 442 | 516 | 590 | 664 | 738 |
| 100% | 82 | 164 | 246 | 328 | 410 | 492 | 574 | 656 | 738 | 820 |

Note: This chart assumes equal contributions by both developed and developing nations, and is meant only for approximations.

Period 1: Take as an average value RTCI = \$70 mil, TOC = \$40 mil

For RTCI this coincides with a 10 percent increase of all the remote-sensing budgets, or for the double of this budget of 10 percent of the nations. Another way to express the same is to take the 30 percent - 30 percent box, i.e. 30 percent of the nations increasing their budget with 30 percent. The reader can find the other applicable combinations in the table. For the TOC we can say it is 0.0005 percent GDP of all the rich nations' GDP.

Period 2: Take as an average value RTCI = \$165 mil, TOC = \$180 mil

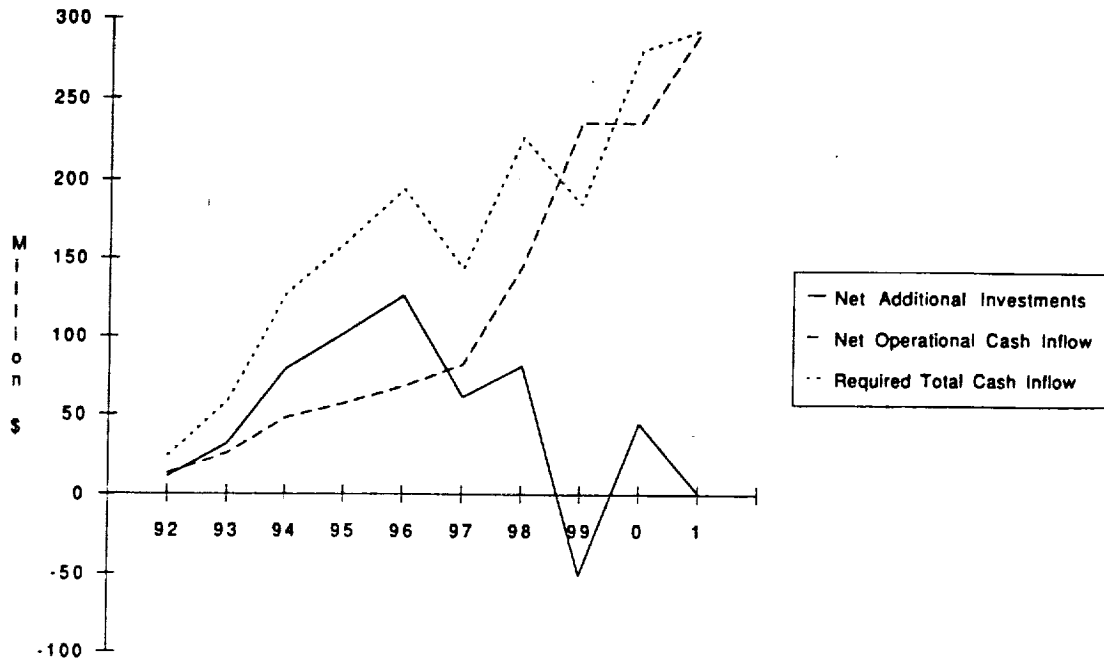
This coincides with the 45%-45percent box. For TOC it coincides with 0.0025percent GDP.

Period 3: Take as an average value RTCI = \$210 mil, TOC = \$375 mil

This coincides with the 50 percent - 50 percent box, or a 30 percent increase of the remote-sensing budget of all the nations, or again doubling the budget the budget for 30 percent of the nations. This is more or less the equilibrium stage, if IPEO would not undertake any new big project. (If this were the case a new financial cycle would begin.) The TOC are now 0.005 percent GDP.]

The next pages will show in charts the evolution of the estimated financial figures over time.

IPEO: 10 Year Financial Outlook (1.)



IPEO: 10 Year Financial Outlook (2.)

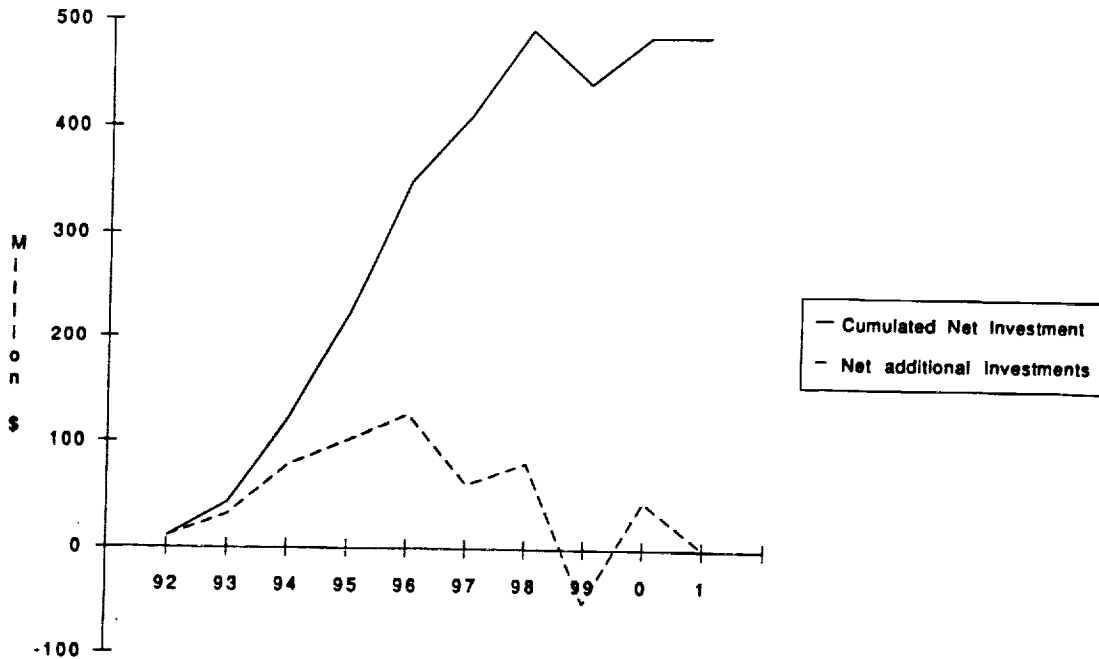


Figure 9.5.2 - 1 Financial Outlook

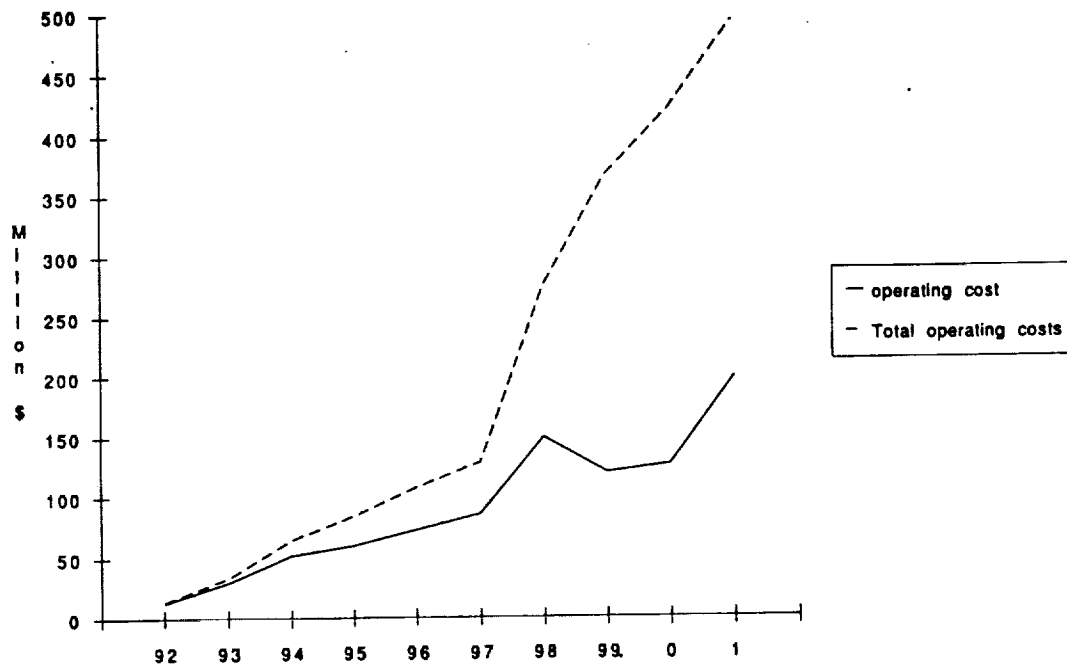


Figure 9.5.2-1 Financial Outlook, con't.

9.6 Financial Strategy

In this section, we concentrate on how to raise funds from the involved governments. First, we will analyze the economic benefits IPEO generates. Second, we shall propose a possible scenario to convince governments to invest.

9.6.1 Economic Effects of IPEO

When planning to set up such large programs as IPEO, it is necessary to analyze their economic effects. The evaluation of these effects is difficult and often needs long theoretical and/or practical studies. Given the one month period allowed to accomplish this study and without the possibility to extend it outside the campus, it was impossible to find straightforward and simple methods (or approximations) which could be implemented under such conditions.

9.6.1.1 Rationale and Methodology

In the section concerning the funding, it is seen that most of the investments in IPEO would be financed by governments.

It is considered, as a scenario, that the financing could either be "mandatory" or "optional". Mandatory financing is used to fund IPEO's essential goals, e.g., cost of GEOD, of data processing, etc. The share of each Member State is based upon a proportion of its GNP. In this case, procurement will be made by the way of competitive bidding.

Optional financing will fund certain new programs. When a new program is proposed, each Member State is asked to participate in the financing at the level of its share in IPEO. The members can decline ; if so, Member States, more interested in the program, will be able to increase their share. As an incentive to participate, they will have a "fair return", e.g., the participating countries will receive an amount of products or services proportional to their share in the program.

Given these hypothesis, it is useful to use macro-economic tools which have been developed to analyze Research & Development programs funded by states.

These studies state that economic effects can be encountered at the level of the Branches of Industry and at the level of the whole Society. Those effects can be direct or indirect.

Rationale and Methodology for the Study of Economic Effects on Society

This section of the study deals mainly with the effects due to the services provided by IPEO : better economic efficiency is the key criterion in the handling remote sensing data and issues.

To analyze those effects, the author's developed a new approach. To validate our assumptions and our results, we have mainly relied on discussions with Faculty or visiting lecturers and on phone calls to individuals in such organizations as United Nations, International Space Year, etc.

Rationale and Methodology for the Study of Economic Effects on Industry

In this subsection, we have considered only the effects produced by new satellites launched under IPEO responsibility. We have assumed that those programs were optional. We have also assumed that the participating Member States were developing countries in matters of Space. As a result the multiplier effect for participants will be maximum in this case. Using these assumptions, we compared the effects of IPEO on Industry to those created with ESA programs, from its creation, on the European and Canadian industries. For this purpose, we referred mainly to two recent studies about this subject performed under the direction of Patrick Cohendet, by BETA (Bureau d'Economie Technique et Appliquée - Université Louis Pasteur, Strasbourg, France).

If certain satellite programs are financed under mandatory programs, the "fair return rule" will not apply. In this case, if the low bidder is a developed country, the economical multiplier effects will be much lower. If the country is intermediate in term of space development, the benefits will be intermediate.

In another connection, economical effects on society intersect with those of Industry, e.g.: a better efficiency due to IPEO will benefit society. This better efficiency could lead , for instance, to diminish the number of satellites launched. This would reduce purchase orders to Industry and consequently the benefits to Industry.

Let us now explore the four categories of economic effects we have introduced. To take into account the lack of precision of the study, we tried in each of these categories to find a range of returns and not a single figure. The results of our studies are represented in the chart below and are discussed in subsequent paragraphs.

Economic Effects

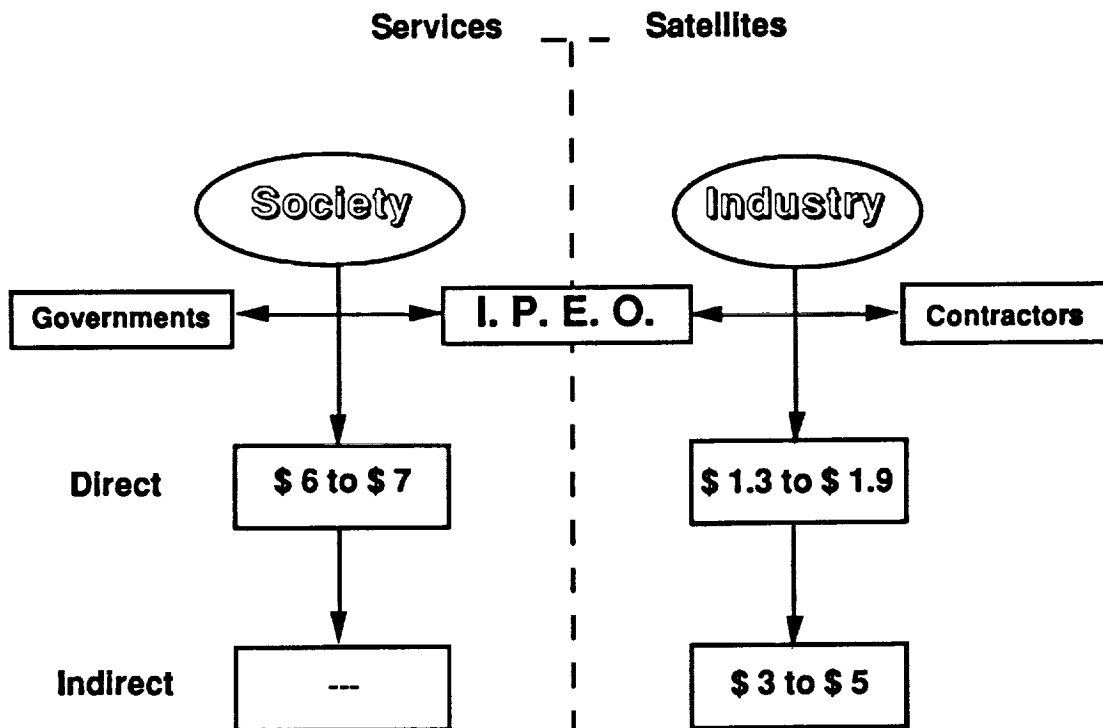


Figure 9.6.1.1-1: Economic Effects of \$ 1 Invested in IPEO.

9.6.1.2 Direct Economic Effects on Society

Direct socio-economic benefits flows directly from the success of the programs involved. The beginning of the space age, for instance, has generated benefits for the parts of the economy impacted by the creation of a space infrastructure. Typically, telecommunication or meteorological satellites have improved dramatically communication systems or weather forecasting.

Economic studies (personal communication with Patrick Cohendet) have been made with respect to the effects of the meteorological satellites. These have shown a great impact on society, in the range of \$40 for each dollar invested. In no way can IPEO impact society as much initially, because many remote sensing satellites are already orbiting the

Earth. Hence, most of the benefits have already been divided among them. IPEO's primary effects will be due to a better economic efficiency and also due to the coverage of previously unmet needs.

In the time allowed for this study, we had not the time, nor the possibility to analyze the effects due to coverage of previously unmet needs. So, we concentrated on the analysis of the effect of better efficiency and more particularly on the avoidance of overlaps between sensors.

As a matter of fact, in considering all existing or planned land/ocean satellite and/or sensors (see Figure 9.6.1.2-1), it appears that many are overlapping. The creation of IPEO could enable the avoidance of some of these overlaps. Of course, for technical or political reasons, some redundancy cannot be avoided, but as we will see, the savings generated by investing in IPEO could be very important.

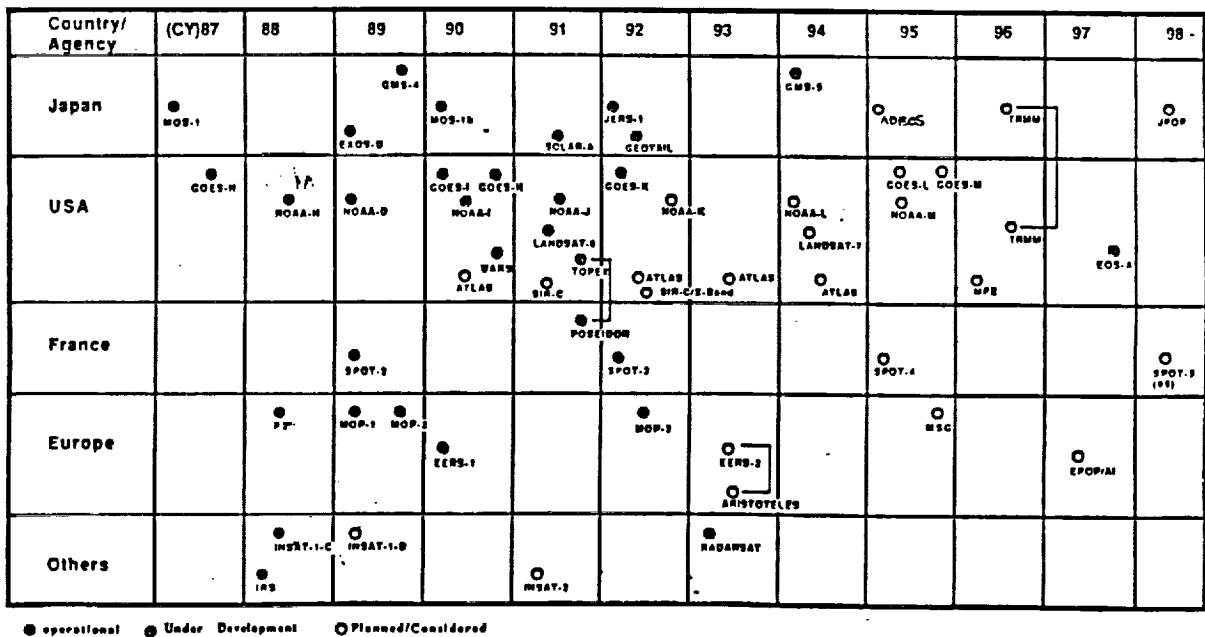


Figure 9.6.1.2-1 World Earth Observations Satellite Programs

Our analysis consisted of computing the potential savings that would have been generated in avoiding overlap between existing (or planned in the near future) satellites, if IPEO existed today and was able to act on behalf of sponsoring Member States.

Analysis of Technical Overlaps in Sensors

We analyzed first the technical overlap between sensors. Then, we tried to find rough estimates of the costs of the satellites/sensors involved in the study. The cost element comes either from books related to these payloads or from information obtained from our classmates, who come from 30 different countries. Thus, the analysis is not very

precise and should be further developed. However, it does give us a first approximation of the kind of impact the IPEO could have on public spending.

The analysis of overlaps between sensors is very complex. To be sure an overlap is a real , it involves checking such parameters as :

- **Spectral resolution overlaps;**
- **Temporal resolution overlaps;**
- **Spatial resolution overlaps; and**
- **Radiometric overlaps.**

Moreover, it requires evaluating the possible synergies between sensors.

We simplified the analysis in defining broad types and classes of sensors. This analysis would have to be further refined in taking into account the above parameters.

We took into account three types of instruments:

- **optical sensors;**
- **radars; and**
- **photographic sensors.**

Optical satellites/sensors have been classified according to their spatial resolution (see Figure 9.6.1.2-2).

Sensors with pixel size less than 500 m have been defined as "high spatial resolution" sensors. "Low spatial resolution" sensors have been defined by a pixel size greater than 500 m.

"High spatial resolution" satellites are split in three main classes :

- **In Class A, are grouped satellites with few wide spectral bands, with a pixel size between 50 m and 200 m. A good example of this Class is the Landsat Multi Spectral Scanner.**
- **In Class B, are grouped satellites with narrower and more numerous spectral bands and a pixel size smaller than 20/30 m. An example of this Class B instrument is the Landsat Thematic Mapper.**
- **Class C includes instruments with pixel dimensions of 15 m or less. An example is SPOT panchromatic resolution of 10 m.**

Satellites with wide spectral band ranges and with a pixel size between 500 m and 2,500 m have been called "Low spatial resolution" satellites. They have typically a

low number of bands. These are usually meteorological satellites like METEOSAT or AVHRR.

| COUNTRY | SATELLITE SYSTEM | CLASS | WAVELENGTH WIDTH | TIME OF PASS | PERIOD | PIXEL SIZE | NOISE-TO SIGNAL RATIO | DATA RATE (Mbps) | QUANTIZATION LEVEL | WEIGHT POWER | SWATH (km) | COST (MUSD) |
|---------------|------------------|-------|--|--------------|---------------------------------------|-------------------------|-----------------------|------------------|--------------------|-------------------|------------|--|
| BRAZIL | SSR1 | A | CCD: .63-.69 μ m .76-.90 | 8:30am | 4days | 200m | | 1.6 | | 170 kg 135 W | 732 | 40 |
| CHINA /BRAZIL | CBERS | B | CCD: .51-.73 μ m(pan), .45-.52, .52-.59, .63-.69, .77-.89 | 10:30am | 25days 3days ($\pm 12^\circ$) | 20m 80m (pan.+IR) | | | | 1400 kg 1100 W | 120 | 150 (C _{sat} +C _{CL}) |
| | | B | IR-MSS: .5-1.1 μ m(pan), 1.5-1.75,2.08-2.35, 10.4-12.5 | 10:30am | 25days | 160m thermal | | | | d' | d' | |
| | | B | WFI: .63-.69 μ m, .76-.90 | 10:30am | 3-5days | 260m (778 km) | | | | d' | d' | |
| INDIA | IRS | A | LISS-1: .45-.86 μ m (4 Channels) | | | 73m | | | | | 148 | 40 (C _{sat} +C _{proc.}) |
| | | B | LISS-2: .45-.86 μ m (4 Channels) | | | 36m | | | | | 148 | |
| | INSAT | | | | | | | | | | | 96 (C _{sat} +C _{proc.}) |

Figure 9.6.1.2 - 2. Overlap in Sensors

Note: All figures related to costs are very rough estimates and must be handled carefully.

| | | | | | | | | | | | | | |
|--------|------------------------------|----------------------|--|-------------------|--------|------------------------------|--|------|---------|-------------------|------------|---|--|
| JAPAN | MOS-1 | A | MESSR: .51-.59µm, .61-.69, .73-.8, .8-1.1 (2Cameras) 2048 CCD each | 10:30am | 17days | 50m (55µ, 909km) | | 8.78 | 8 bits | 70.7 kg 89.8 W | 100 - 185 | 170 (C _{sat} +C _L) | |
| | | L. R. | YIR: .5-.7µm; .6-.7, 10.5-11.5, 11.5-12.5 | 10:30am | 17days | vis:900m Therm: 2700m | vis:1/55db@ 80% albedo Th:1/0.5°C @ 300°C | 1.6 | 8 bits | 30.1 kg 46.1 W | 1500 | | |
| | | RAD | MSR: 23.8GHz±0.2, 31.4GHz±0.25 | 10:30am | 17days | | YI*K YI*K | 2 | 10 bits | 54.0 kg 48.6 W | 317 317 | | |
| | JERS-1 | B | 8 Channels, .52-2.418µm | 10:30- 11:00am | 44days | 18-24 m | | | | | 75 | 320 (C _{sat} +C _L) | |
| | JERS-A | B | AVNIR: 3 Visible, 1 Near IR | 10:15- 10:45am | 41days | vis : 8 m thermal: 16m | | | | | | | |
| ESA | METEOSAT ² 1-3 | L. R. | .4µm, 5.7-7.1 10.5-12.5 | | | | 2.5or5km | | | | | 462 | |
| | ERS-1 | | | 10:30am | | | | | | | 100 | 788 | |
| USA | POES/GOES ³ | L. R. | .55µm, .7µm 4 Channels, 3.90-14.7µm | | | 30min (day) 30min | 1 km 8 km | | | | | 550 | |
| | EOS | | | 4:00pm- | | | | | | | 30-500 | ? | |
| | TOPEX | | | | | | | | | | | 525 | |
| | LANDSAT 6 | A | MSS: .5-.6µm, .6-.7, .7-.8, .8-1.1 | 9:30- 10:00am | 16days | | | | | | | | 340 (C _{sat} +C _G +C _L) |
| | | B | TM: .45-.52µm, .52-.60, .63-.69, .76-.91 | 9:30- 10:00am | 16days | | | | | | | | |
| C | | New: Panchromatic | 9:30- 10:00am | 16days | | | | | | | | | |
| CANADA | RADARSAT | RAD | | 6:00am /6:00pm | | | | | | | 50/500 | 500 (C _{sat} +C _G +C _{proc}) | |
| FRANCE | SPOT-2 | A/B | .51-.73µm(Pan) XSI=.5-.59µm, .61-.64, .79-.89 | 11:00am | 26days | | | | | | | 200 | |
| USSR | RESOURCE- O(PRIRODA) | A | .5-1.1µm (9Channels) 10.4-12.6µm (1Channel) | | | | | | | | | 400 | |
| | | B | .5-.9µm (2Channels) | | | | | | | | | | |

Fig

NOTES:

- C_{sat} : Cost of Satellite Segment
- C_L : Cost of Launching
- C_G : Cost of Ground Segment
- C_{proc} : Cost of Data Processing
- 1 - See Text
- 2,3 - Geostationary Satellite

Figure 9.6.1.2-2. Overlap in Sensors, con't.

In the following table, we have summarized the list of sensors. High resolution optical sensors are listed in Figure 9.7.1.4-1. Radars are listed in Figure 6.1.4.1-1.

Table 9.6.1.2 - 1 : List of Sensors by Types and Classes

• High resolution optical sensors

Class A :

- Landsat 6 - MSS,
- IRS - LISS 1,
- MOS 1 - MESSR,
- part of SPOT -2,
- Prirorda/ Meteor series.

Class B :

- Landsat 6 - TM,
- CBERS,
- IRS - LISS 2,
- MOS 1 - TM,
- part of SPOT-2,
- JERS-A,

Class C :

- SPOT-2,

• Low resolution optical sensors

- METEOSAT,
- TIROS-N- AVHRR/3,
- MOS 1-VTIR,
- METEOR,
- GOES.

• Radars sensors

- ERS 1,
- SIR C / X-SAR,
- JERS -1,
- Canada RADARSAT,
- EOS SAR,
- USSR RADARSAT.

•Civilian satellite - Photographic sensors

- **China** has launched 11 recoverable cameras out of a total number of 26 launches. The Chinese recoverable cameras are used for two different purposes: *general land survey*, used for general remote sensing applications and *camera land measurement*, for cadastral survey and for mapping objects on the ground.
- **USSR** -through SoyuzKarta- sells photographic pictures of about 5 m resolution with its KF-1000 camera. It also sells pictures with 30 m and 100 m resolution.
- **The USA** has used the Large Format Camera and the European Metric Camera from the Shuttle.

Analysis of Cost Savings

In the High Resolution optical sensors, we have found five equivalent or quasi-equivalent sensors in Class A and at least five in Class B. There is obviously technical overlap in these sensors. However, from a technical standpoint, some overlap is necessary, as mentioned above (clouds, repete cycle, etc). In another connection, from a political standpoint, some countries will wish to keep their existing sensors for industrial or other reasons.

Taking these elements into consideration, we think that the savings could reasonably range between 25 percent and 33 percent of the total costs of all sensors plus all supporting systems, if IPEO acted to reduce international remote sensing redundancy.

This total amount is equal to \$2.0 billion. Thus the saving for optical land satellites could reasonably range between \$0.5 billion and \$0.7 billion. To be conservative, we do not include in this study low resolution optical satellites. These are usually meteorological satellites contributed in part to the WMO (World Meteorological Organization) which require virtually 24 hours continuous atmosphere coverage.

Overlap in sensor specifications for current and planned radar satellites appears to be limited. Different bands, look angles or polarization settings are planned, so these satellites may be largely complementary in their respective operations. Owing to the very large amount of money spent for the Research & Development of those instruments, we think (from a "global taxpayer" perspective) that at least 25 percent of this amount can be seen as unnecessarily duplicative. A conservative assumption is that the amount of R & D in radar programs represents roughly between 15 percent and 20 percent of the program budget.

In fact, we did not succeed in finding costs for all radar satellites. But, we found they range between \$300 million and \$500 million (JERS-1 is approximately \$320 million, RADARSAT roughly \$500 million -not including all costs). We found 6 satellites in this

category. With an average cost of \$ 400 million, this accounts for a total of \$2.4 billion. The Research & Development needed for those contracts could be in a range between \$360 million and \$480 million. The savings of joint IPEO development could be between \$ 90 million and \$ 120 million.

The total savings on optical and radar satellites altogether could be thus in a range of \$ 0.7 billion to \$0.8 billion. This amount has to be compared to the amount of money spent in the IPEO organization, excluding the deforestation satellite which covers unmet needs. This has been calculated in previous Chapters to amount to a \$ 35 million yearly expense. If we take into account the fact that the average time life of the satellites we studied is 3 to 4 years (for example, all existing polar satellites will be replaced at the end of such period), the relevant investment will be approximately, over 3 years and a half, of \$ 120 million. So the ratio of benefit to investment will be between :

$$\$0.7 \text{ billion} / \$0.120 \text{ billion} \approx \$6$$

and

$$\$0.8 \text{ billion} / \$0.120 \text{ billion} \approx \$7$$

In these figures, we have not taken into consideration:

- overlap in some sensors;
- unmet need coverage by new satellites; or
- possible savings in the ground segment in receiving station processing, etc..

These factors, plus others listed above, imply that these benefits per each public \$ invested are conservative. These are rough estimates and would need to be refined in a complete study analyzing carefully if the overlaps are real or not.

9.6.1.3 Indirect Economic Effects on Society

Indirect effects on society are those which are not directly incurred by the society. For example, inflation generated by space projects employ many people. This was noticeable in such large programs as the Apollo program. Compared to the Apollo program, IPEO is a small project. So, to the best of our knowledge, we could not find relevant indirect effects on society which would be due to IPEO.

9.6.1.4 Direct Economic Effects on Industry

If companies fulfill their objectives, they can benefit directly from economic effects. For instance, existing studies show that, in Europe, the creation from scratch of a Space

Industry created commercial benefits for the companies involved. Some examples of new markets created in this scope can be given :

- the launcher market;
- the satellite market; and
- the ground station market.

Direct economic effects are somewhat dependent on the level of technology of the industry concerned. Typically, the effects for all industries range between \$1.2 and \$1.9 for each dollar invested. Less innovative industries (for example, building) will generate a return \$1.2 while in highly innovative Branches of Industry \$1.9 per public dollar invested is generated. The average figure of all industries is \$1.3. To be conservative, we have chosen for IPEO a range of \$1.3 to \$1.9 per dollar invested.

9.6.1.5 Indirect Economic Effects on Industry

Indirect economic effects on industry (or industrial spin-offs) are not related to direct sales outside the company or the industry. These effects do exist in the space industry, because it is very innovative ; they would probably not exist to much extent in an industry such as the road industry.

Rationale

Three type of methods can be used to analyze indirect effects to industry. First, there are the methods based on macro-economic models. We had to discard such methods because they are too complex. For instance, in 1988, NASA asked for a study to analyze the indirect effects of the Apollo program on industry: one hundred economists were appointed to perform this study! Not knowing the data parameters necessary to be taken into account, it was not possible for us to do economic modelling for IPEO.

Second are the micro-economic models based on the supply curves. A new program such as IPEO (or new technologies developed in the deforestation satellite) could shift the supply curve in markets influenced by IPEO. At constant demand, this shift creates a "consumer surplus" reflecting the impact of innovation. This method can be applied to Research & Development programs funded by governments. However, IPEO influences many markets -some of them being so new that they do not even show a supply curve. Thus, we could not use this method.

The third method consists in analyzing the micro-economic diffusion of the public investment along the chain originating in the contracting companies up to the creation of new markets. This method is based on Shumpeter's works and was used by BETA in its 1988 study about effects of ESA investments on European Industry.

Analysis of the Micro-economic Diffusion of IPEO in Industry

In the referenced study, indirect effects have been analyzed for a large sample of different companies. This gives us insight about IPEO. Moreover, as those spin-offs are split into four categories : technological, commercial, organization and critical mass of engineers effects, we were able to sharpen our analysis.

The results given by BETA are based on interviews made in 67 companies. The conclusion is a spin-off of \$ 3.2 for each dollar invested by ESA. The benefits approximately range between \$ 2 for very basic and less innovative projects, like Ariane 1 or 2 rocket launches, to \$ 12 for very innovative satellites, like METEOSAT. A split between the various components of these indirect effects is given hereunder :

- **Technological** indirect effects are linked to the capacity of the industry to create new products derived from technology used on space programs. In European industry, this effect accounts for 32 percent of the total.
- If a company is working in (or for) the space industry, it can advertise the image of space in terms of high technology : this is a **marketing** indirect effect for the industry. In the study, this effect amounts to 8 percent.
- The organization set up for such large contracts can be transferred to other industries. This is considered as an **organization** indirect economic effect built on acquired administrative skills. A proportion of 6 percent of the total is found in this category.
- The fact that a large number of engineers are working on such projects can help companies to win other contracts in the same type of activities, and even to diversify in contiguous fields where they can build on their experience. This **critical mass of engineers** constitutes an important indirect economic effect amounting to 54 percent of the total.





APPENDIX A COUNTRY NOTES

A.1 Introduction

The concept of Country Notes has been addressed in chapter 3.3 and then detailed in chapter 5.1.3. During the ISU session 1990, the students filled in one questionnaire, for each country represented. They used their own knowledge as well as the materials available about their country or brought in by ISU. They consulted faculty members and contacted some of their colleagues or acquaintances. Most of the 40 questions about national remote sensing and environmental orientations have thus found an answer. Two books have been used:

- The Interavia Spaceflight Directory (1989)
- The World Space Industry Survey (1988 Euroconsult).

Because of the short period of time allocated to this task, some answers are probably incomplete, or missing. However, most Country Notes contain a large amount of focused information. They do not constitute official statements. They are only preliminary notes. The results must be handled carefully. These precautions being taken, an outline of national interests for Earth Observation can be elaborated. A brief analysis of compiled and selected results is presented hereafter.

List of the 27 countries examined:

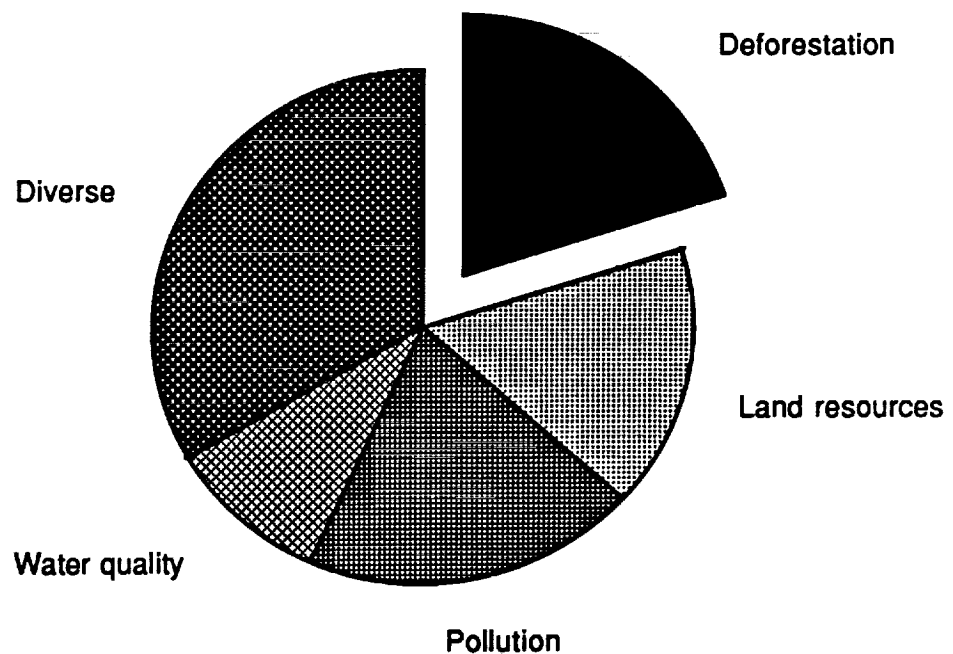
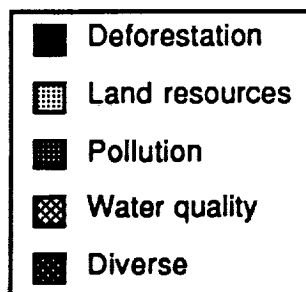
| | | |
|------------|----------------|--------------|
| -Australia | -Great-Britain | -Sweden |
| -Austria | -India | -Switzerland |
| -Belgium | -Ireland | -Syria |
| -Brazil | -Italy | -USSR |
| -Bulgaria | -Japan | -USA |
| -Canada | -Kenya | |
| -China | -Luxembourg | |
| -Colombia | -Netherlands | |
| -Egypt | -Norway | |
| -Finland | -Saudi Arabia | |
| -France | -Spain | |

A.2 Index of National Interests and Results

A.2.1 First Priority

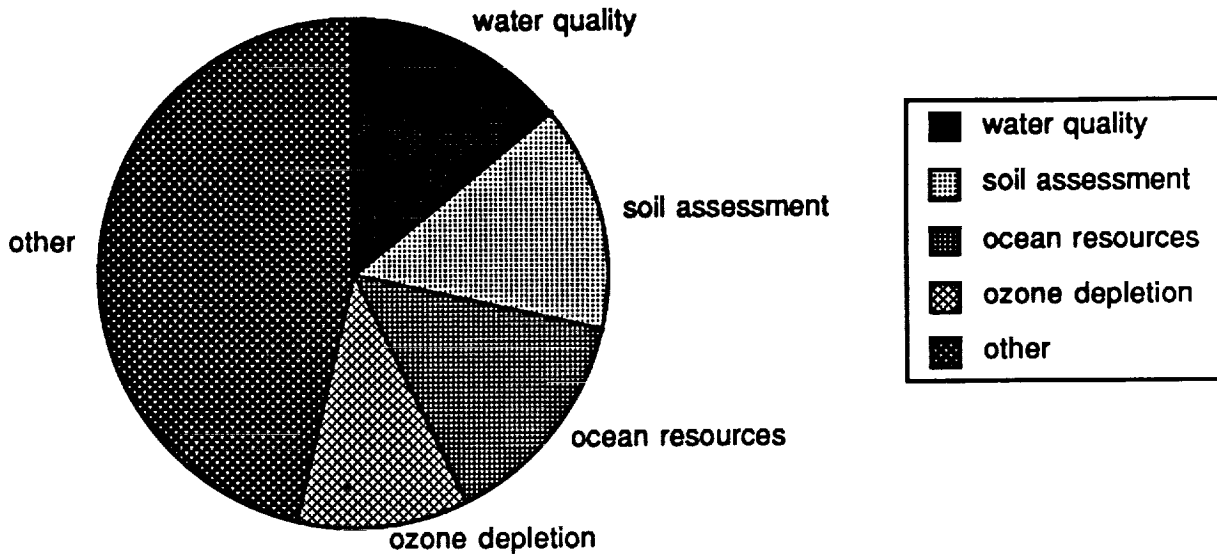
Each nation faces specific problems related to its environment or its resources. The following graphics indicates the relative number of countries for which one issue is considered as a first priority. It shows the divergence of national interests.

Approximately 1/3 of the nations focus their efforts in the problems of deforestation or land resources, while another 1/3 is concerned with air or water pollution, and the other 1/3 deal with one out of more than ten other issues. (Diverse covers all those ten issues). The reason for this dispersion is partially explained by the interest of the people and the government for short-term problems.



A.2.2 Second Priority

When looking at the second priorities now, the distribution of national issues is very different, and four new problems seem most significant.



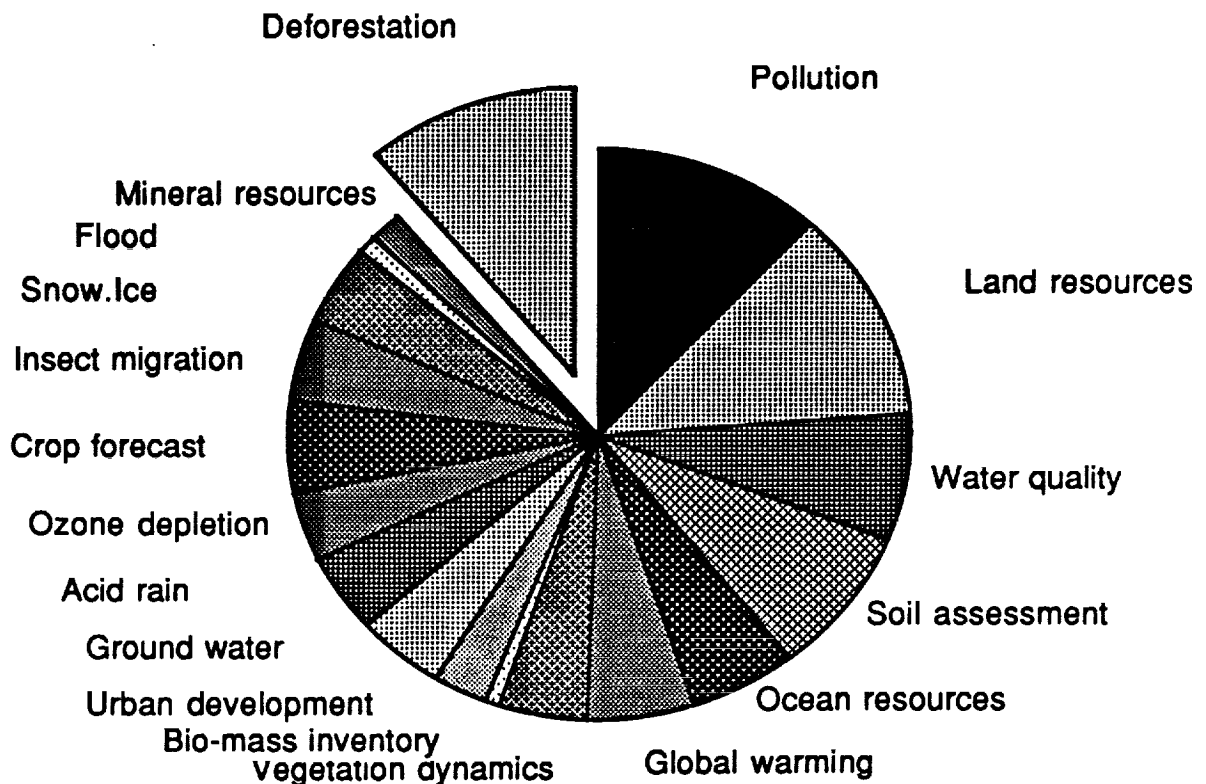
A.2.3 What should be the IPEO Priorities?

From the precedent outputs, one could think that trying and addressing the main national concerns in the frame of an international organization could be far from reach. However, all the 20 issues called forth previously are usually not unrelated. They participate sometimes in a common phenomenon, and they may also be monitored in similar ways. On the other hand, local characteristics of the Earth, the Ocean, or the air are submitted to global changes. No one can ignore this fact. And so, national interests are most of the time consistent with the general and international interest.

Therefore, it is interesting to consider several first priorities for each country instead of just one. The four top priorities of each nation have been reported a list of 20 issues, leading to the pie chart on the next page.

Most frequent priorities appear to be deforestation, pollution (air) and land resources. They represent the main issues of our time. They result in the Global Change phenomenon.

As for deforestation new data are requested by 1/3 of the nations examined in the Country Notes. A better coverage of the tropical belt would satisfy approximately 1/3 of the countries as well.



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A.2.4 Involvement in IPEO

According to the Country Notes, almost all the 27 countries would be willing to get involved in IPEO. With the exception of two, nations would be ready to provide some technical support as well as the results of their ground truth campaigns. Half the countries would also be ready to invest money in the program.

A.3 Conclusions

From the previous graphics and analysis, several trends have been identified. They are in phase with the IPEO design. As the Country Notes were filled in, the assumptions and the preliminary options taken for IPEO were confirmed, in many respects. As survey samples, the Country Notes were used as the first feedbacks from the users. They should be refined for the implementation of IPEO. An enhanced version of the existing notes should be developed, and the results of the preliminary questionnaire should be now crosschecked.

More countries should be investigated. The questions about the international and bilateral programs should be more self-explanatory, so that answers are more homogeneous for all the countries.

In an advanced form, Country Notes would be of great use in providing relevant information about national interests, needs and capabilities in Earth Observation. They would be a precious tool for better understanding real issues and assessing true needs. They would be useful for responding to particular needs while defining better the so-called general interest.

As a result, better satisfaction would be given to the existing or potential actors of a global change program. Then a good synergy between all the nations and between all the users of IPEO would be created.

AUSTRALIA

II. INVOLVEMENT IN SPACE ACTIVITIES.

Does your country have a national remote sensing program? If yes, under whose authority?

No Yes :

Federal Australian Centre for Remote Sensing (ACRES),
Canberra, AUSTRALIA, part of the Remote Sensing Unit
of the Australian Surveying and Land Information
Group (AUSLIG)

Also seven state government remote sensing programmes run
autonomously from the federal government. eg Queensland,
NSW, Tasmania, Sth Australia, Victoria, Western Australia and
Northern Territory.

Does your country possess Earth Observation satellite(s)? If yes, name the program(s).

No Yes :

Does your country design and/or build remote sensing payload(s)?
If yes, name the payload(s) and the prime manufacturer(s).

No Yes :

ERS-1 1. Digital electronic unit, providing control and timing of the
along track scanning radiometer
2. Design involvement with radiometer itself.
3. Main elements of the high speed image processor
Prime manufacturers are British Aerospace Australia and COSSA who
are the space arm of the CSIRO (Commonwealth Scientific Research
Organisation)

Does your country possess any capability to directly receive data from a spacecraft?
If yes, from which satellite(s)? Where are the receiving stations?

No Yes : Landsat/Spot/ERS-1/MOS-1&GMS/NOAA
through Alice Springs tracking station.

III. INVOLVEMENT IN INTERNATIONAL ACTIVITIES.

Does your country take part in :

? S.A.F.I.S.Y. U.N.E.P. I.C.S.U.
? COSPAR A.R.T.E.M.I.S. Other :

Looking at the near, middle and long term future, what are the main objectives and strategies of your country in Earth Observation, and more specifically in environmental programs?

1. Retain 12% of value added market.
2. Penetrate pacific rim commercial market for value added.
3. Ocean health monitoring for fisheries and marine national parks.
4. Ozone depletion
5. Deforestation investigation of dieback disease afflicting trees.
6. Technological development.

IV/ UTILIZATION OF REMOTE SENSING DATA.

Does your country make use of remote sensing data? If yes, for which purpose?

No Yes : Research Application

- As for application, which ones?

- | | | | |
|-------------------------------------|----------------|-------------------------------------|--|
| <input checked="" type="checkbox"/> | Deforestation | <input checked="" type="checkbox"/> | Land and Topographical Mapping |
| <input type="checkbox"/> | Global Warming | <input checked="" type="checkbox"/> | Vegetation Dynamics |
| <input checked="" type="checkbox"/> | Pollution | <input type="checkbox"/> | Desertification |
| <input checked="" type="checkbox"/> | Other : | | Sea Ice, Crop inventory, Minerals, Climatic (atmospheric temp/press/moist/wind), Hydrology (rain /flood /erosion) Fisheries |

- As for research, which areas are of the concern?

Ozone, sea surface temp/chlorophyl/ice, wave height, crop stress,
Hydrology, fisheries, reef management, soil research (spectral)
Mineral exploration

What kind of remote sensing data sets does your country use more often?

1. Spot
2. Landsat
3. NOAA
4. Aerial
5. Mos-1/GMS

Does your country have the capability to produce its own G.I.S. data?

If yes, which centers are involved in this?

No Yes : Federal A.C.R.E.S.
State Seven states
Private Many companies

See attached sheet

What kind of G.I.S. data are most often used?

- | | | | |
|-------------------------------------|-------------------|-------------------------------------|--------------------------------|
| <input checked="" type="checkbox"/> | Digital Elevation | <input checked="" type="checkbox"/> | Land Use/Land Cover |
| <input checked="" type="checkbox"/> | Roads | <input checked="" type="checkbox"/> | Soils |
| <input checked="" type="checkbox"/> | Hydrology | <input type="checkbox"/> | Political Boundaries |
| <input checked="" type="checkbox"/> | Geology | <input checked="" type="checkbox"/> | Other : As detailed previously |

What is the status of development of the remote sensing value added industry?

- Well Established Starting Non Existing

Does your country provide training courses in remote sensing?

- Yes, at academic and private course level.
Both very well established

VI. COMPLEMENTARY DATA FOR EARTH OBSERVATION.

Does your country have the capability to perform reference measurements (useful for the calibration of satellite sensors, or models validation) ?

- in situ* measurements
 Low altitude observation (inferior to 10000 ft.)
 High altitude observation

Concerning the measurement acquisition, does your country have just reference plots, subjectively located, or does it have a collection of plots selected through a rational sample design?

?

Is your country equipped with :

- ? GPS (Global Positioning System)
 ARGOS

VII. FINANCIAL INVOLVEMENT.

What is the annual space budget (in U.S. \$) of your country? \$US 10 M.

What percentage of the GNP does this represent? ?

What is the annual space budget for Earth Observation from space? \$US 7 M.

Does your country foresee an expansion of its involvement in remote sensing activities? In which directions?

Yes, mainly in the value added area for software and training. Also further hardware participation in both the space and ground segments.

Does industry play a role in remote sensing activities in your country? Which one?

Yes, in hardware, production (electronic) and testing/calibration of scanners etc.
Software development and training, also research.

*Give other financial indicators if any, such as revenues of the remote sensing images sold...
What is the total value (social, environmental, commercial) contributed by remote sensing to your country (e.g. in forest and soil resources saved through better management)? Use the best figures you can find and/or your best guess.*

\$US 40M from value added image sales.

VIII REMOTE SENSING CENTERS OF THE COUNTRY.

In the following table, list and characterize the main institutions of your country dealing with remote sensing data (analysis, processing, interpretation, correlation with other data, model development...).

| <i>Remote Sensing Institution</i> | <i>Status</i> | <i>Fields of Application</i> | <i>Origin of the Raw Data</i> | <i>Hardware Tools</i> | <i>Software Tools</i> | <i>Use of a GIS</i> | <i>Annual budget</i> |
|---|---------------|-------------------------------------|----------------------------------|-----------------------|-----------------------|---------------------|----------------------|
| <u>FEDERAL</u> ACRES | Govern | Raw data reception and coordination | Spot Landsat MOS-1 NOAA | | | | |
| <u>OLD STATE</u> Geoimage Pty Ltd | Private | Value added General | | | | | |
| Mapping & Monitoring Technology | Private | | | | | | |

| <i>Remote Sensing Institution</i> | <i>Status</i> | <i>Fields of Application</i> | <i>Origin of the Raw Data</i> | <i>Hardware Tools</i> | <i>Software Tools</i> | <i>Use of a GIS</i> | <i>Annual budget</i> |
|-----------------------------------|---------------|------------------------------|-------------------------------|-----------------------|-----------------------|---------------------|----------------------|
| Carpentari Exploration | Private | geophysic and mining | | | | | |
| CSIRO Townsville | Federal Gov | soils reseach | | | | | |
| CSIRO Brisbane | Federal Gov | Geomechs | | | | | |
| CSIRO Brisbane | Federal Gov | Tropical crops pastures | | | | | |
| Dept of Primary Industry | Qld State Gov | Primary Industry | | | | | |
| Dept of Water Resources | Qld State Gov | Water Resources | | | | | |
| <u>NSW STATE</u> | | | | | | | |
| Dept of Agricult. Fisheries | NSW State Gov | Agricult and fisheries | | | | | |
| Univ of NSW | Univ. | SAR Techology | | | | | |
| Australian Defence Force Academy | Federal Gov. | | | | | | |

| <i>Remote Sensing Institution</i> | <i>Status</i> | <i>Fields of Application</i> | <i>Origin of the Raw Data</i> | <i>Hardware Tools</i> | <i>Software Tools</i> | <i>Use of a GIS</i> | <i>Annual budget</i> |
|--------------------------------------|---------------|------------------------------|-------------------------------|-----------------------|-----------------------|---------------------|----------------------|
| <u>VICTORIA STATE</u> | | | | | | | |
| CSIRO | Federal Gov. | Atmosph Research | | | | | |
| Dept of Conservatn Forests and Lands | VIC State Gov | Forests and Lands | | | | | |
| <u>STH AUST STATE</u> | | | | | | | |
| Dept of Lands | Sth Aust Gov | Land use | | | | | |
| <u>NTH TERRITORY</u> | | | | | | | |
| CSIRO | Federal Gov | Wild life Ecology Erosion | | | | | |
| <u>WEST AUST STATE</u> | | | | | | | |
| Geoscan Pty Ltd | Private | Value added general | | | | | |
| CSIRO | Federal Gov | Exploration Geoscience | | | | | |
| Dept of Lands | West Aust Gov | Broad range-inc Oceans | | | | | |

| <i>Remote Sensing</i> | <i>Status</i> | <i>Fields of</i> | <i>Origin of the</i> | <i>Hardware Tools</i> | <i>Software Tools</i> | <i>Use of a</i> | <i>Annual budget</i> |
|-----------------------|---------------|------------------|----------------------|-----------------------|-----------------------|-----------------|----------------------|
|-----------------------|---------------|------------------|----------------------|-----------------------|-----------------------|-----------------|----------------------|

| <i>Institution</i> | | <i>Application</i> | <i>Raw Data</i> | | | <i>G.I.S</i> | |
|------------------------------|-------------|--------------------------------------|-----------------|--|--|--------------|--|
| <u>TASMANIA STATE</u> | | | | | | | |
| CSIRO | Federal Gov | Broad range-inc Oceans | | | | | |
| <u>AUS CAPITOL TERRITORY</u> | | | | | | | |
| CSIRO | Federal Gov | Central Coordinator | | | | | |
| Australian Space Office | Feral Gov | Central Coordinator of Space Affairs | | | | | |

VIII. POTENTIAL IMPLEMENTATION OF I.P.E.O. IN THE COUNTRY.

Considering previous answers or more personal views, do you think that new data or information related to the deforestation phenomenon would be useful to the country?

No Yes Maybe

1. Disease monitoring of trees to research dieback epidemic.
2. Logging impacts.

More precisely, would your country be interested in having access to high resolution radar data for deforestation monitoring (in a region 35°S to 35°N latitude, every ten days)? For which purpose?

No Yes Maybe :

1. To monitor tree disease
2. Clear felling.

Does your country have sufficient land mapping at appropriate scales?

No Yes Maybe not

Would your country be interested in having access to space-based mapping data? (land and topographical mapping)

No Yes Probably

Which ground resolution?

larger than 20 m. 20 m.
 10 m. 5 m.
 smaller than 5 m. no idea.

Which accuracy in altitude?

larger than 20 m. 20 m.
 10 m. 5 m.
 smaller than 5 m. no idea.

What are the other areas in which the improvement of existing remote sensing raw or processed data could be useful for your country?

Relatively content with current situation.

What spin-offs of I.P.E.O. could be envisioned for the country? In particular those driven by a global change studies? (general welfare, public opinion satisfaction, technology transfer, education...)*

1. General welfare
2. Technology transfer
3. Market penetration of value added industry
(Hardware/Training)

Would your country be willing to commit itself in I.P.E.O.? If yes, how?

No Yes :

via technical contribution
 by financial participation
 with *in situ* measurements
 in marketing
 other :

IXI MISCELLANEOUS.

Most countries have a reference book for remote sensing. Such documents exist also for groups of countries (for example, the Earsel Directory for Europe). Does such a reference book exist for your country? What is its name? Where can it be found?

"Remote Sensing in Australia" - Government description
But no specific directory on company/institution participation.

LIST MATERIALS USED FOR THIS SURVEY.

1. "The international polar platform. Australian and New Zealand Requirements", Volume 1 and 2.

2. "The Australian Space Office brochure"
3. "European Space Directory" 1990 by Euroconsult
4. Janes Spaceflight
5. Private communication- Ms Gail Kelly of the Sunmap centre in Queensland AUS
6. A.K.C.L.I.S. "Australian key centre for land information studies", University of Queensland notes.

LIST PEOPLE CONTACTED FOR THIS SURVEY AND GIVE THEIR REFERENCES.

1. Dr Ed Kruzins , British Aerospace U.K./ ISU 90
2. Mr Paul Wilson , Queensland University of Technology AUS/ ISU 90
3. Mr Steven Pietrobon, Sth Australian Inst of technology AUS/ISU 90
4. Ms Gail Kelly, Sunmap Centre of Queensland

Is there any material you are expecting? Any further research you would like to do? Any person you would contact later on?

No

Please join to this Country Note any synthetic document or copies that you find particularly relevant.

AUSTRIA

II INVOLVEMENT IN SPACE ACTIVITIES.

Does your country have a national remote sensing program? If yes, under whose authority?

No Yes : Ministry of Science and Research,
Austrian Space Agency (ASA)

Does your country possess Earth Observation satellite(s)? If yes, name the program(s).

No Yes :

Does your country design and/or build remote sensing payload(s)?
If yes, name the payload(s) and the prime manufacturer(s).

No Yes :

diverse instruments : University of Technology Graz,
Schrack Aerospace, ORS. Inc.

Does your country possess any capability to directly receive data from a spacecraft?
If yes, from which satellite(s)? Where are the receiving stations?

No Yes : METEOSAT (various receiving stations)

III INVOLVEMENT IN INTERNATIONAL ACTIVITIES.

Does your country take part in :

| | |
|--|--|
| <input checked="" type="checkbox"/> S.A.F.I.S.Y. | <input checked="" type="checkbox"/> U.N.E.P. |
| <input checked="" type="checkbox"/> I.C.S.U. | <input checked="" type="checkbox"/> COSPAR |
| <input type="checkbox"/> A.R.T.E.M.I.S. | <input type="checkbox"/> Other : |

Is your country involved in one of the core or working group projects of I.G.B.P. (International Geosphere Biosphere Program)?

No Yes : Global Change, etc.

Does your country participate in international Earth Observation programs (in particular environmental programs)?

If yes, describe the type of participation (technical exchange, financial investment, other...).

No Yes : Indirect through personal Austrian-NASA
connections

Same question for bilateral Earth Observation programs.

No Yes :

III. SENSITIVITY TO ENVIRONMENTAL ISSUES.

- Which of the following environmental issues (or common interests) are of importance to your country or to specific regions of your country?

Deforestation (1) ; Global Warming (2) ; Pollution (3) ; Land Resources (4) ; Vegetation Dynamics (5) ; Bio-mass Inventory (6) ; Water Quality (7) ; Soil Assessment (8) ; Urban Development (9) ; Ground Water (10) ; Acid Rain (11) ; Ozone Depletion (12) ; Crop Forecast (13) ; Insect Migration (14) ; Snow / Ice (15) ; Ocean Resources (16) ; Wildlife Monitoring (17) ; Flood (18) ; Desertification (19) ; Other... (be precise).

| Priority | Issues | Is your country actively involved in modelling and monitoring the problem? If yes, how? | Annual Budget or Percentage of Environmental Budget Spent on This Issue. |
|------------------------|---------------|---|--|
| 1 st prior. | 3, 10,11 | ? | ? |
| 2 nd prior. | 7, 8, 9 12 | model greenhouse effect | ? ? |
| 3 rd prior. | 15 | ? | ? |

Looking at the near, middle and long term future, what are the main objectives and strategies of your country in Earth Observation, and more specifically in environmental programs?

Environmental Monitoring
Protected Landscapes (Natl. Parks)
Glacier and Snow Monitoring (Water Supply)

IV. UTILIZATION OF REMOTE SENSING DATA.

Does your country make use of remote sensing data? If yes, for which purpose?

No Yes : Research Application
- As for application, which ones?

Deforestation Land and Topographical Mapping
 Global Warming Vegetation Dynamics
 Pollution Desertification
 Other : Regional Planning, Snow and Ice

- As for research, which areas are of the concern?

Snow and Ice, Greenhouse effect

What kind of remote sensing data sets does your country use more often?

SPOT, LANDSAT, Aerial Photos

Does your country have the capability to produce its own G.I.S. data?
If yes, which centers are involved in this?

No Yes : Umwelt-Bundesamt (Vienna)

What kind of G.I.S. data are most often used?

| | |
|---|--|
| <input checked="" type="checkbox"/> Digital Elevation | <input checked="" type="checkbox"/> Land Use/Land Cover |
| <input checked="" type="checkbox"/> Roads | <input type="checkbox"/> Soils |
| <input checked="" type="checkbox"/> Hydrology | <input checked="" type="checkbox"/> Political Boundaries |
| <input type="checkbox"/> Geology | <input type="checkbox"/> Other : |

What is the status of development of the remote sensing value added industry?

Well Established Starting Non Existing

Does your country provide training courses in remote sensing?

Summer Schools and Courses at Universities

VI. COMPLEMENTARY DATA FOR EARTH OBSERVATION.

Does your country have the capability to perform reference measurements (useful for the calibration of satellite sensors, or models validation) ?

in situ measurements
 Low altitude observation (inferior to 10000 ft.)
 High altitude observation

Concerning the measurement acquisition, does your country have just reference plots, subjectively located, or does it have a collection of plots selected through a rational sample design?

Selected through rational sample design

Is your country equipped with :

GPS (Global Positionning System)
 ARGOS

VII. FINANCIAL INVOLVEMENT.

What is the annual space budget (in U.S. \$) of your country? ?
What percentage of the GNP does this represent? ?

What is the annual space budget for Earth Observation from space? ?

Does your country foresee an expansion of its involvement in remote sensing activities? In which directions?

Sensor Development, Application Methodology

Does industry play a role in remote sensing activities in your country? Which one?

No

Give other financial indicators if any, such as revenues of the remote sensing images sold...
What is the total value (social, environmental, commercial) contributed by remote sensing to your country (e.g. in forest and soil resources saved through better management)? Use the best figures you can find and/or your best guess.

?

VIII REMOTE SENSING CENTERS OF THE COUNTRY.

In the following table, list and characterize the main institutions of your country dealing with remote sensing data (analysis, processing, interpretation, correlation with other data, model development...).

| Remote Sensing Institution | Status | Fields of Application | Origin of the Raw Data | Hardware Tools | Software Tools | Use of a GIS | Annual budget |
|--|-----------------------------|-----------------------|--------------------------|-------------------------------|----------------|--------------|---------------|
| Institute for Digital Imaging Processing Graz | regional governm commerc | 7,10,11,15,8, 9 | SPOT Landsat ERS-1 | several Mainfr. Workst. | ? | ? | ? |
| Inst. for Meteorolog and Geophysics University Innsbruck | academic | 3,15 | as above | several Workst. | ? | ? | ? |

| | | | | | | | |
|---|----------|------------|-----------------|--------------------|---|----|---|
| Inst. for Photogram metry Univ. of Technology Wien | academic | 15, ? | as above | several Workst. | ? | ? | ? |
| Beckel Geospace Bad Ischl | commerc | 8, 9, 5, 4 | SPOT Landsat | several Workst. | ? | Y | ? |
| Inst. for Meteorolog and Geophysics Univ. Graz | academic | 2,12 | no | Workst., PCs | ? | no | ? |
| Inst. for Meteorolog and Climatology Univ. of Agricultur Vienna | academic | 1,6,5 | SPOT Landsat | several Workst. | ? | ? | ? |
| Inst. for Geography Univ. Klagenfurt | academic | 5,6 | SPOT Landsat | Workst. | ? | ? | ? |
| Inst. for Cartograph Remote Sensing Univ. of Agricultur | academic | 1,6,5 | SPOT Landsat | Workst. | ? | ? | ? |
| Inst. for Electrical Engineering Univ. of Techn. Graz | academic | 15 | aerial Radar | Mainf. Workst. | ? | ? | ? |

VIII/ POTENTIAL IMPLEMENTATION OF I.P.E.O. IN THE COUNTRY.

Considering previous answers or more personal views, do you think that new data or information related to the deforestation phenomenon would be useful to the country?

No Yes Maybe Deforestation, forest disease in Austria,

More precisely, would your country be interested in having access to high resolution radar data for deforestation monitoring (in a region 35°S to 35°N latitude, every ten days)? For which purpose?

No Yes Maybe : For high resolution Radar data for snow and Ice cover

Does your country have sufficient land mapping at appropriate scales?

No Yes Maybe not Not sufficient data about vegetation, land use

Would your country be interested in having access to space-based mapping data? (land and topographical mapping)

No Yes Probably

Which ground resolution?

larger than 20 m. 20 m.
 10 m. 5 m.
 smaller than 5 m. no idea.

Which accuracy in altitude?

larger than 20 m. 20 m.
 10 m. 5 m.
 smaller than 5 m. no idea.

What are the other areas in which the improvement of existing remote sensing raw or processed data could be useful for your country?

Regional Planning

What spin-offs of I.P.E.O. could be envisioned for the country*? In particular those driven by a global change studies? (general welfare, public opinion satisfaction, technology transfer, education...)

Technology transfer

Would your country be willing to commit itself in I.P.E.O.? If yes, how?

- No Yes :
- via technical contribution
 - by financial participation
 - with *in situ* measurements
 - in marketing
 - other : Research and Development

IX. MISCELLANEOUS.

Most countries have a reference book for remote sensing. Such documents exist also for groups of countries (for example, the Earsel Directory for Europe). Does such a reference book exist for your country? What is its name? Where can it be found?

Earsel Directory

LIST MATERIALS USED FOR THIS SURVEY.

LIST PEOPLE CONTACTED FOR THIS SURVEY AND GIVE THEIR REFERENCES.

Doz. Dr. M. Buchroithner,
Head of the Institute for Digital Imaging Processing
JOANNEUM RESEARCH,
Wastiangasse 6, A-8010 Graz,
FAX: (316) 8021-20

Is there any material you are expecting? Any further research you would like to do? Any person you would contact later on?

No information available from the Ministry

Please join to this Country Note any synthetic document or copies that you find particularly relevant.

BELGIUM

II INVOLVEMENT IN SPACE ACTIVITIES.

Does your country have a national remote sensing program? If yes, under whose authority?

No Yes

Multiannual RTD programme : "Program for research in the field of remote sensing by satellite"

Does your country possess Earth Observation satellite(s)? If yes, name the program(s).

No Yes

*Does your country design and/or build remote sensing payload(s)?
If yes, name the payload(s) and the prime manufacturer(s).*

No Yes ERS1, Landsat : ground receiving stations.

*Does your country possess any capability to directly receive data from a spacecraft?
If yes, from which satellite(s)? Where are the receiving stations?*

No Yes : At Redu, ESA station

No Earth Observation receiving stations

III INVOLVEMENT IN INTERNATIONAL ACTIVITIES.

Does your country take part in :

| | | | |
|---|------------------|--------------------|--------------|
| ? | [] S.A.F.I.S.Y. | [] U.N.E.P. | [] I.C.S.U. |
| ? | [] COSPAR | [] A.R.T.E.M.I.S. | [] Other : |

Is your country involved in one of the core or working group projects of I.G.B.P. (International Geosphere Biosphere Program)?

No Yes ?

Does your country participate in international Earth Observation programs (in particular environmental programs)?

If yes, describe the type of participation (technical exchange, financial investment, other...).

No Yes : ?

Same question for bilateral Earth Observation programs.

Land use planning and cartography
Agriculture & forestry: Inventory, production, health of crops and forest
Land and marine Geology
Global change

Programmes involving Belgium and developping countries.

What kind of remote sensing data sets does your country use more often?

SPOT, METEOSAT, Aerial photos.

*Does your country have the capability to produce its own G.I.S. data?
If yes, which centers are involved in this?*

No Yes :

What kind of G.I.S. data are most often used?

| | | | | |
|---|--------------------------|-------------------|--------------------------|----------------------|
| | <input type="checkbox"/> | Digital Elevation | <input type="checkbox"/> | Land Use/Land Cover |
| ? | <input type="checkbox"/> | Roads | <input type="checkbox"/> | Soils |
| ? | <input type="checkbox"/> | Hydrology | <input type="checkbox"/> | Political Boundaries |
| | <input type="checkbox"/> | Geology | <input type="checkbox"/> | Other : |

What is the status of development of the remote sensing value added industry?

Well Established Starting Non Existing

Does your country provide training courses in remote sensing? ?

VI. COMPLEMENTARY DATA FOR EARTH OBSERVATION.

Does your country have the capability to perform reference measurements (useful for the calibration of satellite sensors, or models validation) ?

? *in situ* measurements

Low altitude observation (inferior to 10000 ft.)

High altitude observation

Concerning the measurement acquisition, does your country have just reference plots, subjectively located, or does it have a collection of plots selected through a rational sample design?

?

Is your country equipped with :

? GPS (Global Positionning System)

? [] ARGOS

VII FINANCIAL INVOLVEMENT.

What is the annual space budget (in U.S. \$) of your country?

3 898 000 000 BEF ---> 100 000 \$ K US

What percentage of the GNP does this represent? ?

What is the annual space budget for Earth Observation from space?

225 700 000 BEF ---> 7 000 \$ K US

Does your country foresee an expansion of its involvement in remote sensing activities? In which directions?

Future SPOT programs ESA / PPF programs

Does industry play a role in remote sensing activities in your country? Which one?

ETCA, an associate of Spot Image : power-pack electronic subsystems.
Bell Tel. Man is participating in Spot ground stations alongside SEP and is supplying equipment for Landsat and ERS-1 receiving stations.

Give other financial indicators if any, such as revenues of the remote sensing images sold...
What is the total value (social, environmental, commercial) contributed by remote sensing to your country (e.g. in forest and soil resources saved through better management)? Use the best figures you can find and/or your best guess.

?

VIII REMOTE SENSING CENTERS OF THE COUNTRY.

In the following table, list and characterize the main institutions of your country dealing with remote sensing data (analysis, processing, interpretation, correlation with other data, model development...).

| Remote Sensing Institution | Status | Fields of Application | Origin of the Raw Data | Hardware Tools | Software Tools | Use of a GJS | Annual budget |
|----------------------------|--------|-----------------------|------------------------|----------------|----------------|--------------|---------------|
| EUROSENSE | Comm. | | Airbore SPOT | I2S | ? | ? | ? |

VIII POTENTIAL IMPLEMENTATION OF I.P.E.O. IN THE COUNTRY.

Considering previous answers or more personal views, do you think that new data or information related to the deforestation phenomenon would be useful to the country?

No Yes Maybe

More precisely, would your country be interested in having access to high resolution radar data for deforestation monitoring (in a region 35°S to 35°N latitude, every ten days)? For which purpose?

No Yes Maybe :

Does your country have sufficient land mapping at appropriate scales?

No Yes Maybe not

Would your country be interested in having access to space-based mapping data? (land and topographical mapping)

No Yes Probably

Which ground resolution? larger than 20 m. 20 m.
 10 m. 5 m.
 smaller than 5 m. no idea.

Which accuracy in altitude? larger than 20 m. 20 m.
 10 m. 5 m.
 smaller than 5 m. no idea.

What are the other areas in which the improvement of existing remote sensing raw or processed data could be useful for your country?

?

What spin-offs of I.P.E.O. could be envisioned for the country? In particular those driven by a global change studies? (general welfare, public opinion satisfaction, technology transfer, education...)*

Public-opinion satisfaction, ?

Would your country be willing to commit itself in I.P.E.O.? If yes, how?

? No Yes

IX/ MISCELLANEOUS.

LIST MATERIALS USED FOR THIS SURVEY.

Interavia Spaceflight Directory
 Belgium and Spacen (science policy office - Belgium)

BRAZIL

II INVOLVEMENT IN SPACE ACTIVITIES.

Does your country have a national remote sensing program? If yes, under whose authority?

No Yes : Instituto de Pesquisas Espaciais (INPE)

Does your country possess Earth Observation satellite(s)? If yes, name the program(s).

No Yes :

Does your country design and/or build remote sensing payload(s)?
If yes, name the payload(s) and the prime manufacturer(s).

No Yes : MECB Missão Espacial Completa Brasileira
(Brazilian Complete Space Mission)
Prime manufacturer: INPE (Brazil)

CBERS (China-Brazil Earth Resources Satellite)
70% CAST (China) 30% INPE (Brazil)

Does your country possess any capability to directly receive data from a spacecraft?
If yes, from which satellite(s)? Where are the receiving stations?

No Yes : LANDSAT 4/ Cuiaba
SPOT / Cuiaba
NOAA Tiros / Cachoeira Paulista
GOES/ Cachoeira Paulista
METEOSAT/ Cachoeira Paulista

III INVOLVEMENT IN INTERNATIONAL ACTIVITIES.

Does your country take part in :

S.A.F.I.S.Y. U.N.E.P. I.C.S.U.
 COSPAR A.R.T.E.M.I.S. Other :

Is your country involved in one of the core or working group projects of I.G.B.P. (International Geosphere Biosphere Program)?

No Yes :

Does your country participate in international Earth Observation programs (in particular environmental programs)?

If yes, describe the type of participation (technical exchange, financial investment, other...).

No Yes: EOS/long-term monitoring of the amazon ecosystems through the EOS, from patterns to processes

Same question for bilateral Earth Observation programs.

No Yes: CBERS/China-Brazil

III SENSITIVITY TO ENVIRONMENTAL ISSUES.

Which of the following environmental issues (or common interests) are of importance to your country or to specific regions of your country?

Deforestation (1) ; Global Warming (2) ; Pollution (3) ; Land Resources (4) ; Vegetation Dynamics (5) ; Bio-mass Inventory (6) ; Water Quality (7) ; Soil Assessment (8) ; Urban Development (9) ; Ground Water (10) ; Acid Rain (11) ; Ozone Depletion (12) ; Crop Forecast (13) ; Insect Migration (14) ; Snow / Ice (15) ; Ocean Resources (16) ; Wildlife Monitoring (17) ; Flood (18) ; Desertification (19) ; Other... (be precise).

| Priority | Issues | Is your country actively involved in modelling and monitoring the problem? If yes, how? | Annual Budget or Percentage of Environmental Budget Spent on This Issue. |
|------------------------|--------|--|--|
| 1 st prior. | 1 | A periodic assessment of the amount of deforestation in the Amazon region is being done since 1980 using LANDSAT data. | |
| 2 nd prior. | 4 | Research, development of methodologies and on-going activities on survey of land resources are being conducted. | |
| 3 rd prior. | 13 | * | |

* INPE is currently dedicating a considerable effort in crop survey and forecast using remote sensing techniques. Sugarcane is the subject of a special project that focuses on assessments of cultivated areas and productivity (e.g. size, distribution of the crops). Studies of irrigated rice and wheat crops are providing promising results encouraging the use of remote sensing techniques as an auxiliary tool in the inventory and production forecast of those cultures in the state of Rio Grande do Sul.

Looking at the near, middle and long term future, what are the main objectives and strategies of your country in Earth Observation, and more specifically in environmental programs?

Near term, 1990-1995:

- To provide users with remote sensing data obtained both through opto-electronic sensors (LANDSAT, SPOT, CBERS and MECB satellites) and radar (ERS-1 and RADARSAT).
- To build and launch a remote sensing satellite for monitoring the Amazon region.
- To participate in the EOS program.

Middle and long terms, 1996-2005:

- To participate in an international consortium for using remote sensing satellite services.
- To build and launch a medium size Earth observation satellite.
- To build and launch the follow-on MECB remote sensing satellites in equatorial orbits.
- To create a data transmission system using satellite link between the receiving stations and data processing centers.

VI. UTILIZATION OF REMOTE SENSING DATA.

Does your country make use of remote sensing data? If yes, for which purpose?

No Yes : Research Application

- As for application, which ones?

- | | | | |
|-------------------------------------|----------------|-------------------------------------|--------------------------------|
| <input checked="" type="checkbox"/> | Deforestation | <input checked="" type="checkbox"/> | Land and Topographical Mapping |
| <input type="checkbox"/> | Global Warming | <input type="checkbox"/> | Vegetation Dynamics |
| <input checked="" type="checkbox"/> | Pollution | <input type="checkbox"/> | Desertification |
| <input type="checkbox"/> | Other : | | |

- As for research, which areas are of the concern?

Image processing
Data handling

What kind of remote sensing data sets does your country use more often?

SPOT, LANDSAT

Does your country have the capability to produce its own G.I.S. data?
If yes, which centers are involved in this?

No Yes : INPE has been working in order to build data banks with processed data concerning the different application areas checked below.

What kind of G.I.S. data are most often used?

- | | | | |
|-------------------------------------|-------------------|-------------------------------------|----------------------|
| <input type="checkbox"/> | Digital Elevation | <input checked="" type="checkbox"/> | Land Use/Land Cover |
| <input type="checkbox"/> | Roads | <input type="checkbox"/> | Soils |
| <input checked="" type="checkbox"/> | Hydrology | <input type="checkbox"/> | Political Boundaries |
| <input checked="" type="checkbox"/> | Geology | <input type="checkbox"/> | Other : |

What is the status of development of the remote sensing value added industry?

- Well Established Starting Non Existing

Does your country provide training courses in remote sensing?

Yes

VI COMPLEMENTARY DATA FOR EARTH OBSERVATION.

Does your country have the capability to perform reference measurements (useful for the calibration of satellite sensors, or models validation) ?

- in situ* measurements
 Low altitude observation (inferior to 10000 ft.)
 High altitude observation

Concerning the measurement acquisition, does your country have just reference plots, subjectively located, or does it have a collection of plots selected through a rational sample design?

?

Is your country equipped with :

- GPS (Global Positioning System)
 ARGOS

Some companies (private and governmental) and individuals have GPS receivers and use them for a varied number of applications. One of the applications is geodesy done at IAG (INSTITUTE OF ASTROPHYSICS AND GEOPHYSICS).

VII FINANCIAL INVOLVEMENT.

What is the annual space budget (in U.S. \$) of your country? approx. 100 million USD

What percentage of the GNP does this represent? ?

What is the annual space budget for Earth Observation from space?

approximately 2 to 3 million USD

Does your country foresee an expansion of its involvement in remote sensing activities? In which directions?

Yes. ?

Does industry play a role in remote sensing activities in your country? Which one?

Yes. ?

Give other financial indicators if any, such as revenues of the remote sensing images sold... What is the total value (social, environmental, commercial) contributed by remote sensing to your country (e.g. in forest and soil resources saved through better management)? Use the best figures you can find and/or your best guess.

VII. REMOTE SENSING CENTERS OF THE COUNTRY.

In the following table, list and characterize the main institutions of your country dealing with remote sensing data (analysis, processing, interpretation, correlation with other data, model development...).

| Remote Sensing Institution | Status | Fields of Application | Origin of the Raw Data | Hardware Tools | Software Tools | Use of a GIS | Annual budget |
|----------------------------|---------|-------------------------------|------------------------|------------------------|----------------|--------------|---------------|
| INPE | Govern. | 1, 3, 4, 6, 9, 12, 13, 16, 18 | SPOT LANDSAT | VAX SUNWork-station | Home made | Yes | |

VIII. POTENTIAL IMPLEMENTATION OF I.P.E.O. IN THE COUNTRY.

Considering previous answers or more personal views, do you think that new data or information related to the deforestation phenomenon would be useful to the country?

No Yes Maybe

More precisely, would your country be interested in having access to high resolution radar data for deforestation monitoring (in a region 35°S to 35°N latitude, every ten days)? For which purpose?

No Yes Maybe For monitoring the tropical belt

Does your country have sufficient land mapping at appropriate scales?

No Yes Maybe not

Would your country be interested in having access to space-based mapping data? (land and topographical mapping)

No Yes Probably

Which ground resolution?

larger than 20 m. 20 m.
 10 m. 5 m.
 smaller than 5 m. no idea.

Which accuracy in altitude?

larger than 20 m. 20 m.
 10 m. 5 m.
 smaller than 5 m. no idea.

What are the other areas in which the improvement of existing remote sensing raw or processed data could be useful for your country?

AVHRR processing

What spin-offs of I.P.E.O. could be envisioned for the country? In particular those driven by a global change studies? (general welfare, public opinion satisfaction, technology transfer, education...)

- general welfare
- technology transfer
- training for user applications

Would your country be willing to commit itself in I.P.E.O.? If yes, how?

No Yes :

via technical contribution
 by financial participation
 with *in situ* measurements
 in marketing
 other :

IX/ MISCELLANEOUS.

Most countries have a reference book for remote sensing. Such documents exist also for groups of countries (for example, the Earsel Directory for Europe). Does such a reference book exist for your country? What is its name? Where can it be found?

Not available

LIST MATERIALS USED FOR THIS SURVEY.

- [1] INPE SPACE NEWS, The Newsletter of the Institute for Space Research, vol. 1, number 1, São José dos Campos, SP, Brasil, Jan/Feb/Mar 1990.

- [2] Raupp, M.A.; Cunha, R.P.; Novaes, R.A. **Brazil's Remote Sensing Activities in the Eighties.** INPE, São José dos Campos, SP, Brasil, Oct. 1985. (INPE-3671-PRE/825).
- [3] Barbosa, M.N. **O programa brasileiro de sensoriamento remoto por satélite.** INPE, São José dos Campos, SP, Brasil, 1986.
- [4] INPE. **Avaliação da alteração da cobertura florestal na amazônia legal utilizando sensoriamento remoto.** INPE, São José dos Campos, SP, Brasil, Apr. 1989.
- [5] INPE. **Relatório de Atividades 1988-1989.** INPE, São José dos Campos, SP, Brasil, 1989.

LIST PEOPLE CONTACTED FOR THIS SURVEY AND GIVE THEIR REFERENCES.

Dr. Mucio Roberto Dias (INPE)
Dr. Roberto Pereira da Cunha (INPE)

Is there any material you are expecting? Any further research you would like to do? Any person you would contact later on?

No

Please join to this Country Note any synthetic document or copies that you find particularly relevant.

BULGARIA

II INVOLVEMENT IN SPACE ACTIVITIES.

Does your country have a national remote sensing program? If yes, under whose authority?

No Yes :

National Committee for Research and Peaceful Use of the Outer Space;
Department of Remote Sensing, Space Research Institute of the
Bulgarian Academy of Science

Does your country possess Earth Observation satellite(s)? If yes, name the program(s).

No Yes : Meteor - Priroda, in collaboration with the
Space Research Institute, USSR AS :
INTERCOSMOS program

*Does your country design and/or build remote sensing payload(s)?
If yes, name the payload(s) and the prime manufacturer(s).*

No Yes : SPECTRUM 15 K , SPECTRUM 256
Department of Remote Sensing, Space
Research Institute, BAS

*Does your country possess any capability to directly receive data from a spacecraft?
If yes, from which satellite(s)? Where are the receiving stations?*

No Yes : weather and remote sensing satellites,
INTERCOSMOS program

III INVOLVEMENT IN INTERNATIONAL ACTIVITIES.

Does your country take part in :

| | |
|---|---|
| <input type="checkbox"/> S.A.F.I.S.Y. | <input checked="" type="checkbox"/> U.N.E.P. |
| <input type="checkbox"/> I.C.S.U. | <input checked="" type="checkbox"/> COSPAR |
| <input type="checkbox"/> A.R.T.E.M.I.S. | <input checked="" type="checkbox"/> Other : UNESCO, IAF |

Is your country involved in one of the core or working group projects of I.G.B.P. (International Geosphere Biosphere Program)?

No Yes : Information not available

Does your country participate in international Earth Observation programs (in particular environmental programs)?

If yes, describe the type of participation (technical exchange, financial investment, other...).

No Yes: INTERCOSMOS , technical exchange, ground-based measurements, in situ measurements

Same question for bilateral Earth Observation programs.

No Yes: Same as above

III SENSITIVITY TO ENVIRONMENTAL ISSUES.

Which of the following environmental issues (or common interests) are of importance to your country or to specific regions of your country?

Deforestation (1) ; Global Warming (2) ; Pollution (3) ; Land Resources (4) ; Vegetation Dynamics (5) ; Bio-mass Inventory (6) ; Water Quality (7) ; Soil Assessment (8) ; Urban Development (9) ; Ground Water (10) ; Acid Rain (11) ; Ozone Depletion (12) ; Crop Forecast (13) ; Insect Migration (14) ; Snow / Ice (15) ; Ocean Resources (16) ; Wildlife Monitoring (17) ; Flood (18) ; Desertification (19) ; Other... (be precise).

| Priority | Issues | Is your country actively involved in modelling and monitoring the problem? If yes, how? | Annual Budget or Percentage of Environmental Budget Spent on This Issue. |
|------------------------|--------|---|--|
| 1 st prior. | 3 | ? | ? |
| 2 nd prior. | 7 | ? | ? |
| 3 rd prior. | 1 | ? | ? |
| 4 th prior. | 8 | ? | ? |
| 5 th prior. | 4 | ? | ? |

Looking at the near, middle and long term future, what are the main objectives and strategies of your country in Earth Observation, and more specifically in environmental programs?

Monitoring the amount of pollutants, the degree of pollution, water quality and deforestation.

Measures for reduction and clearing of the hazardous pollutants, reforestation and terminating industries and production that are environmentally dangerous. Stimulating research and implementation of new environmentally save production and technologies.

IV/ UTILIZATION OF REMOTE SENSING DATA.

Does your country make use of remote sensing data? If yes, for which purpose?

No Yes : Research Application

- As for application, which ones?

Deforestation Land and Topographical Mapping
 Global Warming Vegetation Dynamics
 Pollution Desertification
 Other : water quality, soil assesment

- As for research, which areas are of the concern?

All above, geological mapping, global warming, ozone depletion, crop forecast

What kind of remote sensing data sets does your country use more often?

INTERCOSMOS : METEOR - PRIRODA, LANDSAT (?)
 Soyuz-Karta, Aerial Photos

Does your country have the capability to produce its own G.I.S. data?
 If yes, which centers are involved in this?

No Yes : ?

What kind of G.I.S. data are most often used?

Digital Elevation
 Land Use/Land Cover
 Roads
 Soils
 Hydrology
 Political Boundaries
 Geology
 Other :

What is the status of development of the remote sensing value added industry?

Well Established Starting Non Existing

Does your country provide training courses in remote sensing? Yes

VI. COMPLEMENTARY DATA FOR EARTH OBSERVATION.

Does your country have the capability to perform reference measurements (useful for the calibration of satellite sensors, or models validation) ?

- in situ* measurements
- Low altitude observation (inferior to 10000 ft.)
- High altitude observation

Concerning the measurement acquisition, does your country have just reference plots, subjectively located, or does it have a collection of plots selected through a rational sample design?

?

Is your country equipped with :

- GPS (Global Positioning System)
- ARGOS

VII. FINANCIAL INVOLVEMENT.

What is the annual space budget (in U.S. \$) of your country? About \$ 10-15 M

What percentage of the GNP does this represent? ?

What is the annual space budget for Earth Observation from space? About \$ 2.5 M

Does your country foresee an expansion of its involvement in remote sensing activities? In which directions?

Monitoring and modelling the environmental changes.

Does industry play a role in remote sensing activities in your country? Which one?

Yes, Optics and Electronics

Give other financial indicators if any, such as revenues of the remote sensing images sold...

What is the total value (social, environmental, commercial) contributed by remote sensing to your country (e.g. in forest and soil resources saved through better management)? Use the best figures you can find and/or your best guess.

?

VIII. REMOTE SENSING CENTERS OF THE COUNTRY.

In the following table, list and characterize the main institutions of your country dealing with remote sensing data (analysis, processing, interpretation, correlation with other data, model development...).

| Remote Sensing Institution | Status | Fields of Application | Origin of the Raw Data | Hardware Tools | Software Tools | Use of a GIS | Annual budget |
|-------------------------------|--------------------------------|-----------------------|------------------------------------|--------------------------------|----------------|--------------|---------------|
| Space Research Institute, BAS | governm academic commerc | 3, 7, 1, 8, 4. | INTER-COSMOS METEOR- PRIRODA | 1 VAX, PC, 10 IBM AT,DOS | ? | ? | ? |

VIII POTENTIAL IMPLEMENTATION OF I.P.E.O. IN THE COUNTRY.

Considering previous answers or more personal views, do you think that new data or information related to the deforestation phenomenon would be useful to the country?

No Yes Maybe

More precisely, would your country be interested in having access to high resolution radar data for deforestation monitoring (in a region 35°S to 35°N latitude, every ten days)? For which purpose?

No Yes Maybe :

Does your country have sufficient land mapping at appropriate scales?

No Yes Maybe not

Would your country be interested in having access to space-based mapping data? (land and topographical mapping)

No Yes Probably

Which ground resolution?

larger than 20 m. 20 m.
 10 m. 5 m.
 smaller than 5 m. no idea.

Which accuracy in altitude?

larger than 20 m. 20 m.
 10 m. 5 m.
 smaller than 5 m. no idea.

What are the other areas in which the improvement of existing remote sensing raw or processed data could be useful for your country?

Geological Mapping, Vegetation Dynamics, Soil Assessment.

What spin-offs of I.P.E.O. could be envisioned for the country*? In particular those driven by a global change studies? (general welfare, public opinion satisfaction, technology transfer, education...)

Public opinion satisfaction, technology transfer, education

Would your country be willing to commit itself in I.P.E.O.? If yes, how?

No Yes :

- via technical contribution
- by financial participation
- with *in situ* measurements
- in marketing
- other :

IX/ MISCELLANEOUS.

Most countries have a reference book for remote sensing. Such documents exist also for groups of countries (for example, the Earsel Directory for Europe). Does such a reference book exist for your country? What is its name? Where can it be found?

?

LIST MATERIALS USED FOR THIS SURVEY.

LIST PEOPLE CONTACTED FOR THIS SURVEY AND GIVE THEIR REFERENCES.

Is there any material you are expecting? Any further research you would like to do? Any person you would contact later on?

I would like to contact Prof. Dimitar Mishev,
Chief of Remote Sensing Department,
Space Research Institute,
Bulgarian Academy of Sciences,
Acad. G. Bonchev str., block 3,
1113 Sofia, Bulgaria Telex: 23 351 CLSRBG

Please join to this Country Note any synthetic document or copies that you find particularly relevant.

CANADA

II INVOLVEMENT IN SPACE ACTIVITIES.

Does your country have a national remote sensing program? If yes, under whose authority?

No Yes Energy Mines and Resources (EMR)

Does your country possess Earth Observation satellite(s)? If yes, name the program(s).

No Yes RADARSAT, to be launched in 1994
SPAR AEROSPACE prime contractor
Can. Marconi/Canadian Astronautics payload.

Does your country design and/or build remote sensing payload(s)?
If yes, name the payload(s) and the prime manufacturer(s).

No Yes :

| | | |
|-------------------------------------|------|----------------------------|
| | SPAR | SAR |
| Canadian Astronautics Ltd.(CAL) | | Ultraviolet Imager(Viking) |
| MacDonald Dettwiler&Associates(MDA) | | SAR |
| SED SYSTEMS INC | | WAMDII,SMS |

Does your country possess any capability to directly receive data from a spacecraft?
If yes, from which satellite(s)? Where are the receiving stations?

No Yes :

SPOT series, LANDSAT series, ERS-1, MOS-1, NOAA, RADARSAT(1994)
Stations : Prince Albert (Saskatchewan), Gatineau (Quebec)

III INVOLVEMENT IN INTERNATIONAL ACTIVITIES.

Does your country take part in :

| | |
|--|--|
| <input checked="" type="checkbox"/> S.A.F.I.S.Y. | <input checked="" type="checkbox"/> U.N.E.P. |
| <input checked="" type="checkbox"/> I.C.S.U. | <input checked="" type="checkbox"/> COSPAR |
| <input checked="" type="checkbox"/> A.R.T.E.M.I.S. | <input checked="" type="checkbox"/> Other : UNESCO |

Is your country involved in one of the core or working group projects of I.G.B.P. (International Geosphere Biosphere Program)?

No Yes CP 1:Terrestrial Bioatmosphere
WG1:Data and Information System
CP.4:Effect of climate on Terrestrial Geosphere
WG2:Regional Research Center
SSC:on Global Changes of the Past

Does your country participate in International Earth Observation programs (in particular environmental programs)?

If yes, describe the type of participation (technical exchange, financial investment, other...).

No Yes :

ESA-Associate member, Financial investment in ERS-1
 RADARSAT-technical, exchange, financial, investment with NASA
 Member of CEOS

Same question for bilateral Earth Observation programs.

No Yes : Technical : SPOT, LANDSAT, MOS-1, ERS-1, JERS-I

III. SENSITIVITY TO ENVIRONMENTAL ISSUES.

Which of the following environmental issues (or common interests) are of importance to your country or to specific regions of your country?

Deforestation (1) ; Global Warming (2) ; Pollution (3) ; Land Resources (4) ; Vegetation Dynamics (5) ; Bio-mass Inventory (6) ; Water Quality (7) ; Soil Assessment (8) ; Urban Development (9) ; Ground Water (10) ; Acid Rain (11) ; Ozone Depletion (12) ; Crop Forecast (13) ; Insect Migration (14) ; Snow / Ice (15) ; Ocean Resources (16) ; Wildlife Monitoring (17) ; Flood (18) ; Desertification (19) ; Other... (be precise).

| Priority | Issues | Is your country actively involved in modelling and monitoring the problem? If yes, how?* | Annual Budget or Percentage of Environmental Budget Spent on This Issue.** |
|------------------------|--------|--|--|
| 1 st prior. | 4 | Land resources, data bases are developed based on data received from NOAA, LANDSAT, SPOT | |
| 2 nd prior. | 5,1 | Vegetation Dynamics/deforestation-management systems under development | |
| 3 rd prior. | 16 | Ocean Resources-ocean information systems under development | |
| 4 th prior. | 13 | Crop Forecast-Crop info system is in place, NOAA/LANDSAT | |
| 5 th prior. | 2 | Global Warming-establishment of data base to monitor changes and develop models | |

- * Priority varies by agency. Also, many of these issues are inter-related. There are a number of comprehensive R&D as well as full operational programs (some of which are in place, e.g. 1,4,9,13,15,17)
- ** There is no budget breakdown for these priorities.

Looking at the near, middle and long term future, what are the main objectives and strategies of your country in Earth Observation, and more specifically in environmental programs?

1. Complete the development of procedures, models and data handling systems which are required to use satellite data for:
 - a) Detecting global changes over Canadian territory with emphasis on the boreal forest, grasslands, agricultural regions, the global zone, and the atmosphere,
 - b) Assessing the magnitude of the changes, and,
 - c) Determining the current and future impact of the change.
2. Develop next generation satellite data processing and modelling technology with emphasis on integration of Image Analysis, GIS, and Digital Telecommunications networks.
3. Contribute to the definition, development, and implementation of international satellite observation programs for global change studies.

IV/ UTILIZATION OF REMOTE SENSING DATA.

- Does your country make use of remote sensing data? If yes, for which purpose?

No Yes : Research Application

- As for application, which ones?

| | | | |
|-------------------------------------|----------------|-------------------------------------|--|
| <input checked="" type="checkbox"/> | Deforestation | <input checked="" type="checkbox"/> | Land and Topographical Mapping |
| <input checked="" type="checkbox"/> | Global Warming | <input checked="" type="checkbox"/> | Vegetation Dynamics |
| <input checked="" type="checkbox"/> | Pollution | <input type="checkbox"/> | Desertification |
| <input checked="" type="checkbox"/> | Other : | | Ice surveillance |
| | | | Hydrology, cartography |
| | | | Integration of GIS and RS for regional resource management |

- As for research, which areas are of the concern?

Develop application for RADARSAT (e.g. land/ocean resource monitoring, terrain monitoring, hydrology, tropical forest monitoring, etc.)

What kind of remote sensing data sets does your country use more often?

Aerial photos, LANDSAT, AVHRR, SPOT, MOS, Radar imagery(airborne)
Does your country have the capability to produce its own G.I.S. data?
If yes, which centers are involved in this?

No Yes :

- Canadian Federal Dept. of Energy Mines and Resources (EMR)- Surveys, Mapping, and Remote Sensing sector,
- Canadian Center for Remote Sensing (CCRS),
- Provincial Remote Sensing Centers and Government mapping agencies.

What kind of G.I.S. data are most often used?

- | | |
|---|---|
| <input checked="" type="checkbox"/> Digital Elevation | <input checked="" type="checkbox"/> Land Use/Land Cover |
| <input checked="" type="checkbox"/> Roads | <input checked="" type="checkbox"/> Soils |
| <input checked="" type="checkbox"/> Hydrology | <input checked="" type="checkbox"/> Political Boundaries |
| <input type="checkbox"/> Geology | <input checked="" type="checkbox"/> Other : Forest type CADASTAL, CULTURAL |

What is the status of development of the remote sensing value added industry?

Well Established Starting Non Existing

Does your country provide training courses in remote sensing?

Yes

VI. COMPLEMENTARY DATA FOR EARTH OBSERVATION.

Does your country have the capability to perform reference measurements (useful for the calibration of satellite sensors, or models validation) ?

- in situ* measurements
- Low altitude observation (inferior to 10000 ft.)
- High altitude observation

Concerning the measurement acquisition, does your country have just reference plots, subjectively located, or does it have a collection of plots selected through a rational sample design?

Yes, all of the above

Is your country equipped with :

- GPS (Global Positioning System)
- ARGOS

VII. FINANCIAL INVOLVEMENT.

What is the annual space budget (in U.S. \$) of your country?

Over the past five years, the budget averaged One million US dollars per year (US\$ 114 M in 1986)

What percentage of the GNP does this represent?

?

What is the annual space budget for Earth Observation from space?

The second most important item in Canada's space budget. CDN\$ 75 M per year on average (1986 \$ 73.5 M.)

Does your country foresee an expansion of its involvement in remote sensing activities? In which directions?

- Yes
- Value added Remote Sensing
 - RADARSAT capabilities (Image processing/interpretation)
 - Image analysis
 - Data reception
 - Synthetic Aperture Radar (SAR)-R&D in resource management and environmental protection

Does industry play a role in remote sensing activities in your country? Which one?

Yes Many companies (over 120), see Reference(2) for a detailed list.

Give other financial indicators if any, such as revenues of the remote sensing images sold... What is the total value (social, environmental, commercial) contributed by remote sensing to your country (e.g. in forest and soil resources saved through better management)? Use the best figures you can find and/or your best guess.

- Images sold (LANDSAT and SPOT) \$1.2 Million
- Over 120 Remote Sensing companies exist across CANADA
- Estimated R.S. employment is 2500-3000
- Estimated percentage of the population which is familiar with earth observation from space (via media coverage) is 60% of adults.
- Sale of image posters&books-between CDN\$3 to 5 Million per year.

VIII REMOTE SENSING CENTERS OF THE COUNTRY.

In the following table, list and characterize the main institutions of your country dealing with remote sensing data (analysis, processing, interpretation, correlation with other data, model development...).

| Remote | Fields | Origin | Hardware | Software | Use | Annual |
|--------|--------|--------|----------|----------|-----|--------|
|--------|--------|--------|----------|----------|-----|--------|

| <i>Sensing Institution</i> | <i>Status</i> | <i>of Application</i> | <i>of the Raw Data</i> | <i>Tools</i> | <i>Tools</i> | <i>of a GIS</i> | <i>budget</i> |
|--|--|--|--|--|--|-----------------|---------------|
| Canada Center for Remote Sensing (CCRS) 1547 Merivale Ottawa, Ont. K1A-OY7 | Federal Dept. of Energy Mines and Resource (EMR) | 1,2,3,4,5,7,9, 10,11,12,13, 15,16,17 | LANDSAT NOAA SPOT CCRS SAR | main- frame ,PCI, MERIDIAN, DIPEX, etc. | ARIES PCI MERIDIAN Earth- probe Pamap etc. | yes | \$22 M |
| Applied Terravision Systems Inc., Calgary | private | 8, petroleum seismology | LANDSAT SPOT | Appolo (Unix- based) | LANDSCAN | yes | ? |
| Array Systems Computing Inc., Downsview, Ontario | Private | meteo- rology | NOAA HRPT GEOS Meteosat COPAS/S ARSAT | FAX, X- 25,HDLC, DecNet | MAPS | ? | ? |
| Canadian Astronautic Ltd., Ottawa | Private | Manufac- turing of Radar, space, and military advanced systems | LANDSAT SLAR SARSAT and many others | SLAR 100 | ? | ? | ? |
| DIGIM Inc., Montreal | Private | 1,5,6 | SPOT | DIPIX Aries IBM PC AT Meridian | ? | yes | ? |

| <i>Remote Sensing Institution</i> | <i>Status</i> | <i>Fields of Application</i> | <i>Origin of the Raw Data</i> | <i>Hardware Tools</i> | <i>Software Tools</i> | <i>Use of a GIS</i> | <i>Annual budget</i> |
|--|---------------|--|--|-------------------------|-----------------------|---------------------|----------------------|
| EIDETIC Digital Imaging Ltd., Brentwood Bay B.C. | Private | Digital Image Analysis Systems | ? | PC XT/AT and PC/Z IBM | CCT EOSAT | ? | ? |
| HERMES Electronics Ltd., N.S. | Private | Manufacturing of Oceanic Meteorolog. data equipment | ? | ARGOS ARGOS PTT HT-101A | ? | ? | ? |
| INTERA Technologies Ltd., Calgary | Private | 15,16,9,1,4 | LANDSAT SPOT, SEA SAT, airborne SAR, airborne MSS and MEIS | STAR-1 STAR-VUE | EASIA ARIES | ? | ? |
| MacDonald Dettwiler & Associates, Richmond, B.C. | Private | Meteorological data, surface observ. for weather forecasting Radar mapping Ground stations | SAR airborne Radar systems | MERIDIAN | Meridian | ? | ? |

| <i>Remote Sensing Institution</i> | <i>Status</i> | <i>Fields of Application</i> | <i>Origin of the Raw Data</i> | <i>Hardware Tools</i> | <i>Software Tools</i> | <i>Use of a G.I.S</i> | <i>Annual budget</i> |
|--|-------------------------------|---|--|---|-----------------------|-----------------------|----------------------|
| SPAR Aerospace Ltd., Toronto, Montreal | Public | Space Defense communication and Teleoperation systems | Payloads for Anik-A,B,C,D for Telesat Canada, TDRSS for TRW, Olympus for ESA, Palapa B and Intelsat VI | ? | ? | ? | ? |
| SED Systems Inc., Saskatoon | Private | Turnkey ground stations, TTC systems, Meteorological data reduction systems | LANDSAT NOAA SPOT via PASS station | main-frame, VAX, PCI DIPEX | ARIES | ? | ? |
| Ontario Center for Remote Sensing, Toronto | Ontario Govn't | 1 to 15 | LANDSAT NOAA SPOT RADAR | main-frame VAX PCI, DIPEX Image Analys. | ARIES EASI/PACE | yes | ? |
| Manitoba R.S. Center, Winnipeg | Manito. Govn't | 1 to 15 | LANDSAT NOAA SPOT RADAR | same as above | ARIES EASI/PACE | yes | ? |
| ISTS, YORK University Toronto | Research center of excellence | 1 to 15 | same as above | same as above | ARIES EASI/PACE | yes | ? |

| <i>Remote Sensing Institution</i> | <i>Status</i> | <i>Fields of Application</i> | <i>Origin of the Raw Data</i> | <i>Hardware Tools</i> | <i>Software Tools</i> | <i>Use of a GIS</i> | <i>Annual budget</i> |
|-----------------------------------|---------------|------------------------------|-------------------------------|-----------------------|-----------------------|---------------------|----------------------|
| CARTEL, Sherbrooke University | Research | 1 to 15 | same as above | main-frame VAX PCI | ARIES EASI/PACE | yes | ? |
| PCI Inc., Toronto | Private | | same as above | same as above | EASI/PACE | yes | ? |

VIII. POTENTIAL IMPLEMENTATION OF I.P.E.O. IN THE COUNTRY.

Considering previous answers or more personal views, do you think that new data or information related to the deforestation phenomenon would be useful to the country?

No Yes Maybe

More precisely, would your country be interested in having access to high resolution radar data for deforestation monitoring (in a region 35°S to 35°N latitude, every ten days)? For which purpose?

No Yes Maybe : Forest Management
Geology & Terrain

Does your country have sufficient land mapping at appropriate scales?

No Yes Maybe not

Would your country be interested in having access to space-based mapping data? (land and topographical mapping)

No Yes Probably

Which ground resolution? larger than 20 m. 20 m.
 10 m. 5 m.
 smaller than 5 m. no idea.

Which accuracy in altitude? larger than 20 m. 20 m.
 10 m. 5 m.
 smaller than 5 m. no idea.

What are the other areas in which the improvement of existing remote sensing raw or processed data could be useful for your country?

Engineering: Infrastructure mapping-Urban expansion, local environmental planning, location of land fill sites, etc.

What spin-offs of I.P.E.O. could be envisioned for the country? In particular those driven by a global change studies? (general welfare, public opinion satisfaction, technology transfer, education...)

- Increased public awareness of global environment problems,
- Technology transfer,
- Boost to value-added industry(e.g. forestry consulting),
- Modelling of global changes,
- etc.

Would your country be willing to commit itself in I.P.E.O.? If yes, how?

- No Yes :
- via technical contribution
 - by financial participation
 - with *in situ* measurements
 - in marketing
 - other :Technology transfer
Training
Aid programs

IXI MISCELLANEOUS.

Most countries have a reference book for remote sensing. Such documents exist also for groups of countries (for example, the Earsel Directory for Europe). Does such a reference book exist for your country? What is its name? Where can it be found?

No

LIST MATERIALS USED FOR THIS SURVEY.

1. "CONTRIBUTION OF SATELLITE OBSERVATIONS TO THE CANADIAN GLOBAL CHANGE PROGRAM", J. Cihlar et al., Publication of Energy Mines and Resources Report No.3, 1989.
2. "REMOTE SENSING PRODUCTS AND SERVICES FOR WORLD MARKETS", Publication of the Dept. of External Affairs, Ottawa, 1987.
3. " WORLD SPACE INDUSTRY: TEN YEARS OUTLOOK", Publication of the Euroconsult, Villain et al., April 1988.

LIST PEOPLE CONTACTED FOR THIS SURVEY AND GIVE THEIR REFERENCES.

- | | |
|--|---|
| <ol style="list-style-type: none"> 1. Dr. Vern Singhory, CCRS 1547 Merivale Rd., Ottawa, Ontario K1A-0Y7 3. Mr. Don Epp SED Systems Inc. P.O.Box 1464 Saskatoon, SASK. S7K 3P7 | <ol style="list-style-type: none"> 2. Dr. Robert Ryerson (same as in 1) 4. Mr. Jeff Whiting Saskatchewan Research Council SEDCO place Innovation Place Saskatoon, SASK. S7K 3P7 |
|--|---|

Is your country involved in one of the core or working group projects of I.G.B.P. (International Geosphere Biosphere Program)?

No Yes : ?

Does your country participate in international Earth Observation programs (in particular environmental programs)?

If yes, describe the type of participation (technical exchange, financial investment, other...).

No Yes : ?

Same question for bilateral Earth Observation programs.

No Yes : China/Brazil, joint venture
 Matra (Fr) : payload on CHINA 20 SETE
 TTC Xian
 West German Research Ministries : Payload

III. SENSITIVITY TO ENVIRONMENTAL ISSUES.

Which of the following environmental issues (or common interests) are of importance to your country or to specific regions of your country?

Deforestation (1) ; Global Warming (2) ; Pollution (3) ; Land Resources (4) ; Vegetation Dynamics (5) ; Bio-mass Inventory (6) ; Water Quality (7) ; Soil Assessment (8) ; Urban Development (9) ; Ground Water (10) ; Acid Rain (11) ; Ozone Depletion (12) ; Crop Forecast (13) ; Insect Migration (14) ; Snow / Ice (15) ; Ocean Resources (16) ; Wildlife Monitoring (17) ; Flood (18) ; Desertification (19) ; Other... (be precise).

| Priority | Issues | Is your country actively involved in modelling and monitoring the problem? If yes, how? | Annual Budget or Percentage of Environmental Budget Spent on This Issue. |
|------------|--------|---|--|
| 1st prior. | (4) | Satellite Application | It is difficult to count the budget in China. However, satellite application on these issues will be a priority in space program in China in 1990's. |
| 2nd prior. | (2) | 1. Satellite Application 2. Government regulations | |
| 3rd prior. | (5) | Satellite Application | |
| 4th prior. | (1) | 1. Satellite Application 2. Government regulations | |
| 5th prior. | (18) | Satellite Application | |
| | (3) | 1. Satellite Application 2. Government regulations | |

Looking at the near, middle and long term future, what are the main objectives and strategies of your country in Earth Observation, and more specifically in environmental programs?

1. Satellite application in this area will be priority which is carried out by Government in 1990's.
2. Government is willing to involve international cooperation if China can be benefited from international program.
3. Government has highly committed to solve environmental problems in China.

IV. UTILIZATION OF REMOTE SENSING DATA.

- *Does your country make use of remote sensing data? If yes, for which purpose?*

No Yes : Research Application

- *As for application, which ones?*

| | | | |
|-------------------------------------|----------------|-------------------------------------|--------------------------------|
| <input checked="" type="checkbox"/> | Deforestation | <input checked="" type="checkbox"/> | Land and Topographical Mapping |
| <input checked="" type="checkbox"/> | Global Warming | <input checked="" type="checkbox"/> | Vegetation Dynamics |
| <input checked="" type="checkbox"/> | Pollution | <input checked="" type="checkbox"/> | Desertification |
| <input checked="" type="checkbox"/> | Other : flood. | | |

- *As for research, which areas are of the concern?*

1. Land resources.
2. Deforestation.
3. Vegetation dynamics.

What kind of remote sensing data sets does your country use more often?

Landsat.

*Does your country have the capability to produce its own G.I.S. data?
If yes, which centers are involved in this?*

No Yes : If yes, involving centers would be in Chinese Academy of Science in China.

What is the status of development of the remote sensing value added industry?

Well Established Starting Non Existing

Established, but not well.

Does your country provide training courses in remote sensing?

Yes.

VI. COMPLEMENTARY DATA FOR EARTH OBSERVATION.

Does your country have the capability to perform reference measurements (useful for the calibration of satellite sensors, or models validation) ?

- in situ* measurements
- Low altitude observation (inferior to 10000 ft.)
- High altitude observation

Concerning the measurement acquisition, does your country have just reference plots, subjectively located, or does it have a collection of plots selected through a rational sample design?

?

Is your country equipped with :

- GPS (Global Positionning System)
- ARGOS

VII. FINANCIAL INVOLVEMENT.

What is the annual space budget (in U.S. \$) of your country? ?

What percentage of the GNP does this represent? ?

What is the annual space budget for Earth Observation from space? ?

Does your country foresee an expansion of its involvement in remote sensing activities? In which directions?

Yes. Land resources, deforestation and global warming.

Does industry play a role in remote sensing activities in your country? Which one?

Yes. Ministry of Aerospace Industry.

Give other financial indicators if any, such as revenues of the remote sensing images sold...
What is the total value (social, environmental, commercial) contributed by remote sensing to your country (e.g. in forest and soil resources saved through better management)? Use the best figures you can find and/or your best guess.

About 3-4 billions.

VIII. REMOTE SENSING CENTERS OF THE COUNTRY.

In the following table, list and characterize the main institutions of your country dealing with remote sensing data (analysis, processing, interpretation, correlation with other data, model development...).

| Remote Sensing Institution | Status | Fields of Application | Origin of the Raw Data | Hardware Tools | Software Tools | Use of a GIS | Annual budget |
|--|---|-----------------------------|---|---|----------------|--------------|---------------|
| Chinese Academy of Science | Ministry of Forestry and Agricult. Universities | Refer to the previous table | Landsat Recoverable satellite FY-1 SPOT | ? | ? | ? | ? |
| Beijing's Satellite Meteorolog. Centre | | Meteo | NOAA FY | 3 IBM 4381 3S 2 IBM 7350 2 IBM 5080 | | | |

VIII/ POTENTIAL IMPLEMENTATION OF I.P.E.O. IN THE COUNTRY.

Considering previous answers or more personal views, do you think that new data or information related to the deforestation phenomenon would be useful to the country?

No Yes Maybe

More precisely, would your country be interested in having access to high resolution radar data for deforestation monitoring (in a region 35°S to 35°N latitude, every ten days)? For which purpose?

No Yes Maybe :

If it can be beneficial and is not too expensive.

Does your country have sufficient land mapping at appropriate scales?

No Yes Maybe not

However, China is working on this now.

Would your country be interested in having access to space-based mapping data? (land and topographical mapping)

No Yes Probably

Which ground resolution?

larger than 20 m. 20 m.

- 10 m.
- smaller than 5 m.
- 5 m.
- no idea.

Which accuracy in altitude?

- larger than 20 m.
- 10 m.
- smaller than 5 m.
- 20 m.
- 5 m.
- no idea.

What are the other areas in which the improvement of existing remote sensing raw or processed data could be useful for your country?

?

What spin-offs of I.P.E.O. could be envisioned for the country*? In particular those driven by a global change studies? (general welfare, public opinion satisfaction, technology transfer, education...)

?

Would your country be willing to commit itself in I.P.E.O.? If yes, how?

- No
- Yes : via technical contribution
- If it is beneficial by financial participation
- with *in situ* measurements
- in marketing
- other :

IX/ MISCELLANEOUS.

Most countries have a reference book for remote sensing. Such documents exist also for groups of countries (for example, the Earsel Directory for Europe). Does such a reference book exist for your country? What is its name? Where can it be found?

May be. You may contact Chinese Academy of Science for details.

LIST MATERIALS USED FOR THIS SURVEY.

LIST PEOPLE CONTACTED FOR THIS SURVEY AND GIVE THEIR REFERENCES.

Is there any material you are expecting? Any further research you would like to do? Any person you would contact later on?

Yes.

COLOMBIA

II INVOLVEMENT IN SPACE ACTIVITIES.

Does your country have a national remote sensing program? If yes, under whose authority?

No Yes :

Does your country possess Earth Observation satellite(s)? If yes, name the program(s).

No Yes :

Does your country design and/or build remote sensing payload(s)? If yes, name the payload(s) and the prime manufacturer(s).

No Yes :

*Does your country possess any capability to directly receive data from a spacecraft?
If yes, from which satellite(s)? Where are the receiving stations?*

No Yes : INTELSAT Estacion Receptora de Choconta
 Instituto de Radio y Television, Bogota
 10-15 repetition stations

III INVOLVEMENT IN INTERNATIONAL ACTIVITIES.

Does your country take part in :

S.A.F.I.S.Y. U.N.E.P. I.C.S.U.
 COSPAR A.R.T.E.M.I.S. Other : ?

Is your country involved in one of the core or working group projects of I.G.B.P. (International Geosphere Biosphere Program)?

No Yes :

Does your country participate in international Earth Observation programs (in particular environmental programs)?

If yes, describe the type of participation (technical exchange, financial investment, other...).

No Yes :

To map the country for military purposes primarily contracting services with U.S. Later Colombia will have services from a European

satellite. Other services are technical exchange for topographic, forestal, meteorological and sysmic data.

Same question for bilateral Earth Observation programs.

[] No [X] Yes :

Colombia will have in a few years an agreement - already in process, with other SouthAmerican countries to share satellite program.

III SENSITIVITY TO ENVIRONMENTAL ISSUES.

Which of the following environmental issues (or common interests) are of importance to your country or to specific regions of your country?

Deforestation (1) ; Global Warming (2) ; Pollution (3) ; Land Resources (4) ; Vegetation Dynamics (5) ; Bio-mass Inventory (6) ; Water Quality (7) ; Soil Assessment (8) ; Urban Development (9) ; Ground Water (10) ; Acid Rain (11) ; Ozone Depletion (12) ; Crop Forecast (13) ; Insect Migration (14) ; Snow / Ice (15) ; Ocean Resources (16) ; Wildlife Monitoring (17) ; Flood (18) ; Desertification (19) ; Other... (be precise).

| Priority | Issues | Is your country actively involved in modelling and monitoring the problem? If yes, how? | Annual Budget or Percentage of Environmental Budget Spent on This Issue. |
|------------|--------|---|--|
| 1st prior. | 7 | Soil assessment to control the land uses somehow, and study urban growing patterns. | ? |
| 2nd prior. | 8 | Urban development projections by studying past urban growing models and comparing with reality. | ? |
| 3rd prior. | 4-13 | Moderately active for research purposes by studying bio-ecological issues as well as climatology and meteorology. | ? |
| 4th prior. | 13-5 | Id | |
| 5th prior. | 18 | Minimal deforestation studies in small areas of the country. | ? |

Looking at the near, middle and long term future, what are the main objectives and strategies of your country in Earth Observation, and more specifically in environmental programs?

Economic power, then towards the improvement of topographical, land and demographic mapping of much of the unknown areas of the country.

-> Localisation of human and natural resources of exploitation.

IV/ UTILIZATION OF REMOTE SENSING DATA.

Does your country make use of remote sensing data? If yes, for which purpose?

No Yes : Research Application

- *As for application, which ones?*

| | | | |
|---|--|------------------------------|--------------------------------|
| <input checked="" type="checkbox"/> [3] | Deforestation | <input type="checkbox"/> [1] | Land and Topographical Mapping |
| <input type="checkbox"/> [] | Global Warming | <input type="checkbox"/> [2] | Vegetation Dynamics |
| <input type="checkbox"/> [] | Pollution | <input type="checkbox"/> [4] | Desertification |
| <input checked="" type="checkbox"/> [5] | Other : Mining possibilities, Meteorology. | | |

- *As for research, which areas are of the concern?*

Urban, vegetal and climate dynamics.

*What kind of remote sensing data sets does your country use more often?
(SPOT, LANDSAT, AVHRR, METEOSAT, MOS, IRS, Soyuz-Karta, Aerial Photos...)*

More than one satellite (?)
Aerial photos.

*Does your country have the capability to produce its own G.I.S. data?
If yes, which centers are involved in this?*

[] No [] Yes : ?

Probably Instituto Geografico Agustin Codazzi.

What kind of G.I.S. data are most often used?

| | | | |
|---|-------------------|---|---------------------------|
| <input type="checkbox"/> [?] | Digital Elevation | <input checked="" type="checkbox"/> [X] | Land Use/Land Cover |
| <input checked="" type="checkbox"/> [X] | Roads | <input checked="" type="checkbox"/> [X] | Soils |
| <input checked="" type="checkbox"/> [X] | Hydrology | <input checked="" type="checkbox"/> [X] | Political Boundaries |
| <input checked="" type="checkbox"/> [X] | Geology | <input checked="" type="checkbox"/> [X] | Other : Military options. |

What is the status of development of the remote sensing value added industry?

[] Well Established [X] Starting [] Non Existing

Does your country provide training courses in remote sensing?

Yes.

VI. COMPLEMENTARY DATA FOR EARTH OBSERVATION.

Does your country have the capability to perform reference measurements (useful for the calibration of satellite sensors, or models validation) ?

- in situ* measurements
- Low altitude observation (inferior to 10000 ft.)
- High altitude observation

Concerning the measurement acquisition, does your country have just reference plots, subjectively located, or does it have a collection of plots selected through a rational sample design?

Maybe. ?

Is your country equipped with :

- GPS (Global Positioning System) ?
- ARGOS ?

VII. FINANCIAL INVOLVEMENT.

What is the annual space budget (in U.S. \$) of your country? None

What percentage of the GNP does this represent? None

What is the annual space budget for Earth Observation from space? None

Does your country foresee an expansion of its involvement in remote sensing activities? In which directions?

Buying more satellite shared services.

Does industry play a role in remote sensing activities in your country? Which one?

?

Give other financial indicators if any, such as revenues of the remote sensing images sold...
What is the total value (social, environmental, commercial) contributed by remote sensing to your country (e.g. in forest and soil resources saved through better management)? Use the best figures you can find and/or your best guess.

?

VIII. REMOTE SENSING CENTERS OF THE COUNTRY.

In the following table, list and characterize the main institutions of your country dealing with remote sensing data (analysis, processing, interpretation, correlation with other data, model development...).

| <i>Remote Sensing Institution</i> | <i>Status</i> | <i>Fields of Application</i> | <i>Origin of the Raw Data</i> | <i>Hardware Tools</i> | <i>Software Tools</i> | <i>Use of a GIS</i> | <i>Annual budget</i> |
|---------------------------------------|---------------|---|-------------------------------|-----------------------|-----------------------|---------------------|----------------------|
| Instituto Geografico Augustin Codazzi | govnmnt | 1,4, 5, 6, 8, 9 Meteo, Oil Mining | ? | ? | ? | ? | ? |

Ingeominas : Mining Department.

Instituto Geografico Augustin Codazi : Land Use/Cover and Meteorological Mapping for public consultancy.

Ecopetrol : Resources Hunting Location and Protection.

Instituto Colombiano Agropecuario : Forest and Vegetation Mapping and Research.

Sysmic Institute : Meteorological and Sysmic data.

VIII/ POTENTIAL IMPLEMENTATION OF I.P.E.O. IN THE COUNTRY.

Considering previous answers or more personal views, do you think that new data or information related to the deforestation phenomenon would be useful to the country?

No Yes Maybe

More precisely, would your country be interested in having access to high resolution radar data for deforestation monitoring (in a region 35°S to 35°N latitude, every ten days)? For which purpose?

No Yes Maybe :

Land Use and Missuse, Vegetation Evolution
Demography, Climatology.

Does your country have sufficient land mapping at appropriate scales?

No Yes Maybe not

Would your country be interested in having access to space-based mapping data? (land and topographical mapping)

No Yes Probably

Which ground resolution?

larger than 20 m. 20 m.
 10 m. 5 m.
 smaller than 5 m. no idea.

Which accuracy in altitude?

- larger than 20 m. 20 m.
- 10 m. 5 m.
- smaller than 5 m. no idea.

What are the other areas in which the improvement of existing remote sensing raw or processed data could be useful for your country?

Knowledge of the natural resources as much as possible and adequate planning for their utilization.
Urban and demographic understanding and implementation.

What spin-offs of I.P.E.O. could be envisioned for the country? In particular those driven by a global change studies? (general welfare, public opinion satisfaction, technology transfer, education...)

Improved knowledge of the country environment to understand what is important for its development, such as missused and unused resources, urban areas.
Make easier to have technological and economical development.

Would your country be willing to commit itself in I.P.E.O.? If yes, how?

- No Yes :
- via technical contribution
- by financial participation
- with *in situ* measurements
- in marketing
- other :

IXL MISCELLANEOUS.

Most countries have a reference book for remote sensing. Such documents exist also for groups of countries (for example, the Earsel Directory for Europe). Does such a reference book exist for your country? What is its name? Where can it be found?

?

LIST MATERIALS USED FOR THIS SURVEY.

LIST PEOPLE CONTACTED FOR THIS SURVEY AND GIVE THEIR REFERENCES.

Is there any material you are expecting? Any further research you would like to do? Any person you would contact later on?

EGYPT

II. INVOLVEMENT IN SPACE ACTIVITIES.

Does your country have a national remote sensing program? If yes, under whose authority?

No Yes :

Does your country possess Earth Observation satellite(s)? If yes, name the program(s).

No Yes :

Does your country design and/or build remote sensing payload(s)?
If yes, name the payload(s) and the prime manufacturer(s).

No Yes :

Does your country possess any capability to directly receive data from a spacecraft?
If yes, from which satellite(s)? Where are the receiving stations?

No Yes :

III. INVOLVEMENT IN INTERNATIONAL ACTIVITIES.

Does your country take part in :

S.A.F.I.S.Y. U.N.E.P. I.C.S.U.
 COSPAR A.R.T.E.M.I.S. Other :

Is your country involved in one of the core or working group projects of I.G.B.P. (International Geosphere Biosphere Program)?

No Yes :

Does your country participate in international Earth Observation programs (in particular environmental programs)?
If yes, describe the type of participation (technical exchange, financial investment, other...).

No Yes :

Same question for bilateral Earth Observation programs.

No Yes : ?

III. SENSITIVITY TO ENVIRONMENTAL ISSUES.

Which of the following environmental issues (or common interests) are of importance to your country or to specific regions of your country?

Deforestation (1) ; Global Warming (2) ; Pollution (3) ; Land Resources (4) ; Vegetation Dynamics (5) ; Bio-mass Inventory (6) ; Water Quality (7) ; Soil Assessment (8) ; Urban Development (9) ; Ground Water (10) ; Acid Rain (11) ; Ozone Depletion (12) ; Crop Forecast (13) ; Insect Migration (14) ; Snow / Ice (15) ; Ocean Resources (16) ; Wildlife Monitoring (17) ; Flood (18) ; Desertification (19) ; Other... (be precise).

| Priority | Issues | Is your country actively involved in modelling and monitoring the problem? If yes, how? | Annual Budget or Percentage of Environmental Budget Spent on This Issue. |
|------------|--------------------|---|--|
| 1st prior. | 3 land degradation | Monitoring by temporal data analysis | varies |
| 2nd prior. | 10 | Search for potential sites for groundwater exploration | Both government and private sector are involved. Budgets vary |

Looking at the near, middle and long term future, what are the main objectives and strategies of your country in Earth Observation, and more specifically in environmental programs?

Analysis of space-borne data

IV/ UTILIZATION OF REMOTE SENSING DATA.

Does your country make use of remote sensing data? If yes, for which purpose?

No Yes : Research Application

- As for application, which ones?

Deforestation Land and Topographical Mapping
 Global Warming Vegetation Dynamics
 Pollution Desertification
 Other : Groundwater research

- As for research, which areas are of the concern?

Digital image processing

What kind of remote sensing data sets does your country use more often?

-LANDSAT
 -SPOT

Does your country have the capability to produce its own G.I.S. data?
 If yes, which centers are involved in this?

No Yes :

What kind of G.I.S. data are most often used?

| | |
|---|---|
| <input checked="" type="checkbox"/> Digital Elevation | <input checked="" type="checkbox"/> Land Use/Land Cover |
| <input checked="" type="checkbox"/> Roads | <input checked="" type="checkbox"/> Soils |
| <input checked="" type="checkbox"/> Hydrology | <input type="checkbox"/> Political Boundaries |
| <input checked="" type="checkbox"/> Geology | <input checked="" type="checkbox"/> Other : Ground water maps |

What is the status of development of the remote sensing value added industry?

Well Established Starting Non Existing

Does your country provide training courses in remote sensing?

Yes

VI. COMPLEMENTARY DATA FOR EARTH OBSERVATION.

Does your country have the capability to perform reference measurements (useful for the calibration of satellite sensors, or models validation) ?

? *in situ* measurements
 Low altitude observation (inferior to 10000 ft.)
 High altitude observation

Concerning the measurement acquisition, does your country have just reference plots, subjectively located, or does it have a collection of plots selected through a rational sample design?

?

Is your country equipped with :

? GPS (Global Positioning System)
? ARGOS

VII. FINANCIAL INVOLVEMENT.

What is the annual space budget (in U.S. \$) of your country? N/A

What percentage of the GNP does this represent? N/A

What is the annual space budget for Earth Observation from space? N/A

Does your country foresee an expansion of its involvement in remote sensing activities? In which directions?

Yes, through the establishment of additional centers for specific applications.

Does industry play a role in remote sensing activities in your country? Which one?

?

Give other financial indicators if any, such as revenues of the remote sensing images sold... What is the total value (social, environmental, commercial) contributed by remote sensing to your country (e.g. in forest and soil resources saved through better management)? Use the best figures you can find and/or your best guess.

U.S.AID funded programs

VIII REMOTE SENSING CENTERS OF THE COUNTRY.

In the following table, list and characterize the main institutions of your country dealing with remote sensing data (analysis, processing, interpretation, correlation with other data, model development...).

| Remote Sensing Institution | Status | Fields of Application | Origin of the Raw Data | Hardware Tools | Software Tools | Use of a GIS | Annual budget |
|--|------------|-----------------------|------------------------|----------------|----------------|------------------|---------------|
| National Center for Remote Sensing | since 1972 | varies | LANDSAT SPOT | main-frame | ERDAS | s o m e | varies |
| Desert Research Institute | 1976 | Land&Soil surveys | LANDSAT | main-frame | - | - | " |
| Egyptian Geological Survey & mineral Authority: R.S.Unit | 1980 | Geological mapping | LANDSAT | main-frame | - | yes | " |
| Remote Sensing of the Institute of Ground-water | 1986 | Hydrological mapping | LAND-SPOT | DEC | PCI | yes | " |

VIII/1 POTENTIAL IMPLEMENTATION OF I.P.E.O. IN THE COUNTRY.

Considering previous answers or more personal views, do you think that new data or information related to the deforestation phenomenon would be useful to the country?

No Yes Maybe

More precisely, would your country be interested in having access to high resolution radar data for deforestation monitoring (in a region 35°S to 35°N latitude, every ten days)? For which purpose?

No Yes Maybe :

To reveal paleodrainage systems in desert areas

Does your country have sufficient land mapping at appropriate scales?

No Yes Maybe not

Would your country be interested in having access to space-based mapping data? (land and topographical mapping)

No Yes Probably

Which ground resolution?

larger than 20 m. 20 m.
 10 m. 5 m.
 smaller than 5 m. no idea.

Which accuracy in altitude?

larger than 20 m. 20 m.
 10 m. 5 m.
 smaller than 5 m. no idea.

What are the other areas in which the improvement of existing remote sensing raw or processed data could be useful for your country?

A receiving station would expedite data collection and provides revenues of material collected from nearby countries.

What spin-offs of I.P.E.O. could be envisioned for the country? In particular those driven by a global change studies? (general welfare, public opinion satisfaction, technology transfer, education...)

Environmental protection

Would your country be willing to commit itself in I.P.E.O.? If yes, how?

No Yes : via technical contribution
 by financial participation
 with *in situ* measurements

[] in marketing
[] other :

IX/ MISCELLANEOUS.

Most countries have a reference book for remote sensing. Such documents exist also for groups of countries (for example, the Earsel Directory for Europe). Does such a reference book exist for your country? What is its name? Where can it be found?

Directory at the Academy of Scientific Research & Technology, Cairo

LIST MATERIALS USED FOR THIS SURVEY.

1. "Space Activities of the United Nations and International Organizations"
UN Publication No. A/AC.105/358, New York, 1986.

LIST PEOPLE CONTACTED FOR THIS SURVEY AND GIVE THEIR REFERENCES.

Dr. Farouk El-Baz, Director
Center for Remote Sensing
Boston University
725 Commonwealth Ave.,
Boston, MAA
02215-1401
U.S.A.

Is there any material you are expecting? Any further research you would like to do? Any person you would contact later on?

No

Please attach to this Country Note any synthetic document or copies that you find particularly relevant.

FINLAND

II INVOLVEMENT IN SPACE ACTIVITIES.

Does your country have a national remote sensing program? If yes, under whose authority?

No Yes; Technology Development Centre, TEKES
Finnish Space Committee

Does your country possess Earth Observation satellite(s)? If yes, name the program(s).

No Yes :

Does your country design and/or build remote sensing payload(s)?
If yes, name the payload(s) and the prime manufacturer(s).

No Yes: GOMOS:
Global Ozone Monitoring by Occultation of Stars

Does your country possess any capability to directly receive data from a spacecraft?
If yes, from which satellite(s)? Where are the receiving stations?

No Yes: NOAA/TIROS-N : Finnish Meteorological Centre
METEOSAT : Finnish Meteorological Centre
NOAA/TIROS-N : Finnish Marine Research Centre

III INVOLVEMENT IN INTERNATIONAL ACTIVITIES.

Does your country take part in :

S.A.F.I.S.Y. U.N.E.P. I.C.S.U.
 COSPAR A.R.T.E.M.I.S. Other : EARSELL

Is your country involved in one of the core or working group projects of I.G.B.P. (International Geosphere Biosphere Program)?

No Yes :

Does your country participate in international Earth Observation programs (in particular environmental programs)?

If yes, describe the type of participation (technical exchange, financial investment, other...).

No Yes:
EOPP, Earth Observation Preparatory Programme (ESA)

ERS-2 (ESA)
 EUMETSAT
 P/POR (a programme for international polar research)

Same question for bilateral Earth Observation programs.

No Yes :

III. SENSITIVITY TO ENVIRONMENTAL ISSUES.

Which of the following environmental issues (or common interests) are of importance to your country or to specific regions of your country?

Deforestation (X1) ; Global Warming (2) ; Pollution (X3) ; Land Resources (X4) ; Vegetation Dynamics (X5) ; Bio-mass Inventory (6) ; Water Quality (X7) ; Soil Assessment (8) ; Urban Development (X9) ; Ground Water (10) ; Acid Rain (11) ; Ozone Depletion (X12) ; Crop Forecast (13) ; Insect Migration (14) ; Snow / Ice (X15) ; Ocean Resources (16) ; Wildlife Monitoring (17) ; Flood (18) ; Desertification (19) ; Other... (be precise).

Forest Research and Inventory (20)

| Priority | Issues | Is your country actively involved in modelling and monitoring the problem? If yes, how? | Annual Budget or Percentage of Environmental Budget Spent on This Issue. |
|------------|--------|---|--|
| 1st prior. | 1,20 | Yes | |
| 2nd prior. | 7 | Yes | ? |
| 3rd prior. | 15 | Yes | |

Looking at the near, middle and long term future, what are the main objectives and strategies of your country in Earth Observation, and more specifically in environmental programs?

The objective is to concentrate in the questions important for a northern country.

We participate in the international programmes in order to get access to the data important for us.

IV. UTILIZATION OF REMOTE SENSING DATA.

Does your country make use of remote sensing data? If yes, for which purpose?

No Yes : Research Application

- As for application, which ones?

- | | | | |
|-------------------------------------|---|-------------------------------------|--------------------------------|
| <input checked="" type="checkbox"/> | Deforestation | <input checked="" type="checkbox"/> | Land and Topographical Mapping |
| <input type="checkbox"/> | Global Warming | <input checked="" type="checkbox"/> | Vegetation Dynamics |
| <input checked="" type="checkbox"/> | Pollution | <input type="checkbox"/> | Desertification |
| <input checked="" type="checkbox"/> | Other : Meteorology, Forest ecosystem analysis, Mineral exploration | | |

- As for research, which areas are of the concern?

Forest ecosystem analysis
Vegetation cover mapping
Topology & mapping
Snow & Ice

What kind of remote sensing data sets does your country use more often?

LANDSAT, SPOT, NOAA, METEOSAT, NIMBUS, METEOR, Aerial Photos

Does your country have the capability to produce its own G.I.S. data?
If yes, which centers are involved in this?

No Yes : Technical Research Centre of Finland
National Board of Survey

What kind of G.I.S. data are most often used?

| | | | |
|-------------------------------------|-------------------|-------------------------------------|----------------------|
| <input checked="" type="checkbox"/> | Digital Elevation | <input checked="" type="checkbox"/> | Land Use/Land Cover |
| <input type="checkbox"/> | Roads | <input type="checkbox"/> | Soils |
| <input type="checkbox"/> | Hydrology | <input checked="" type="checkbox"/> | Political Boundaries |
| <input type="checkbox"/> | Geology | <input type="checkbox"/> | Other : |

What is the status of development of the remote sensing value added industry?

Well Established Starting Non Existing

Does your country provide training courses in remote sensing?

Yes

VI. COMPLEMENTARY DATA FOR EARTH OBSERVATION.

Does your country have the capability to perform reference measurements (useful for the calibration of satellite sensors, or models validation) ?

- in situ* measurements
 Low altitude observation (inferior to 10000 ft.)
 High altitude observation

Concerning the measurement acquisition, does your country have just reference plots, subjectively located, or does it have a collection of plots selected through a rational sample design?

?

Is your country equipped with :

- GPS (Global Positioning System)
- ARGOS

VII. FINANCIAL INVOLVEMENT.

What is the annual space budget (in U.S. \$) of your country? \$ 25 Million

What percentage of the GNP does this represent? 0.3 % (year 1990)?

What is the annual space budget for Earth Observation from space? \$ 9 Million

Does your country foresee an expansion of its involvement in remote sensing activities? In which directions?

Yes, in the ESA programs and in the applications

Does industry play a role in remote sensing activities in your country? Which one?

Yes, electronics and software industry

Give other financial indicators if any, such as revenues of the remote sensing images sold...
 What is the total value (social, environmental, commercial) contributed by remote sensing to your country (e.g. in forest and soil resources saved through better management)? Use the best figures you can find and/or your best guess.

US \$ 70 - 80 Million / year (estimate for year 1996)

VIII. REMOTE SENSING CENTERS OF THE COUNTRY.

In the following table, list and characterize the main institutions of your country dealing with remote sensing data (analysis, processing, interpretation, correlation with other data, model development...).

| Remote Sensing Institution | Status | Fields of Application | Origin of the Raw Data | Hardware Tools | Software Tools | Use of a GIS | Annual budget |
|----------------------------|--------|-----------------------|------------------------|----------------|----------------|--------------|---------------|
| | | | | | | | |

| | | | | | | | |
|--------------------------------------|--------------------------|--------------------------|-------------------|-----|--|-----|--|
| Technical Research Centre of Finland | Academ. govern. consult. | 1, 3, 4, 5, 7, 9, 15, 20 | LANDSAT SPOT NOAA | VAX | | Yes | |
| Finnish Forest Research Institute | Academ. consult. | 1, 5, 20 | LANDSAT SPOT | | | ? | |
| Finnish Institute of Marine Research | Academ. govern. consult. | 15 | NOAA ERS-1 KOSMOS | | | Yes | |
| Geological Survey of Finland | Academ. govern. | 4 | LANDSAT | | | Yes | |
| Helsinki University of Technology | Academ. govern. | 15 | NOAA NIMBUS | | | ? | |
| National Board of Survey | Academ. govern. | 4, 9 | SPOT LANDSAT | | | Yes | |
| Finnish Meteorological Institute | Academ. govern. | 2, 3, 12 | NOAA METEOSAT | | | Yes | |

VIII. POTENTIAL IMPLEMENTATION OF I.P.E.O. IN THE COUNTRY.

Considering previous answers or more personal views, do you think that new data or information related to the deforestation phenomenon would be useful to the country?

No Yes Maybe Global warming

More precisely, would your country be interested in having access to high resolution radar data for deforestation monitoring (in a region 35°S to 35°N latitude, every ten days)? For which purpose?

No Yes Maybe :

Does your country have sufficient land mapping at appropriate scales?

- No
- Yes
- Maybe not

Would your country be interested in having access to space-based mapping data? (land and topographical mapping)

- No
- Yes
- Probably

Which ground resolution?

- larger than 20 m.
- 10 m.
- smaller than 5 m.
- 20 m.
- 5 m.
- no idea.

Which accuracy in altitude?

- larger than 20 m.
- 10 m.
- smaller than 5 m.
- 20 m.
- 5 m.
- no idea.

What are the other areas in which the improvement of existing remote sensing raw or processed data could be useful for your country?

Ice/snow mapping (SAR- data)

What spin-offs of I.P.E.O. could be envisioned for the country? In particular those driven by a global change studies? (general welfare, public opinion satisfaction, technology transfer, education...)

Technology, science & global exploration

Would your country be willing to commit itself in I.P.E.O.? If yes, how?

- No
- Yes
- :
- via technical contribution
- by financial participation
- with *in situ* measurements
- in marketing
- other :

IX/ MISCELLANEOUS.

Most countries have a reference book for remote sensing. Such documents exist also for groups of countries (for example, the Earsel Directory for Europe). Does such a reference book exist for your country? What is its name? Where can it be found?

Remote Sensing in Finland, Surveying Science in Finland.

Risto Kuittinen
Technical Research Centre of Finland
Laboratory of Urban Planning and Building Design
Itätuulentie 2 A
SF-02100 ESPOO, Finland

LIST MATERIALS USED FOR THIS SURVEY.

Space Research in Finland 1988-1989
Space Program in Finland 1991-1996
Frontiers in Space Technology (Finland)
Annual Report 1989, Laboratory of Space Technology, Helsinki
University of Technology
Survey to Photogrammetric in Finland
Remote Sensing in Finland, Surveying Science in Finland, 1986

LIST PEOPLE CONTACTED FOR THIS SURVEY AND GIVE THEIR REFERENCES.

Kari Tilli, Director (Space Technnology), Technology Development Centre

Is there any material you are expecting? Any further research you would like to do? Any person you would contact later on?

No

Please join to this Country Note any synthetic document or copies that you find particularly relevant.

FM PROJECTS LTD OY, Helsinki
Exclusive contract with Soviet Soyuz Karta
-> Soviet Remote Sensing Satellite Imagery.

FRANCE

II INVOLVEMENT IN SPACE ACTIVITIES.

Does your country have a national remote sensing program? If yes, under whose authority?

No Yes :French Space Agency CNES
CNRS, INRA, IFREMER, ORSTOM
Meteorologie Nationale (National Weather Service)
SPOT

Does your country possess Earth Observation satellite(s)? If yes, name the program(s).

No Yes : SPOT 1-2
In cooperation with ESA : METEOSAT...

Does your country design and/or build remote sensing payload(s)?
If yes, name the payload(s) and the prime manufacturer(s).

No Yes : TOPEX/POSEIDON : CNES
SPOT 4 : MATRA
ScaRab (radiometer) (-> Mir Station)
Future : BEST (Radar), GLOBSAT
ERS 1, European earth observation preparatory.

Does your country possess any capability to directly receive data from a spacecraft?
If yes, from which satellite(s)? Where are the receiving stations?

No Yes :

SPOT Two receiving Stations : Toulouse and Kiruna (Sweden)
(Capacity 500,000 im/year)

NOAA Lannion
METEOSAT
Landsat
Sarsat, Cospas Toulouse (2 stations)

III INVOLVEMENT IN INTERNATIONAL ACTIVITIES.

Does your country take part in :

S.A.F.I.S.Y. U.N.E.P. I.C.S.U.
 COSPAR A.R.T.E.M.I.S. Other :

Looking at the near, middle and long term future, what are the main objectives and strategies of your country in Earth Observation, and more specifically in environmental programs?

Objectives : to increase the understanding of Earth environment.
Strategies : participation in different programmes.

CNES/NOAA merging Spot/Landsat programs.

VI UTILIZATION OF REMOTE SENSING DATA.

Does your country make use of remote sensing data? If yes, for which purpose?

No Yes : Research Application

- As for application, which ones?

- Deforestation
- Land and Topographical Mapping Statistics (agriculture)
- Global Warming Vegetation Dynamics : Productivity
- Pollution Desertification
- Other : Flood
- Urban planning
- Insurance -> damage analysis and survey

- As for research, which areas are of the concern?

Surveys, processes, modelling in the following areas :
Atmosphere (dynamics, radiation, chemistry, greenhouse effect),
Ocean (circulation, fluxes of matter, productivity), Biosphere
(vegetation dynamics)...
-> Modelling human being/environment interaction.

What kind of remote sensing data sets does your country use more often?

All (MOS and Soyuz-Karta difficult to obtain)

Does your country have the capability to produce its own G.I.S. data?
If yes, which centers are involved in this?

No Yes : IGN (National Geographical Institute)
 Research Institutions (geography, geology...)
 Districts (Agriculture, forestry)

What kind of G.I.S. data are most often used?

- Digital Elevation Land Use/Land Cover
- Roads Soils
- Hydrology Political Boundaries
- Geology Other : Dedicated GIS

What is the status of development of the remote sensing value added industry?

Well Established Starting Non Existing

CNES has established 16 subsidiaries and working groups (Economical Interest Group) to exploit and market its space activities : Arianespace, Intespace, Spot Image, Scot (Earth Observation Consultancy), GDTA (remote sensing training), Prospace (promotion of French space sector products and services)

Some private or mixed firms from research centers

Does your country provide training courses in remote sensing?

Yes. Ministere de la Cooperation
GDTA

GDTA (Aerospace Remote Sensing Development Group) is an Economical Interest Group founded in 1973 including :

CNES : French Space Agency.

IGN : National Geographic Institute.

BRGM : Geology and Mining Research Office.

IFP : French Petroleum Institute.

BDPA : Agricultural Production Development Office.

Its aims is to promote remote sensing development AND the use of space imagery around the world . .

GDTA offers remote sensing training either at an introductory level or through advanced sessions for specialists whose professional activities are enhanced by the use of remote sensing technology : geology, oil exploration, cartography, agriculture, urban planning, oceanography, etc.

GDTA acts for technology transfer in foreign countries as operator of French Cooperation and Foreign Affairs Ministries. Besides remote sensing training, it provides advisory services for setting up or developping remote sensing center. GDTA experts are currently at work in Ouagadougou (Burkina Faso), Nairobi (Kenya), Bangkok (Thailand), Jakarta (Indonesia) and Bogota (Columbia).

VI. COMPLEMENTARY DATA FOR EARTH OBSERVATION.

Does your country have the capability to perform reference measurements (useful for the calibration of satellite sensors, or models validation) ?

in situ measurements

Low altitude observation (inferior to 10000 ft.)

High altitude observation

Concerning the measurement acquisition, does your country have just reference plots, subjectively located, or does it have a collection of plots selected through a rational sample design?

Yes, selected through a rational sample design.

Is your country equipped with :

- GPS (Global Positioning System)
- ARGOS

VII. FINANCIAL INVOLVEMENT.

What is the annual space budget (in U.S. \$) of your country? 1987 U.S. 854 M. \$

What percentage of the GNP does this represent? ?

What is the annual space budget for Earth Observation from space?

Major item in the current French space applications budget, accounting for 68.8% of funding for applications (excluding launch vehicles) in 1987. Earth observation/remote sensing credits, including data collection : FFR 1,157 M. in 1987.
PNTS (Remote Sensing National Programme) : 5 MF/year

Does your country foresee an expansion of its involvement in remote sensing activities? In which directions?

Yes. ?

Does industry play a role in remote sensing activities in your country? Which one?

Yes. Matra. Aerospatiale : prime contractors
MS2I, Alcatel Espace.

Give other financial indicators if any, such as revenues of the remote sensing images sold...
What is the total value (social, environmental, commercial) contributed by remote sensing to your country (e.g. in forest and soil resources saved through better management)? Use the best figures you can find and/or your best guess.

SPOT

Prices in 1986 and 1987 ranged from USD 1,475 to USD 1,600 depending on the format of the primary scenes supplied on magnetic storage medium. 1988 revenue from data/product sales and receiving stations fees totalled \$16 M.

VIII. REMOTE SENSING CENTERS OF THE COUNTRY.

In the following table, list and characterize the main institutions of your country dealing with remote sensing data (analysis, processing, interpretation, correlation with other data, model development...).

| Remote Sensing Institution | Status | Fields of Application | Origin of the Raw Data | Hardware Tools | Software Tools | Use of a G.I.S | Annual budget |
|----------------------------|---------|-----------------------------|-----------------------------------|----------------|----------------|----------------|---------------|
| IGN | Govern | mapping, topography geodesy | Aerial, Spot Landsat ... | | | Yes | |
| GDTA | Govern | All | Meteosat Landsat Spot NOAA aerial | Pericolor | Multiscope | Yes | |
| MS2I | Private | | Spot Landsat ERS 1 NOAA | VAX MicroVax | Geographe | Yes | |
| Spot Image | Comm, | Image interpretation | Spot | | | | |
| ORSTOM | | Cartography | | | | Yes | |

VIII POTENTIAL IMPLEMENTATION OF I.P.E.O. IN THE COUNTRY.

Considering previous answers or more personal views, do you think that new data or information related to the deforestation phenomenon would be useful to the country?

No Yes Maybe

More precisely, would your country be interested in having access to high resolution radar data for deforestation monitoring (in a region 35°S to 35°N latitude, every ten days)? For which purpose?

No Yes Maybe : CNRS, ORSTOM

Does your country have sufficient land mapping at appropriate scales?

No Yes Maybe not

Would your country be interested in having access to space-based mapping data? (land and topographical mapping)

No Yes Probably

Which ground resolution?

larger than 20 m. 20 m.
 10 m. 5 m.
 smaller than 5 m. no idea.

Which accuracy in altitude?

larger than 20 m. 20 m.
 10 m. 5 m.
 smaller than 5 m. no idea.

What are the other areas in which the improvement of existing remote sensing raw or processed data could be useful for your country?

Stereo topographical mapping -> cheap data for GIS layer.

What spin-offs of I.P.E.O. could be envisioned for the country? In particular those driven by a global change studies? (general welfare, public opinion satisfaction, technology transfer, education...)

Public opinion satisfaction/environmental problem.
Education

Would your country be willing to commit itself in I.P.E.O.? If yes, how?

No Yes : via technical contribution
 by financial participation
 with *in situ* measurements
 in marketing
 other : Coordinate with the different organisations existing in France.

IXI MISCELLANEOUS.

Most countries have a reference book for remote sensing. Such documents exist also for groups of countries (for example, the Earsel Directory for Europe). Does such a reference book exist for your country? What is its name? Where can it be found?

Yes. ?

LIST MATERIALS USED FOR THIS SURVEY.

Interavia Space Directory.
CNES Rapport d'activites.
Spot Services/Products.
Sahara and Sahel Observatory

LIST PEOPLE CONTACTED FOR THIS SURVEY AND GIVE THEIR REFERENCES.

Is there any material you are expecting? Any further research you would like to do? Any person you would contact later on?

Please join to this Country Note any synthetic document or copies that you find particularly relevant.

GREAT BRITAIN

II INVOLVEMENT IN SPACE ACTIVITIES.

Does your country have a national remote sensing program? If yes, under whose authority?

No Yes British National Remote Sensing Centre

Does your country possess Earth Observation satellite(s)? If yes, name the program(s).

No Yes Part of ESA : ERS-1, METEOSAT...

Does your country design and/or build remote sensing payload(s)?
If yes, name the payload(s) and the prime manufacturer(s).

No Yes

British Aerospace (Space Systems) Ltd (Polar Platform, AVHRR, AMSU B)
Rutherford Appleton Laboratory (ATSR)
Marconi Space Systems Ltd (AMI), subcontractor for Meteosar program.

Does your country possess any capability to directly receive data from a spacecraft?
If yes, from which satellite(s)? Where are the receiving stations?

No Yes : Spot/Meteosat/ERS-1/Farnborough

III INVOLVEMENT IN INTERNATIONAL ACTIVITIES.

Does your country take part in :

S.A.F.I.S.Y. U.N.E.P. I.C.S.U.
 COSPAR A.R.T.E.M.I.S. Other :

Is your country involved in one of the core or working group projects of I.G.B.P. (International Geosphere Biosphere Program)?

No Yes ?

Does your country participate in international Earth Observation programs (in particular environmental programs)?

If yes, describe the type of participation (technical exchange, financial investment, other...).

No Yes :

World Weather Watch / Meteorological Office-Financial, Scientific, Processing
Polar Platform
ERS-1, Meteosat, Earthnet network.

Same question for bilateral Earth Observation programs.

No Yes :

III SENSITIVITY TO ENVIRONMENTAL ISSUES.

Which of the following environmental issues (or common interests) are of importance to your country or to specific regions of your country?

Deforestation (1) ; Global Warming (2) ; Pollution (3) ; Land Resources (4) ; Vegetation Dynamics (5) ; Bio-mass Inventory (6) ; Water Quality (7) ; Soil Assessment (8) ; Urban Development (9) ; Ground Water (10) ; Acid Rain (11) ; Ozone Depletion (12) ; Crop Forecast (13) ; Insect Migration (14) ; Snow / Ice (15) ; Ocean Resources (16) ; Wildlife Monitoring (17) ; Flood (18) ; Desertification (19) ; Other... (be precise).

| Priority | Issues | Is your country actively involved in modelling and monitoring the problem? If yes, how? | Annual Budget or Percentage of Environmental Budget Spent on This Issue. |
|------------------------|---------|---|--|
| 1 st prior. | 4 | Yes : reception and analysis of Landsat and SPOT imagery and analysis | No budget available |
| 2 nd prior. | 2, 12 | Yes | No budget available |
| 3 rd prior. | 16 | Yes | No buget available |
| 4 th prior. | Geology | Yes | No budget available |
| 5 th prior. | | All others except 14,18 and 17 ! | |

Looking at the near, middle and long term future, what are the main objectives and strategies of your country in Earth Observation, and more specifically in environmental programs?

Near term:conforming to European regulations on environment
Middle term:Encourage commercial aspects
Long term:

IV UTILIZATION OF REMOTE SENSING DATA.

Does your country make use of remote sensing data? If yes, for which purpose?

No Yes : Research Application

- As for application, which ones?

Deforestation Land and Topographical Mapping
 Global Warming Vegetation Dynamics
 Pollution Desertification
 Other : SEE SECTION III

- As for research, which areas are of the concern?

Atmospheric Research

What kind of remote sensing data sets does your country use more often?

Meteosat, GOES, NOAA, Landsat, SPOT, Seasat, Nimbus 7 CZCS (Coastal Zone Color Scanner)

Does your country have the capability to produce its own G.I.S. data?
If yes, which centers are involved in this?

No Yes National Remote Sensing Centre

What kind of G.I.S. data are most often used?

Digital Elevation Land Use/Land Cover
 Roads Soils
 Hydrology Political Boundaries
 Geology Other :

What is the status of development of the remote sensing value added industry?

Well Established Starting Non Existing

Does your country provide training courses in remote sensing?

Yes, many at all levels (including up to Phd)

VI COMPLEMENTARY DATA FOR EARTH OBSERVATION.

Does your country have the capability to perform reference measurements (useful for the calibration of satellite sensors, or models validation) ?

in situ measurements
 Low altitude observation (inferior to 10000 ft.)
 High altitude observation

Concerning the measurement acquisition, does your country have just reference plots, subjectively located, or does it have a collection of plots selected through a rational sample design?

National (?)

Is your country equipped with :

- GPS (Global Positioning System)
 ARGOS

VII. FINANCIAL INVOLVEMENT

What is the annual space budget (in U.S. \$) of your country? Civil: US \$ 270 M.

What percentage of the GNP does this represent? ?

What is the annual space budget for Earth Observation from space? US \$ 125 M.

Does your country foresee an expansion of its involvement in remote sensing activities? In which directions?

Yes: commercial activities

Does industry play a role in remote sensing activities in your country? Which one?

Yes

Give other financial indicators if any, such as revenues of the remote sensing images sold...

What is the total value (social, environmental, commercial) contributed by remote sensing to your country (e.g. in forest and soil resources saved through better management)? Use the best figures you can find and/or your best guess.

?

VIII. REMOTE SENSING CENTERS OF THE COUNTRY.

In the following table, list and characterize the main institutions of your country dealing with remote sensing data (analysis, processing, interpretation, correlation with other data, model development...).

| Remote Sensing Institution | Status | Fields of Application | Origin of the Raw Data | Hardware Tools | Software Tools | Use of a GIS | Annual budget |
|----------------------------|--------|-----------------------|------------------------|----------------|----------------|--------------|---------------|
| | | | | | | | |

See book : UK Remote Sensing Directory, published by the National Remote Sensing Centre, RAe Farnborough, England

VIII. POTENTIAL IMPLEMENTATION OF L.P.E.O. IN THE COUNTRY.

Considering previous answers or more personal views, do you think that new data or information related to the deforestation phenomenon would be useful to the country?

No Yes Maybe

More precisely, would your country be interested in having access to high resolution radar data for deforestation monitoring (in a region 35°S to 35°N latitude, every ten days)? For which purpose?

No Yes Maybe :

Does your country have sufficient land mapping at appropriate scales?

No Yes Maybe not

Would your country be interested in having access to space-based mapping data? (land and topographical mapping)

No Yes Probably

Which ground resolution?

| | | | |
|-------------------------------------|-------------------|-------------------------------------|----------|
| <input type="checkbox"/> | larger than 20 m. | <input type="checkbox"/> | 20 m. |
| <input type="checkbox"/> | 10 m. | <input checked="" type="checkbox"/> | 5 m. |
| <input checked="" type="checkbox"/> | smaller than 5 m. | <input type="checkbox"/> | no idea. |

Which accuracy in altitude?

| | | | |
|--------------------------|-------------------|-------------------------------------|----------|
| <input type="checkbox"/> | larger than 20 m. | <input type="checkbox"/> | 20 m. |
| <input type="checkbox"/> | 10 m. | <input checked="" type="checkbox"/> | 5 m. |
| <input type="checkbox"/> | smaller than 5 m. | <input type="checkbox"/> | no idea. |

What are the other areas in which the improvement of existing remote sensing raw or processed data could be useful for your country?

Pollution, Global Warming, Land resources, Vegetation Dynamics, Water Quality, Urban Development

What spin-offs of I.P.E.O. could be envisioned for the country*? In particular those driven by a global change studies? (general welfare, public opinion satisfaction, technology transfer, education...)

Tourism, public hygiene, education on global, environmental issues

Would your country be willing to commit itself in I.P.E.O.? If yes, how?

No Yes : via technical contribution

- by financial participation
- with *in situ* measurements
- in marketing
- other :

IXI MISCELLANEOUS.

Most countries have a reference book for remote sensing. Such documents exist also for groups of countries (for example, the Earsel Directory for Europe). Does such a reference book exist for your country? What is its name? Where can it be found?

UK Directory of Remote Sensing, pub 1990 by NRSC, RAe Farnborough, England

LIST MATERIALS USED FOR THIS SURVEY.

LIST PEOPLE CONTACTED FOR THIS SURVEY AND GIVE THEIR REFERENCES.

K.Dudley- British Aerospace (Space Systems) Ltd, Stevenage, England
G.Weaver-Marconi Space Systems Ltd, Portsmouth, England
J.Hunter-British Aerospace (Space Systems) Ltd, Bristol, England

Is there any material you are expecting? Any further research you would like to do? Any person you would contact later on?

Many areas can be expanded once we've returned to England!

Please join to this Country Note any synthetic document or copies that you find particularly relevant.

INDIA

II INVOLVEMENT IN SPACE ACTIVITIES.

Does your country have a national remote sensing program? If yes, under whose authority?

No Yes : National Remote Sensing Agency
 Department of Space
 Government of India

Does your country possess Earth Observation satellite(s)? If yes, name the program(s).

No Yes : Baskhara or SEO series
 IRS series
 INSAT meteorological payload (VHRR)
 1 main processing station (Delhi)
 22 secondary centers (connected with INSATO)

Does your country design and/or build remote sensing payload(s)?
 If yes, name the payload(s) and the prime manufacturer(s).

No Yes : VHRR, LIS (camera)
 Indian Space Research Organisation (ISRO)
 IRS Series

Does your country possess any capability to directly receive data from a spacecraft?
 If yes, from which satellite(s)? Where are the receiving stations?

No Yes : Landsat 4/5, SPOT, NOAA, IRS, Tiros-N, ERS
 Hyderrabad (NRSA)

III INVOLVEMENT IN INTERNATIONAL ACTIVITIES.

Does your country take part in :

S.A.F.I.S.Y. U.N.E.P. I.C.S.U.
 COSPAR A.R.T.E.M.I.S. Other :

Is your country involved in one of the core or working group projects of I.G.B.P. (International Geosphere Biosphere Program)?

No Yes : ?

Does your country participate in international Earth Observation programs (in particular environmental programs)?

If yes, describe the type of participation (technical exchange, financial investment, other...).

No Yes : ?

Same question for bilateral Earth Observation programs.

No Yes :

IRS 1A optical equipment for multispectral camera (Matra).
West Germany, microwave systems technology.

III. SENSITIVITY TO ENVIRONMENTAL ISSUES.

Which of the following environmental issues (or common interests) are of importance to your country or to specific regions of your country?

Deforestation (1) ; Global Warming (2) ; Pollution (3) ; Land Resources (4) ; Vegetation Dynamics (5) ; Bio-mass Inventory (6) ; Water Quality (7) ; Soil Assessment (8) ; Urban Development (9) ; Ground Water (10) ; Acid Rain (11) ; Ozone Depletion (12) ; Crop Forecast (13) ; Insect Migration (14) ; Snow / Ice (15) ; Ocean Resources (16) ; Wildlife Monitoring (17) ; Flood (18) ; Desertification (19) ; Other... (be precise).

| Priority | Issues | Is your country actively involved in modelling and monitoring the problem? If yes, how? | Annual Budget or Percentage of Environmental Budget Spent on This Issue. |
|------------------------|--------|---|--|
| 1 st prior. | 5 | IRS 1A data and aerial photography databank | |
| 2 nd prior. | 1 | Landsat, IRS 1A data used for modeling and change detection. | |
| 3 rd prior. | 4 | Irs 1A data bank and NNRMS activities | |
| 4 th prior. | 10 | Landsat, Spot, IRS 1A, data used by NRSA, NNRMS centers | |
| 5 th prior. | 16 | Costal zone monitoring, fisheries | |

Looking at the near, middle and long term future, what are the main objectives and strategies of your country in Earth Observation, and more specifically in environmental programs?

A National Natural Resource Management System is established in the country with a number of interaction systems at regional and state levels. Some features of this scheme are continuous reception of data from various Earth resources satellites, conversion of it in readily usable data on prioritized sectors, and dissemination of data to a wide section of users at all levels. Emphasis will be given to environment

through water resources assessment, deforestation assessment and pollution monitoring.

IV/ UTILIZATION OF REMOTE SENSING DATA.

Does your country make use of remote sensing data? If yes, for which purpose?

No Yes : Research Application

- *As for application, which ones?*

| | | | |
|-------------------------------------|----------------|-------------------------------------|--------------------------------|
| <input checked="" type="checkbox"/> | Deforestation | <input checked="" type="checkbox"/> | Land and Topographical Mapping |
| <input type="checkbox"/> | Global Warming | <input checked="" type="checkbox"/> | Vegetation Dynamics |
| <input checked="" type="checkbox"/> | Pollution | <input checked="" type="checkbox"/> | Desertification |
| <input type="checkbox"/> | Other : | | |

- *As for research, which areas are of the concern?*

Deforestation, desertification.

What kind of remote sensing data sets does your country use more often?

Lansat, Spot, IRS 1A, Aerial photos.

*Does your country have the capability to produce its own G.I.S. data?
If yes, which centers are involved in this?*

No Yes :

What kind of G.I.S. data are most often used?

| | | | |
|-------------------------------------|-------------------|-------------------------------------|----------------------|
| <input checked="" type="checkbox"/> | Digital Elevation | <input checked="" type="checkbox"/> | Land Use/Land Cover |
| <input type="checkbox"/> | Roads | <input type="checkbox"/> | Soils |
| <input checked="" type="checkbox"/> | Hydrology | <input type="checkbox"/> | Political Boundaries |
| <input type="checkbox"/> | Geology | <input type="checkbox"/> | Other : |

What is the status of development of the remote sensing value added industry?

Well Established Starting Non Existing

Does your country provide training courses in remote sensing?

RRSSC : Regional Remote Sensing Service Centers (Dehra Dun)
Trains users and spread low-cost data processing.

VI/ COMPLEMENTARY DATA FOR EARTH OBSERVATION.

Does your country have the capability to perform reference measurements (useful for the calibration of satellite sensors, or models validation) ?

- in situ* measurements
 Low altitude observation (inferior to 10000 ft.)
 High altitude observation

Concerning the measurement acquisition, does your country have just reference plots, subjectively located, or does it have a collection of plots selected through a rational sample design?

?

Is your country equipped with :

- GPS (Global Positioning System)
 ARGOS

VII FINANCIAL INVOLVEMENT.

What is the annual space budget (in U.S. \$) of your country? 19867 US 246 M.

What percentage of the GNP does this represent? ?

What is the annual space budget for Earth Observation from space? US 25-35 M.

Does your country foresee an expansion of its involvement in remote sensing activities? In which directions?

Yes, having wide spread use of remote sensing data in agriculture, ground water, flood control, land use, deforestation... through various NNRMS centers

Does industry play a role in remote sensing activities in your country? Which one?

Yes, computer industry.

Give other financial indicators if any, such as revenues of the remote sensing images sold...
 What is the total value (social, environmental, commercial) contributed by remote sensing to your country (e.g. in forest and soil resources saved through better management)? Use the best figures you can find and/or your best guess.

The total value directly contributed is not yet assessed.
 However it could be US 10 M.

VIII REMOTE SENSING CENTERS OF THE COUNTRY.

In the following table, list and characterize the main institutions of your country dealing with remote sensing data (analysis, processing, interpretation, correlation with other data, model development...).

| Remote Sensing Institution | Status | Fields of Application | Origin of the Raw Data | Hardware Tools | Software Tools | Use of a GIS | Annual budget |
|---|------------|--|-----------------------------------|---|-----------------------------------|--------------|---------------|
| National Remote Sensing Agency Hyderabad | Government | All | IRS 1A LANDSAT SPOT NOAA | VAX SUN IBM PC-AT based system | in-house and Spot Image sw. | Yes | ? |
| National Natural Resources Managem. System Bangalore | Government | All | From NRSA and in situ reports | | | | |
| Indian Institute of Remote Sensing Dehra Dun | Academ. | All | NRSA | | | | |
| RRSSC Bangalore Nagpur Kharagpur Jodhpur Shillong Dehra Dun | Government | Forestry Geology Hydrology Agricuilt. | IRS 1A NOAA | 9 Vizir | in house sw. | | |

VIII. POTENTIAL IMPLEMENTATION OF I.P.E.O. IN THE COUNTRY.

Considering previous answers or more personal views, do you think that new data or information related to the deforestation phenomenon would be useful to the country?

No Yes Maybe

More precisely, would your country be interested in having access to high resolution radar data for deforestation monitoring (in a region 35°S to 35°N latitude, every ten days)? For which purpose?

No Yes Maybe :

For monitoring the monsoon forest growth and drought degradation in small scale forests, feeling degradation in the medium level forests.

Does your country have sufficient land mapping at appropriate scales?

No Yes Maybe not

Would your country be interested in having access to space-based mapping data? (land and topographical mapping)

No Yes Probably

Which ground resolution? larger than 20 m. 20 m.
 10 m. 5 m.
 smaller than 5 m. no idea.

Which accuracy in altitude? larger than 20 m. 20 m.
 10 m. 5 m.
 smaller than 5 m. no idea.

What are the other areas in which the improvement of existing remote sensing raw or processed data could be useful for your country?

Vegetation Dynamics.

What spin-offs of I.P.E.O. could be envisioned for the country*? In particular those driven by a global change studies? (general welfare, public opinion satisfaction, technology transfer, education...)

General welfare

Public opinion satisfaction

Education of global changes and control of pollution and deforestation.

Would your country be willing to commit itself in I.P.E.O.? If yes, how?

? No Yes : via technical contribution
 by financial participation
 with *in situ* measurements
 in marketing
 other :

IXI. MISCELLANEOUS.

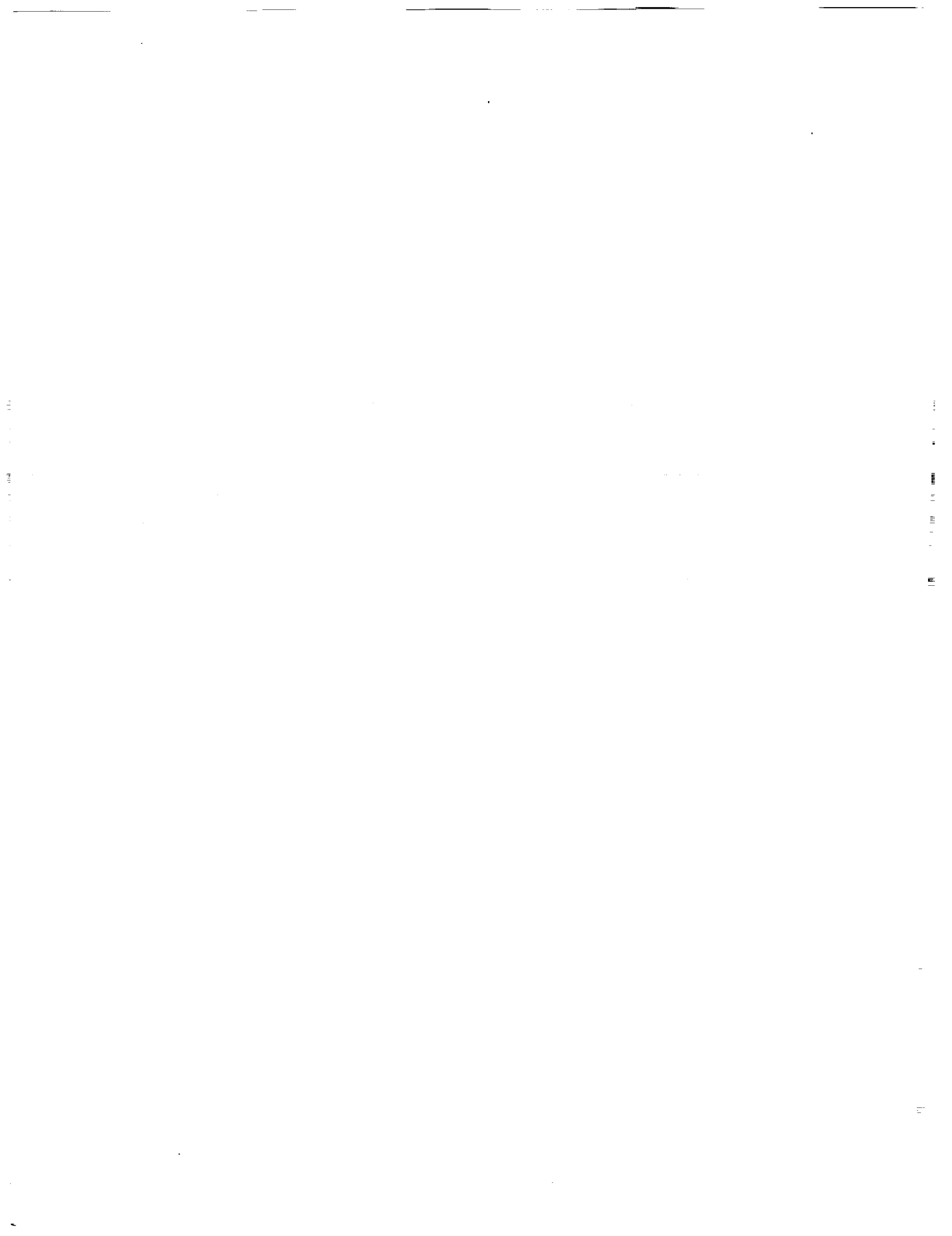
Most countries have a reference book for remote sensing. Such documents exist also for groups of countries (for example, the Earsel Directory for Europe). Does such a reference book exist for your country? What is its name? Where can it be found?

See National Remote Sensing Agency, Hyderabad.

LIST MATERIALS USED FOR THIS SURVEY.

Space India, published by Indian Space Research Organization.

Indian Space Program, published by P&PRU, ISRO Head Quarters, Bangalore 560009



IRELAND

II INVOLVEMENT IN SPACE ACTIVITIES.

Does your country have a national remote sensing program? If yes, under whose authority?

No Yes :

Does your country possess Earth Observation satellite(s)? If yes, name the program(s).

No Yes :

Does your country design and/or build remote sensing payload(s)?
If yes, name the payload(s) and the prime manufacturer(s).

No Yes :

Does your country possess any capability to directly receive data from a spacecraft?
If yes, from which satellite(s)? Where are the receiving stations?

No Yes :

III INVOLVEMENT IN INTERNATIONAL ACTIVITIES.

Does your country take part in :

? S.A.F.I.S.Y. U.N.E.P. I.C.S.U.
? COSPAR A.R.T.E.M.I.S. Other :

Is your country involved in one of the core or working group projects of I.G.B.P. (International Geosphere Biosphere Program)?

? No Yes :

Does your country participate in international Earth Observation programs (in particular environmental programs)?

If yes, describe the type of participation (technical exchange, financial investment, other...).

No Yes : On a University Research level

Same question for bilateral Earth Observation programs.

No Yes : On a university level

III SENSITIVITY TO ENVIRONMENTAL ISSUES.

Which of the following environmental issues (or common interests) are of importance to your country or to specific regions of your country?

Deforestation (1) ; Global Warming (2) ; Pollution (3) ; Land Resources (4) ; Vegetation Dynamics (5) ; Bio-mass Inventory (6) ; Water Quality (7) ; Soil Assessment (8) ; Urban Development (9) ; Ground Water (10) ; Acid Rain (11) ; Ozone Depletion (12) ; Crop Forecast (13) ; Insect Migration (14) ; Snow / Ice (15) ; Ocean Resources (16) ; Wildlife Monitoring (17) ; Flood (18) ; Desertification (19) ; Other... (be precise).

| Priority | Issues | Is your country actively involved in modelling and monitoring the problem? If yes, how? | Annual Budget or Percentage of Environmental Budget Spent on This Issue. |
|------------|--------|---|--|
| 1st prior. | 4 | Research work by Dept. of Forestation | ? |
| 2nd prior. | 8 | Research work | ? |
| 3rd prior. | 3 | Research work at universities | ? |
| 4th prior. | 13 | Research program | ? |

Looking at the near, middle and long term future, what are the main objectives and strategies of your country in Earth Observation, and more specifically in environmental programs?

Mostly involved in Research on a local level and also collaborative work on a European level.

IV/ UTILIZATION OF REMOTE SENSING DATA.

Does your country make use of remote sensing data? If yes, for which purpose?

No Yes : Research Application

- As for application, which ones?

Deforestation Land and Topographical Mapping
 Global Warming Vegetation Dynamics
 Pollution Desertification
 Other : Weather forecast

- As for research, which areas are of the concern?

Deforestation, land mapping, archaeology, and geography

What kind of remote sensing data sets does your country use more often?

LANDSAT, SPOT, AVHRR, METEOSAT

Does your country have the capability to produce its own G.I.S. data?
 If yes, which centers are involved in this?

No Yes : University College Dublin UCD
MAPREC

What kind of G.I.S. data are most often used?

Digital Elevation Land Use/Land Cover
 Roads Soils
 Hydrology Political Boundaries
 Geology Other :

What is the status of development of the remote sensing value added industry?

Well Established Starting Non Existing

Does your country provide training courses in remote sensing?

Yes

VI. COMPLEMENTARY DATA FOR EARTH OBSERVATION.

Does your country have the capability to perform reference measurements (useful for the calibration of satellite sensors, or models validation) ?

in situ measurements GROUND TRUTH FOR FOREST MAPPING
 Low altitude observation (inferior to 10000 ft.)
 High altitude observation

Concerning the measurement acquisition, does your country have just reference plots, subjectively located, or does it have a collection of plots selected through a rational sample design?

?

Is your country equipped with :

? GPS (Global Positioning System)
 ? ARGOS

VII. FINANCIAL INVOLVEMENT.

What is the annual space budget (in U.S. \$) of your country? ?

What percentage of the GNP does this represent? ?

What is the annual space budget for Earth Observation from space? ?
Does your country foresee an expansion of its involvement in remote sensing activities? In which directions?

?

Does industry play a role in remote sensing activities in your country? Which one?

Yes. Land Mapping: MAPTEC, ERA

Give other financial indicators if any, such as revenues of the remote sensing images sold...
What is the total value (social, environmental, commercial) contributed by remote sensing to your country (e.g. in forest and soil resources saved through better management)? Use the best figures you can find and/or your best guess.

?

VIII REMOTE SENSING CENTERS OF THE COUNTRY.

In the following table, list and characterize the main institutions of your country dealing with remote sensing data (analysis, processing, interpretation, correlation with other data, model development...).

| Remote Sensing Institution | Status | Fields of Application | Origin of the Raw Data | Hardware Tools | Software Tools | Use of a GIS | Annual budget |
|---|-----------------|--|------------------------|--|----------------|--------------|---------------|
| Univ. College, Dublin Dr. Omangain Mr. MacSurtain | Acad. | Forestry Geology Archeology Applied Physics research | | | | | |
| TRINITY NRDC Prof. A. Philips | Acad. | | | | | | |
| MAPTEC- ERA MR. M. Critchley | Commer- cial | land mapping | SPOT LANDSAT | 9 EMS Image Processor Linstronic printer | | | |

VIII POTENTIAL IMPLEMENTATION OF L.P.E.O. IN THE COUNTRY.

Considering previous answers or more personal views, do you think that new data or information related to the deforestation phenomenon would be useful to the country?

No Yes Maybe

More precisely, would your country be interested in having access to high resolution radar data for deforestation monitoring (in a region 35°S to 35°N latitude, every ten days)? For which purpose?

No Yes Maybe :

Does your country have sufficient land mapping at appropriate scales?

No Yes Maybe not

Would your country be interested in having access to space-based mapping data? (land and topographical mapping)

No Yes Probably

Which ground resolution? larger than 20 m. 20 m.
 10 m. 5 m.
 smaller than 5 m. no idea.

Which accuracy in altitude? larger than 20 m. 20 m.
 10 m. 5 m.
 smaller than 5 m. no idea.

What are the other areas in which the improvement of existing remote sensing raw or processed data could be useful for your country?

To sell processed data to other countries

What spin-offs of I.P.E.O. could be envisioned for the country? In particular those driven by a global change studies? (general welfare, public opinion satisfaction, technology transfer, education...)*

?

Would your country be willing to commit itself in I.P.E.O.? If yes, how?

No Yes : via technical contribution
 by financial participation
 with *in situ* measurements
 in marketing
 other :

IXI MISCELLANEOUS.

Most countries have a reference book for remote sensing. Such documents exist also for groups of countries (for example, the Earsel Directory for Europe). Does such a reference book exist for your country? What is its name? Where can it be found?

?

LIST MATERIALS USED FOR THIS SURVEY.

LIST PEOPLE CONTACTED FOR THIS SURVEY AND GIVE THEIR REFERENCES.

Prof. Adrian Philips, Mr. MacSurtain, and Dr. Omangain
Trinity College at Dubrin

Martin Critchley, ERA

Is there any material you are expecting? Any further research you would like to do? Any person you would contact later on?

No

Please join to this Country Note any synthetic document or copies that you find particularly relevant.

No Yes : West Germany, SIR.

III/ SENSITIVITY TO ENVIRONMENTAL ISSUES.

Which of the following environmental issues (or common interests) are of importance to your country or to specific regions of your country?

Deforestation (1) ; Global Warming (2) ; Pollution (3) ; Land Resources (4) ; Vegetation Dynamics (5) ; Bio-mass Inventory (6) ; Water Quality (7) ; Soil Assessment (8) ; Urban Development (9) ; Ground Water (10) ; Acid Rain (11) ; Ozone Depletion (12) ; Crop Forecast (13) ; Insect Migration (14) ; Snow / Ice (15) ; Ocean Resources (16) ; Wildlife Monitoring (17) ; Flood (18) ; Desertification (19) ; Other... (be precise).

| Priority | Issues | Is your country actively involved in modelling and monitoring the problem? If yes, how? | Annual Budget or Percentage of Environmental Budget Spent on This Issue. |
|------------------------|--------|---|--|
| 1 st prior. | 3 | Italian Ministry of Environment (convention with TELESPAZIO Remote Sensing Division) | ? |
| 2 nd prior. | 7 | | |
| 3 rd prior. | 4 | Remote Sensing Center of Matera | |
| 4 th prior. | 8 | | |

Looking at the near, middle and long term future, what are the main objectives and strategies of your country in Earth Observation, and more specifically in environmental programs?

The recently formed Italian Space Agency is planning to increase the capabilities of the Remote Sensing Center located in Matera.

IV/ UTILIZATION OF REMOTE SENSING DATA.

Does your country make use of remote sensing data? If yes, for which purpose?

No Yes : Research Application

- As for application, which ones?

Deforestation Land and Topographical Mapping
 Global Warming Vegetation Dynamics
 Pollution Desertification
 Other :

- As for research, which areas are of the concern?

Modeling based on SAR data, pollution of Adriatic and Mediterranean sea

What kind of remote sensing data sets does your country use more often?

SPOT, LANDSAT

Does your country have the capability to produce its own G.I.S. data? If yes, which centers are involved in this?

No Yes :

What kind of G.I.S. data are most often used?

- | | |
|--|---|
| <input type="checkbox"/> Digital Elevation | <input type="checkbox"/> Land Use/Land Cover |
| <input type="checkbox"/> Roads | <input type="checkbox"/> Soils |
| <input type="checkbox"/> Hydrology | <input type="checkbox"/> Political Boundaries |
| <input type="checkbox"/> Geology | <input type="checkbox"/> Other : |

What is the status of development of the remote sensing value added industry?

Well Established Starting Non Existing

Does your country provide training courses in remote sensing?

Yes

VI. COMPLEMENTARY DATA FOR EARTH OBSERVATION.

Does your country have the capability to perform reference measurements (useful for the calibration of satellite sensors, or models validation) ?

- in situ measurements
- Low altitude observation (inferior to 10000 ft.)
- High altitude observation

Concerning the measurement acquisition, does your country have just reference plots, subjectively located, or does it have a collection of plots selected through a rational sample design?

?

Is your country equipped with :

- GPS (Global Positionning System)
- ARGOS

VII. FINANCIAL INVOLVEMENT.

Italy

What is the annual space budget (in U.S. \$) of your country?

About 600 millions plus 15% of ESA budget

What percentage of the GNP does this represent? ?

What is the annual space budget for Earth Observation from space? ?

Does your country foresee an expansion of its involvement in remote sensing activities? In which directions?

?

Does industry play a role in remote sensing activities in your country? Which one?

?

Give other financial indicators if any, such as revenues of the remote sensing images sold...
What is the total value (social, environmental, commercial) contributed by remote sensing to your country (e.g. in forest and soil resources saved through better management)? Use the best figures you can find and/or your best guess.

?

VIII REMOTE SENSING CENTERS OF THE COUNTRY.

In the following table, list and characterize the main institutions of your country dealing with remote sensing data (analysis, processing, interpretation, correlation with other data, model development...).

| <i>Remote Sensing Institution</i> | <i>Status</i> | <i>Fields of Application</i> | <i>Origin of the Raw Data</i> | <i>Hardware Tools</i> | <i>Software Tools</i> | <i>Use of a GIS</i> | <i>Annual budget</i> |
|-----------------------------------|---------------|------------------------------|-------------------------------|-----------------------|-----------------------|---------------------|----------------------|
| Telespazio SpA | gouvern | | Landsat Spot | | | | |

VIII/1 POTENTIAL IMPLEMENTATION OF L.P.E.O. IN THE COUNTRY.

Considering previous answers or more personal views, do you think that new data or information related to the deforestation phenomenon would be useful to the country?

No Yes Maybe

More precisely, would your country be interested in having access to high resolution radar data for deforestation monitoring (in a region 35°S to 35°N latitude, every ten days)? For which purpose?

No Yes Maybe :
 Scientific collaboration with developing countries

Does your country have sufficient land mapping at appropriate scales?

No Yes Maybe not

Would your country be interested in having access to space-based mapping data? (land and topographical mapping)

No Yes Probably

Which ground resolution?

larger than 20 m. 20 m.
 10 m. 5 m.
 smaller than 5 m. no idea.

Which accuracy in altitude?

larger than 20 m. 20 m.
 10 m. 5 m.
 smaller than 5 m. no idea.

What are the other areas in which the improvement of existing remote sensing raw or processed data could be useful for your country?

?

What spin-offs of I.P.E.O. could be envisioned for the country? In particular those driven by a global change studies? (general welfare, public opinion satisfaction, technology transfer, education...)*

General Welfare
 Public opinion satisfaction
 Land use management
 Hydrological basins management
 Water pollution

Would your country be willing to commit itself in I.P.E.O.? If yes, how?

No Yes : via technical contribution
 by financial participation
 with *in situ* measurements
 in marketing
 other :

IX/ MISCELLANEOUS.

Italy

Most countries have a reference book for remote sensing. Such documents exist also for groups of countries (for example, the Earsel Directory for Europe). Does such a reference book exist for your country? What is its name? Where can it be found?

?

LIST MATERIALS USED FOR THIS SURVEY.

LIST PEOPLE CONTACTED FOR THIS SURVEY AND GIVE THEIR REFERENCES.

Is there any material you are expecting? Any further research you would like to do? Any person you would contact later on?

Please join to this Country Note any synthetic document or copies that you find particularly relevant.

JAPAN

II INVOLVEMENT IN SPACE ACTIVITIES.

Does your country have a national remote sensing program? If yes, under whose authority?

No Yes : Science and Technology Agency,
NASDA

Does your country possess Earth Observation satellite(s)? If yes, name the program(s).

No Yes MOS-1a,b (launched) (Marine Obs. Sat.)
GMS Serie (Geos. Meteo. Sat)
JERS-1 (Scheduled) (Japan's Earth Res. Sat.)
ADEOS..(Scheduled) (Advanced Earth Obs. Sat.)
TRUMM (Scheduled)

Does your country design and/or build remote sensing payload(s)?
If yes, name the payload(s) and the prime manufacturer(s).

No Yes : MOS-1 : MESSR, VTIR, MSR....., NEC
JERS-1 : SAR..., MELCO
(Mitsubishi Electric Corporation)
OPS..., NEC
ADEOS : NSCAT... TOMS... NASA
POLDER CNES
IMG, ILAS, RIS ... JAPAN
EGP(Experimental Geodesic Payload)
(Kawasaki)
Space Station : ASMR, ITIR (NASDA)

Does your country possess any capability to directly receive data from a spacecraft?
If yes, from which satellite(s)? Where are the receiving stations?

No Yes : LANDSAT, MOS-1, NOAA, SPOT,
GMS (-> Japan Meteorological Agency)
Earth Observation Center at Hatoyama

III INVOLVEMENT IN INTERNATIONAL ACTIVITIES.

Does your country take part in :

? S.A.F.I.S.Y. U.N.E.P. I.C.S.U.
? COSPAR A.R.T.E.M.I.S. Other :

Is your country involved in one of the core or working group projects of I.G.B.P. (International Geosphere Biosphere Program)?

No Yes ?

Does your country participate in international Earth Observation programs (in particular environmental programs)?

If yes, describe the type of participation (technical exchange, financial investment, other...).

No Yes :

Seven nations (in Canada, Australia, Thailand, and ESA Earthnet network) signed an agreement for receiving MOS 1 data.

Same question for bilateral Earth Observation programs.

No Yes : ?

III SENSITIVITY TO ENVIRONMENTAL ISSUES.

Which of the following environmental issues (or common interests) are of importance to your country or to specific regions of your country?

Deforestation (1) ; Global Warming (2) ; Pollution (3) ; Land Resources (4) ; Vegetation Dynamics (5) ; Bio-mass Inventory (6) ; Water Quality (7) ; Soil Assessment (8) ; Urban Development (9) ; Ground Water (10) ; Acid Rain (11) ; Ozone Depletion (12) ; Crop Forecast (13) ; Insect Migration (14) ; Snow / Ice (15) ; Ocean Resources (16) ; Wildlife Monitoring (17) ; Flood (18) ; Desertification (19) ; Other... (be precise).

| Priority | Issues | Is your country actively involved in modelling and monitoring the problem? If yes, how? | Annual Budget or Percentage of Environmental Budget Spent on This Issue. |
|------------------------|------------------------------|---|--|
| 1 st prior. | Energy and Mineral Resources | Yes We are going to launch a satellite for the problem in 1991 ..[JERS-1] | 18.7 x 100 million yen for earth observation data management (in 1989) |
| 2 nd prior. | 16 | Yes We have a satellite [MOS-1] and will have one more [ADEOS] in 1995 | |
| 3 rd prior. | 2 | Yes We are developping the sensor for the problem [ADEOS; IMG] | |
| 4 th prior. | 3 | No | |

Looking at the near, middle and long term future, what are the main objectives and strategies of your country in Earth Observation, and more specifically in environmental programs?

Near : To fill the gap which will be made between UARS and EOS.[ADEOS]
 Middle and Long : To contribute global observation of environmental change to international community.

IV/ UTILIZATION OF REMOTE SENSING DATA.

Does your country make use of remote sensing data? If yes, for which purpose?

No Yes : Research Application

- As for application, which ones?

| | | | |
|-------------------------------------|----------------|--------------------------|-----------------------------------|
| <input type="checkbox"/> | Deforestation | <input type="checkbox"/> | Land and Topographical Mapping |
| <input type="checkbox"/> | Global Warming | <input type="checkbox"/> | Vegetation Dynamics |
| <input type="checkbox"/> | Pollution | <input type="checkbox"/> | Desertification |
| <input checked="" type="checkbox"/> | Other : | | Monitoring ocean weather |
| | | | Ozone and greenhouse effect gases |
| | | | Urban developing |

- As for research, which areas are of the concern?

Monitoring ocean weather, ozon, and greenhouse effect gases.

What kind of remote sensing data sets does your country use more often?

SPOT, LANDSAT, AVHRR, MOS :
 TOMS, SBUV

*Does your country have the capability to produce its own G.I.S. data?
 If yes, which centers are involved in this?*

No Yes :

What kind of G.I.S. data are most often used?

| | | | |
|-------------------------------------|-------------------|-------------------------------------|----------------------|
| <input checked="" type="checkbox"/> | Digital Elevation | <input checked="" type="checkbox"/> | Land Use/Land Cover |
| <input checked="" type="checkbox"/> | Roads | <input type="checkbox"/> | Soils |
| <input checked="" type="checkbox"/> | Hydrology | <input checked="" type="checkbox"/> | Political Boundaries |
| <input checked="" type="checkbox"/> | Geology | <input type="checkbox"/> | Other : |

What is the status of development of the remote sensing value added industry?

Well Established Starting Non Existing

Does your country provide training courses in remote sensing?

RESTEC has some lectures for utilization of Remote Sensing data.

VI. COMPLEMENTARY DATA FOR EARTH OBSERVATION.

Does your country have the capability to perform reference measurements (useful for the calibration of satellite sensors, or models validation) ?

- in situ* measurements
- Low altitude observation (inferior to 10000 ft.)
- High altitude observation

Concerning the measurement acquisition, does your country have just reference plots, subjectively located, or does it have a collection of plots selected through a rational sample design?

Japan dose not have a good training area.

Is your country equipped with :

- GPS (Global Positionning System)
- ARGOS

VII FINANCIAL INVOLVEMENT.

What is the annual space budget (in U.S. \$) of your country?

1259.6 x 100 million yen (about U.S.\$ 8.4 x 100 million)
(U.S.\$ 1.= 150 yen)

What percentage of the GNP does this represent?

18.7 x 100 million yen (about U.S.\$ 12.5 x 100 million)

What is the annual space budget for Earth Observation from space?

Yes. Directions ? Undecided

Does your country foresee an expansion of its involvement in remote sensing activities? In which directions?

?

Does industry play a role in remote sensing activities in your country? Which one? ?

Give other financial indicators if any, such as revenues of the remote sensing images sold...
What is the total value (social, environmental, commercial) contributed by remote sensing to your country (e.g. in forest and soil resources saved through better management)? Use the best figures you can find and/or your best guess.

?

VIII REMOTE SENSING CENTERS OF THE COUNTRY.

In the following table, list and characterize the main institutions of your country dealing with remote sensing data (analysis, processing, interpretation, correlation with other data, model development...).

| Remote Sensing Institution | Status | Fields of Application | Origin of the Raw Data | Hardware Tools | Software Tools | Use of a GIS | Annual budget |
|---|----------|--|--|---|----------------|--------------|---------------|
| RESTEC Remote Sensing Technology Center of JAPAN Uni- roppongi building, 7-15-17, Roppongi, minatoku, Tokyo, 106 JAPAN Tokyo Communic. Equipment Co Ltd | academic | Mineral resources 16 Ocean monitoring 13 Forestry monitoring Land use Urban developing | MOS-1 LANDSAT SPOT NOAA/ Argos | Main frame: M780/20 Wkstation : VAX11 PC: NEC 9801E | | No | |

VIII. POTENTIAL IMPLEMENTATION OF I.P.E.O. IN THE COUNTRY.

Considering previous answers or more personal views, do you think that new data or information related to the deforestation phenomenon would be useful to the country?

No Yes Maybe

More precisely, would your country be interested in having access to high resolution radar data for deforestation monitoring (in a region 35°S to 35°N latitude, every ten days)? For which purpose?

No Yes Maybe :

Does your country have sufficient land mapping at appropriate scales?

No Yes Maybe not

Would your country be interested in having access to space-based mapping data? (land and topographical mapping)

No Yes Probably

Which ground resolution? larger than 20 m. 20 m.
 10 m. 5 m.
 smaller than 5 m. no idea.

Which accuracy in altitude? larger than 20 m. 20 m.
 10 m. 5 m.
 smaller than 5 m. no idea.

What are the other areas in which the improvement of existing remote sensing raw or processed data could be useful for your country?

Land & Ocean Resources

What spin-offs of I.P.E.O. could be envisioned for the country*? In particular those driven by a global change studies? (general welfare, public opinion satisfaction, technology transfer, education...)

?

Would your country be willing to commit itself in I.P.E.O.? If yes, how?

No Yes : via technical contribution
 by financial participation
 with *in situ* measurements
 in marketing
 other :

IXI MISCELLANEOUS.

Most countries have a reference book for remote sensing. Such documents exist also for groups of countries (for example, the Earsel Directory for Europe). Does such a reference book exist for your country? What is its name? Where can it be found?

?

LIST MATERIALS USED FOR THIS SURVEY.

NASDA annual reports
 RESTEC bulletin

LIST PEOPLE CONTACTED FOR THIS SURVEY AND GIVE THEIR REFERENCES.

Is there any material you are expecting? Any further research you would like to do? Any person you would contact later on?

Takashi Moriyama : Earth Observation Center, NASDA

KENYA

II INVOLVEMENT IN SPACE ACTIVITIES.

Does your country have a national remote sensing program? If yes, under whose authority?

No Yes Department of Resource.
Surveys and Remote Sensing formerly known as
Environmental Resources Unit (KREMU), under the
Ministry of Planning and National Development.

Does your country possess Earth Observation satellite(s)? If yes, name the program(s).

No Yes :

Does your country design and/or build remote sensing payload(s)?
If yes, name the payload(s) and the prime manufacturer(s).

No Yes :

Does your country possess any capability to directly receive data from a spacecraft?
If yes, from which satellite(s)? Where are the receiving stations?

No Yes :

III INVOLVEMENT IN INTERNATIONAL ACTIVITIES.

Does your country take part in :

S.A.F.I.S.Y. U.N.E.P. I.C.S.U.
 COSPAR A.R.T.E.M.I.S. Other :

Is your country involved in one of the core or working group projects of I.G.B.P. (International Geosphere Biosphere Program)?

No Yes :

Does your country participate in international Earth Observation programs (in particular environmental programs)?
If yes, describe the type of participation (technical exchange, financial investment, other...).

No Yes :

Same question for bilateral Earth Observation programs.

No Yes :

Monitoring of soil erosion / soil classification in the arid and semi-arid regions .These projects are carried in conjunction with FAO thru UNEP and the Kenya government.

III SENSITIVITY TO ENVIRONMENTAL ISSUES.

Which of the following environmental issues (or common interests) are of importance to your country or to specific regions of your country?

Deforestation (1) ; Global Warming (2) ; Pollution (3) ; Land Resources (4) ; Vegetation Dynamics (5) ; Bio-mass Inventory (6) ; Water Quality (7) ; Soil Assessment (8) ; Urban Development (9) ; Ground Water (10) ; Acid Rain (11) ; Ozone Depletion (12) ; Crop Forecast (13) ; Insect Migration (14) ; Snow / Ice (15) ; Ocean Resources (16) ; Wildlife Monitoring (17) ; Flood (18) ; Desertification (19) ; Other... (be precise).

| Priority | Issues | Is your country actively involved in modelling and monitoring the problem? If yes, how? | Annual Budget or Percentage of Environmental Budget Spent on This Issue. |
|------------------------|--------|---|--|
| 1 st prior. | 4 | YES | |
| 2 nd prior. | 13 | YES | |
| 3 rd prior. | 8 | YES | |
| 4 th prior. | 9 | YES | |
| 5 th prior. | 17 | YES | |

Looking at the near, middle and long term future, what are the main objectives and strategies of your country in Earth Observation, and more specifically in environmental programs?

Main objectives are the uses of earth observation information for purposes of economic development. Essentially in monitoring renewable natural resources and wildlife migration.

IV UTILIZATION OF REMOTE SENSING DATA.

Does your country make use of remote sensing data? If yes, for which purpose?

No Yes : Research Application

- As for application, which ones?

- | | | | |
|-------------------------------------|----------------|-------------------------------------|--------------------------------|
| <input checked="" type="checkbox"/> | Deforestation | <input checked="" type="checkbox"/> | Land and Topographical Mapping |
| <input type="checkbox"/> | Global Warming | <input checked="" type="checkbox"/> | Vegetation Dynamics |
| <input type="checkbox"/> | Pollution | <input checked="" type="checkbox"/> | Desertification |
| <input type="checkbox"/> | Other : | | |

What kind of remote sensing data sets does your country use more often?

LANDSAT , SPOT , AVHRR , METEOSAT , Aerial Photos

*Does your country have the capability to produce its own G.I.S. data?
If yes, which centers are involved in this?*

No Yes :

- UNEP (GRID / GEMS)
- The Regional Centre for Surveying Services and Remote Sensing
- Department of Resource Surveys and Remote Sensing.(KREMU)

What kind of G.I.S. data are most often used?

- | | | | |
|-------------------------------------|-------------------|-------------------------------------|----------------------|
| <input type="checkbox"/> | Digital Elevation | <input checked="" type="checkbox"/> | Land Use/Land Cover |
| <input type="checkbox"/> | Roads | <input checked="" type="checkbox"/> | Soils |
| <input type="checkbox"/> | Hydrology | <input type="checkbox"/> | Political Boundaries |
| <input checked="" type="checkbox"/> | Geology | <input type="checkbox"/> | Other : |

What is the status of development of the remote sensing value added industry?

Well Established Starting Non Existing

Does your country provide training courses in remote sensing?

YES Applications of remote sensing technology.

VI. COMPLEMENTARY DATA FOR EARTH OBSERVATION.

Does your country have the capability to perform reference measurements (useful for the calibration of satellite sensors, or models validation) ? ?

- ? *in situ* measurements
 Low altitude observation (inferior to 10000 ft.)
 High altitude observation

Concerning the measurement acquisition, does your country have just reference plots, subjectively located, or does it have a collection of plots selected through a rational sample design?

?

Is your country equipped with :

- GPS (Global Positioning System)
- ARGOS

VII. FINANCIAL INVOLVEMENT.

What is the annual space budget (in U.S. \$) of your country? N/A

What percentage of the GNP does this represent? N/A

What is the annual space budget for Earth Observation from space? N/A

Does your country foresee an expansion of its involvement in remote sensing activities? In which directions?

YES Applications of /and research in remote sensing

Does industry play a role in remote sensing activities in your country? Which one? NO

Give other financial indicators if any, such as revenues of the remote sensing images sold...
 What is the total value (social, environmental, commercial) contributed by remote sensing to your country (e.g. in forest and soil resources saved through better management)? Use the best figures you can find and/or your best guess.

?

VIII. REMOTE SENSING CENTERS OF THE COUNTRY.

In the following table, list and characterize the main institutions of your country dealing with remote sensing data (analysis, processing, interpretation, correlation with other data, model development...).

| Remote Sensing Institution | Status | Fields of Application | Origin of the Raw Data | Hardware Tools | Software Tools | Use of a GIS | Annual budget |
|----------------------------|-----------------------|--------------------------|------------------------|----------------|---|--------------|---------------|
| UNEP /GEMS | INT'L | 4, 5, 7, 13, 14, 16, 17. | Various insts' | IBM /PC-AT'S | ARC/INFO IDRISI ELAS TYDAC/SPANS | YES | ? |
| REGIONAL CENTRE | REGIONAL (E&C AFRICA) | 1 thru 18 | Various insts' | IBM/PC'S | ARC/INFO ERDAS | YES | ? |

| Remote Sensing Institution | Status | Fields of Application | Origin of the Raw Data | Hardware Tools | Software Tools | Use of a GIS | Annual budget |
|----------------------------|--------|-----------------------|------------------------|----------------|----------------|--------------|---------------|
|----------------------------|--------|-----------------------|------------------------|----------------|----------------|--------------|---------------|

| | | | | | | | |
|-------|-----------------|----------------|-------------------------------------|-----------|-------------------|-----|---|
| KREMU | National Center | 4, 7, 8, 9, 17 | LANDSAT THRU FAO & SPOT, NOAA | IBM /PC's | ARC/INFO ERDAS | YES | ? |
|-------|-----------------|----------------|-------------------------------------|-----------|-------------------|-----|---|

VIII. POTENTIAL IMPLEMENTATION OF I.P.E.O. IN THE COUNTRY.

Considering previous answers or more personal views, do you think that new data or information related to the deforestation phenomenon would be useful to the country?

No Yes Maybe

More precisely, would your country be interested in having access to high resolution radar data for deforestation monitoring (in a region 35°S to 35°N latitude, every ten days)? For which purpose?

No Yes Maybe :

Does your country have sufficient land mapping at appropriate scales?

No Yes Maybe not

Would your country be interested in having access to space-based mapping data? (land and topographical mapping)

No Yes Probably

Which ground resolution?

larger than 20 m. 20 m.
 10 m. 5 m.
 smaller than 5 m. no idea.

Which accuracy in altitude?

larger than 20 m. 20 m.
 10 m. 5 m.
 smaller than 5 m. no idea.

What are the other areas in which the improvement of existing remote sensing raw or processed data could be useful for your country?

Environmental observation

What spin-offs of I.P.E.O. could be envisioned for the country*? In particular those driven by a global change studies? (general welfare, public opinion satisfaction, technology transfer, education...)

Technology transfer
Education

Would your country be willing to commit itself in I.P.E.O.? If yes, how?

- No Yes :
- via technical contribution
 - by financial participation
 - with *in situ* measurements
 - in marketing
 - other :

IX/ MISCELLANEOUS.

Most countries have a reference book for remote sensing. Such documents exist also for groups of countries (for example, the Earsel Directory for Europe). Does such a reference book exist for your country? What is its name? Where can it be found?

NO

LIST MATERIALS USED FOR THIS SURVEY.

LIST PEOPLE CONTACTED FOR THIS SURVEY AND GIVE THEIR REFERENCES.

Is there any material you are expecting? Any further research you would like to do? Any person you would contact later on?

NO

Please join to this Country Note any synthetic document or copies that you find particularly relevant.

LUXEMBOURG

II INVOLVEMENT IN SPACE ACTIVITIES.

Does your country have a national remote sensing program? If yes, under whose authority?

No Yes :

Does your country possess Earth Observation satellite(s)? If yes, name the program(s).

No Yes :

*Does your country design and/or build remote sensing payload(s)?
If yes, name the payload(s) and the prime manufacturer(s).*

No Yes :

*Does your country possess any capability to directly receive data from a spacecraft?
If yes, from which satellite(s)? Where are the receiving stations?*

No Yes : ASTRA / Societe Europeenne de Satellites (SES),
P.O.B 1781, L-1017 LUXEMBOURG
The SES Satellite Control Centre provides transfer
orbit services as part of the TELESAT Canada
tracking network for Ku-band satellites.

III INVOLVEMENT IN INTERNATIONAL ACTIVITIES.

Does your country take part in :

S.A.F.I.S.Y. U.N.E.P. I.C.S.U.
 COSPAR A.R.T.E.M.I.S. Other : ?

Is your country involved in one of the core or working group projects of I.G.B.P. (International Geosphere Biosphere Program)?

No Yes : ?

Does your country participate in international Earth Observation programs (in particular environmental programs)?

If yes, describe the type of participation (technical exchange, financial investment, other...).

No Yes :
Same question for bilateral Earth Observation programs.

No Yes :

III SENSITIVITY TO ENVIRONMENTAL ISSUES.

Which of the following environmental issues (or common interests) are of importance to your country or to specific regions of your country?

Deforestation (1) ; Global Warming (2) ; Pollution (3) ; Land Resources (4) ; Vegetation Dynamics (5) ; Bio-mass Inventory (6) ; Water Quality (7) ; Soil Assessment (8) ; Urban Development (9) ; Ground Water (10) ; Acid Rain (11) ; Ozone Depletion (12) ; Crop Forecast (13) ; Insect Migration (14) ; Snow / Ice (15) ; Ocean Resources (16) ; Wildlife Monitoring (17) ; Flood (18) ; Desertification (19) ; Other... (be precise).

| Priority | Issues | Is your country actively involved in modelling and monitoring the problem? If yes, how? | Annual Budget or Percentage of Environmental Budget Spent on This Issue. |
|------------------------|--------|---|--|
| 1 st prior. | 1 | Various studies, basically under the responsibility of the Administration des Eaux et Forêts, but also on an individual basis by Fonds Ecologiques, Mouvement Ecologique... | ? |
| 2 nd prior. | 8 | | |
| 3 rd prior. | 3 | | |
| 4 th prior. | 11 | | |
| 5 th prior. | 5 | | |

Looking at the near, middle and long term future, what are the main objectives and strategies of your country in Earth Observation, and more specifically in environmental programs?

Main objective : general monitoring of the environment (forestry, water, soil), assessment of environmental problems and of the effects of certain environment-related actions, monitoring of environmental regulations...

IV/ UTILIZATION OF REMOTE SENSING DATA.

Does your country make use of remote sensing data? If yes, for which purpose?

No Yes : Research Application

- As for application, which ones?

Deforestation Land and Topographical Mapping
 Global Warming Vegetation Dynamics
 Pollution Desertification
 Other :

What kind of remote sensing data sets does your country use more often?

SPOT, LANDSAT, METEOSAT, Aerial Photos

Does your country have the capability to produce its own G.I.S. data?
If yes, which centers are involved in this?

No Yes :

What is the status of development of the remote sensing value added industry?

Well Established Starting Non Existing

Does your country provide training courses in remote sensing? Probably not

V/ COMPLEMENTARY DATA FOR EARTH OBSERVATION.

Does your country have the capability to perform reference measurements (useful for the calibration of satellite sensors, or models validation) ?

in situ measurements
 Low altitude observation (inferior to 10000 ft.)
 High altitude observation

Concerning the measurement acquisition, does your country have just reference plots, subjectively located, or does it have a collection of plots selected through a rational sample design?

?

Is your country equipped with :

GPS (Global Positionning System)
 ARGOS

No

VII. FINANCIAL INVOLVEMENT.

What is the annual space budget (in U.S. \$) of your country?

None (except for the participation in INTELSAT, EUTELSAT & SES, but this cannot really be considered as space budget)

What percentage of the GNP does this represent? None

What is the annual space budget for Earth Observation from space? None

Does your country foresee an expansion of its involvement in remote sensing activities? In which directions?

Not at the moment.

Does industry play a role in remote sensing activities in your country? Which one?

No.

Give other financial indicators if any, such as revenues of the remote sensing images sold...
 What is the total value (social, environmental, commercial) contributed by remote sensing to your country (e.g. in forest and soil resources saved through better management)? Use the best figures you can find and/or your best guess.

?

VII. REMOTE SENSING CENTERS OF THE COUNTRY.

In the following table, list and characterize the main institutions of your country dealing with remote sensing data (analysis, processing, interpretation, correlation with other data, model development...).

| Remote Sensing Institution | Status | Fields of Application | Origin of the Raw Data | Hardware Tools | Software Tools | Use of a GIS | Annual budget |
|----------------------------|--------|-----------------------|------------------------|----------------|----------------|--------------|---------------|
| ??? | ??? | ??? | ??? | ??? | ??? | ??? | ??? |

VIII. POTENTIAL IMPLEMENTATION OF I.P.E.O. IN THE COUNTRY.

Considering previous answers or more personal views, do you think that new data or information related to the deforestation phenomenon would be useful to the country?

No Yes Maybe

More precisely, would your country be interested in having access to high resolution radar data for deforestation monitoring (in a region 35°S to 35°N latitude, every ten days)? For which purpose?

No Yes Maybe :

Does your country have sufficient land mapping at appropriate scales?

No Yes Maybe not

Would your country be interested in having access to space-based mapping data? (land and topographical mapping)

No Yes Probably

Which ground resolution? larger than 20 m. 20 m.
 10 m. 5 m.
 smaller than 5 m. no idea.

Which accuracy in altitude? larger than 20 m. 20 m.
 10 m. 5 m.
 smaller than 5 m. no idea.

What are the other areas in which the improvement of existing remote sensing raw or processed data could be useful for your country?

?

What spin-offs of I.P.E.O. could be envisioned for the country*? In particular those driven by a global change studies? (general welfare, public opinion satisfaction, technology transfer, education...)

- a) build-up remote-sensing industry (hardware, software...) / technology transfer
- b) general welfare

Would your country be willing to commit itself in I.P.E.O.? If yes, how?

No Yes : via technical contribution
 by financial participation
 with *in situ* measurements
 in marketing
 other :

IXI MISCELLANEOUS.

Most countries have a reference book for remote sensing. Such documents exist also for groups of countries (for example, the Earsel Directory for Europe). Does such a reference book exist for your country? What is its name? Where can it be found?

?

LIST MATERIALS USED FOR THIS SURVEY.

LIST PEOPLE CONTACTED FOR THIS SURVEY AND GIVE THEIR REFERENCES.

Is there any material you are expecting? Any further research you would like to do? Any person you would contact later on?

Ms Mady MOLITOR, Administration des Eaux et Forets, LUXEMBOURG
Mr Paul FABER, Fonds Ecologique, LUXEMBOURG

NETHERLANDS

II INVOLVEMENT IN SPACE ACTIVITIES.

Does your country have a national remote sensing program? If yes, under whose authority?

No Yes : BCRS
PO Box 5023
2600 GA Delft
The Netherlands

Does your country possess Earth Observation satellite(s)? If yes, name the program(s).

No Yes :

Does your country design and/or build remote sensing payload(s)?
If yes, name the payload(s) and the prime manufacturer(s).

No Yes : Fokker : TERS-concept, ERS 1
integration and payload tests.
TPD-TNO Delft : Instruments
NLR : Experiments

Does your country possess any capability to directly receive data from a spacecraft?
If yes, from which satellite(s)? Where are the receiving stations?

No Yes : NPOC : NLR
PO Box 153
8300 AD Emmeloord
The Netherlands

III INVOLVEMENT IN INTERNATIONAL ACTIVITIES.

Does your country take part in :

S.A.F.I.S.Y. U.N.E.P. I.C.S.U.
 COSPAR A.R.T.E.M.I.S. Other :

Is your country involved in one of the core or working group projects of I.G.B.P. (International Geosphere Biosphere Program)?

No Yes : ?

Does your country participate in international Earth Observation programs (in particular environmental programs)?

If yes, describe the type of participation (technical exchange, financial investment, other...).

No Yes : ESA - ERS 1
Niwers reasearch programme

Same question for bilateral Earth Observation programs.

No Yes : Phase A TERS (with Indonesia)

III SENSITIVITY TO ENVIRONMENTAL ISSUES.

- Which of the following environmental issues (or common interests) are of importance to your country or to specific regions of your country?

Deforestation (1) ; Global Warming (2) ; Pollution (3) ; Land Resources (4) ; Vegetation Dynamics (5) ; Bio-mass Inventory (6) ; Water Quality (7) ; Soil Assessment (8) ; Urban Development (9) ; Ground Water (10) ; Acid Rain (11) ; Ozone Depletion (12) ; Crop Forecast (13) ; Insect Migration (14) ; Snow / Ice (15) ; Ocean Resources (16) ; Wildlife Monitoring (17) ; Flood (18) ; Desertification (19) ; Other... (be precise).

| Priority | Issues | Is your country actively involved in modelling and monitoring the problem? If yes, how? | Annual Budget or Percentage of Environmental Budget Spent on This Issue. |
|------------------------|----------------|---|--|
| 1 st prior. | Water Quality | Integral Water Management by Rijkswaterstaat (7) | ?, total approx. few ten million Dfl. |
| 2 nd prior. | Acid Rain | Acid Rain Research Program in the Netherlands (11) ; | ? |
| 3 rd prior. | Ozone | Monitoring of trace gases in the troposphere + preparations for participation in Ozone monitoring missions planed by ESA, US (12) | ? |
| 4 th prior. | Defores-tation | Dutch Tropenbos Programme and priority area in National Remote Sensing Programme 1991-1995 | ? |
| 5 th prior. | 2 | Dutch participation in WCRP | ? |

Looking at the near, middle and long term future, what are the main objectives and strategies of your country in Earth Observation, and more specifically in environmental programs?

IV/ UTILIZATION OF REMOTE SENSING DATA.

Does your country have the capability to perform reference measurements (useful for the calibration of satellite sensors, or models validation) ?

- in situ measurements
- ? Low altitude observation (inferior to 10000 ft.)
- High altitude observation

Concerning the measurement acquisition, does your country have just reference plots, subjectively located, or does it have a collection of plots selected through a rational sample design?

?

Is your country equipped with :

- GPS (Global Positioning System)
- ARGOS

VII FINANCIAL INVOLVEMENT

What is the annual space budget (in U.S. \$) of your country?

Around Dfl. 180 million 1986 U.S. 30 M\$

What percentage of the GNP does this represent? ?

What is the annual space budget for Earth Observation from space? Dfl. 25-30 million

Does your country foresee an expansion of its involvement in remote sensing activities? In which directions?

Netherlands foresee an expansion in its involvement in remote sensing activities through (a) participation in new ESA development programmes such as Columbus polar platform; (b) application oriented activities with the aid of the data provided by these new facilities, with emphasis on 'planet earth' and environmental applications; (c) participation in International Geosphere/Biosphere Program.

Does industry play a role in remote sensing activities in your country? Which one?

Yes, Fokker Space & Systems

Give other financial indicators if any, such as revenues of the remote sensing images sold...
What is the total value (social, environmental, commercial) contributed by remote sensing to your country (e.g. in forest and soil resources saved through better management)? Use the best figures you can find and/or your best guess.

E.O programmes in Netherlands mainly government funded.

VIII REMOTE SENSING CENTERS OF THE COUNTRY

In the following table, list and characterize the main institutions of your country dealing with remote sensing data (analysis, processing, interpretation, correlation with other data, model development...).

| Remote Sensing Institution | Status | Fields of Application | Origin of the Raw Data | Hardware Tools | Software Tools | Use of a GIS | Annual budget |
|--|-----------|---|--|--|----------------|--------------|---------------|
| National Aerospace Laboratory (NLR) | Semi-gov. | National Data Center (NPOC) RS user support System dev. Airborne RS | ESA Earthnet Euri-mage SPOT IMAGE EOSAT Meteosat NOAA-AVHRR NLR-airborne sensor data | Sun 4/390 wstation I ² S system 600 Optronics C-4300 Hamamatsu C-1000 Matrix Camara Gentian Digitizer | | | |
| Physics & Electronics Laboratory TNO The Hague | semi-gov. | Radar research Radar syst.dev. | Dutch NPOC (NLR), national point of contact, NLR airborne sensor data JPL-SAR data | | | | |
| Staring Centre Wageningen | gov. | Land use Hydrology Global change | NPOC | ERDAS | ARC Info | yes | |
| DHV | private | Land use planning Urban Planning | NPOC EOSAT Spot Image | ERDAS | ARC Info | yes | |

| Remote Sensing | Status | Fields of | Origin of the | Hardware Tools | Software Tools | Use of a | Annual budget |
|----------------|--------|-----------|---------------|----------------|----------------|----------|---------------|
|----------------|--------|-----------|---------------|----------------|----------------|----------|---------------|

| <i>Institution</i> | | <i>Application</i> | <i>Raw Data</i> | | | <i>GIS</i> | |
|--------------------|------|--------------------|--------------------------------|------|--|------------|--|
| ITC | gov. | Education training | NPOC EOSAT Spot Image | many | | yes | |

VIII. POTENTIAL IMPLEMENTATION OF I.P.E.O. IN THE COUNTRY.

Considering previous answers or more personal views, do you think that new data or information related to the deforestation phenomenon would be useful to the country?

No Yes Maybe.

For the Netherlands there is no need for any small space system of its own for remote sensing of its own territory.

The global deforestation problem is of course influencing the local situation (eg. sea level) and Dutch earth observation interest goes beyond its borders. It is further felt that presently available data are not sufficiently exploited. Need for data base and easy access is endorsed.

More precisely, would your country be interested in having access to high resolution radar data for deforestation monitoring (in a region 35°S to 35°N latitude, every ten days)? For which purpose?

No Yes Maybe : See above reasons

Does your country have sufficient land mapping at appropriate scales?

No Yes Maybe not

New data, especially to monitor most recent developments remain necessary both from existing satellite systems like Landsat and Spot but also Radar data from ERS-1 and similar in order to circumvent the problem of cloud cover.

Would your country be interested in having access to space-based mapping data? (land and topographical mapping)

No Yes Probably

Which ground resolution?

larger than 20 m. 20 m.
 10 m. 5 m.
 smaller than 5 m. no idea.

Which accuracy in altitude?

larger than 20 m. 20 m.
 10 m. 5 m.

smaller than 5 m. no idea.

What are the other areas in which the improvement of existing remote sensing raw or processed data could be useful for your country?

- Improved observation frequency by optical sensors would be useful for:
1. Water pollution monitoring for coastal zone water management
 2. Ocean circulation monitoring for climate research

What spin-offs of I.P.E.O. could be envisioned for the country? In particular those driven by a global change studies? (general welfare, public opinion satisfaction, technology transfer, education...)

- Contribution to protection of own environment
- Public opinion satisfaction in view of contribution to solution of global problems
- Better bargaining position towards neighbouring countries in environmental issues (such as Rhine pollution) because the Dutch are taking their share of the environmental burden.
- Demonstration of national capabilities in the high tech field of earth observation acts as marketing agent for Netherlands products in general. It will enhance e.g. a slogan like: The Fokker 100 comes from Holland; no wonder it is the most environment friendly aircraft!
- Educational capabilities, concentrated in ITC, will be promoted by IPEO and will be in greater demand.

Would your country be willing to commit itself in I.P.E.O.? If yes, how?

No Yes

In fact we are doing already much that could be considered as technical contribution to IPEO and an IPEO-like initiative may well trigger a gradual increase of these activities.

IX. MISCELLANEOUS.

Most countries have a reference book for remote sensing. Such documents exist also for groups of countries (for example, the Earsel Directory for Europe). Does such a reference book exist for your country? What is its name? Where can it be found?

BCRS

LIST MATERIALS USED FOR THIS SURVEY.

National RS programme (BCRS)
Water Reports from Space
Land & Water International

LIST PEOPLE CONTACTED FOR THIS SURVEY AND GIVE THEIR REFERENCES.

1. Dr Ir N.J.J . Bunnink, fax dated August 15, 1990
2. NIVR/ Space Division
Ir. P.F.J. Linssen
PO Box 35
fax 31-15623096
tel 31-15787328

Is there any material you are expecting? Any further research you would like to do? Any person you would contact later on?

No

NORWAY

II INVOLVEMENT IN SPACE ACTIVITIES.

Does your country have a national remote sensing program? If yes, under whose authority?

No Yes : The Norwegian Space Centre

Does your country possess Earth Observation satellite(s)? If yes, name the program(s).

No Yes : As an ESA member state Norway participates in EO programs, and therefore is one of many owners of EO satellites (ERS1, ERS2 etc.)

Does your country design and/or build remote sensing payload(s)?
If yes, name the payload(s) and the prime manufacturer(s).

No Yes : Not complete payloads but parts :

Chirp generator for radar altimeter (ERS1) - AME Space as
Radarsignal processing receiver (Radarsat) - AME Space as

Does your country possess any capability to directly receive data from a spacecraft?
If yes, from which satellite(s)? Where are the receiving stations?

No Yes : Satellite / Receiving Stations

COSPAS/SARSAT, NOAA, MOS1, ERS1 / TSS - Tromso Satellite Station
NOAA, METEOSAT / Oslo (The Norw. Meteorological Institute)

III INVOLVEMENT IN INTERNATIONAL ACTIVITIES.

Does your country take part in :

S.A.F.I.S.Y. U.N.E.P. I.C.S.U.
 COSPAR A.R.T.E.M.I.S. Other :

SCAR (Scientific Committee on Antarctic Research)
SCOSTEP (Scientific Committee on Solar-Terrestrial Physics)
URSI (International Union of Radio Science)
ISPRS (International Society for Photogrammetry and Remote Sensing)
IPOMS (Int. Polar Orbiting Meteorological Satellite Group)
EARSEL (European Association of Remote Sensing Laboratories)

Is your country involved in one of the core or working group projects of I.G.B.P. (International Geosphere Biosphere Program)?

No Yes : The core project : A study of global change
(Ref. I. Isaksen - University of Oslo, P.Haugen - Nansen Center for RS)

Does your country participate in international Earth Observation programs (in particular environmental programs)?

If yes, describe the type of participation (technical exchange, financial investment, other...).

No Yes : Program / Participation.

ERS1, ERS2 / Financial (via ESA), technical (HW,SW), receiving data
Polar Platform (POEM) / Financial, technical (HW, SW)
EOPP / Financial
EUMETSAT / Financial, member of council
IPOMS / Associated member - political decisions
EARSEL / Member
ISPRS / Member

Same question for bilateral Earth Observation programs.

No Yes : RADARSAT / Receiving data (planned)

III SENSITIVITY TO ENVIRONMENTAL ISSUES.

Which of the following environmental issues (or common interests) are of importance to your country or to specific regions of your country?

Deforestation (1) ; Global Warming (2) ; Pollution (3) ; Land Resources (4) ; Vegetation Dynamics (5) ; Bio-mass Inventory (6) ; Water Quality (7) ; Soil Assessment (8) ; Urban Development (9) ; Ground Water (10) ; Acid Rain (11) ; Ozone Depletion (12) ; Crop Forecast (13) ; Insect Migration (14) ; Snow / Ice (15) ; Ocean Resources (16) ; Wildlife Monitoring (17) ; Flood (18) ; Desertification (19) ; Other... (be precise).

| Priority | Issues | Is your country actively involved in modelling and monitoring the problem? If yes, how? | Annual Budget or Percentage of Environmental Budget Spent on This Issue. |
|------------------------|--------|--|---|
| 1 st prior. | 15 / 1 | Ice cover, ice types, ice drift, snow melting (also used for ship traffic monitoring). Modelling, monitoring and research - especially by the Nansen Remote Sensing Center and the Norw. Polar Research Institute. | The total budget for the Department of Environment is 1600 Mill. NOK (1990). Less than 0.5% of this goes to remote sensing activities - in a broad sense. |
| 2 nd prior. | 16 | Wind, waves, currents, temperature, chlorophyll, suspended matter. | The Norw. Space Center handles the remote sensing budget for environmental issues. |

| Priority | Issues | Is your country actively involved in modelling and monitoring the problem? If yes, how? | Annual Budget or Percentage of Environmental Budget Spent on This Issue. |
|------------------------|--------|--|--|
| 3 rd prior. | 3 | Toxic algal blooms monitoring, oil pollution monitoring (Oceanor, governmental agencies). Not operational with satellite data. | Total annual budget for this is 8-10 Mill. NOK |
| 4 th prior. | 4-5 | Monitoring of forest and natural vegetation | |
| 5 th prior. | 12 | Establishment of ozone climate for northern latitudes based on NIMBUS-7 data. | |

Looking at the near, middle and long term future, what are the main objectives and strategies of your country in Earth Observation, and more specifically in environmental programs?

Norway wants to develop industry based on

- Electronics and computer systems for the ground segment
- Electronics for the space segment
- User's needs for operational services & data

Priorities are on applications within

- Surveillance and monitoring of oceans, atmosphere, ice (also in Arctic regions)
- Monitoring of environment, resources + mapping

Participation in international programs for

- Development of operational systems
- Continuity of data + industrial projects

IV. UTILIZATION OF REMOTE SENSING DATA.

Does your country make use of remote sensing data? If yes, for which purpose?

No Yes : Research (2) Application (1)

- As for application, which ones?

- Deforestation Land and Topographical Mapping
- Global Warming Vegetation Dynamics
- Pollution : Algal blooms, oil spills etc.
- Desertification Other : Fishing industry (ocean colour)
Shipping (ice monitoring)
Weather forecasting

- As for research, which areas are of the concern?

[X] ARGOS

VII FINANCIAL INVOLVEMENT

What is the annual space budget (in U.S. \$) of your country?

The budget of the Norwegian Space Center is 200 Mill. NOK (1990) - this includes the ESA contribution. Total investment in research and development related to space is 300 Mill. NOK.

What percentage of the GNP does this represent? ?

What is the annual space budget for Earth Observation from space?

| | | |
|--------|------------------------------------|-----------------|
| 1990 : | ESA EO programs : | 20 Mill. NOK |
| | Infrastructure : | 10-15 Mill. NOK |
| | Research, applications, industry : | 10-15 Mill. NOK |
| | | ----- |
| | Total : | 40-50 Mill. NOK |

Does your country foresee an expansion of its involvement in remote sensing activities? In which directions?

The goal is to increase the applications of RS data, i.e. more operative services

Does industry play a role in remote sensing activities in your country? Which one?

?

Give other financial indicators if any, such as revenues of the remote sensing images sold...
 What is the total value (social, environmental, commercial) contributed by remote sensing to your country (e.g. in forest and soil resources saved through better management)? Use the best figures you can find and/or your best guess.

The total revenues for space related activities (products and services) is 900 Mill. NOK (1990), and the goal is a growth of 10-15% per year. These revenues are divided between :

- The Norwegian PTT (27%)
- Research services (13%)
- EB Nera - satellite comm (36%)
- ESA industrial contracts (10%)
- Other industry (14%)

VIII REMOTE SENSING CENTERS OF THE COUNTRY.

In the following table, list and characterize the main institutions of your country dealing with remote sensing data (analysis, processing, interpretation, correlation with other data, model development...).

| Remote | Fields | Origin | Hardware | Software | Use | Annual |
|--------|--------|--------|----------|----------|-----|--------|
|--------|--------|--------|----------|----------|-----|--------|

| <i>Sensing Institution</i> | <i>Status</i> | <i>of Application</i> | <i>of the Raw Data</i> | <i>Tools</i> | <i>Tools</i> | <i>of a GIS</i> | <i>budget *</i> |
|------------------------------------|--------------------|----------------------------|------------------------|---|--------------|-----------------|--------------------------------|
| Nansen Remote Sensing Centre | Academ Consult | 15,3,16,5,2,12 | NOAA, MOS,CZCS (ERS1) | Context-vision computers, MicroVAX | | | NOK 14 M. |
| FORUT | Academ Consult | 4,5,16,12 | NOAA Landsat SAR-data | I2S MicroVAX | | | NOK 53 M. |
| OCEANOR | Commerc | 16,3 | AVHRR SAR-data (ERS1) | PC MicroVAX | | | NOK 65 M. |
| Norwegian Defense Research Establ. | Government Consult | 16, 15, 4 ship monitoring | SPOT Sar-data | Apollo 1000, design of high performance SAR processor | | Y | NOK 265 M. |
| Norwegian Mapping Authority | Government | 4,5 | SPOT, Landsat | Terragon | | Y | NOK 290 M. |
| Norwegian Meteorolog. Institute | Government | 16, 3, 15 weather forecast | NOAA METEO-SAT | I2S | | | NOK 180 M. |
| TSS-Tromso Satellite Station | Commerc (Govern) | Data acq, dataproc. | NOAA, MOS, (ERS1) | I2S | | | NOK 10 M. (+ NOK 10 M. invest) |

| <i>Remote Sensing Institution</i> | <i>Status</i> | <i>Fields of Application</i> | <i>Origin of the Raw Data</i> | <i>Hardware Tools</i> | <i>Software Tools</i> | <i>Use of a GIS</i> | <i>Annual budget *</i> |
|-----------------------------------|---------------|------------------------------|-------------------------------|-----------------------|-----------------------|---------------------|------------------------|
|-----------------------------------|---------------|------------------------------|-------------------------------|-----------------------|-----------------------|---------------------|------------------------|

| | | | | | | | |
|---|---------|---------------------|----------------------|---------------------------|--|---|-----------|
| Norwegian Computing Center | Consult | Statistical methods | All above satellites | Context vision computers | | Y | NOK 42 M. |
| NORSPACE | Commerc | Dataproc. | | ND - Norsk Data computers | | | |
| NPRI Norwegian Polar Research Institute | Governm | 15 Arctic Antartica | SPOT Landsat | PC ERDAS | | Y | NOK 60 M. |

* Budgets are total, not only remote sensing

VIII. POTENTIAL IMPLEMENTATION OF L.P.E.O. IN THE COUNTRY.

Considering previous answers or more personal views, do you think that new data or information related to the deforestation phenomenon would be useful to the country?

No Yes Maybe

More precisely, would your country be interested in having access to high resolution radar data for deforestation monitoring (in a region 35°S to 35°N latitude, every ten days)? For which purpose?

No Yes Maybe :

Does your country have sufficient land mapping at appropriate scales?

No Yes Maybe not

Would your country be interested in having access to space-based mapping data? (land and topographical mapping)

No Yes Probably

Which ground resolution?

larger than 20 m. 20 m.
 10 m. 5 m.
 smaller than 5 m. all of them

Which accuracy in altitude?

larger than 20 m. 20 m.
 10 m. 5 m.

smaller than 5 m. all of them

What are the other areas in which the improvement of existing remote sensing raw or processed data could be useful for your country?

Improvement of existing remote sensing data could lead to more extensive use of these data in institutions which have responsibility for monitoring resources (for example AVHRR data could be used for monitoring snow melting in the mountains during spring, sea surface temperatures in the coastal areas etc.)

What spin-offs of I.P.E.O. could be envisioned for the country? In particular those driven by a global change studies? (general welfare, public opinion satisfaction, technology transfer, education...)*

The Norwegian public research strategy defines environmental technology as a priority area, and the government policy and legislation is to provide incentives to both industry and scientific communities. I.P.E.O clearly falls into the right category, and all of the above mentioned spin-offs could be envisioned.

Would your country be willing to commit itself in I.P.E.O.? If yes, how?

No Yes : via technical contribution
 by financial participation
 with *in situ* measurements
 in marketing
 other :

IXI MISCELLANEOUS.

Most countries have a reference book for remote sensing. Such documents exist also for groups of countries (for example, the Earsel Directory for Europe). Does such a reference book exist for your country? What is its name? Where can it be found?

No such book exists for Norway, but it is planned for next year

LIST MATERIALS USED FOR THIS SURVEY.

- Norwegian long-term plan for space activities (Norwegian Space Centre)
- Norway exports Space Technology and Services - publication
- Norway in Space - publication
- Annual reports (1989) - the Norwegian Earth Observ. program

LIST PEOPLE CONTACTED FOR THIS SURVEY AND GIVE THEIR REFERENCES.

Guro Dahle Strom, Norwegian Space Centre
 Tlph. + 47 - 2 - 52 38 00
 Fax. + 47 - 2 - 52 23 97

Norway

Is there any material you are expecting? Any further research you would like to do? Any person you would contact later on?

No

Please join to this Country Note any synthetic document or copies that you find particularly relevant.

SAUDI ARABIA

II INVOLVEMENT IN SPACE ACTIVITIES.

Does your country have a national remote sensing program? If yes, under whose authority?

No Yes: Saudi Center for Remote Sensing under King
Abdulaziz City for science and Technology.

Does your country possess Earth Observation satellite(s)? If yes, name the program(s).

No Yes :

Does your country design and/or build remote sensing payload(s)?
If yes, name the payload(s) and the prime manufacturer(s).

No Yes :

Does your country possess any capability to directly receive data from a spacecraft?
If yes, from which satellite(s)? Where are the receiving stations?

No Yes: Landsat, Spot, NOAA in KASCT Riyadh

III INVOLVEMENT IN INTERNATIONAL ACTIVITIES.

Does your country take part in :

S.A.F.I.S.Y. U.N.E.P. I.C.S.U.
 COSPAR A.R.T.E.M.I.S. Other :

Is your country involved in one of the core or working group projects of I.G.B.P. (International Geosphere Biosphere Program)?

No Yes :

Does your country participate in international Earth Observation programs (in particular environmental programs)?

If yes, describe the type of participation (technical exchange, financial investment, other...).

No Yes: SIR/C

Same question for bilateral Earth Observation programs.

No Yes: ?

III SENSITIVITY TO ENVIRONMENTAL ISSUES.

Which of the following environmental issues (or common interests) are of importance to your country or to specific regions of your country?

Deforestation (1) ; Global Warming (2) ; Pollution (3) ; Land Resources (4) ; Vegetation Dynamics (5) ; Bio-mass Inventory (6) ; Water Quality (7) ; Soil Assessment (8) ; Urban Development (9) ; Ground Water (10) ; Acid Rain (11) ; Ozone Depletion (12) ; Crop Forecast (13) ; Insect Migration (14) ; Snow / Ice (15) ; Ocean Resources (16) ; Wildlife Monitoring (17) ; Flood (18) ; Desertification (19) ; Other... (be precise).

| Priority | Issues | Is your country actively involved in modelling and monitoring the problem? If yes, how? | Annual Budget or Percentage of Environmental Budget Spent on This Issue. |
|------------|--------|---|--|
| 1st prior. | 4 | | |
| 2nd prior. | 9 | | |
| 3rd prior. | 10 | No | |
| 4th prior. | 3 | | |
| 5th prior. | 8 | | |

Looking at the near, middle and long term future, what are the main objectives and strategies of your country in Earth Observation, and more specifically in environmental programs?

?

IV/ UTILIZATION OF REMOTE SENSING DATA.

Does your country make use of remote sensing data? If yes, for which purpose?

No Yes : Research Application

- As for application, which ones?

Deforestation Land and Topographical Mapping
 Global Warming Vegetation Dynamics
 Pollution Desertification
 Other : Geology, Exploration.

- As for research, which areas are of the concern?

POLLUTION, GEOLOGY, MAPPING

What kind of remote sensing data sets does your country use more often?

SPOT, LANDSAT

Does your country have the capability to produce its own G.I.S. data?

If yes, which centers are involved in this?

No Yes SAUDI CENTER FOR REMOTE SENSING

What kind of G.I.S. data are most often used?

- | | |
|---|---|
| <input checked="" type="checkbox"/> Digital Elevation | <input checked="" type="checkbox"/> Land Use/Land Cover |
| <input checked="" type="checkbox"/> Roads | <input type="checkbox"/> Soils |
| <input type="checkbox"/> Hydrology | <input type="checkbox"/> Political Boundaries |
| <input checked="" type="checkbox"/> Geology | <input type="checkbox"/> Other : |

What is the status of development of the remote sensing value added industry?

Well Established Starting Non Existing

Does your country provide training courses in remote sensing?

?

VI. COMPLEMENTARY DATA FOR EARTH OBSERVATION.

VII. FINANCIAL INVOLVEMENT.

Information not available.

VIII. REMOTE SENSING CENTERS OF THE COUNTRY.

In the following table, list and characterize the main institutions of your country dealing with remote sensing data (analysis, processing, interpretation, correlation with other data, model development...).

| Remote Sensing Institution | Status | Fields of Application | Origin of the Raw Data | Hardware Tools | Software Tools | Use of a GIS | Annual budget |
|---------------------------------------|---------|-----------------------|------------------------|--------------------|----------------|--------------|---------------|
| SAUDI CENTER OF REMOTE SENSING (SCRS) | GOVERN. | 4,9,10,3 | NOAA SPOT LANDSAT | VAX 3 WORK STATION | ERDAS MERIDIAN | YES | |

| Remote Sensing Institution | Status | Fields of Application | Origin of the Raw Data | Hardware Tools | Software Tools | Use of a GIS | Annual budget |
|----------------------------|--------|-----------------------|------------------------|----------------|----------------|--------------|---------------|
| | | | | | | | |

| | | | | | | | |
|---|---------|----------|-----------------|------------------|--|----|--|
| RESEARCH INSTITUTE KING FAHD UNIVRTITY OF PETROLEUM AND MINERALS | Academ. | 4,9,10,3 | SPOT LANDSAT | HP PC | | NO | |
| FACULTY OF EARTH SCIENCE KING ABDULAZIZ University | Academ. | GEOLOGY | SPOT LANDSAT | I ² S | | NO | |

VIII. POTENTIAL IMPLEMENTATION OF I.P.E.O. IN THE COUNTRY.

Considering previous answers or more personal views, do you think that new data or information related to the deforestation phenomenon would be useful to the country?

No Yes Maybe

More precisely, would your country be interested in having access to high resolution radar data for deforestation monitoring (in a region 35°S to 35°N latitude, every ten days)? For which purpose?

No Yes Maybe :

Does your country have sufficient land mapping at appropriate scales?

No Yes Maybe not

Would your country be interested in having access to space-based mapping data? (land and topographical mapping)

No Yes Probably

Which ground resolution?

larger than 20 m. 20 m.
 10 m. 5 m.
 smaller than 5 m. no idea.

Which accuracy in altitude?

larger than 20 m. 20 m.
 10 m. 5 m.

smaller than 5 m. no idea.

What are the other areas in which the improvement of existing remote sensing raw or processed data could be useful for your country?

?

What spin-offs of I.P.E.O. could be envisioned for the country? In particular those driven by a global change studies? (general welfare, public opinion satisfaction, technology transfer, education...)*

TECHNOLOGY AND EDUCATION TRANSFER

Would your country be willing to commit itself in I.P.E.O.? If yes, how?

No Yes :

- via technical contribution
- by financial participation
- with *in situ* measurements
- in marketing
- other :

IXI MISCELLANEOUS.

Most countries have a reference book for remote sensing. Such documents exist also for groups of countries (for example, the Earsel Directory for Europe). Does such a reference book exist for your country? What is its name? Where can it be found?

NO

LIST MATERIALS USED FOR THIS SURVEY.

LIST PEOPLE CONTACTED FOR THIS SURVEY AND GIVE THEIR REFERENCES.

Mr. NASR AL-SAHAF
SAUDI CENTER FOR REMOTE CENTER
KING ABDULAZIZ CITY FOR SCIENCE AND TECHNOLOGY

Is there any material you are expecting? Any further research you would like to do? Any person you would contact later on?

Does your country participate in international Earth Observation programs (in particular environmental programs)?

If yes, describe the type of participation (technical exchange, financial investment, other...).

No Yes : ERS, Polar Platform.

Same question for bilateral Earth Observation programs.

No Yes : ?

III SENSITIVITY TO ENVIRONMENTAL ISSUES.

Which of the following environmental issues (or common interests) are of importance to your country or to specific regions of your country?

Deforestation (1) ; Global Warming (2) ; Pollution (3) ; Land Resources (4) ; Vegetation Dynamics (5) ; Bio-mass Inventory (6) ; Water Quality (7) ; Soil Assessment (8) ; Urban Development (9) ; Ground Water (10) ; Acid Rain (11) ; Ozone Depletion (12) ; Crop Forecast (13) ; Insect Migration (14) ; Snow / Ice (15) ; Ocean Resources (16) ; Wildlife Monitoring (17) ; Flood (18) ; Desertification (19) ; Other... (be precise).

| Priority | Issues | Is your country actively involved in modelling and monitoring the problem? If yes, how? | Annual Budget or Percentage of Environmental Budget Spent on This Issue. |
|------------------------|--------|---|--|
| 1 st prior. | 18 | | |
| 2 nd prior. | 16 | | |
| 3 rd prior. | 1 | ? | ? |
| 4 th prior. | 2 | | |
| 5 th prior. | 3 | | |

Looking at the near, middle and long term future, what are the main objectives and strategies of your country in Earth Observation, and more specifically in environmental programs?

?

IV UTILIZATION OF REMOTE SENSING DATA.

Does your country make use of remote sensing data? If yes, for which purpose?

No Yes : Research Application

What kind of remote sensing data sets does your country use more often?

METEOSAT

Does your country have the capability to produce its own G.I.S. data?
If yes, which centers are involved in this?

No Yes : ?

What is the status of development of the remote sensing value added industry?

Well Established Starting Non Existing ?

Does your country provide training courses in remote sensing?

?

VI COMPLEMENTARY DATA FOR EARTH OBSERVATION.

Information not available.

VII FINANCIAL INVOLVEMENT.

What is the annual space budget (in U.S. \$) of your country? 1985 27 M. ECUS

VIII REMOTE SENSING CENTERS OF THE COUNTRY.

In the following table, list and characterize the main institutions of your country dealing with remote sensing data (analysis, processing, interpretation, correlation with other data, model development...).

| Remote Sensing Institution | Status | Fields of Application | Origin of the Raw Data | Hardware Tools | Software Tools | Use of a G.I.S | Annual budget |
|----------------------------|--------|-----------------------|------------------------|-------------------------------|----------------|----------------|---------------|
| Ibersat | | | NOAA NIMBUS SPOT | IPS 600 DIPIX ARies III | | | |

VIII POTENTIAL IMPLEMENTATION OF I.P.E.O. IN THE COUNTRY.

SWEDEN

II INVOLVEMENT IN SPACE ACTIVITIES.

Does your country have a national remote sensing program? If yes, under whose authority?

No Yes : Under the authority of the Swedish National Space Board (SBSA) The program is managed by the Swedish Space Corporation (SSC) and SSC-Satellitbild which is linked to the Swedish participation in the Spot project.

Does your country possess Earth Observation satellite(s)? If yes, name the program(s).

No Yes : Sweden participates in the Spot project and through ESA in the ERS 1/2 , and the Columbus Polar Platform projects.

*Does your country design and/or build remote sensing payload(s)?
If yes, name the payload(s) and the prime manufacturer(s).*

No Yes : IR-camera by AGA.
SLAR by ERICSSON.

*Does your country possess any capability to directly receive data from a spacecraft?
If yes, from which satellite(s)? Where are the receiving stations?*

No Yes : Satellite / Receiving Stations

A variety of ground stations are located in the vicinity of Kiruna (Esrangle).

The ground stations for Spot, Landsat, and Mos-1A/1B are located at Esrangle. The ESA ERS-1 ground station is located at Salmijaervi close to Esrangle. An agreement has been reached between Sweden and the USSR (SSC and Glavkosmos) for the reception and marketing of image data from the Soviet RESURS and OKEAN satellite systems. Negotiations are underway to install a ground station for the Japanese Earth Resources Satellite JERS-1 at Esrangle.

III INVOLVEMENT IN INTERNATIONAL ACTIVITIES.

Does your country take part in :

S.A.F.I.S.Y. U.N.E.P. I.C.S.U.
 COSPAR A.R.T.E.M.I.S. Other :

Sweden participates via ESA in SAFISY, and as far as we know at least in COSPAR and UNEP.

Is your country involved in one of the core or working group projects of I.G.B.P. (International Geosphere Biosphere Program)?

No Yes : ?

Does your country participate in international Earth Observation programs (in particular environmental programs)?

If yes, describe the type of participation (technical exchange, financial investment, other...).

No Yes : Program / Participation

Sweden participates in the Earth Observation Program and the Space Station Program of ESA (ERS 1/2 and the Columbus Polar Platform). Sweden additionally participates in the Spot Project. SSC and SIDA (Swedish International Development Agency) participates jointly in the Global Deforestation Assessment. EOPP (ESA).

Same question for bilateral Earth Observation programs.

No Yes : Program / Participation.

On a bilateral level, SSC has provided consultancy in a forestry survey for India. Remote sensing projects have been carried out in Nigeria and the Philippines by SSC and SIDA.

III SENSITIVITY TO ENVIRONMENTAL ISSUES.

Which of the following environmental issues (or common interests) are of importance to your country or to specific regions of your country?

Deforestation (1) ; Global Warming (2) ; Pollution (3) ; Land Resources (4) ; Vegetation Dynamics (5) ; Bio-mass Inventory (6) ; Water Quality (7) ; Soil Assessment (8) ; Urban Development (9) ; Ground Water (10) ; Acid Rain (11) ; Ozone Depletion (12) ; Crop Forecast (13) ; Insect Migration (14) ; Snow / Ice (15) ; Ocean Resources (16) ; Wildlife Monitoring (17) ; Flood (18) ; Desertification (19) ; Other... (be precise).

| Priority | Issues | Is your country actively involved in modelling and monitoring the problem? If yes, how? | Annual Budget or Percentage of Environmental Budget Spent on This Issue. |
|------------------------|--------------------|---|--|
| 1 st prior. | 1 Forestry | ? | ? |
| 2 nd prior. | 15 Snow/ Ice | ? | ? |

| Priority | Issues | Is your country actively involved in modelling and monitoring the problem? If yes, how? | Annual Budget or Percentage of Environmental Budget Spent on This Issue. |
|------------|------------------|---|--|
| 3rd prior. | 4 Topographic | ? | ? |
| 4th prior. | 3 | ? | ? |
| 5th prior. | 12 | ? | ? |

Looking at the near, middle and long term future, what are the main objectives and strategies of your country in Earth Observation, and more specifically in environmental programs?

Consolidate Sweden's position as one of the leading suppliers of remote sensing information on the world market, and to continue to build a "remote sensing factory" in Kiruna. Sweden considers that the world's most complete and integrated production line for remote sensing data products is operated by SSC in Kiruna; SSC/Satellitbild for data processing and production of maps and other end products, and Esrange for reception of satellite data.

IV. UTILIZATION OF REMOTE SENSING DATA.

Does your country make use of remote sensing data? If yes, for which purpose?

No Yes : Research Application

- As for application, which ones?

Deforestation Land and Topographical Mapping
 Global Warming Vegetation Dynamics
 Pollution Desertification
 Other : forestry, snow/ice monitoring and meteorology

- As for research, which areas are of the concern?

Forestry and ozone depletion.

What kind of remote sensing data sets does your country use more often?
 (SPOT, LANDSAT, AVHRR, METEOSAT, MOS, IRS Soyuz-Karta, Aerial Photos...)

Spot, Landsat, Meteosat, Aerial photos.

Does your country have the capability to produce its own G.I.S. data?

If yes, which centers are involved in this?

No Yes : SSC

What kind of G.I.S. data are most often used?

| | |
|---|---|
| <input checked="" type="checkbox"/> Digital Elevation | <input checked="" type="checkbox"/> Land Use/Land Cover |
| <input type="checkbox"/> Roads | <input type="checkbox"/> Soils |
| <input type="checkbox"/> Hydrology | <input type="checkbox"/> Political Boundaries |
| <input type="checkbox"/> Geology | <input type="checkbox"/> Other : |

What is the status of development of the remote sensing value added industry?

Well Established Starting Non Existing

Does your country provide training courses in remote sensing?

Yes, provided by SSC.

VI. COMPLEMENTARY DATA FOR EARTH OBSERVATION.

Does your country have the capability to perform reference measurements (useful for the calibration of satellite sensors, or models validation) ?

in situ measurements
 Low altitude observation (inferior to 10000 ft.)
 High altitude observation

Concerning the measurement acquisition, does your country have just reference plots, subjectively located, or does it have a collection of plots selected through a rational sample design?

?

Is your country equipped with :

GPS (Global Positioning System)
 ARGOS

VII. FINANCIAL INVOLVEMENT.

What is the annual space budget (in U.S. \$) of your country?

Under the authority of the Swedish National Space Board:

1988/89 394 MSEK (60.6 M\$)

1989/90 419 MSEK (64.5 M\$)

assuming 1\$=6.5SEK

What percentage of the GNP does this represent? ?

What is the annual space budget for Earth Observation from space?

| | |
|----------------------------------|---------|
| National remote sensing program: | 12 MSEK |
| ESA Earth Observation Program : | 28 MSEK |
| Bilateral Programs (Spot etc.) : | 30 MSEK |
| | ----- |
| Total | 70 MSEK |

Does your country foresee an expansion of its involvement in remote sensing activities? In which directions?

Yes. An expansion of the remote sensing program is foreseen in order to maintain and develop the present knowledge and technical resources in Sweden, and to enable a fruitful Swedish participation in global environmental cooperations.

Does industry play a role in remote sensing activities in your country? Which one?

?
Satimage receive (Kiruna), analyse and market SPOT images.

*Give other financial indicators if any, such as revenues of the remote sensing images sold...
What is the total value (social, environmental, commercial) contributed by remote sensing to your country (e.g. in forest and soil resources saved through better management)? Use the best figures you can find and/or your best guess.*

?

VIII REMOTE SENSING CENTERS OF THE COUNTRY.

In the following table, list and characterize the main institutions of your country dealing with remote sensing data (analysis, processing, interpretation, correlation with other data, model development...).

| <i>Remote Sensing Institution</i> | <i>Status</i> | <i>Fields of Application</i> | <i>Origin of the Raw Data</i> | <i>Hardware Tools</i> | <i>Software Tools</i> | <i>Use of a GIS</i> | <i>Annual budget</i> |
|--|---------------|------------------------------|-------------------------------|-----------------------|-----------------------|---------------------|----------------------|
| Swedish Space Corp. Estrange / Kiruna | Commerc | | Landsat Spot Mos ERS | Ground stations | Data processing | Yes | as above |

VIII/ POTENTIAL IMPLEMENTATION OF L.P.E.O. IN THE COUNTRY.

Considering previous answers or more personal views, do you think that new data or information related to the deforestation phenomenon would be useful to the country?

No Yes Maybe

More precisely, would your country be interested in having access to high resolution radar data for deforestation monitoring (in a region 35°S to 35°N latitude, every ten days)? For which purpose?

No Yes Maybe : Because of the earlier mentioned involvement of SSC and SIDA in the Global deforestation Assessment project.

Does your country have sufficient land mapping at appropriate scales?

No Yes Maybe not

Would your country be interested in having access to space-based mapping data? (land and topographical mapping)

No Yes Probably

Which ground resolution?

larger than 20 m. 20 m.
 10 m. 5 m.
 smaller than 5 m. no idea.

Which accuracy in altitude?

larger than 20 m. 20 m.
 10 m. 5 m.
 smaller than 5 m. no idea.

What are the other areas in which the improvement of existing remote sensing raw or processed data could be useful for your country?

?

What spin-offs of I.P.E.O. could be envisioned for the country*? In particular those driven by a global change studies? (general welfare, public opinion satisfaction, technology transfer, education...)

?

Would your country be willing to commit itself in I.P.E.O.? If yes, how?

No Yes : via technical contribution

?

- by financial participation
- with *in situ* measurements
- in marketing
- other :

IXI MISCELLANEOUS.

Most countries have a reference book for remote sensing. Such documents exist also for groups of countries (for example, the Earsel Directory for Europe). Does such a reference book exist for your country? What is its name? Where can it be found?

?

LIST MATERIALS USED FOR THIS SURVEY.

"Remote sensing in Sweden in the mid-80's", SSC, 1982.

"Remote sensing - information from the Swedish Space Corporation", No 19, SSC, June 1990.

A variety of reprints of commercial material from SSC including reprints from various SSC biannual newsletter "Remote sensing".

LIST PEOPLE CONTACTED FOR THIS SURVEY AND GIVE THEIR REFERENCES.

None

Is there any material you are expecting? Any further research you would like to do? Any person you would contact later on?

?

Please join to this Country Note any synthetic document or copies that you find particularly relevant.

SWITZERLAND

II. INVOLVEMENT IN SPACE ACTIVITIES.

Does your country have a national remote sensing program? If yes, under whose authority?

No Yes :

Does your country possess Earth Observation satellite(s)? If yes, name the program(s).

No Yes :

Does your country design and/or build remote sensing payload(s)?
If yes, name the payload(s) and the prime manufacturer(s).

No Yes :

Does your country possess any capability to directly receive data from a spacecraft?
If yes, from which satellite(s)? Where are the receiving stations?

No Yes :

METEOSAT, EUMETSAT, INTELSAT, EUTELSAT, and meteorological satellites
Receiving Stations: Radio Swiss Ltd. at Colovrex, Geneva

III. INVOLVEMENT IN INTERNATIONAL ACTIVITIES.

Does your country take part in :

| | | | |
|--|---|--|--|
| <input type="checkbox"/> S.A.F.I.S.Y. | <input type="checkbox"/> U.N.E.P. | <input checked="" type="checkbox"/> I.C.S.U. | |
| <input checked="" type="checkbox"/> COSPAR | <input type="checkbox"/> A.R.T.E.M.I.S. | <input type="checkbox"/> Other : | |

Is your country involved in one of the core or working group projects of I.G.B.P. (International Geosphere Biosphere Program)?

No Yes :

Does your country participate in international Earth Observation programs (in particular environmental programs)?

If yes, describe the type of participation (technical exchange, financial investment, other...).

| | | |
|-----------------------------|---|---|
| <input type="checkbox"/> No | <input checked="" type="checkbox"/> Yes : | NOAA: Tech, financial |
| | | METEOSAT 1-5: Tech., exchange, financial |
| | | HCMM: Tech., financial |
| | | NIMBUS 7: Tech., construction, financial |
| | | LANDSAT 1-5: Financial |
| | | EUMETSAT: Financial |
| | | SPOT: Financial ERS: Financial |

Same question for bilateral Earth Observation programs.

No Yes : Sri Lanka/Swiss Remote Sensing Project
 Mali, Nigeria, Kenya, Sudan, Ethiopia, Algeria,
 Nepal, N.Yemen, Bolivia, India, Pakistan

III. SENSITIVITY TO ENVIRONMENTAL ISSUES.

Which of the following environmental issues (or common interests) are of importance to your country or to specific regions of your country?

Deforestation (1) ; Global Warming (2) ; Pollution (3) ; Land Resources (4) ; Vegetation Dynamics (5) ; Bio-mass Inventory (6) ; Water Quality (7) ; Soil Assessment (8) ; Urban Development (9) ; Ground Water (10) ; Acid Rain (11) ; Ozone Depletion (12) ; Crop Forecast (13) ; Insect Migration (14) ; Snow / Ice (15) ; Ocean Resources (16) ; Wildlife Monitoring (17) ; Flood (18) ; Desertification (19) ; Other... (be precise).

| Priority | Issues | Is your country actively involved in modelling and monitoring the problem? If yes, how? | Annual Budget or Percentage of Environmental Budget Spent on This Issue. |
|------------|--------|---|--|
| 1st prior. | 7 | yes | |
| 2nd prior. | 15 | yes | |
| 3rd prior. | 3 | yes | |
| 4th prior. | 11 | yes | |
| 5th prior. | 10 | yes | |

Looking at the near, middle and long term future, what are the main objectives and strategies of your country in Earth Observation, and more specifically in environmental programs?

Financial and Technical support of environmental and earth observation programs

IV. UTILIZATION OF REMOTE SENSING DATA.

Does your country make use of remote sensing data? If yes, for which purpose?

No Yes : Research Application

- As for application, which ones?

Deforestation Land and Topographical Mapping
 Global Warming Vegetation Dynamics
 Pollution Desertification
 Other : Meteorology, Glacier research.

- As for research, which areas are of the concern?

Ozone pollution, global warming, ceimatology, oceanology, snow and ice, forestry and vegetation

What kind of remote sensing data sets does your country use more often?

SPOT, LANDSAT, METEOSAT

Does your country have the capability to produce its own G.I.S. data?
If yes, which centers are involved in this?

No Yes :

What is the status of development of the remote sensing value added industry?

Well Established Starting Non Existing

Does your country provide training courses in remote sensing?

Yes

VI COMPLEMENTARY DATA FOR EARTH OBSERVATION.

Does your country have the capability to perform reference measurements (useful for the calibration of satellite sensors, or models validation) ?

in situ measurements
 Low altitude observation (inferior to 10000 ft.)
 High altitude observation

Concerning the measurement acquisition, does your country have just reference plots, subjectively located, or does it have a collection of plots selected through a rational sample design?

?

Is your country equipped with :

GPS (Global Positionning System)
 ARGOS

VII FINANCIAL INVOLVEMENT.

What is the annual space budget (in U.S. \$) of your country? \$40 Million

What percentage of the GNP does this represent? Less than 1%

What is the annual space budget for Earth Observation from space?

\$2 Million

Does your country foresee an expansion of its involvement in remote sensing activities? In which directions?

?

Does industry play a role in remote sensing activities in your country? Which one?

Yes, manufacturing and technology
CIR(Compagnie Industrielle Radioelectrique), remote central and telemetry systems, ground monitoring and reception systems

Give other financial indicators if any, such as revenues of the remote sensing images sold...
What is the total value (social, environmental, commercial) contributed by remote sensing to your country (e.g. in forest and soil resources saved through better management)? Use the best figures you can find and/or your best guess.

Example: APT, AVHRR : space sales in 1983 was 7 million CHF.

VII REMOTE SENSING CENTERS OF THE COUNTRY.

In the following table, list and characterize the main institutions of your country dealing with remote sensing data (analysis, processing, interpretation, correlation with other data, model development...).

| Remote Sensing Institution | Status | Fields of Application | Origin of the Raw Data | Hardware Tools | Software Tools | Use of a GIS | Annual budget |
|----------------------------|--------|-----------------------|------------------------|----------------|----------------|--------------|---------------|
| ? | ? | ? | ? | ? | ? | ? | ? |

VIII POTENTIAL IMPLEMENTATION OF L.P.E.O. IN THE COUNTRY.

Considering previous answers or more personal views, do you think that new data or information related to the deforestation phenomenon would be useful to the country?

No Yes Maybe

More precisely, would your country be interested in having access to high resolution radar data for deforestation monitoring (in a region 35°S to 35°N latitude, every ten days)? For which purpose?

No Yes Maybe :

Does your country have sufficient land mapping at appropriate scales?

No Yes Maybe not

Would your country be interested in having access to space-based mapping data? (land and topographical mapping)

No Yes Probably

Which ground resolution?

larger than 20 m. 20 m.
 10 m. 5 m.
 smaller than 5 m. no idea.

Which accuracy in altitude?

larger than 20 m. 20 m.
 10 m. 5 m.
 smaller than 5 m. no idea.

What are the other areas in which the improvement of existing remote sensing raw or processed data could be useful for your country?

?

What spin-offs of I.P.E.O. could be envisioned for the country*? In particular those driven by a global change studies? (general welfare, public opinion satisfaction, technology transfer, education...)

?

Would your country be willing to commit itself in I.P.E.O.? If yes, how?

No Yes :

- via technical contribution
- by financial participation
- with *in situ* measurements
- in marketing
- other :

IX/ MISCELLANEOUS.

Most countries have a reference book for remote sensing. Such documents exist also for groups of countries (for example, the Earsel Directory for Europe). Does such a reference book exist for your country? What is its name? Where can it be found?

Remote Sensing Systems Report and Outlook, BUNDESAMT FUR LANDESTOPOGRAPHIE, Seftign Str. 264, CH-3084 WABERN

LIST MATERIALS USED FOR THIS SURVEY.

- 1 Switzerland and Space (Report by the FSAAC)
2. Significance of Remote Sensing for Switzerland (Status Report and Outlook 1987/88)

3. The SiriLanka/Swiss Remote Sensing Project(DEH)
4. Unipress 62
5. Lecture Notes, Space Policy and Law 5.02 (Alain Dupas)

LIST PEOPLE CONTACTED FOR THIS SURVEY AND GIVE THEIR REFERENCES.

1. Professor K.O.Itten
University of Zurich, Geographisches Institute
Winterthurer Str. 190, CH-8057 Zurich
2. University of Bern, Institut fur Angenandte Physik
Sidler Str. 5, CH-3012 BERN
Contacts: Dr. Matzler, Dr. Kamfer

Is there any material you are expecting? Any further research you would like to do? Any person you would contact later on?

Please join to this Country Note any synthetic document or copies that you find particularly relevant.

SYRIA

II. INVOLVEMENT IN SPACE ACTIVITIES.

Does your country have a national remote sensing program? If yes, under whose authority?

No Yes : General Organization of Remote Sensing

Does your country possess Earth Observation satellite(s)? If yes, name the program(s).

No Yes :

Does your country design and/or build remote sensing payload(s)?
If yes, name the payload(s) and the prime manufacturer(s).

No Yes :

Does your country possess any capability to directly receive data from a spacecraft?
If yes, from which satellite(s)? Where are the receiving stations?

No Yes : Satellite / Receiving Stations

III. INVOLVEMENT IN INTERNATIONAL ACTIVITIES.

Does your country take part in :

| | |
|---|--|
| <input type="checkbox"/> S.A.F.I.S.Y. | <input checked="" type="checkbox"/> U.N.E.P. |
| <input type="checkbox"/> I.C.S.U. | <input checked="" type="checkbox"/> COSPAR) |
| <input type="checkbox"/> A.R.T.E.M.I.S. | <input type="checkbox"/> Other : |

Is your country involved in one of the core or working group projects of I.G.B.P. (International Geosphere Biosphere Program)?

No Yes :

Does your country participate in international Earth Observation programs (in particular environmental programs)?

If yes, describe the type of participation (technical exchange, financial investment, other...).

No Yes :

Same question for bilateral Earth Observation programs.

No Yes :

III. SENSITIVITY TO ENVIRONMENTAL ISSUES.

Which of the following environmental issues (or common interests) are of importance to your country or to specific regions of your country?

Deforestation (1) ; Global Warming (2) ; Pollution (3) ; Land Resources (4) ; Vegetation Dynamics (5) ; Bio-mass Inventory (6) ; Water Quality (7) ; Soil Assessment (8) ; Urban Development (9) ; Ground Water (10) ; Acid Rain (11) ; Ozone Depletion (12) ; Crop Forecast (13) ; Insect Migration (14) ; Snow / Ice (15) ; Ocean Resources (16) ; Wildlife Monitoring (17) ; Flood (18) ; Desertification (19) ; Other... (be precise).

| Priority | Issues | Is your country actively involved in modelling and monitoring the problem? If yes, how? | Annual Budget or Percentage of Environmental Budget Spent on This Issue. |
|------------------------|--------|---|--|
| 1 st prior. | 4 | By using remotely sensed data | \$ 6,000 |
| 2 nd prior. | 10 | | \$ 5,000 |
| 3 rd prior. | 8 | | \$ 10,000 |
| 4 th prior. | 7 | | \$ 3,000 |
| 5 th prior. | 15 | | \$ 2,000 |

Looking at the near, middle and long term future, what are the main objectives and strategies of your country in Earth Observation, and more specifically in environmental programs?

The objectives are in applications of remote sensing to hydrology, hydrogeology, geology, agriculture, pollution and deforestation.

VI. UTILIZATION OF REMOTE SENSING DATA.

Does your country make use of remote sensing data? If yes, for which purpose?

No Yes : Research Application

- As for application, which ones?

- Deforestation Land and Topographical Mapping
- Global Warming Vegetation Dynamics
- Pollution Desertification
- Other : Geology, hydrology and hydrogeology.

What kind of remote sensing data sets does your country use more often?

Aerial Photos, METEOSAT, LANDSAT, SPOT and AVHRR.

Does your country have the capability to produce its own G.I.S. data?
If yes, which centers are involved in this?

No Yes :

What is the status of development of the remote sensing value added industry?

Well Established Starting Non Existing

Does your country provide training courses in remote sensing? Yes.

VI. COMPLEMENTARY DATA FOR EARTH OBSERVATION.

Does your country have the capability to perform reference measurements (useful for the calibration of satellite sensors, or models validation) ?

- in situ* measurements
- Low altitude observation (inferior to 10000 ft.)
- High altitude observation

Concerning the measurement acquisition, does your country have just reference plots, subjectively located, or does it have a collection of plots selected through a rational sample design?

Yes.

Is your country equipped with :

- GPS (Global Positionning System)
- ARGOS

VII. FINANCIAL INVOLVEMENT

What is the annual space budget (in U.S. \$) of your country? \$ 10 M.

What percentage of the GNP does this represent? 6 %

What is the annual space budget for Earth Observation from space? \$ 3.5 M..

Does your country foresee an expansion of its involvement in remote sensing activities? In which directions?

Applications of remote sensing.

Does industry play a role in remote sensing activities in your country? Which one?

No.

*Give other financial indicators if any, such as revenues of the remote sensing images sold...
What is the total value (social, environmental, commercial) contributed by remote sensing to your country (e.g. in forest and soil resources saved through better management)? Use the best figures you can find and/or your best guess.*

Nil.

VII. REMOTE SENSING CENTERS OF THE COUNTRY.

In the following table, list and characterize the main institutions of your country dealing with remote sensing data (analysis, processing, interpretation, correlation with other data, model development...).

| <i>Remote Sensing Institution</i> | <i>Status</i> | <i>Fields of Application</i> | <i>Origin of the Raw Data</i> | <i>Hardware Tools</i> | <i>Software Tools</i> | <i>Use of a G.I.S</i> | <i>Annual budget</i> |
|--|-----------------|---------------------------------|---|-----------------------|-----------------------|-----------------------|----------------------|
| <i>General Organization of Remote Sensing Dr.Eng. Hussein Ibrahim P.O.Box 12586 Damascus Syria.</i> | <i>Govrnmnt</i> | <i>1, 3, 4, 7, 8,9,10,15,18</i> | <i>LANDSAT NOAA METEOSAT SPOT</i> | <i>P.C. IBM</i> | <i>MS-DOS</i> | <i>No</i> | <i>\$ 3.5 M</i> |

VIII. POTENTIAL IMPLEMENTATION OF I.P.E.O. IN THE COUNTRY.

Considering previous answers or more personal views, do you think that new data or information related to the deforestation phenomenon would be useful to the country?

No Yes Maybe

More precisely, would your country be interested in having access to high resolution radar data for deforestation monitoring (in a region 35°S to 35°N latitude, every ten days)? For which purpose?

No Yes Maybe :

Does your country have sufficient land mapping at appropriate scales?

No Yes Maybe not

Would your country be interested in having access to space-based mapping data? (land and topographical mapping)

No Yes Probably

Which ground resolution?

larger than 20 m. 20 m.
 10 m. 5 m.
 smaller than 5 m. no idea.

Which accuracy in altitude?

larger than 20 m. 20 m.
 10 m. 5 m.
 smaller than 5 m. no idea.

What are the other areas in which the improvement of existing remote sensing raw or processed data could be useful for your country?

In ground water and pollution.

What spin-offs of I.P.E.O. could be envisioned for the country? In particular those driven by a global change studies? (general welfare, public opinion satisfaction, technology transfer, education...)*

Public opinion satisfaction.
 Education.

Would your country be willing to commit itself in I.P.E.O.? If yes, how?

No Yes :

via technical contribution
 by financial participation
 with *in situ* measurements
 in marketing
 other :

IX/ MISCELLANEOUS.

Most countries have a reference book for remote sensing. Such documents exist also for groups of countries (for example, the Earsel Directory for Europe). Does such a reference book exist for your country? What is its name? Where can it be found?

It can be found by the UN reference book.

LIST MATERIALS USED FOR THIS SURVEY.

LIST PEOPLE CONTACTED FOR THIS SURVEY AND GIVE THEIR REFERENCES.

Is there any material you are expecting? Any further research you would like to do? Any person you would contact later on?

Please join to this Country Note any synthetic document or copies that you find

USSR

II INVOLVEMENT IN SPACE ACTIVITIES.

Does your country have a national remote sensing program? If yes, under whose authority?

- No Yes Priroda (=Nature) State Scientific Research Centre of the USSR Council of Ministers, Main Administration of Geodesy and Cartography. Glavkosmos, the Soviet civil space agency.

Does your country possess Earth Observation satellite(s)? If yes, name the program(s).

- No Yes Meteor Series
GOMS Geostationary Orbit Meteorological Sat.
Resurs series, Okean O, radar oceanographic Satellite, Prognoz
Radar Cosmos, Recoverable photographic reconnaissance sat.
Earth Observation from orbital stations, Radarsat, SoyuzKarta.

*Does your country design and/or build remote sensing payload(s)?
If yes, name the payload(s) and the prime manufacturer(s).*

- No Yes Future Priroda Module on Mir/Soyuz (1992)

*Does your country possess any capability to directly receive data from a spacecraft?
If yes, from which satellite(s)? Where are the receiving stations?*

- No Yes : Meteor Series, Okean O, Resurs O
Moscow, Novosibirsk. Khabarovsk.

Ground segment of Resurs O and Okean : Kiruna (Sweden), Great Britain.
Ability to communicate with almost any satellite in orbit using ground stations all over the territory of USSR and several ship-based stations.

III INVOLVEMENT IN INTERNATIONAL ACTIVITIES.

Does your country take part in :

- S.A.F.I.S.Y. U.N.E.P. I.C.S.U.
 COSPAR A.R.T.E.M.I.S. Other :
Interkosmos, Intersputnik.

Is your country involved in one of the core or working group projects of I.G.B.P. (International Geosphere Biosphere Program)?

No Yes :

Does your country participate in international Earth Observation programs (in particular environmental programs)?

If yes, describe the type of participation (technical exchange, financial investment, other...).

No Yes: Global Atmosphere Research Program (the world meteorology observation testing) with GOMS.

IASEL : International Automatic Space Ecological Laboratory.

Same question for bilateral Earth Observation programs.

No Yes: France, Belgium, Finland, China, Great Britain
Germany -> to launch joint instruments.
ESA : exchange of data.
Marconi : antenna systems.
USSR/USA mutual observation.

III. SENSITIVITY TO ENVIRONMENTAL ISSUES.

Which of the following environmental issues (or common interests) are of importance to your country or to specific regions of your country?

Deforestation (1) ; Global Warming (2) ; Pollution (3) ; Land Resources (4) ; Vegetation Dynamics (5) ; Bio-mass Inventory (6) ; Water Quality (7) ; Soil Assessment (8) ; Urban Development (9) ; Ground Water (10) ; Acid Rain (11) ; Ozone Depletion (12) ; Crop Forecast (13) ; Insect Migration (14) ; Snow / Ice (15) ; Ocean Resources (16) ; Wildlife Monitoring (17) ; Flood (18) ; Desertification (19) ; Other... (be precise).

| Priority | Issues | Is your country actively involved in modelling and monitoring the problem? If yes, how? | Annual Budget or Percentage of Environmental Budget Spent on This Issue. |
|------------------------|--------|---|--|
| 1 st prior. | 2 | Data storage and analysis, simulation of global processes and influence of particular items on long term and short term changes. Compiling data base from operational sat. and orbital stations, to monitor the above changes using the data obtained as baselines. | 10-15% of the annual civil budget for space science and application. |
| 2 nd prior. | 4 | | |
| 3 rd prior. | 12 | | |
| 4 th prior. | 8 | | |
| 5 th prior. | 1 | | |

Looking at the near, middle and long term future, what are the main objectives and strategies of your country in Earth Observation, and more specifically in environmental programs?

?

IV. UTILIZATION OF REMOTE SENSING DATA.

Does your country make use of remote sensing data? If yes, for which purpose?

No Yes : Research Application

- As for application, which ones?

| | | | |
|-------------------------------------|----------------|-------------------------------------|--------------------------------|
| <input checked="" type="checkbox"/> | Deforestation | <input checked="" type="checkbox"/> | Land and Topographical Mapping |
| <input checked="" type="checkbox"/> | Global Warming | <input checked="" type="checkbox"/> | Vegetation Dynamics |
| <input checked="" type="checkbox"/> | Pollution | <input checked="" type="checkbox"/> | Desertification |
| <input checked="" type="checkbox"/> | Other : | | |

- As for research, which areas are of the concern?

All above.

What kind of remote sensing data sets does your country use more often?

All Soviet remote sensing satellites, Aerial photos.

Does your country have the capability to produce its own G.I.S. data?
If yes, which centers are involved in this?

No Yes :

What kind of G.I.S. data are most often used?

| | | | |
|--------------------------|-------------------|--------------------------|----------------------|
| <input type="checkbox"/> | Digital Elevation | <input type="checkbox"/> | Land Use/Land Cover |
| <input type="checkbox"/> | Roads | <input type="checkbox"/> | Soils |
| <input type="checkbox"/> | Hydrology | <input type="checkbox"/> | Political Boundaries |
| <input type="checkbox"/> | Geology | <input type="checkbox"/> | Other : |

What is the status of development of the remote sensing value added industry?

Well Established Starting Non Existing ?

Does your country provide training courses in remote sensing?

Yes

VI. COMPLEMENTARY DATA FOR EARTH OBSERVATION.

Does your country have the capability to perform reference measurements (useful for the calibration of satellite sensors, or models validation) ?

- in situ* measurements
- Low altitude observation (inferior to 10000 ft.)
- High altitude observation

Concerning the measurement acquisition, does your country have just reference plots, subjectively located, or does it have a collection of plots selected through a rational sample design?

?

Is your country equipped with :

- GPS (Global Positioning System)
- ARGOS

Tsikada
Global Navigation Satellite System (GLONASS)

VII. FINANCIAL INVOLVEMENT.

What is the annual space budget (in U.S. \$) of your country? 13 Billion R.

What percentage of the GNP does this represent? ?

What is the annual space budget for Earth Observation from space? ?

Does your country foresee an expansion of its involvement in remote sensing activities? In which directions?

Certainly.

Does industry play a role in remote sensing activities in your country? Which one?

VNIEM (Moscow) : All-Union Science Research Institute of Electromechanics. (platforms)
Yuzhnoy (platforms)
Moscow Institute of Space Devices Engineering (payloads)
LOMO (Leningrad)
IKI (Moscow)

Development and manufacturing of satellites and hardware for observationnal programs ; creation and exploitation of the ground network and its permanent improvement.

Give other financial indicators if any, such as revenues of the remote sensing images sold...
What is the total value (social, environmental, commercial) contributed by remote sensing to your country (e.g. in forest and soil resources saved through better management)? Use the best figures you can find and/or your best guess.

Soyuz Karta : Soviet Trade associatiuon under the Ministry of Cartography and Geodesy. Sales revenue over June 1987 to October 1988 totalled some U.S. \$ 3 M. Large initial contract signed with Australia.

VII REMOTE SENSING CENTERS OF THE COUNTRY.

In the following table, list and characterize the main institutions of your country dealing with remote sensing data (analysis, processing, interpretation, correlation with other data, model development...).

| <i>Remote Sensing Institution</i> | <i>Status</i> | <i>Fields of Application</i> | <i>Origin of the Raw Data</i> | <i>Hardware Tools</i> | <i>Software Tools</i> | <i>Use of a GIS</i> | <i>Annual budget</i> |
|-----------------------------------|---------------|------------------------------|-------------------------------|-----------------------|-----------------------|---------------------|----------------------|
| Goskom-gedromet | hydro-meteo. | 8, 4, 13, 3... | Soviet data | | | | |
| SoyuzKarta | Comm. | All | Id | | | | |

VIII POTENTIAL IMPLEMENTATION OF I.P.E.O. IN THE COUNTRY.

Considering previous answers or more personal views, do you think that new data or information related to the deforestation phenomenon would be useful to the country?

No Yes Maybe

More precisely, would your country be interested in having access to high resolution radar data for deforestation monitoring (in a region 35°S to 35°N latitude, every ten days)? For which purpose?

No Yes Maybe :

Does your country have sufficient land mapping at appropriate scales?

No Yes Maybe not

Would your country be interested in having access to space-based mapping data? (land and topographical mapping)

No Yes Probably

Which ground resolution?

larger than 20 m. 20 m.
 10 m. 5 m.
 smaller than 5 m. no idea.

Which accuracy in altitude?

- larger than 20 m. 20 m.
- 10 m. 5 m.
- smaller than 5 m. no idea.

What are the other areas in which the improvement of existing remote sensing raw or processed data could be useful for your country?

Ecology, pollution, acid rains.

What spin-offs of I.P.E.O. could be envisioned for the country? In particular those driven by a global change studies? (general welfare, public opinion satisfaction, technology transfer, education...)

Would your country be willing to commit itself in I.P.E.O.? If yes, how?

- No Yes :
- via technical contribution
- by financial participation
- with *in situ* measurements
- in marketing
- other :

IXI MISCELLANEOUS.

Most countries have a reference book for remote sensing. Such documents exist also for groups of countries (for example, the Earsel Directory for Europe). Does such a reference book exist for your country? What is its name? Where can it be found?

?

LIST MATERIALS USED FOR THIS SURVEY.

LIST PEOPLE CONTACTED FOR THIS SURVEY AND GIVE THEIR REFERENCES.

Dunayen, Glavkosmos.

Is there any material you are expecting? Any further research you would like to do? Any person you would contact later on?

Please join to this Country Note any synthetic document or copies that you find particularly relevant.

USA

II INVOLVEMENT IN SPACE ACTIVITIES.

Does your country have a national remote sensing program? If yes, under whose authority?

No Yes NASA, NOAA, EOSAT, DOD, DOC, DOT, DOL

Does your country possess Earth Observation satellite(s)? If yes, name the program(s).

No Yes LANDSAT Series (Eosat)
NOAA/GOES Tiros, TOS, ESSA, ITOS, SMS
SEASAT
EOS

Does your country design and/or build remote sensing payload(s)?
If yes, name the payload(s) and the prime manufacturer(s).

No Yes NASA, NOAA, Hughes, TRW, Ford Aerospace,
Boeing, United Technology General Electric.
Landsat 6 : GE prime, Hughes (sensors)
UARS Upper Atmosphere Research Satellite

Does your country possess any capability to directly receive data from a spacecraft?
If yes, from which satellite(s)? Where are the receiving stations?

No Yes : NOAA/Alaska, California, Maryland.
LANDSAT/Id.

LANDSAT ground receiving stations : Canada, Brazil, Italy, Spain,
Sweden, Japan, Thailand, India, Australia, Argentina, Chile, Zaire, Iran,
China, South Africa, New Zealand, Ecuador, Pakistan, Indonesia, Saudi
Arabia.

GOES ground receiving stations : Switzerland, Maryland, California,
Wallops Island

III INVOLVEMENT IN INTERNATIONAL ACTIVITIES.

Does your country take part in :

S.A.F.I.S.Y. U.N.E.P. I.C.S.U.
 COSPAR A.R.T.E.M.I.S. Other : ?

Is your country involved in one of the core or working group projects of I.G.B.P. (International Geosphere Biosphere Program)?

No Yes :

Does your country participate in international Earth Observation programs (in particular environmental programs)?

If yes, describe the type of participation (technical exchange, financial investment, other...).

No Yes : Sarsat-Cospas, Earthnet, WCRP, IOC

Same question for bilateral Earth Observation programs.

No Yes : TOPEX/POSEIDON with CNES (Fr)
Radarsat (Canada)
J-GEMS (NASDA)

III SENSITIVITY TO ENVIRONMENTAL ISSUES.

Which of the following environmental issues (or common interests) are of importance to your country or to specific regions of your country?

Deforestation (1) ; Global Warming (2) ; Pollution (3) ; Land Resources (4) ; Vegetation Dynamics (5) ; Bio-mass Inventory (6) ; Water Quality (7) ; Soil Assessment (8) ; Urban Development (9) ; Ground Water (10) ; Acid Rain (11) ; Ozone Depletion (12) ; Crop Forecast (13) ; Insect Migration (14) ; Snow / Ice (15) ; Ocean Resources (16) ; Wildlife Monitoring (17) ; Flood (18) ; Desertification (19) ; Other... (be precise).

| Priority | Issues | Is your country actively involved in modelling and monitoring the problem? If yes, how? | Annual Budget or Percentage of Environmental Budget Spent on This Issue. |
|------------------------|--------|---|--|
| 1 st prior. | 2 | yes, EOS | 1 Billion\$(?) |
| 2 nd prior. | 3 | EPA, USGS, NASA | ? |
| 3 rd prior. | 6 | EPA | |
| 4 th prior. | 5 | NASA | |
| 5 th prior. | 10 | NSF, USGS | |

Looking at the near, middle and long term future, what are the main objectives and strategies of your country in Earth Observation, and more specifically in environmental programs?

Meteorological satellites (applications and modeling)
Mission to planet Earth (EOS)

IV. UTILIZATION OF REMOTE SENSING DATA.

Rational Design

Is your country equipped with :

- GPS (Global Positioning System)
- ARGOS

VII FINANCIAL INVOLVEMENT

What is the annual space budget (in U.S. \$) of your country?

1986 USD 21.2 billions, 34.3% NASA, 63.3% DoD

What percentage of the GNP does this represent?

Less than 1%.

What is the annual space budget for Earth Observation from space?

1987 USD 321 M.

Does your country foresee an expansion of its involvement in remote sensing activities? In which directions?

Yes-EOS

Does industry play a role in remote sensing activities in your country? Which one?

Yes, processing, distribution, satellite production, modelling.

Give other financial indicators if any, such as revenues of the remote sensing images sold...
 What is the total value (social, environmental, commercial) contributed by remote sensing to your country (e.g. in forest and soil resources saved through better management)? Use the best figures you can find and/or your best guess.

Value is actually quite high, but not well understood by the public. It saves money on food prices, helps us monitor our weather, watch soil erosion, manage our land, makes our maps, acts as an industry, indexes foliage and animals, and much more.

VIII REMOTE SENSING CENTERS OF THE COUNTRY

In the following table, list and characterize the main institutions of your country dealing with remote sensing data (analysis, processing, interpretation, correlation with other data, model development...).

| Remote Sensing | Status | Fields of | Origin of the | Hardware Tools | Software Tools | Use of a | Annual budget |
|----------------|--------|-----------|---------------|----------------|----------------|----------|---------------|
|----------------|--------|-----------|---------------|----------------|----------------|----------|---------------|

| <i>Institution</i> | | <i>Application</i> | <i>Raw Data</i> | | | <i>GJS</i> | |
|-----------------------------------|---------|------------------------|--|------------------|----------------|------------|-------|
| EOSAT | COMM. | 4, 5, 8, 9 | LANDSAT | VAX,IBM | GRASS, GADS | X | 10 M. |
| NASA | GOVERN. | 1-18 | VARIOUS | VAX, IBM CRAY | " | X | 14 B |
| EPA | GOV. | 1-10 | VARIOUS SATS. | " | " | X | 12M |
| DOI | GOV. | 1-18 | " | " | " | X | 7M |
| NOAA | GOV. | 1, 3, 7, 10, 11, 12 | " | " | " | X | 30M |
| Alden Internat. Inc. (Mass) | | Meteo. | GOES Meteosat GMS NOAA Meteor TIROS | | | | |
| Centritrade Services N.Y. | Comm. | | Soviet remote sensing satellites | | | | |

VIII. POTENTIAL IMPLEMENTATION OF I.P.E.O. IN THE COUNTRY.

Considering previous answers or more personal views, do you think that new data or information related to the deforestation phenomenon would be useful to the country?

No Yes Maybe

More precisely, would your country be interested in having access to high resolution radar data for deforestation monitoring (in a region 35°S to 35°N latitude, every ten days)? For which purpose?

No Yes Maybe

Monitor industrial deforestation.

Does your country have sufficient land mapping at appropriate scales?

No Yes Maybe not

Would your country be interested in having access to space-based mapping data? (land and topographical mapping)

No Yes Probably

Which ground resolution?

larger than 20 m. 20 m.
 10 m. 5 m.
 smaller than 5 m. no idea.

Which accuracy in altitude?

larger than 20 m. 20 m.
 10 m. 5 m.
 smaller than 5 m. no idea.

What are the other areas in which the improvement of existing remote sensing raw or processed data could be useful for your country?

Pollution Control, Land Management, Wildlife Preservation, Urban Planning, Water Monitoring, Earth Systems Sciences.

What spin-offs of I.P.E.O. could be envisioned for the country? In particular those driven by a global change studies? (general welfare, public opinion satisfaction, technology transfer, education...)

Education, Environmental Improvement and Planning, Better Access to such data, better application, better instruments, better international relations, better economy, public awareness of remote sensing and its importance.

Would your country be willing to commit itself in I.P.E.O.? If yes, how?

No Yes : via technical contribution
 by financial participation
 with *in situ* measurements
 in marketing
 other : Customer

IXL MISCELLANEOUS.

Most countries have a reference book for remote sensing. Such documents exist also for groups of countries (for example, the Earsel Directory for Europe). Does such a reference book exist for your country? What is its name? Where can it be found?

Landsat Users Guide
NASA Remote Sensing Directory.

LIST MATERIALS USED FOR THIS SURVEY.

Aerospace Facts and Figures, A.A.A.S. Report 14, EOS Reference Book, The Illustrated Encyclopedia of Space Technology, Earth System Science; A Program Guide, International Cooperation and Competition in civilian Space Activities, State of the World Report 1988-90, Time Magazine, Space-Based Remote Sensing of the Earth: A Report to the Congress

LIST PEOPLE CONTACTED FOR THIS SURVEY AND GIVE THEIR REFERENCES.

Paul Maugham, Francois Becker, Vern Singhroy. (ISU'90 Faculty)

Is there any material you are expecting? Any further research you would like to do? Any person you would contact later on?

Please join to this Country Note any synthetic document or copies that you find particularly relevant.



APPENDIX B ORGANIZATIONAL CASE STUDIES

B.1 Introduction

Developing an effective, global Earth remote sensing effort will require the full cooperation of all national, regional and international organizations that collect, process, distribute and use remote sensing data. The International Program for Earth Observations is one of many organizations helping to fulfill remote sensing needs, and to coordinate our efforts with other organizations, a listing of those organizations, their missions, future plans, what organizations they work with or within and how we can work with them is provided below. A textual and graphic comparison by organization of the operational capabilities and international disposition of the IPEO and other Earth remote sensing bodies are provided to facilitate understanding of what services the IPEO might render to these organizations and what they might do for the IPEO and its users. Text and comparison of this kind is instrumental in short and long-term planning for the IPEO, other remote sensing organizations, the International Council of Scientific Unions and global remote sensing users.

B.2 Examples of International Earth Observation Programs

"EARTHNET operations within the framework of the European Space Agency's Earth Observation Program started in 1977. The main role of the EARTHNET program over the past decade has been the acquisition, pre-processing, archiving and distribution of data from the major U.S. remote-sensing satellite missions". EOP/EARTHNET uses data about mapping, climate, land-mass, oceanic and atmospheric for scientific understanding of these biospheric phenomenon. EOP/EARTHNET also purchases remote sensing data from SPOT Image and EOSAT to complement the data from U.S. platforms.

EOP/EARTHNET is primarily for use by European Space Agency nations to develop the remote-sensing capabilities of its members. EOP/EARTHNET will have more of its own remote sensing capability before the next century and will co-operate as a great part of the upcoming global remote-sensing effort beginning in 1992.

The IPEO could provide the EOP/EARTHNET with deforestation information in their countries and areas of particular interest, i.e. Guiana and allow them use of their ground stations. They may also purchase EOSAT and SPOT data from IPEO, use our processed and modelled data, and our GEOD user information and education network.

The proposed U.S. Earth Observing System is a national, comprehensive remote sensing program meeting earth system science needs for the N.A.S.A., other U.S. research agencies and relevant international organizations. This effort is coordinated by the U.S. Global Change Research Program, which would also coordinate with the International Geosphere-Biosphere Program in the coming global remote sensing effort. EOS will gather data on, and monitor the atmosphere, climate, oceans, wildlife, fauna, landmass, pollution and solar influences to name a few.

The Earth Observing System will produce satellites, acquire, process, model, store and distribute multi-disciplinary and single study data to international and national organizations and other users and applications under an "open information" policy. The three components of EOS are its scientific research program, data and information system and the EOS space measurement system, the balance of the mission being scientific. The EOS spacecraft will both be very large and EOS will fly the largest number of instruments in the overall global effort.

The IPEO could add its deforestation/radar data to the EOS effort, assist in data processing and ground support efforts. Likewise, IPEO could use EOS data and distribute it to its users raw or modelled. EOS might also profit from the use of the IPEO GEOD system and its user/educational network.

METEOSAT is Europe's contribution to the World Meteorological Organization. In 1983 METEOSAT was absorbed into the broader European Meteorological Satellite Program (EUMETSAT), where it still serves the WMO's Global Atmospheric Research Program. The purpose of METEOSAT is the collection, processing and dissemination of meteorological data by means of a geostationary satellite and associated ground stations including ground and sea-based sensors.

The METEOSAT program may be discontinued in 1995 pending further discussion. I.P.E.O. might use data from METEOSAT and both may use the others' ground stations. Even if METEOSAT is shut-down when IPEO becomes operative, we can still use their archived data. Currently, the argument is moving toward expansion of the METEOSAT system to include more science, and if other organizations do the same, IPEO may have a very small niche in the future. In any case they would use the IPEO's GEOD system for its new or former users.

Intercosmos is a program of comprehensive cooperation among socialist countries for the peaceful exploration and use of space. One of the five areas studied by this regional body is remote sensing of the Earth's atmosphere, climate, oceans and landmass. Remote sensing is carried out by ten socialist nations who decide on their participation in the program by vote.

Intercosmos has yielded valuable scientific results, and expansion of the manned and unmanned platforms is expected. Soviet participation in the global remote sensing and monitoring effort is under discussion and this may be the body that contributes data to it. Unfortunately, there is not enough information available to know its history and structure for interaction analysis.

Japan has launched successively larger and more sophisticated remote sensing platforms over the past two decades. In addition to its GEMS satellite, it plans to launch the Earth Resources Satellite (ERS-1) in 1991 and make its information and other satellites already in orbit available to the I.C.S.U. effort to complete the currently committed satellite triad. The Japanese satellite program reflects the same kind of national program seen in the U.S. EOS program and we would cooperate in much the same way as we did with EOS.

B.3 The United Nations

The United Nations agency which is responsible for environmental observations is the United Nations Environmental Program (U.N.E.P). U.N.E.P. has its headquarters in Nairobi, Kenya and is actively involved in environmental information. This includes the use of remote sensing as a tool to collect data on environmental variables. The system in which the data is collected is the Global Environmental Monitoring System (GEMS). Within GEMS there is the Global Resource Information Database (GRID) which is a network designed to provide useful information to users.

GEMS is actually an effort of the member states, UNEP, FAO, WHO, WMO and other UN agencies to ensure that data on environmental variables are collected and distributed in an orderly and adequate manner. GRID provides a mechanism for viewing environmental problems holistically.

GRID's harmonization of environmental data was initially started as a two year pilot phase in 1985 by UNEP to improve access to environmental data. The main tasks of the pilot phase were : data collection, GIS support, data supply and technology transfer.

B.4 The International Geosphere-Biosphere Program

B.4.1 Introduction

This report is to present the International Geosphere-Biosphere Program (IGBP) and the relations it could have with International Program for Earth Observation (IPEO). Special attention is paid to IGBP goals and activities which may present some degree of redundancy with planned IPEO objectives.

B.4.2 IGBP Presentation

IGBP is a program of the International Council of Scientific Union (ICSU) whose goal is "to describe and understand physical, chemical and biological processes that regulate the total earth system, the change that are occurring in this system and the influence of human action". IGBP is therefore an international research program, dealing with global change problems and addressing part of the IPEO long term goals.

B.4.3 IGBP Requirements

In order to achieve the IGBP goals, Pilot studies for Remote Sensing and Data Management have been proposed in four different areas.

B.4.3.1 Land Cover Change Pilot Study

This study is to analyze climate and land characteristics of specific geographical sites around the world, using Advanced Very High Resolution Radiometer (AVHRR) of

NOAA, and in situ and aerial measurements. Some samples of high accuracy SPOT or LANDSAT images are foreseen to be used for calibration purpose. One international team will be assigned for each site and for a given number of years. Use of existing IGBP observatories is recommended for site selection.

B.4.3.2 Vegetation Imagery Diskette Pilot Project

This project is to develop and disseminate a floppy diskette condensed data base that could be used for reading and manipulation on a PC. The primary objective is to set up workshops for training research groups in under-developed countries in using remote sensing data for conducting local research projects. This project is conducted in cooperation with United Nation Environmental Program (UNEP).

B.4.3.3 Algorithm Validation Pilot Study

This is a research study devoted to algorithm validation which content is beyond the scope of this report.

B.4.3.4 Global Change Data Directory (GEDD)

This project is to develop a universal Global Change Data inventory in which researchers could find general information on available data sets, accessibility conditions, data set location and content.

B.4.3.5 IGBP Needs

IGBP needs are the following :

1. In Situ and Aerial measurements
2. Satellite images (AVHRR, SPOT, LANDSAT)
3. Geographic Information System (GIS)

The IGBP proposition is to use existing UNEP/GRID system to provide

1. Data archiving facility
2. Data as available
3. GIS analysis facility
4. Output dissemination
5. International context of United Nations.

IGBP will provide :

1. Research on Global Change on subjects found of interest by ICSU.

2. Condensed Remote sensing data base on PC diskettes for training purpose.
3. Global Environment Data Directory for research community.

B.4.3.6 First Set of Conclusions

1. IGBP program is concerned with research on Global change problems. It involves international staff from the different national scientific agencies. This expertise shall be associated to the Advanced programs division of IPEO.
2. IGBP program is concerned with training of researchers in using remote sensing data. For this, a specific condensed data base will be developed and disseminated around the world. This activity shall be associated with the Training/User education division of IPEO.
3. IGBP program is concerned with the development of a Global Environment Data Directory. IGBP recommendations and expertise shall be associated with the IPEO operational division, to design the IPEO global directory which shall have a larger scope, involving for example research expertise distribution and commercial entities. However, at this stage, a complete cooperation agreement is required since IPEO and IGBP goals in this field appear as redundant. Given the importance of such a project with respect to IPEO objectives, the IGBP conclusions and recommendations on GEDD are presented hereafter.

B.4.4 Data and Information System for IGBP

B.4.4.1 IGBP Conclusions and Recommendations

Directories for environment data exist both at national and international levels. One can list the major ones, first at the international level,

- World Meteorological Organization (WMO) 's INFOCLIMA
- United Nations (UN) 's INFOTERRA
- International Oceanographic Commission (IOC) ' s MEDI (Marine Environmental Data Information) and at the national level,
- US NOAA's NEDRES (National Environmental Data Referral System)
- US NASA's MD (Master Directory)

A specific working group inside IGBP is asked to consider the need for a Global Environmental Data Directory (GEDD) as part of the IGBP Data and Information System (DIS). This request was motivated by the following statements:

- Lack of comprehensive inventory of major existing data banks
- Lack of information on accuracy and quality of existing data
- No consistent international policy and protocol for data exchange
- No long term commitment
- Lack of trained people to use such data bases.

According to IGBP/DIS working group, the GEDD should present at least the following features :

- Name of data set
- Unique identification
- Description
- Geographic location, time period, parameters
- Main investigator, related publications, who can provide the data
- Conditions of availability
- Date of updating

GEDD shall not actually archive the data but serve as a directory for research use. Two solutions were considered by IGBP/DIS group. A first solution was to develop a Personal Computer Data Base Management software which copies would be distributed to potential users. This solution was not retained. Instead, IGBP baseline relies upon existing directories, mainly INFOTERRA, INFOCLIMA, MEDI, NEDRES, using NASA Master Directory (MD) for global IGBP directory installed on UNEP/GRID computer in Geneva. As a first step towards coordination of these different directories, use of NASA Directory Interchange Format (DIF) is proposed to facilitate exchange of directory information. INFOCLIMA staff, co-located at UNEP/GRID facility is proposed for loading and maintaining the GEDD descriptions. It should be noted that NASA MD has been recently installed on ESA computers as well as on NOAA computers and is therefore a good candidate for easy standardization.

According to this GEDD baseline, relying on existing capabilities, the IGBP/DIS function will be mainly support and coordination and more specifically

- Facilitate use by encouraging development of standards and protocol for data exchange
- Locate data sets useful for IGBP
- Start pilot studies using such data sets (see part 4)
- Training of users at international level (see part 4)
- Implement and maintain GEDD
- Provide service to IGBP core research project

B.4.5 IPEO Involvement

IGBP/DIS working group objectives, mainly the development of the GEDD, is clearly in full redundancy with Data Base/ Reference Information Department of IPEO Operational Programs division. If research and training objectives of IGBP could be simply associated with IPEO activities, IGBP/DIS program should be more integrated into IPEO effort to develop a referral directory. With some slight modifications (include research entities, programs or commercial entities dealing with environmental problems or data into GEDD), IGBP/DIS could be considered as a part of IPEO program, taking benefit of the international, non-profit organization, highly skilled staff and expertise of IGBP. Most of all, conflicts or difficulties in reaching agreement between IPEO and IGBP should be marginal, considering the consistency of IPEO long term goals and affiliation with IGBP goals.

B.4.6 Annex

The GEDD baseline relies upon existing data directories. This annex provides a short description of those directories which may be of interest for IPEO. Special attention is paid to the compatibilities and international affiliations.

B.4.6.1 GRID (Global Resource Information Database)

GRID is part of GEMS (Global Environmental Monitoring System) which is part of the UNEP program of UN. GRID inputs are maps, satellite images, aerial photographs. GRID is based on use of Geographic Information System (GIS), image processing techniques, training in GIS technology and application and provide information and data.

B.4.6.2 NOAA NESDIS (National Environmental Satellite Data and Information Service) and NEDRES

NEDRES is an on line system which provides climate, satellite, geophysical and environment data access through a telecommunication network on an international basis. NEDRES fields include all the fields required by IGBP and include both US and global data sets. NEDRES can be run on a PC or mini-computer. NESDIS provides environmental data and information products and services and includes the following which should be associated with IPEO :

1. Satellite operation
2. Satellite data processing and distribution
3. Office of research and application
4. National Geophysical Data Center

B.4.6.3 NASA Master Directory (MD)

The NASA Master Directory goal is to develop a system of directories which serve the global change and space science community.

B.4.6.4 MEDI (Maritime Environmental Data Information)

MEDI was developed and designed by International Oceanographic Commission (IOC) on the World Health Organization (WHO) computer facility in Geneva. It provides recording and retrieving of information about marine environmental data files existing in international and national centers through an international communication network. It provides information on which data is available worldwide on a given subject. There is a MEDI center in each of the organizational participants (including UNEP participants).

B.4.6.5 INFOTERRA

INFOTERRA is a database developed and designed by UNEP and operated by the World Health Organization (WHO) in Geneva. It is compatible with MEDI and INFOCLIMA. User access is performed through National Focal Points (NFP) via common communication links. NFP acts as a search service support.

B.4.6.6 INFOCLIMA

INFOCLIMA provides a description of climatic data centers and data sets. For example, NOAA, NEDRES or NESDIS programs input to INFOCLIMA for US.

B.5 U.S. Global Change Research Program

The United States Global Change Research Program (GCRP) is a national effort to coordinate its government agencies involved with understanding the Earth as a system by integrating their work in a unified framework at a high level of the administration (see chart B.5.1) It is directly controlled by the Committee on Earth Science of the Office of Science and Technology Policy of the White House, which is in turn advised by the Federal Coordinating Committee on Science, Engineering, and Technology (FCCSET). FCCSET is at the very highest levels of the government, and the GCRP enjoys an unprecedented support down to the lowest levels of the administration. The Earth Observing System (EOS) (see 4.1.3) is the fundamental cornerstone of the program and its largest budget

item, but the program is more extensive than NASA's EOS. The goal of the GCRP "is to gain a predictive understanding of the interactive physical, geological, chemical, biological, and social processes that regulate the total Earth system and, hence, establish the scientific basis for national and international policy formulation and decisions relating to natural and human-induced changes in the global environment and their regional impacts." It would seem from this impressive goal that the U.S. GCRP is similar to, and even more extensive than IPEO in that it seeks to understand the entire Earth as a system, whereas IPEO is simply studying specific global environmental problems which will aid in the understanding of Earth as a system. In fact, there are a number of similarities and potential synergies between IPEO and GCRP as demonstrated in Figure 4.1.3 - 2 and in Figure B.5 - 1. However, it has also been demonstrated that GCRP's EOS, like the other organizations analyzed, is insufficient to solve the global problems that face the nations of the world.

The Environmental Universe for the U.S.

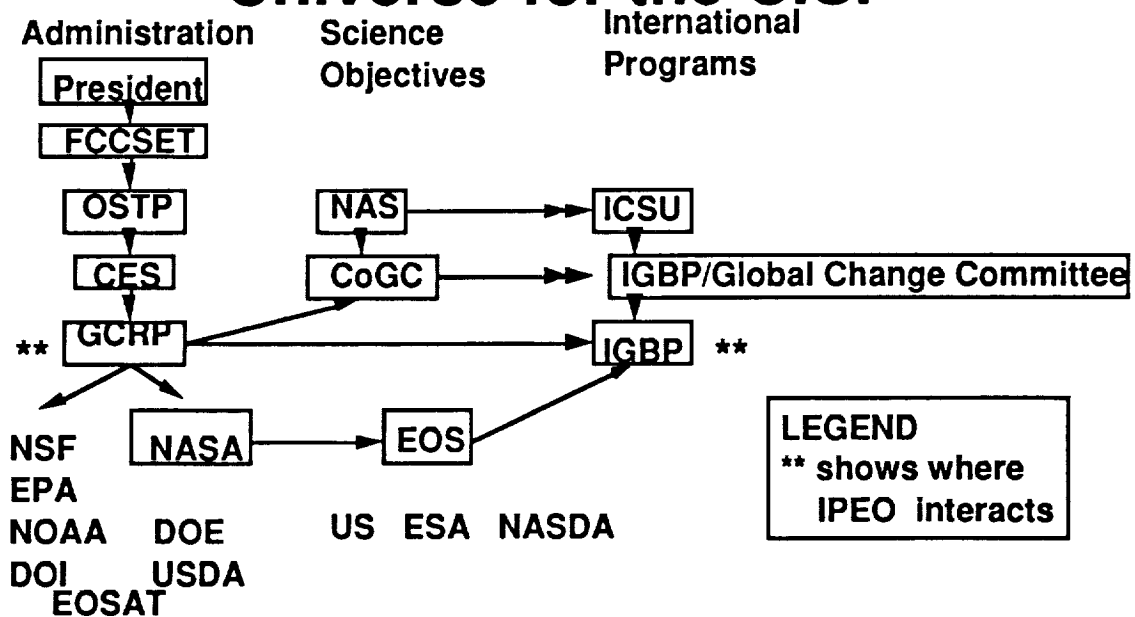


Figure B.5 - 1 The Environmental Universe for the United States

B.6 Remote Sensing In The USSR

The Soviet environmental program is very decentralized. There are four organizations at the State Committee level that deal with remote sensing and environmental

issues. Goskompriroda, the State Committee for the Protection of Nature, was created in 1988 to be the lead agency concerned with the protection of the environment and the utilization of natural resources. Goskompriroda performs a regulatory function similar to the U.S. Environmental Protection Agency, and may receive satellite information through its own receiving station. GUGK, the Main Administration of Geodesy and Cartography, has a position within the political hierarchy below that of state committee. It seems to be charged with coordinating and allocating some funds for remote sensing and satellite mapping. It has a commercial branch, Soyuzkarta, that markets cartographic information generated by GUGK. Goskomgidromet, the State Committee for Hydrometeorology, has been in existence since 1954 and charged with monitoring and reporting on the meteorological condition of the USSR. The State Committee for Public Education controls a number of advanced institutes that are connected with Earth observations. The Leningrad Hydrometeorology Institute researches hydrology, meteorology, and oceanography, and is, therefore, a prime candidate for interaction with IPEO. At the ministerial level of the Soviet government, the AN SSSR, or USSR Academy of Sciences, is a key player in the remote sensing world through its numerous research institutes. Interkosmos, for example, has the authority to sign agreements with foreign organizations and coordinates the Academies space science activities with all other nations. The Vernadsky Institute of Geochemistry and Analytical Chemistry may also be involved in environmental research and is an important facet of the Soviet space program. The Geography Institute of the Academy places its major emphasis on Earth observations and global change, and must be included in any attempt to include the USSR in an international program for Earth observations. Finally, the Institute of Lake Research performs biosphere analysis and ecological monitoring and must, therefore also be included in IPEO. Goskomgidromet is a prime area of integration for IPEO, as is Goskompriroda, GUGK, and the ANSSR. It is very clear that the USSR has a great deal to offer IPEO and the global community, if its assets can be tapped. This organizational structure can be seen in Figure B.6-1.

B.7 Remote Sensing in Thailand

As has been stated in section 3.3, the Thai government has been dedicated to the use of remote sensing for Earth observations since it became involved with the U.S. Landsat program. Thailand's National Remote Sensing Program is situated within the Thai National Research Council (NRC) of the Ministry of Science, Technology, and Energy. The NRC's Remote Sensing Division is over one half of the entire NRC budget, and is overseen by the National Remote Sensing Coordinating Committee of the Cabinet which is made up of all the user agencies of remote sensing data in the Thai government. These user agencies have the experience base to support the growing use and analysis of Earth observation data, but they have been hampered by the lack of analysis equipment and slow turnaround time of data. The structure of these organizational relationships, which

The Environmental Universe for the USSR

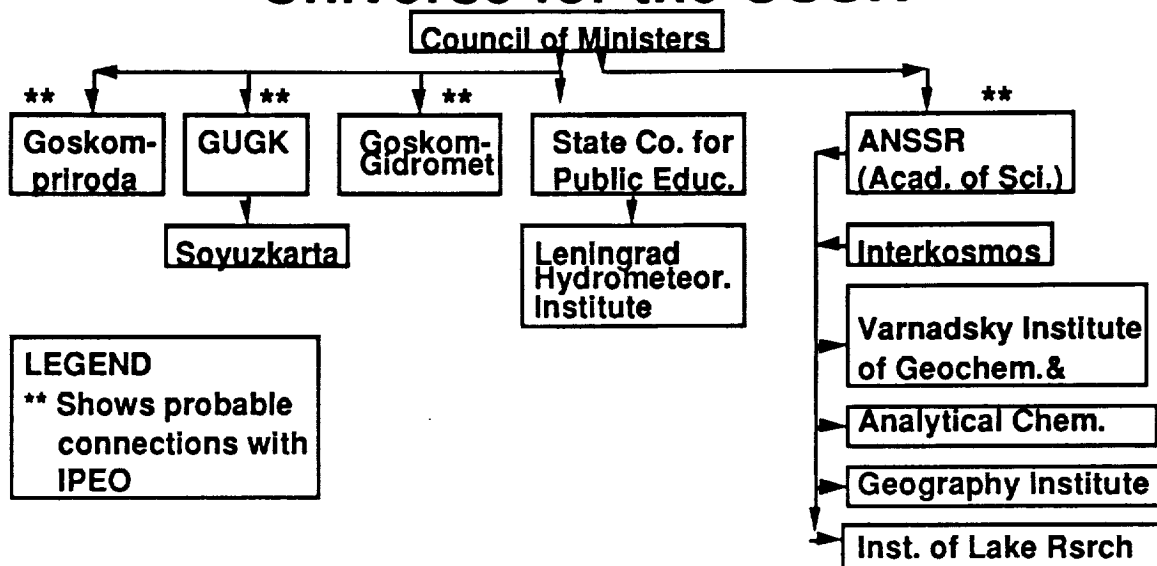


Figure B.6 - 1 The Environmental Universe for the USSR

has itself hampered the utilization of data for environmental problem solving by dissociating the technology from the users, is shown in chart B.7 - 1

The Environmental Universe of Thailand

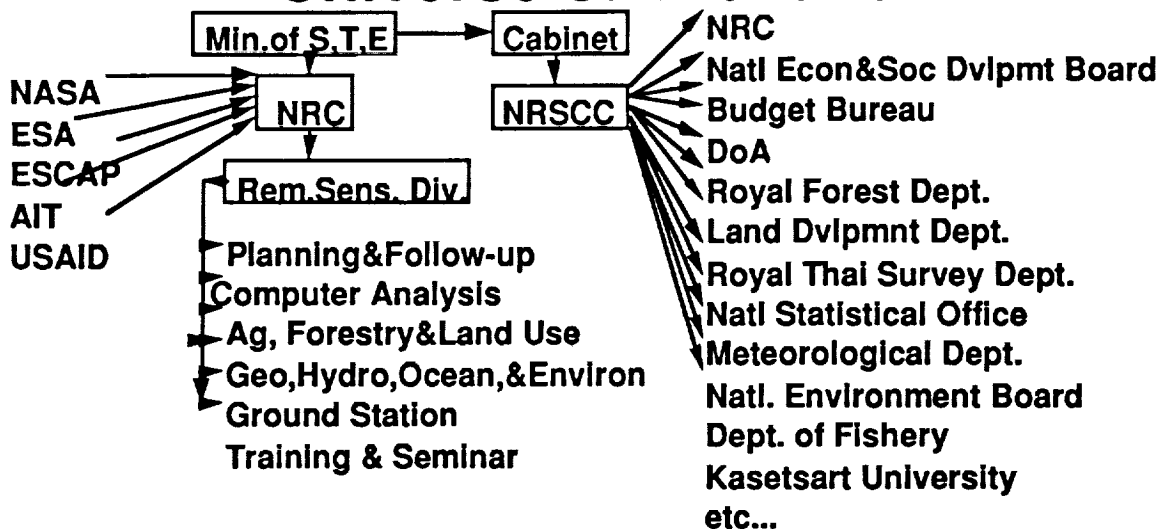


Figure B.7 - 1 The Environmental Universe of Thailand

APPENDIX C COMPUTER ANIMATION FOR THE IPEO PROJECT

C.1 Introduction

A computer animation of the IPEO project has been created through the graphics capability of the Apple Macintosh II & Iic. Software such as ©Super 3D enabled the generation of images and their subsequent animation to portray the operation and objectives of the IPEO program.

The management, storyline, cartoon sequencing, image production and motion are described below. These tools are used to show both the space and ground segments of the project. The space segment animation is dominated by scenes from the launch, deployment orbit and operation in orbit of two satellites. One based upon radar imaging dedicated for deforestation detection (See chapter 7.0) and another based upon an optical sensor for land mapping requirements (See chapter 8.0). Another satellite, a data relay satellite is shown (not part of the design project) relaying the raw and value added data to a regional user ground station. The ground segment animation is dominated by ground station views receiving the raw data. This data is then shown being processed and returned as a value added view typical of the output from a GIS scene (See Appendix D). Emphasis is then placed upon the data user.

Four Apple Macintosh computers and 20 animation scenes were generated for the 10 minute movie. The separate animation scenes were combined with a video camera and subsequent editing. Synchronization of the camera and the computer monitor was accomplished with film editing and a synchronization interface card.

The work was performed over a three week period by four ISU students: Andrey Salnikov, Chief Animator; Yoshihide Kita, Animator; Ed Kruzins, Director; and Max Nelson, Assistant Director and Study Committee Liaison. Some 200 man hours of effort was required for the 10 minute movie.

C.2 Task Outline

The movie (animation) program was divided into five parts. These were:

1. Generation of a story line. (Max and Ed)
2. Sequencing and view selection. (Ed, Max and Andrey)
3. Image production. (Andrey and Yoshi)
4. Integration and motion.(Andrey)
5. Filming and editing (Jessie May Rowntree and York University)

C.3 Storyline

A movie tells a story. The story in this case must display, as much as possible (in image form only), the basis of the IPEO project. The storyline was generated by several

students in informal discussions with various faculty and staff members. The product that developed demonstrates the full range of IPEO activities from satellite launches to end-user analysis.

The animation begins with the opening sequence for ISU '90. Following the introduction sequence, we move to the launch of the deforestation satellite. The launch is shown from two different views to emulate standard launch footage videos. The payload fairing separates from the satellite after it has gained sufficient altitude. Following the payload de-shroud sequence, the satellite and its booster separate and the payload shroud is jettisoned. The solar panels then deploy, the TTC&M antenna and star sensor deploy, and the SAR (Synthetic Aperture Radar) antenna is extended.

After successful deployment, the satellite begins operations and is shown sending the SAR signals back to the Earth. The beams are shown scanning a forest with signal backscatter toward the satellite. The satellite is shown receiving the backscatter and transmitting the data received from the SAR back to Earth. The scene then shifts to the surface of the Earth where we see a ground station which receives the data from the satellite, reorients antennae, and retransmits the signals to a communication satellite in orbit for distribution to the end-users. The communication satellite is shown acquiring the transmitted signal and retransmitting the data to Earth. This signal is received by a smaller, regional ground station (an IPEO regional center). The window of the ground station opens, and we see a large computer storing the data for archiving. The scene shifts and the viewer observes an end-user ground station which encompasses the scene and begins to demonstrate the final analysis of the data and its transformation into information through GIS scene of the seasonal variation of the global biomass.

To complete the demonstration of the IPEO missions envisioned to date, the animation then turns to the Topographical Mapping Lightsat (See chapter 8.0). This story also begins with the satellite's launch. The launch vehicle demonstrated is the Pegasus, and it is shown being launched from a B-52. The vehicle is dropped from the wing of the B-52, and its first stage is fired. The first stage then separates from the second stage and the second stage is fired. The payload shroud is then separated from the satellite when the appropriate altitude is achieved, and the final scene is the topographical satellite shown orbiting the Earth.

C.4 Summary

The animation of the IPEO design project was a difficult undertaking for all involved, but proved to be an experience of immeasurable value. Four people from the Soviet Union, Japan, Australia, and the U.S. worked closely together on a very large task that, we hope, produced a product that all may enjoy. We believe that the IPEO animation helps integrate the immense scope of IPEO in an easily understandable and exciting format. It was our intention to reduce the over four hundred page IPEO final report into a ten minute educational, yet entertaining summary of IPEO. Though all the animation may not be

overly technically accurate, and some of it does not exactly coincide with specific designs shown in the text due to time restrictions; we believe it is a fair representation of the mission and the effort performed by the IPEO students of ISU '90. Samples of the animated scenes follow in figures C.4 - 1 through C.4 - 6.

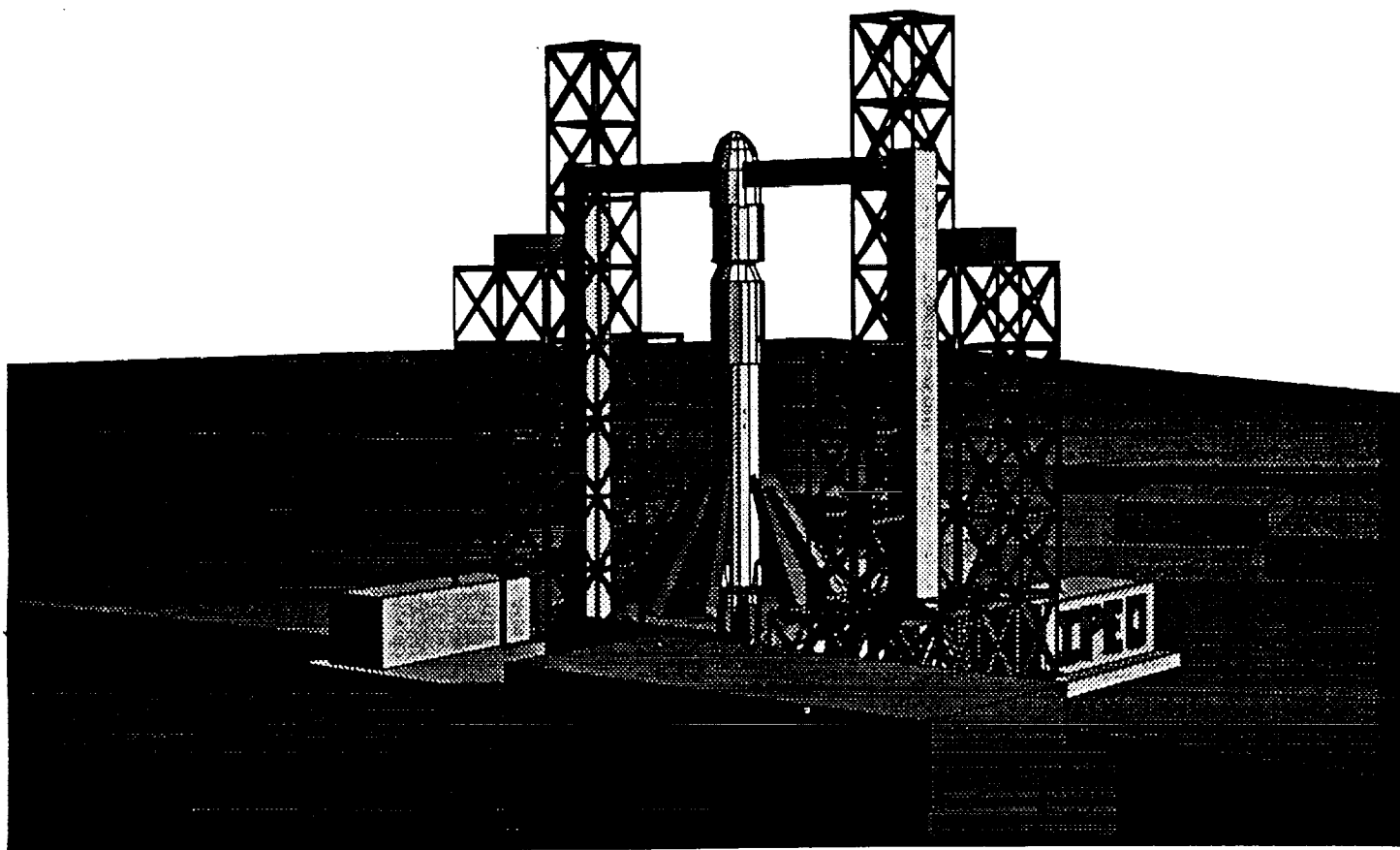


Figure C.4 - 1 Deforestation Satellite Launch

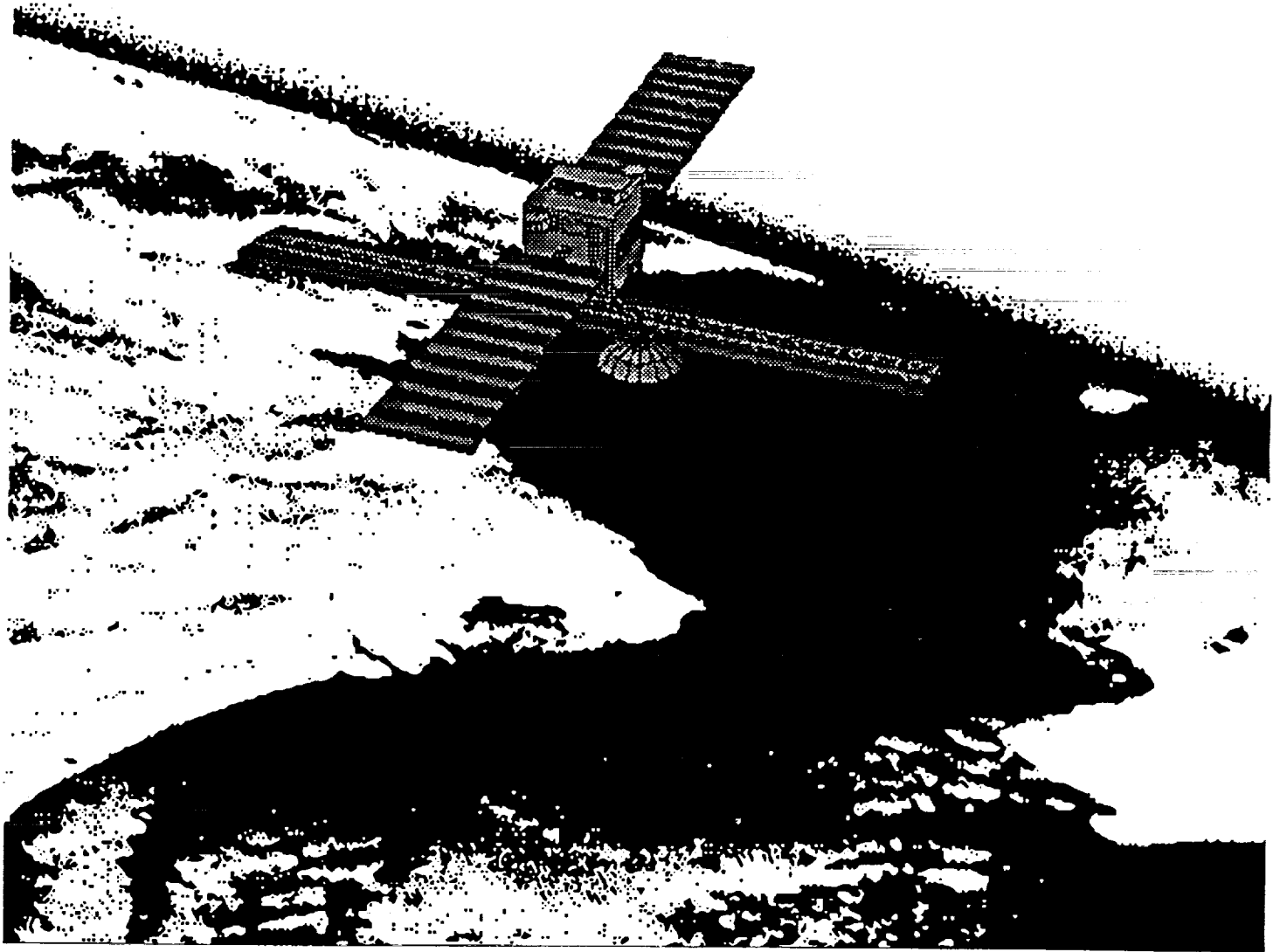


Figure C.4 - 2 Deforestation Satellite

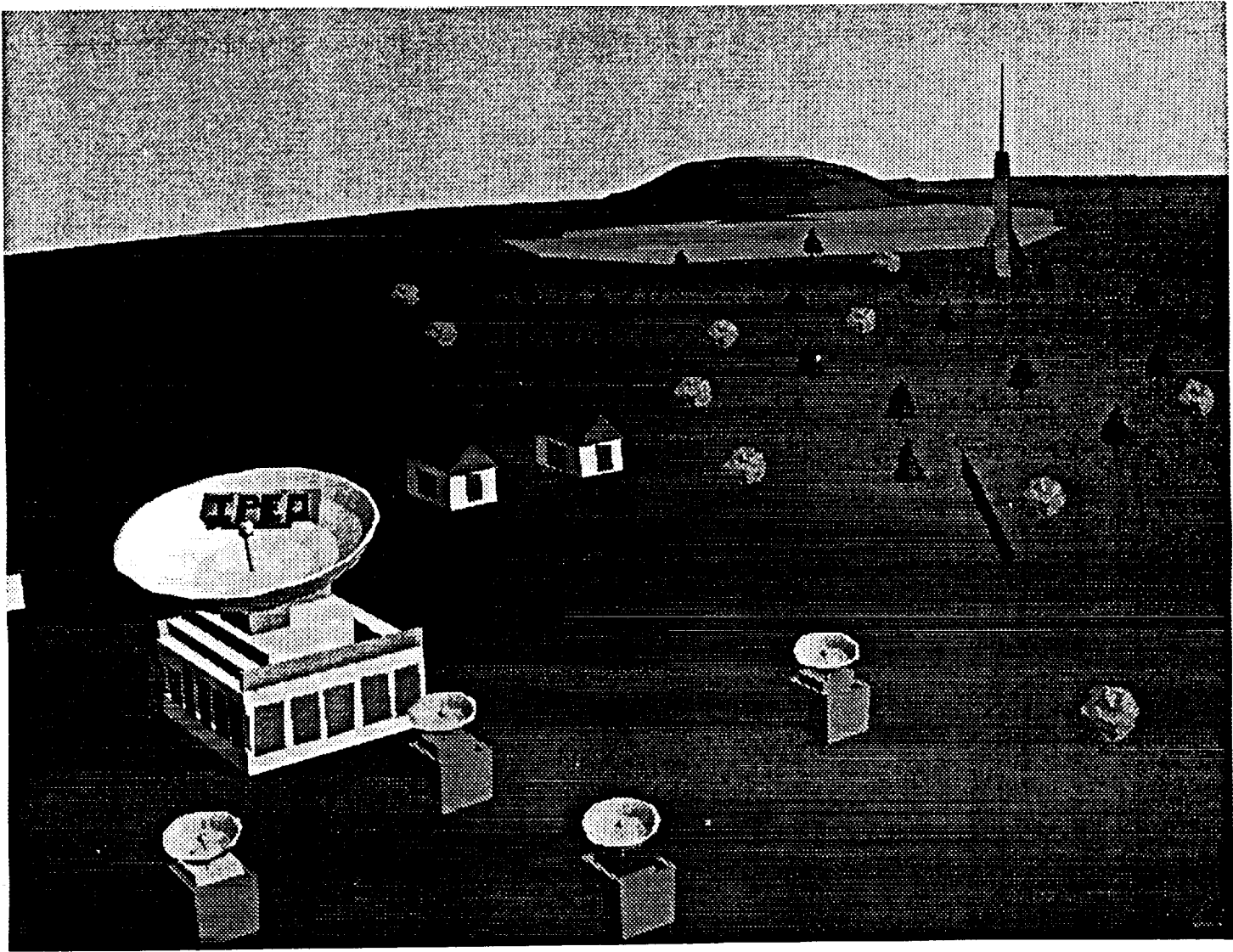


Figure C.4 - 3 Central Ground Station

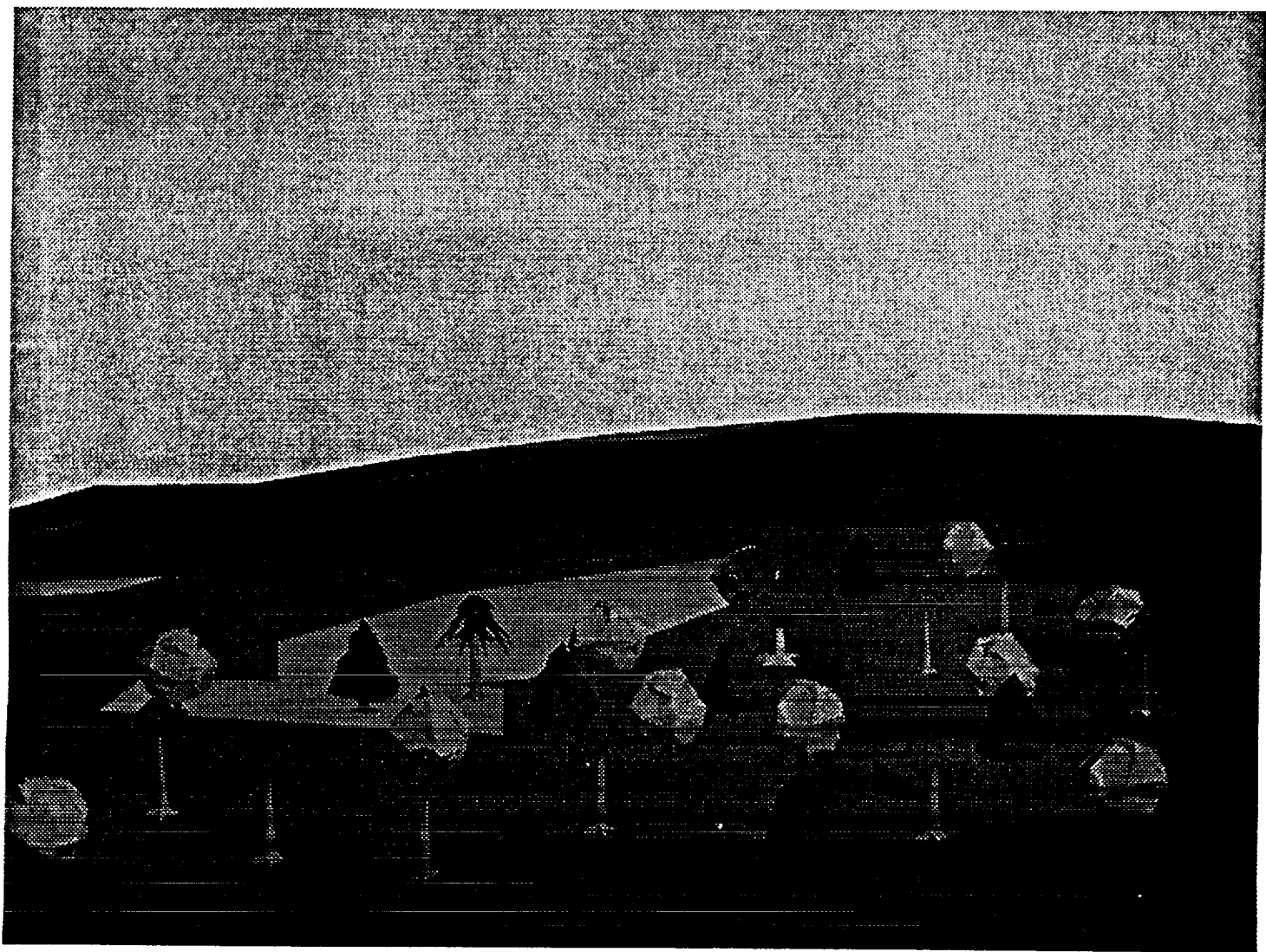


Figure C.4 - 4 Deforestation Scene

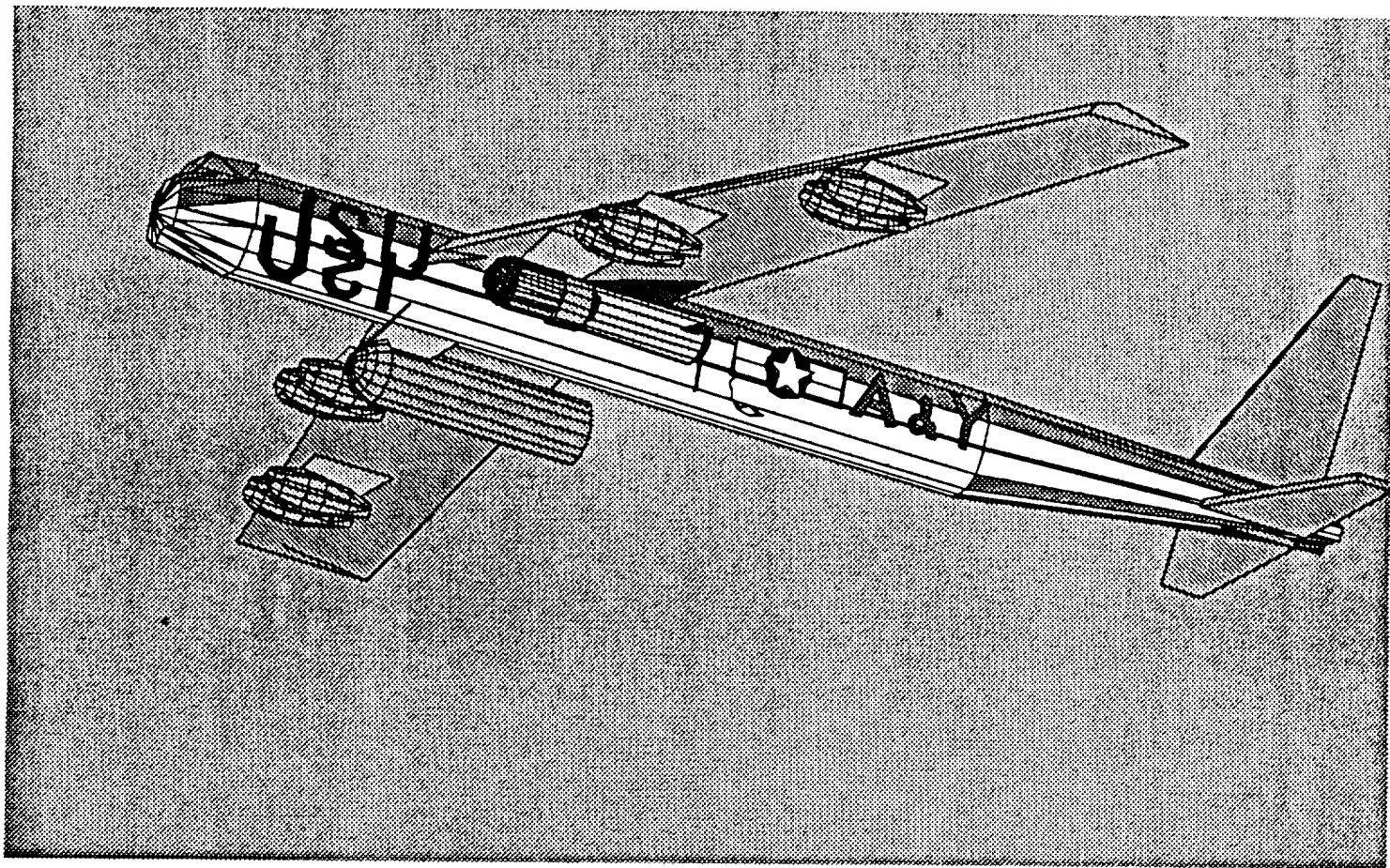


Figure C.4 - 5 Pegasus Launch of Land Mapping Satellite

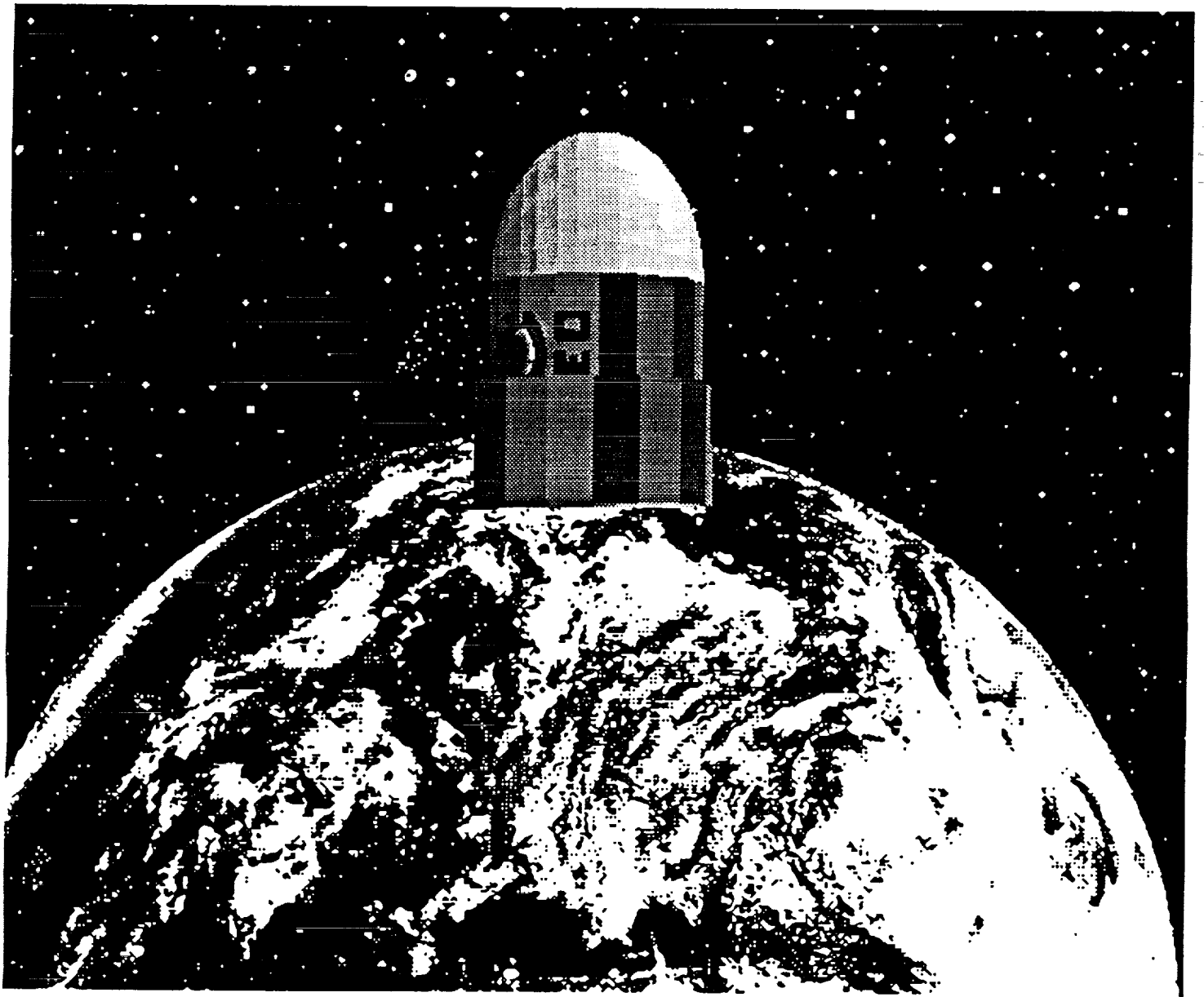


Figure C.4 - 6 Land Mapping Satellite

APPENDIX D GIS CASE STUDY

In an attempt to show some of the potential of a Geographical Information System (GIS), a limited case study was undertaken and the result is presented as the cover of this final report.

The global view is a combination three sets of geographical layers:

- The tropical zone centered around the equator shows the biosphere of the earth which is in itself a combination of two data sets;
 - The land portion shows the normalized vegetation index measured in the middle of June 1988 by the NOAA satellite AVHRR instrument (NOAA - National Oceanographic & Atmospheric Administration of the USA, AVHRR - Advanced Very High Resolution Radar). The data origins from the National Environmental Satellite Data & Information Service (NOAA-NESDIS). No vegetation is indicated in black, through increasing vegetation from blue to green.
 - The marine portion is a composite from the Coastal Zone Color Scanner Satellite during its entire life-time. The measured quantity is the amount of phytoplankton which is directly proportional to marine productivity. The data origins from the NASA Goddard Space Flight Center, Greenbelt, Maryland, USA. Yellow indicates no data, phytoplankton density is low in red areas and increases through green to blue.
- The northern and southern part of the view shows the global topographic map in a combination of elevation and aspect data. The data also origins from NOAA-NESDIS. Elevation spans from black as the deepest part of the ocean through blue, and green, red, brown on land. The aspect of the elevation is indicated in white.
- The outline of the coastline is shown in orange. The data is taken from the file "World Data Bank II" and origins from the National Technical Information Service (NTIS) of the USA.

The case study was produced using the GRASS software package as discussed in Chapter 5.1.1. and all above data are part of the GRASS "standard" global digital data set

(GRASS - Geographic Resources Analysis Support System, developed by the US Army at the Construction Engineering Research Laboratory).

The selection of the data sets is linked to the short term goals of the IPEO as identified earlier in this report, i.e. deforestation in the tropical region, and topographical land mapping on a global scale.

APPENDIX E A SMALL OPTICAL SATELLITE - A STRATEGIC APPROACH

E.1 Introduction

In this appendix we will assume a topographical mapping satellite as it is proposed in Chapter 8. In order to perform a the strategic analysis and design a marketing plan we have decided to focus on a specific market which we are going to enter. Moreover we think that the general idea of the strategic analysis is also applicable for other applications within the IPEO framework.

E.1.1 Mission Statement

We consider a hypothetical company which procures and launches payloads in order to provide the user, namely IPEO, an image of a significant event [for example topographical mapping, earthquakes, oil-spill control] for a low price. Typically, the user is not interested in satellites.

E.1.2 The Strategic Analysis

The essence of formulating competitive strategy is to relate a company to its environment. A thorough analysis of the environment is therefore of extreme importance. This analysis includes an audit of the key macro-environmental forces that influences the company's performance, as well as a structural analysis of the company's competitive environment. Finally, we summarize the main opportunities and threats that face our future business, see also Figure E.1.2 - 1.

E.1.2.1 Audit of Environmental Influences

This paragraph reviews the key macro-environment factors that influence our performance. The audit concerns socio-cultural, economic, political/legal and technological factors and is commonly named "SEPT-analysis", as shown by Johnson and Scholes (1981).

Economic factors

- The worldwide economic situation has an influence on our operations. Although the capital spending in the land-mapping as part of global control is probably more dependant on political and social factors, we think that starting projects with a high risk of success is difficult in times of economical malaise.
- High interest rates will result in an escalation of capital costs and can drive investors towards projects that can give quick return on their investment. Because we only have to invest money for a relative small time before we have a positive return, the NPV (Net Present Value) of a small satellite project can be positive, yet can be negative for a big satellite.

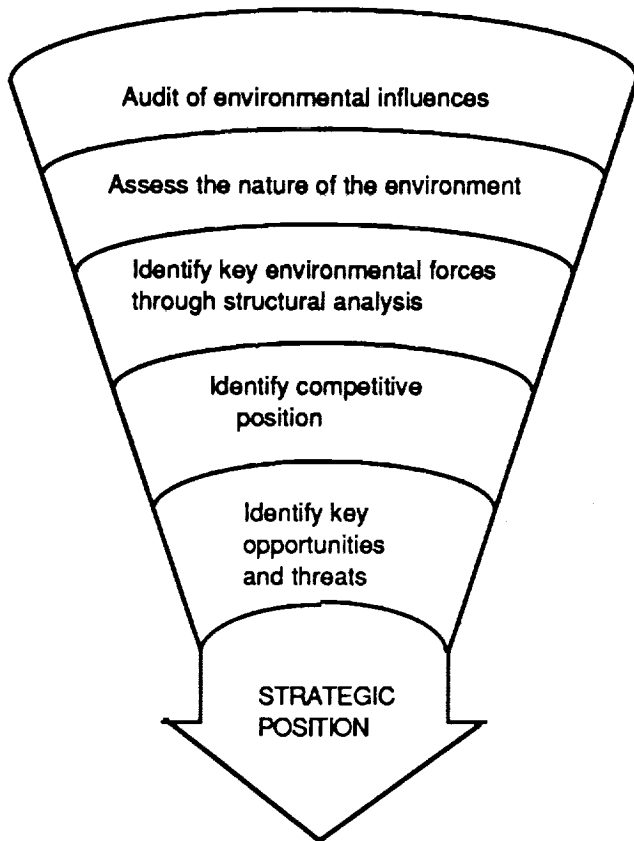


Figure E.1.2 - 1 Steps in the External Environmental Analysis

- The international money market can be a great influence of to the global operating business that we propose. If we position our company in Portugal, a strong Escudo will drive up the price of our exports. Misalignments with other currencies will enable competitors to sell their product at prices we can not meet.
- The space industry is relatively mature, commercial launches are available, and commercial components are available.

Political/legal factors

- There is a strong global interest in "mission to planet earth" -like projects. It is likely then that there is sufficient funding and that government will support us in political issues.
- The US government supports commercial ventures in space. This can remove obstacles.
- The project can be sensitive to foreign trade regulations for high-technology products.

- An united Europe in 1992 could cause trade wars.
- There are political barriers to selling 'Public Good', for example pictures of disasters.

Socio-cultural factors

- The world is becoming a "global village". For disaster control there can be a growing market, because these events have world involvement. This can result in a demand for information (from news agencies and red cross).
- Generally, the public is concerned with environmental issues. A land mapping satellite could help in controlling oil-spills.
- Developing countries want to enter the space market as shown by Afrispace Inc. (Space Business News, Aug. 7, 1990).

Technological factors

- The space transportation market develops more fully; it becomes technically and financially possible to launch small satellites.
- There is a general trend in electronics and mechanics for commercial miniaturization. This provides an opportunity for low cost, sophisticated payloads that fit on a general platform.
- The developments in HDTV can increase the market for precise pictures of significant events.

E.1.2.2 Nature of the Environment

As we can deduct from the audit above, the environment can be characterized as complex and dynamic. One thing that we can conclude is that the political and socio-cultural factors lead to more interest for environmental programs. From the other factors it seems that the timing to provide such a service is of extreme importance.

E.1.2.3 Structural Analysis of the Competitive Environment

The analysis of the competitive environment is aimed to identify the key forces that work in the company's micro- or transactional environment. Porter's model (Porter, 1985) for structural analysis will serve as a guideline. This model distinguishes five competitive forces, which jointly determine the intensity of the industry's future competition. Again we consider that our company is just entering the market.

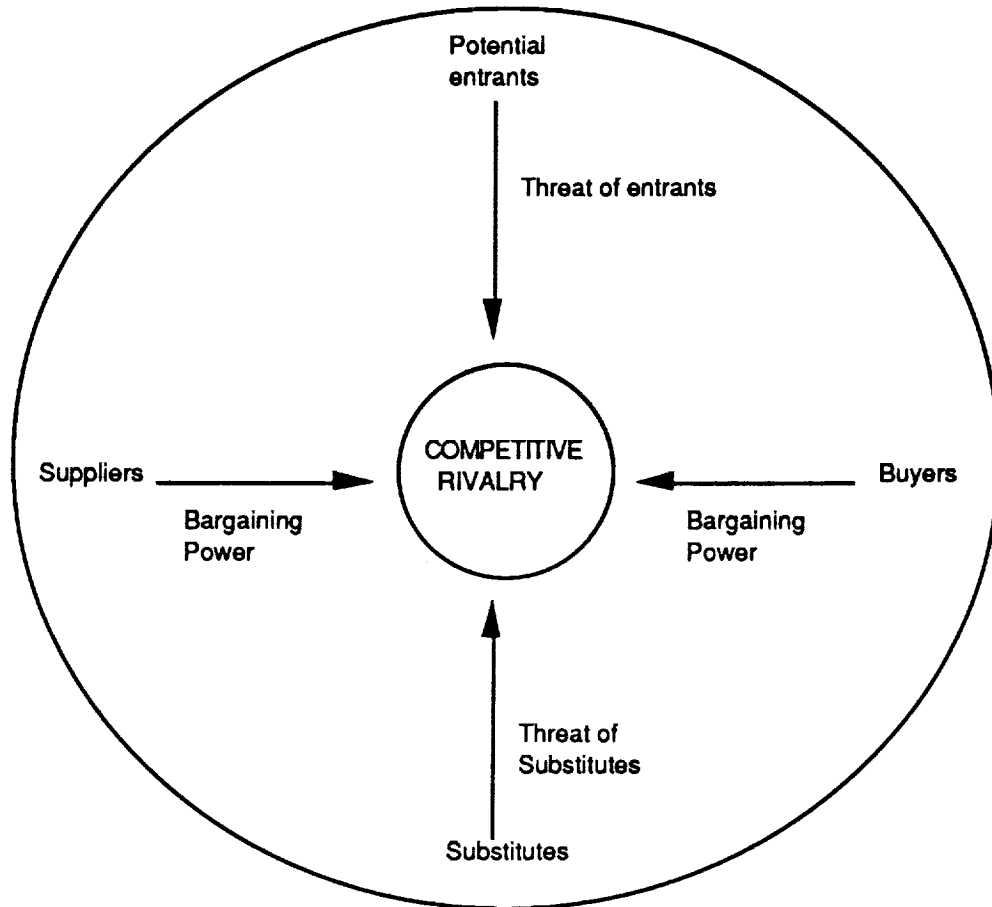


Figure E.1.2.3 - 1. A model for structural analysis (Porter, 1980).

We now consider the factors which will inhibit our company, as shown in Figure E.1.2.3 - 1.

Threat of entry

The threat of entry depends on the barriers to entry in our business. This strongly depends on the potential of the market (in \$), where the ratio of entry costs to market is of prime importance. If this ratio is low (meaning big market and low entry costs) then the threat is high. As we have seen in the cost analysis, the entry costs are not very high, because there is no significant advantage in the economies of scale (after, typically, 10 satellites).

Threat of substitutes

There are a number of substitutes that must be considered. They are: a plane with a camera, in-situ photographs, graphical animation and doing nothing. The drawbacks of the plane and the in-situ cameras is that the company must be able or have the right to access the area. This can be a problem for disasters such as earthquakes. Graphical animation could be complementary to land mapping by satellites.

The bargaining power of buyers

The bargaining power of the buyers can be considered high if there are competitors. In this case the switching costs are thought to be zero. Some buyers, like IPEO, are likely to purchase high volumes of pictures and probably bargain long-term contracts, which makes them very powerful.

The bargaining power of suppliers

The suppliers are thought to be the launch industry, the payload industry and the platform industry. At the moment, the bargaining power of suppliers is low because an overcapacity in industry. This could drastically change if the small satellite market increases.

The competitive rivalry

Rivalry in the industry is at the moment small, if existent. In the future it could increase because of high exit barriers; a distribution network must be established.

E.1.2.4 Organization's Competitive Position

If the timing of entering the business is right, and the company succeeds both technically and economically to provide a flexible land-mapping service, we could have the "first mover advantage". Flexibility is a must if we are to stay ahead of our competition.

E.1.2.5 Opportunities and Threats

An overview of opportunities and threats that can face the company concludes our external analysis.

Opportunities

- Customers need continuity of data. A small satellite can provide this more easily than its bigger brothers, because the investment needed to build another series of satellites is significantly lower.
- Satellites can fly over any area, while planes cannot.
- Small satellites can provide flexibility. If the market changes, or if the market forecast was wrong, changing the mission can be done at relatively low costs.

Threats

- If we cannibalize LANDSAT/Spot business, these companies will react negatively.
- Countries and companies that are "sensed" against their will (oil-spilling countries, countries at war) can counter-react.

- Technical changes in the world could make the design obsolete before we can adapt.
- If we grow (in people and fixed assets) we may lose our flexibility

E.1.2.6 Internal Analysis

Part of the internal analysis is trying to determine the strengths and weaknesses of the small satellite company in the context of strategic capabilities. This capability is determined by the activities within the value chain from supplier through production to the consumer. In order to understand the value that is created in the chain, the linkage between the elements and the balance between the elements will be defined. The analysis tries to give a deeper insight in getting a competitive advantage over other future companies. By identifying the direction which best matches the strategic capability, the first step is to identify the strengths and weaknesses. After that, we will identify the different parts in the value chain.

Strengths

- Low up-front investment, when compared with bigger satellites. This can improve the attractiveness to invest in our project, and makes it less dependent on interest rates (see E.1.2.1., economical factors).
- Flexibility. Flexibility is determined by the possibility to quickly react to a significant event. Because we can launch many small satellites at a low cost, we have a high temporal resolution. On top of that, when we spot a trend in the market we can easily decide to dedicate more satellites to this trend.
- High quality images. The panchromatic images can compete with today's commercially available pictures (SPOT).
- No space debris. Because of the small size and the low orbit the satellite is foreseen to burn completely upon reentry.
- Less invested dollars at risk.
- Short development time. This can contribute greatly to flexibility.
- Flexibility to change location. We are a small value adding service and we can and should move near the critical mass of our customer (for example to IPEO main office or close to a big press agency).

Weaknesses

- No existing infrastructure. The marketing channels must be designed and implemented.
- New market. Market development is needed.
- No guarantee of good margins. We are entering a market that is partially new and certainly not mature.
- Cannot look through clouds. Thus, there is competition from radar satellites.

E.1.2.7 The Value Chain

The value chain is a major tool for identifying potential competitive advantages. Every firm is a collection of activities that are performed to design, produce, market, deliver, and support its product. The value chain disaggregates a firm into nine strategically relevant activities in order to understand the behavior of costs in the specific business and industry and the existing potential sources of differentiation. The nine value activities consist of five primary activities and four support activities (see Figure E.1.2.7 - 1).

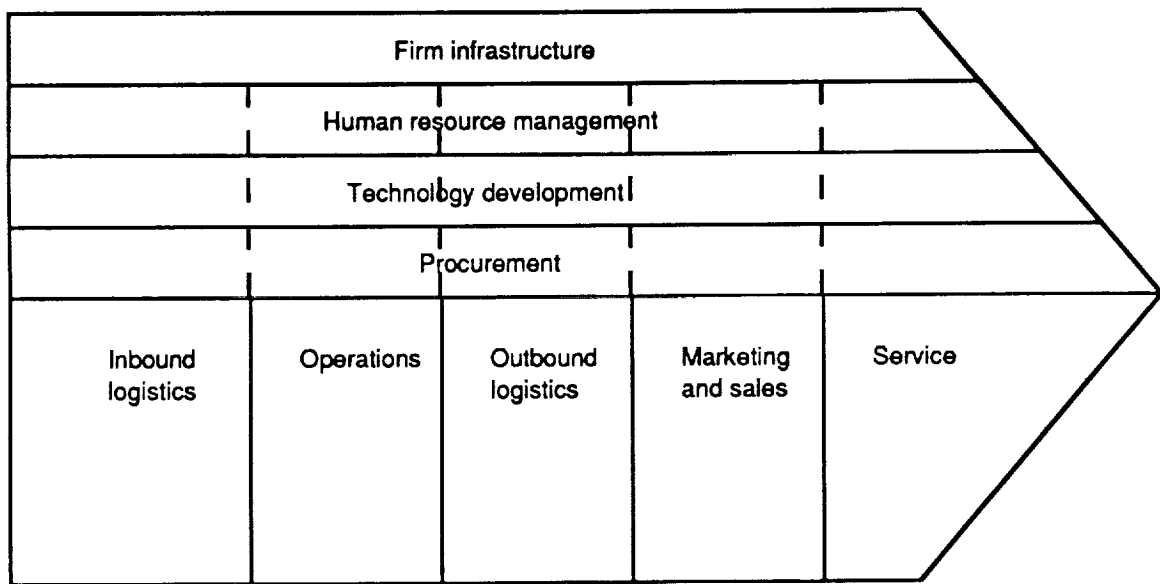


Figure E.1.2.7 - 1 The Value Chain.

We now examine costs and performance in each value activity and recommend improvements. The primary activities are:

Inbound logistics

- For the inbound logistics, partnership with IPEO will be established, to provide the ground support and the legal framework. For this service IPEO will receive free topographical data. An extra possibility is that IPEO will get data that is considered "Public Good" (for example, for earthquakes, the small sat company will provide the data to IPEO for free, see also the Marketing section).

Operations

- For attitude and orbit control, partnership with IPEO will be established.
- The basic operation is collection of topographical mapping data for IPEO.

- A special operations office will be established which, in close cooperation with marketing, defines which satellite will photograph which significant events. This operations office is a key element.
- The time division between topographical data and marketing data is of prime importance.
- Raw data processing capabilities are important.
- Archiving agreements have to be developed with IPEO.

Outbound Logistics

- The time between the significant event and the picture on the desk of the user must be minimized (if technically possible, within 1 day). This is a key issue.
- Specific data processing for special users has to be performed. This too, is a key issue.
- A distribution network has to be established.

Marketing

- The main goal is to 'excite' the customer.
- Close relationship with IPEO and large news agencies, in order to be the first to photograph significant events.
- We segment between two groups of users. The first is IPEO, which will get free access to topographical mapping data and to 'Public Good' data. The second group is purely commercial, to which we will provide pictures of significant events, other than 'Public Good' data.
- If possible a market for sophisticated payloads must be established.
- A lot of work has to be done on a sound Marketing Plan.

Service

- Data analysis will be done by IPEO.

The support activities are:

Firm infrastructure

- It will start with a very small firm to test the market.

Human resources

- People are needed with experience in government and commercial marketing.

Technological

- The use of commercially available components will be predominant.

Procurement

- The procurement is an important activity. Because of the low entry costs of the business, once established, continuous monitoring and stimulation of the market for suppliers must be done. For example a value chain analysis of our suppliers can be mandatory for survival.

E.1.2.8 Key Success Factors

We complete this strategical analysis with an overview of the key success factors.

- Flexibility
- Availability of Space Transportation Systems
- High quality images
- Fast delivery of data to the right user, in the right format
- No legal implications

E.1.3 Marketing Plan

The marketing management process consists of analyzing marketing opportunities, researching and selecting target markets, designing marketing strategies, planning marketing programs, and organizing, implementing, and controlling the marketing effort.

E.1.3.1 The Marketing Opportunities

In this limited study we will focus on two marketing opportunities. The first is the lack of topographical data in the IPEO GIS system. The second one is the opportunity to market images of significant events with a fast reaction time (i.e. a day instead of weeks (as for Spot)). The first one is short term, while the second opportunity is long term.

To identify and evaluate our opportunities more market research is needed, and we should build and operate a reliable marketing information system. Close attention to identifying and monitoring our competitors is mandatory, as we can see from the existing threats (SPOT and LANDSAT).

E.1.3.2 Selection of Target Markets

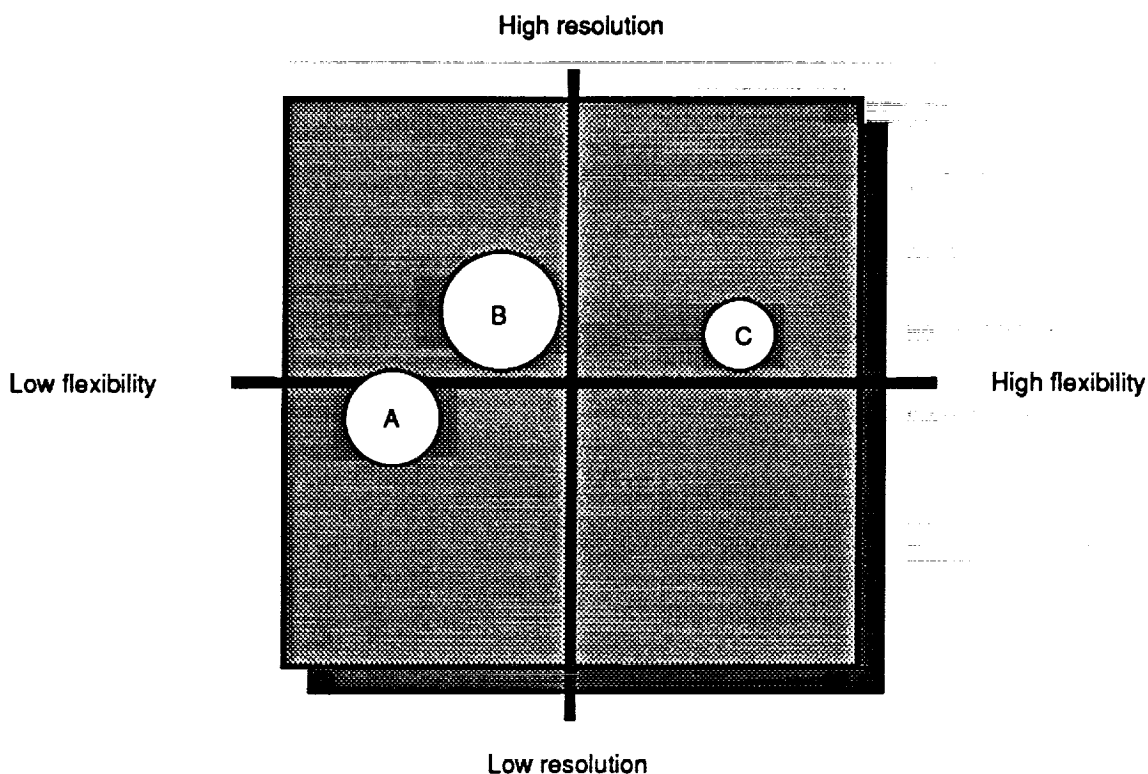
Modern marketing practice calls for dividing the market into major market segments, evaluating them, selecting and targeting certain ones, and deciding on the company's position in each market.

Market segmentation, the task of breaking the total market (which is probably too large to serve) into segments that share common properties, can be done in a number of ways. We can

segment our market by customer size (large, medium, small), customer buying criteria (quality of images, reaction time) and customer industry (non-profit, news agencies).

Based on the strategic/environmental analysis we think the best product/market combinations are the topographical images for IPEO and images of significant events with a fast reaction time for news agencies.

We need to carefully study the positions taken by our major competitors (for example Spot and LANDSAT). If we position ourselves in terms of our response time (strength) and quality (resolution), we can develop the following product-positioning map for the “images of significant events with a fast reaction time”-market:



- A: Landsat
- B: Spot
- C: IPEO small sat

Flexibility = the ability to dedicate the satellite to a- and react on a- significant event

Figure E.1.3.2 - 1 The Product-Positioning map for the “images of significant events with a fast reaction time” market.

The data used for this chart is imaginary, we only want to stress that we not only must be careful to choose our own market but also look at our competitors' positions.

E.1.3.3 Marketing Strategy

A marketing strategy defines the broad principles by which we, IPEO, expect to achieve our marketing objectives in the target markets. It consists of basic decisions on total marketing expenditure, marketing mix, and marketing allocation. For this case study we will focus on the marketing mix. The tool used is McCarthy's Four Ps: product, price place and promotion (McCarthy).

Product

Product is the firm's tangible offer to the market place. On the short term it is mainly the topographical images supplied to the IPEO GIS system. The flexibility of our system is the main feature of our product. We can deliver, on request, topographical data to the database, in the right format.

On the long term our product can be, besides our existing product, the delivery of images of significant events, edited by GIS tools, to news agencies. In this case we can benefit from our high flexibility.

Price.

The financing of the small satellite is foreseen to be part of the IPEO financing, although this is not the baseline at the moment. For return the small satellite will provide topographical data to the IPEO-GIS system for free. However, a fair amount of the observation time must be allocated for the development of the long term marketing goal to develop the "images of significant events with a fast reaction time"-market.

The price for this commercial service must be chosen in a way to prevent buyers to turn to the competitors.

Place.

Place stands for the various activities we undertake to make the product easily accessible and available to the target customers. This means for us, that we should position ourselves to the place where the critical mass of our customer is. Because we are a mainly value-added service, we can easily do this, which is a strength.

Promotion.

Promotion stands for the various activities we undertake to communicate our products' merits and to persuade target customers to buy them. Apart from setting up advertising and promotion, we can set our company's image (and thus publicity) by providing images of disasters (for example, earthquakes) for free to governments.

E.1.4 Cost of Satellites and Launch

We will briefly touch upon the cost of the satellite. Cost can be one of the advantages of small satellites when compared with larger ones.

Typically the cost of a satellite is divided in the following components, as indicated in Figure E.1.4 - 1.

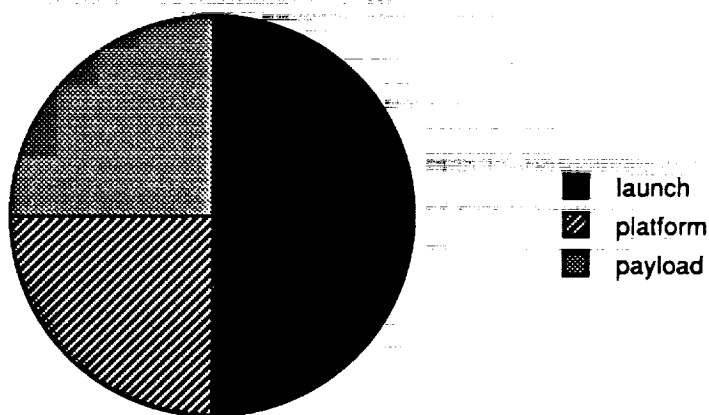


Figure E.1.4 - 1 Typical Cost Division of a Satellite

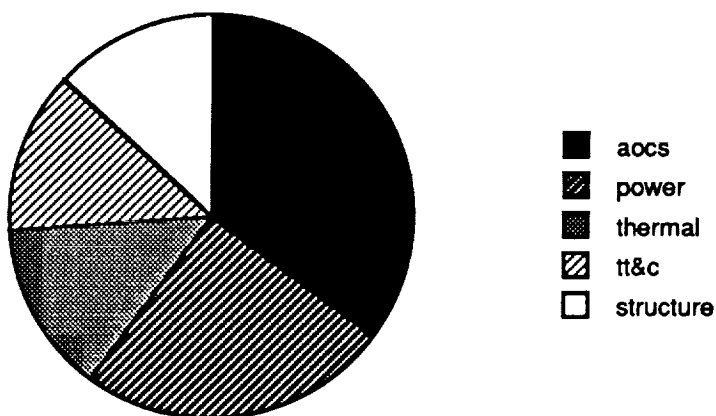


Figure E.1.4.2 - 2 Typical Costs of a Payload.

From these general pictures it is clear that the launch influences the price of a system greatly. Maturity in the market of small space transportation systems (for example Pegasus) is of primary importance for the success of small satellites.

Launch

The cost of a launch is the major part of the costs of the satellite. Typically, the cost of a launch per kg-payload decreases when the weight of the satellite increases.

A Pegasus launch cost at the moment 8.5 M US\$, while costs are likely to come down to 5 M US\$ when Pegasus is launched frequently, as shown by Elias.

Platform

A general purpose small satellite platform could greatly benefit from economies of scale and learning curves. The platform will be constructed from commercially available components to reduce costs. The recurring cost of a typical platform can be 0.25 - 0.42 M US\$ (Ford Aerospace, 1987?).

Non-recurring costs of the platform is not known. To cope with this we will take the 0.42 M US\$ for the first satellite and will use a learning curve with $p = 0.8$ as shown by the Transcost model in by Koelle (1990).

Payload

A sophisticated payload has a typical development cost of 45 M US\$. Because the payloads for a small satellite design will use commercial components the manufacturer of the payload can benefit from a learning curve and economies of scale. Thus, the actual cost can be well below this figure.

Keeping in mind the concept of a multipurpose platform and a sophisticated payload, designed specifically for this platform, it is logical to analyze different prices for the payload. Typical recurring costs of 1, 5 and 10 M US\$ are taken as an example, while the development costs are assumed to be 4.5 times the recurring costs. More research on this assumption must be done.

Cost of Test and Integration

These costs are normally part of the recurring costs (Koelle, 1990). Recurring costs include fabrication, integration and verification.

For smaller satellites, however, the verification costs can be reduced. We propose to do the qualification test only on the first satellite. The acceptance test, necessary for every satellite, can be reduced in case we use a Pegasus type launch vehicle. Because the biggest stress on the vehicle is during the take-off of the airplane that carries the launcher we can, with a simple health check of the payload, decide whether to launch the payload or to return and replace the payload. This reduces the acceptance test to a simple health-check.

The following calculations are very preliminary. If we consider three cases of payloads, to be launched on a Pegasus, we see in Figure E.1.4 - 3, that producing larger number of identical satellites can greatly reduce the cost per satellite.

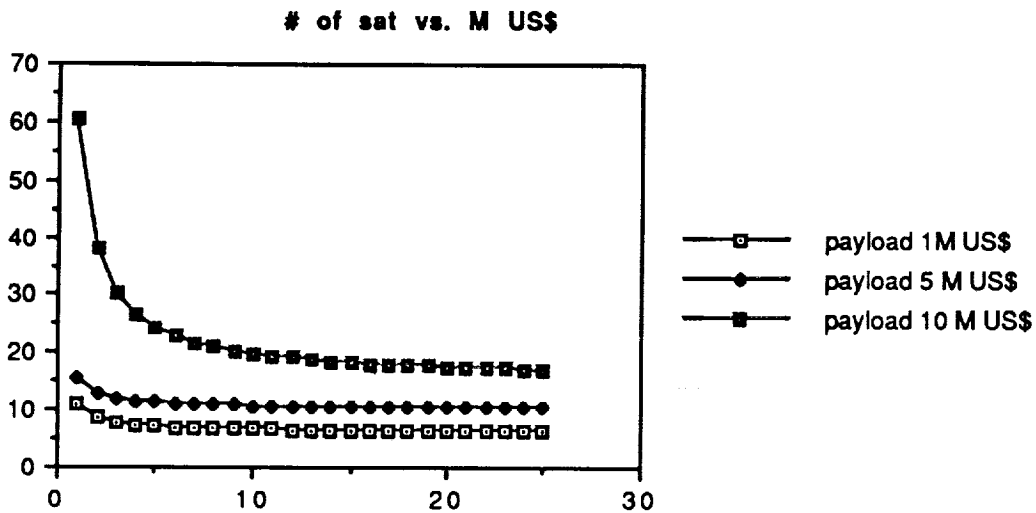


Figure E.1.4 - 3. Satellite Versus Costs (The horizontal axis is the number of satellites, the vertical axis is million US \$)

Typically, a sophisticated payload will have recurring cost around 1 M US\$. This means the development costs will be around 4.5 M US\$. For this case, 8 satellites including 8 launches, will cost around 60 -70 M US \$.

E.1.5 Final Remarks

Although the analysis has been as thorough as is feasible possible within the available time frame, the strategic analysis and marketing study was performed only to indicate the possibilities for small satellites. A more thorough analysis must be performed if the project is to be undertaken.

E.1.6 References

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APPENDIX F SAR THEORY

F.1 Operation Geometry

All references for this Appendix are contained within Section 7 IPEOSAT.

SAR is commonly operated in a boresight mode as shown in Figure F.1 - 1. In this mode, the antenna points perpendicular to the flight track. The radar transmits pulses spaced in time by the pulse repetition interval (PRI) which is the reciprocal of the pulse repetition frequency (PRF).

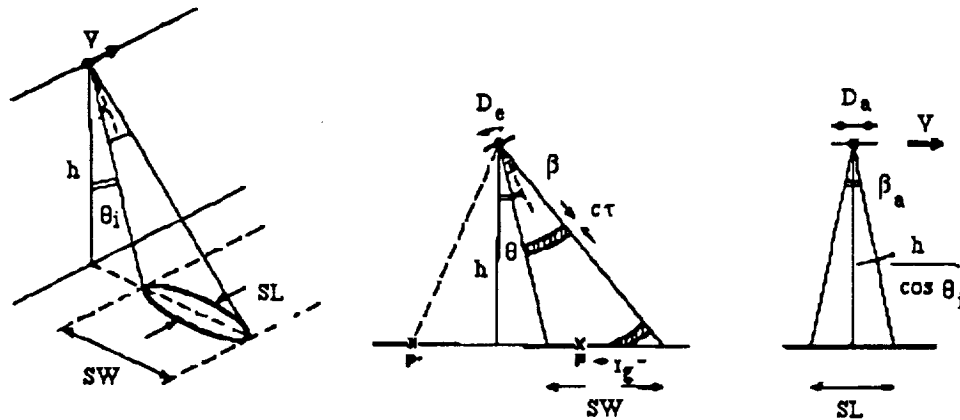


Figure F.1 - 1 Operation Geometry of SAR

The PRF is governed by the minimum sampling rate required (Nyquist rate) to reconstruct the azimuth (along track) phase history of the echo signal stemming from a particular point scatterer on ground. The phase is directly related to the length of the propagation path via the radar frequency (f) or the wavelength (λ). Taking into account the two way propagation path in a monostatic radar configuration the signal exhibits a phase shift $\phi(t)$ where :

$$\phi(t) = 4\pi \frac{R_0 - R(t)}{\lambda}$$

where R indicates the actual slant range to the point target of interest and R_0 is the slant range pertained to the zero phase reference associated with the boresight position of the point scatterer.

The phase change versus time introduces the well known Doppler frequency shift which turns out to be linear in time as a first order approximation (Chirp). Assuming the sampling theorem is satisfied, the length of the azimuth chirp (T_{az}) is governed by the

ground velocity (v_g) and the area covered by the main lobe of the antenna beam. The length of the antenna footprint is defined as L_{fp} and the angular beam width in azimuth is defined as β_{az} .

$$L_{fp} = R_0 \beta_{az}$$

and

$$T_{az} = L_{fp} / v_g.$$

The frequency at the edges of the Doppler spectrum (usually the 6-dB points of the spectrum corresponding to the 3-dB points of the antenna beam pattern are taken) is given by

$$|f_d| = 2 v_g \frac{\sin(\beta_{az}/2)}{\lambda} = v_g \frac{\beta_{az}}{\lambda}$$

for small values of β_{az} .

The width of the Doppler spectrum subtended by the edge frequencies is given by

$$B_d = 2 |f_d| = 2 v_g \beta_{az} / \lambda.$$

The 3-dB beamwidth of the antenna can be expressed by

$$\beta = \frac{k_a \lambda}{D}$$

where D is the dimension of the antenna aperture and k_a is the aperture tapering coefficient taking into account individual excitations functions. For a rectangular aperture with uniform excitation k_a has to be replaced by 0.886.

F.2 Geometric Resolution

- *Time Resolution*

Time resolution is directly related to the spectral bandwidth of the signal used. As a first approximation one can take the time resolution as

$$d_T = 1 / B$$

- *Geometric Resolution in Azimuth (along track)*

The time resolution transforms into ground resolution by means of the ground velocity v_g , i.e.

$$d_a = dT_a v_g$$

Assuming the bandwidth retained in the SAR processing is denoted by B_a with $B_a < B_D$ then the one look resolution is given by

$$d_a = v_g / B_a$$

which results in the intrinsic SAR resolution d_{a_i} when B_a is replaced by B_D .

Setting $k_a = 1$ the well known relation results

$$d_a = D_a / 2$$

Hence, the geometric resolution in azimuth is independent of the slant range. It only depends on the length of the real aperture. Moreover, if the antenna size is reduced the resolution is improved accordingly. However, one has to consider, that this result is only obtainable in the focused case, i.e. the entire knowledge of the phase history is optimally exploited in the SAR processing which may cause serious problems when the length of the synthetic aperture is very large compared to the resolution processed due to higher order terms needed in the approximation as well as the inclusion of so called range migration and range walk effects [Elachi, 1988].

The time bandwidth product (TBP_a) is commonly used as a figure of merit for the complexity of the processing. Inserting the maximum duration T_{az} and the corresponding bandwidth B_D the TBP_a is given by

$$TBP_a = T_{az} B_D.$$

- *Range Resolution*

In general a modulated pulse with duration (T_p) and bandwidth (B_p) is transmitted. In this case the slant range resolution is related to the time resolution via the velocity of light c_0 by

$$d_R = c_0 d_{T_r} = c_0 / B_p.$$

where d_{T_r} is the equivalent pulse length, which is related to the actual pulse length (T_p) by the expansion factor or time bandwidth product (TBP_r).

- *Ground Range Resolution*

The ground range resolution d_{rg} results from the projection of the slant range resolution d_R onto the reference surface (ground surface). With the incidence angle (θ_i , angle subtended by the line of sight, LOS, and the normal to the reference surface). The ground range resolution is given by

$$d_{rg} = d_R / \sin \theta_i.$$

F.3 Image Quality

Image quality is usually measured in terms of radiometric resolution which relates the expected signal to noise ratio detectable in a particular resolution cell to the number of incoherent looks (contents of resolution cells averaged incoherently in time or frequency) as shown in [Elachi, 1988].

F.4 System Parameters

- *Pulse Repetition Frequency (PRF)*

The PRF has to be set such that ambiguous energy due to aliasing in time and frequency is sufficiently suppressed. With given Doppler spread (antenna length) in azimuth the PRF should be at least

$$PRF_{min} = 1.2 B_a.$$

- *Antenna Size*

Since the propagation time is much larger than the PRI, multiple echoes collapse into the receive window left between two pulse transmissions (interpulse period, IPP). Spatial filtering by the antenna diagram in elevation (across track) is the only way to cope with those range ambiguities, which implies a minimum antenna width once the antenna length is fixed by the required along track resolution and number of looks, see [Elachi, 1988] or [Ulaby, 1982].

- *Power*

The following remarks are confined to the identification of those parameters which essentially affect the power demand of the instrument.

With known propagation path

- transmit path within instrument
 - radiated power and antenna gain
- transmit path outside instrument
 - free space loss and atmospheric losses
- receive path within instrument
 - antenna gain
 - system noise figure
- processor characteristics,

signal characteristics

- pulse length
- pulse bandwidth,

assumed backscattering characteristics, e.g. from [Ulaby,1982]

- backscattering coefficient,

and required signal-to-noise (SNR). The peak transmit power as well as the average power demand can be evaluated as shown in [Elachi, 1988].

If the dependency of the backscattering coefficient on the incidence angle is taken into account as discussed in [Bender, 1990], an optimum incidence angle results for a maximum swath width, minimum antenna size and minimum power demand, if only the image quality is fixed.

The power to be provided by the platform bus has to be evaluated according to the operation duty cycles associated with the different levels of operation phasing on the one hand and the power conversion efficiency of the power conditioner on the other hand.

APPENDIX G SHADOW ANALYSIS

It is necessary to evaluate the shadow behind the antenna and satellite bus. This section shows the shadow area behind both the antenna and bus, which is projected to plane (X-Y, Y-Z, Z-X). From the following drawings, Shadow Area is about 1m^2 . This area does not affect the power supplied to the antenna and bus. Because the solar array includes design margin and the angle between sunlight and solar array is 13° , the power supplied is twice the minimum requirement. As a result, it is not necessary to consider the shadow effects.

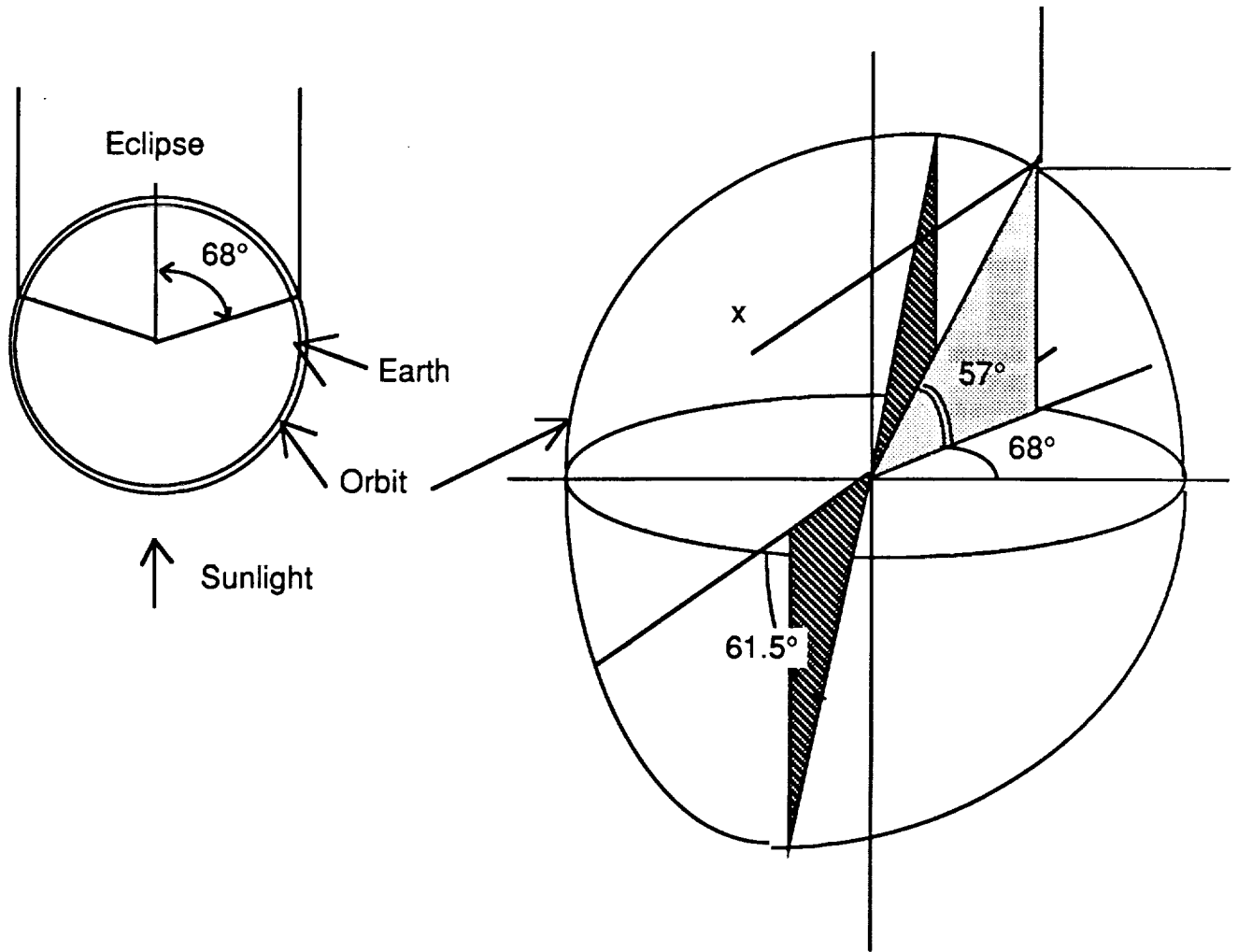


Figure G.1 - 1 Maximum Eclipse Angle and Establishing the Coordinate System

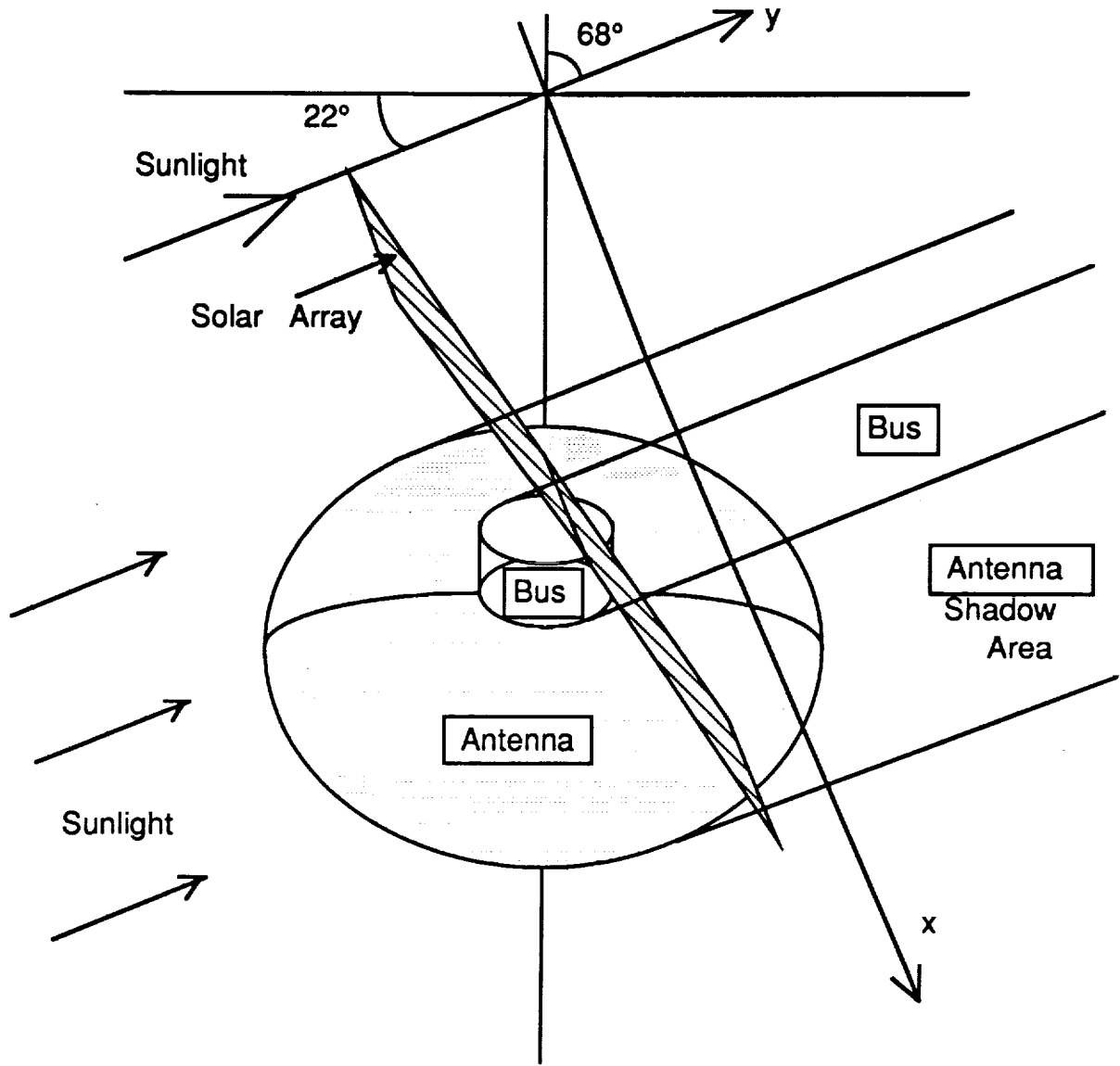


Figure G.1 - 2 Projection on X-Y Plane

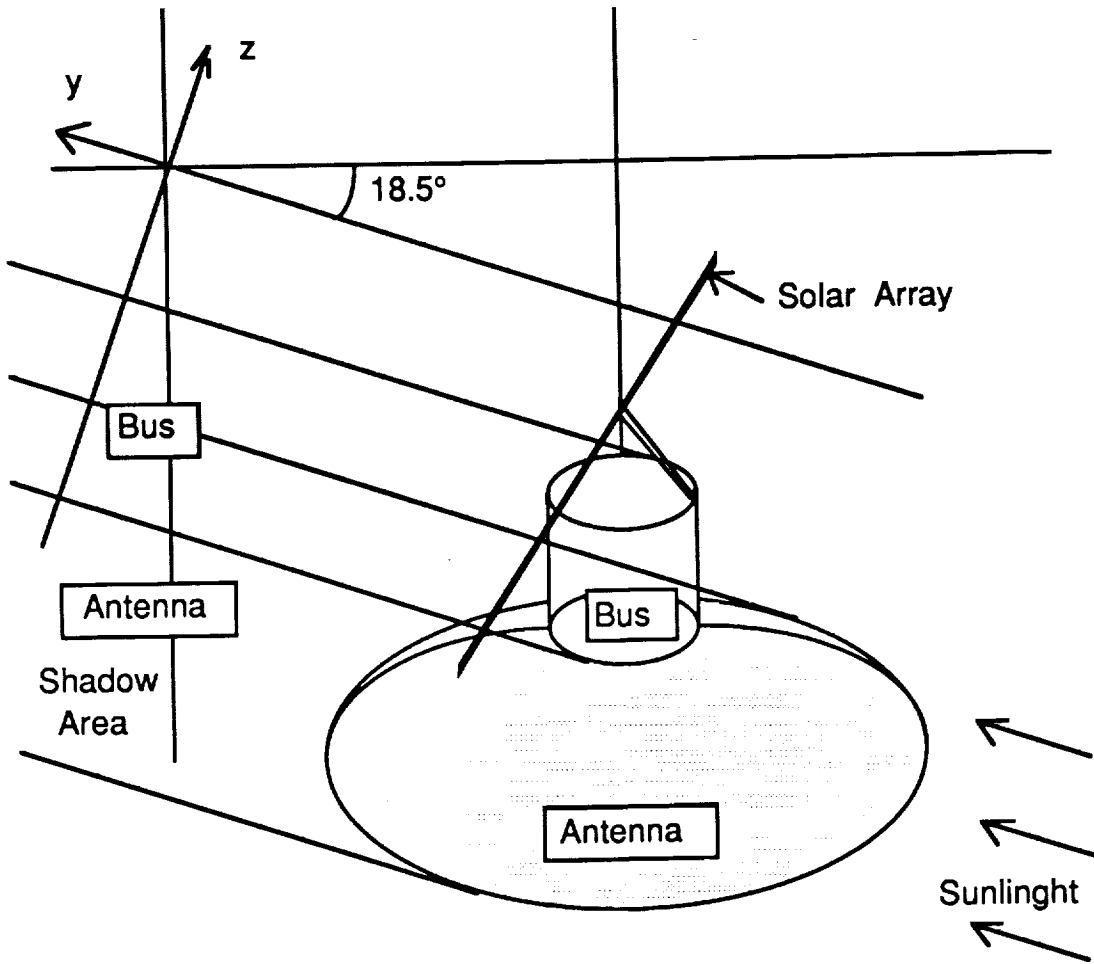


Figure G.1 - 3 Projection of Y-Z Plane

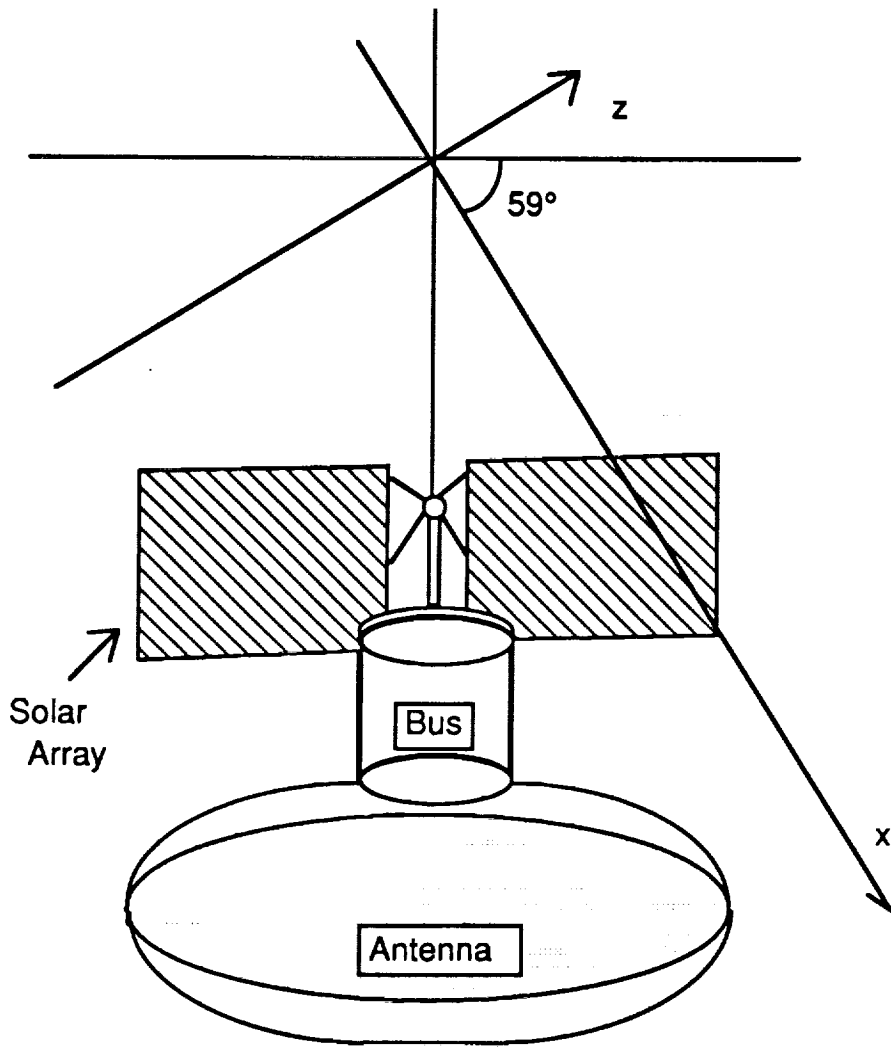


Figure G.1 - 4 Projection on Z-X Plane/Sunlight direction is normal to this paper plane.

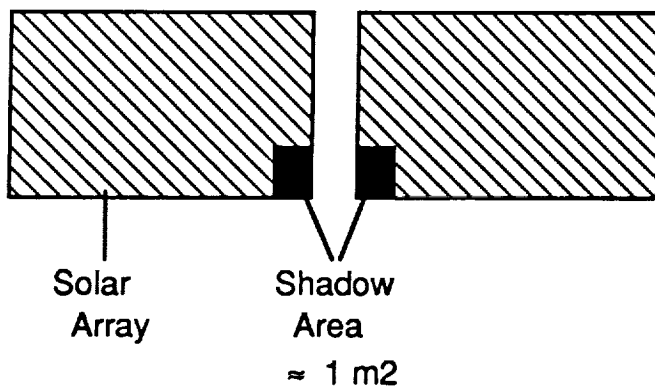


Figure G.1 - 5 Shadow Area