



Report of the

**ISY MISSION
TO PLANET EARTH
CONFERENCE**

*A Planning Conference for the
International Space Year*

*Durham, New Hampshire
April 29-May 1, 1988*

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**REPORT
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ISY MISSION TO PLANET EARTH
CONFERENCE**

A Planning Meeting for the International Space Year

Harvey Meyerson, Editor

Published by
US-ISY Association

April 29-May 1, 1988
DURHAM, NEW HAMPSHIRE USA

This report is dedicated to the memory of
Dr. Henry A. Murray,
Professor Emeritus at Harvard University
and an inspirational member of the
US-ISK Association's advisory board,
who died on June 23, 1988.

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CONFERENCE PROGRAM

Conference Organizer: *US-ISK Association* **Host:** *University of New Hampshire*

Conference Officers

Honorary Chairman:

James C. Fletcher
Administrator
NASA

Chairman:

Hubert Curien
University of Paris
FRANCE

Steering Committee Chairman:

Lennard A. Fisk
Associate Administrator for Space Science and
Applications NASA

Program Committee Chairman:

Shelby G. Tilford
Director of Earth Science and Applications Division
NASA

Deputy:

Thomas B. McCord
Director
Division of Planetary Geosciences
University of Hawaii

Conference Coordinator:

Harvey Meyerson
President
US-ISK Association

Conference Host:

Gordon A. Haaland
President
University of New Hampshire

Working Group Co-Chairmen

Space-Based ISK Mission Components

Tasuku Tanaka
Earth Observation Programmes Department
NASDA

John H. McElroy
Dean of Engineering
University of Texas, Arlington

Environmental Monitoring Objectives

Isaac Revah
Director of Programs
CNES

S. Ichiaque Rasool
Chief Scientist for Global Change
NASA

Social and Economic Development Objectives

Graham Harris
Senior Scientist
CSIRO
Australia

Radford Byerly Jr.
Director
Center for Space and Geosciences Policy
University of Colorado

Global Change Data Objectives

Edryd Shaw
Acting Director General
Radarsat Project
Ministry of Energy and Mines/CCRS

Gregory Withee
Director
National Oceanographic Data Center
NOAA/NESDIS

Global Standards for Observing Systems

Burkhard Pfeiffer
Head, Earth Observation Programs
ESA/ESTEC

Moustafa T. Chahine
Chief Scientist
Jet Propulsion Laboratory

Space Agency Senior Officials

Hubert Curien
University of Paris
France

Schedule

Thursday, April 28

- 2-6:00 p.m. Registration, New England Center
 6-7:30 p.m. Reception and buffet, New England Center and Sise Inn (for guests at those locations)

Friday, April 29

- 8-9:30 a.m. Registration, New England Center
 8-9:30 a.m. Continental breakfast (New England Center and Sise Inn)
 9:30- noon Plenary session, Berkshire Room, New England Center - Presiding: Hubert Curien
 Opening remarks: Harvey Meyerson
 Gordon Haaland
 Keynote address: "ISY and Mission to Planet Earth"
 James C. Fletcher
 Address: "ISY and IGBP"
 Thomas F. Malone
 Introduction of distinguished guests
 noon-1:30 p.m. Luncheon, New England Center Dining Room
 Address: "ISY and the Public"
 Susan Eisenhower
 2-4:30 p.m. Working groups in session (New England Center and Thompson Hall)
 5- 6:30 p.m. Reception with no-host bar
 7:00 p.m. Dinner, New England Center

Saturday, April 30

- 8-9:00 a.m. Continental breakfast (New England Center and Sise Inn)
 9:30-noon Working groups in session
 noon-2:00 p.m. Buffet lunch, New England Center
 2-4:30 p.m. Working groups in session
 6:00 p.m. Shuttle pickup, New England Center and Sise Inn, for New England lobster banquet, The Cliff House restaurant, Ogunquit, Maine

Sunday, May 1

- 9:30-noon Plenary session, Johnson Theatre, University of New Hampshire campus
 Reports of working group chairmen
 Concluding remarks, Hubert Curien
 noon-2:00 p.m. Luncheon, Science Engineering Research Building,
 University of New Hampshire campus

Organization

The conference was organized by the US-ISY Association with support from NASA and hosted by the University of New Hampshire (UNH). It was held at the New England Center on the UNH campus in Durham, New Hampshire, and at other UNH campus locations. Delegates were housed at the New England Center and at the Sise Inn in nearby Portsmouth.

The conference opened with a plenary session. Conference participants then broke up into working groups that met in separate conference rooms. At a concluding plenary session on the third day, working group chairmen presented the recommendations of their working groups.

There were five Earth science working groups and one working group for senior space agency officials with broad management responsibilities. Participation was by invitation and limited to Earth scientists and senior space agency officials in keeping with the character of the working groups. The size of the Earth science working groups was kept to ten or less in order to facilitate decisionmaking during the short time available.

PURPOSE OF THE CONFERENCE

The purpose of the ISY Mission to Planet Earth Conference was twofold:

1. Mission to Planet Earth The International Space Year will consist of coordinated activities carried out during the ISY time frame and coordinated planning for activities extending into the 21st century. Earth observation has emerged as a major (but not exclusive) theme of the ISY. It has particular potential for involving a wide range of participants, from non-launching as well as launching nations, using ground-based as well as space-based measurements. The ISY Mission to Planet Earth Conference permitted development of that theme by Earth scientists. It also allowed consideration of the ISY in the context of Earth science activities planned for the 1990's, including the International Geosphere-Biosphere Programme (IGBP) and the Earth-observing platforms planned by space agencies. Together, those activities could develop into a Mission to Planet Earth that answers a genuine time-critical need amidst growing concern about global threats to the environment, such as the greenhouse effect and ozone depletion.

2. The Role of Space Agencies The ISY was conceived for the purpose of encouraging nations to cooperate in space in

order to meet the unprecedented requirements of space exploration and development. National space activities are directed by space agencies or equivalent national bodies. This conference marked the first time that senior space agency officials with broad management responsibilities met to discuss overall space agency planning for the ISY. During planning for the IGY in the 1950's, space agencies were not involved because they did not yet exist in a meaningful sense. During the intervening three decades, space activities of unprecedented scope and complexity have developed under the aegis of NASA, ESA, IKI, NASDA, ISAS, CNES, ISRO, and other agencies wholly dedicated to space exploration and development. Those agencies have introduced a new dimension for international scientific cooperation. Traditional lines of communication among scientists through international bodies are now complemented by explicit collaboration between governments for the activities of their space agencies. Dramatic examples are the International Halley Mission of 1986 and a solar-terrestrial science program currently being planned. Thus, the agencies with operational responsibility for space missions must play a central role in ISY planning if the ISY is to realize its mission potential. The ISY Mission to Planet Earth Conference initiated that process.

THE CONFERENCE REPORT

Preparation

A preliminary draft of the ISY Mission to Planet Earth Conference report was completed during the conference, under the overall supervision of Dr. Shelby G. Tilford and Dr. Thomas B. McCord. They were assisted by Miss Zeny Cocson; faculty members of the University of New Hampshire assigned to the working groups as rapporteurs (Nancy Defeo, David Skole, Judith Spiller, James Vogelmann, Charles Varosmarty); and the working group co-chairmen. The preliminary draft was expanded and revised by the working group co-chairmen and the report editor. At the US-ISY Association office in Washington, Linda Billings copy edited the manuscript and Stephanie Neyhart corrected its numerous drafts. The report was rushed to completion in time for the first independent meeting of the Space Agency Forum for the ISY (SAFISY), on July 22, 1988, in Espoo, Finland. It is hoped that the report will assist SAFISY, and other interested bodies, in their ISY deliberations.

Executive Summary

The ISY Mission to Planet Earth Conference was highlighted by a declaration of endorsement for the International Space Year by senior officials of 17 national space agencies or equivalent bodies; their agreement to promote the ISY and participate in it; their establishment of a Space Agency Forum on International Space Year (SAFISY) as their coordinating agent; their commitment to make Mission to Planet Earth a major theme of the ISY; and the development of Mission to Planet Earth proposals for consideration by SAFISY.

SAFISY Senior officials of 17 national space agencies or equivalent bodies were founding members of SAFISY. They met in a working group under the chairmanship of Dr. Hubert Curien, who was also the conference chairman. They adopted terms of reference. (See p. 35 for text.) They agreed to meet henceforth at least once a year on a rotating basis among member agencies, and to expand their membership to include other space agencies. Those meetings will complement regular interagency ISY communications. SAFISY members will discuss interagency ISY activities, exchange information on agency programs for the ISY in order to encourage complementarity and compatibility, and review space agency relationships with other bodies involved in ISY activities. In order to consolidate organization and begin defining specific programs, a rapid followup meeting for SAFISY was scheduled for July 22, 1988, at Espoo, Finland, in parallel with the biannual COSPAR meeting.

On the final day of the ISY Mission to Planet Earth Conference, chairmen of the Earth science working groups presented several preliminary proposals to the senior officials working group. The proposals demonstrated clearly the

great potential of Mission to Planet Earth activities for the ISY, in particular their global application and social and economic significance, and led to the endorsement of Mission to Planet Earth as a major (but not exclusive) SAFISY focus. As an initial step, in order to facilitate planning, SAFISY members agreed to send a communication to all space agencies requesting detailed information on the capabilities of all Earth observing systems currently in operation or scheduled during the next decade. (See p. 7 for text of message.) SAFISY members also agreed to establish two advisory panels of Earth science experts to assist in evaluating Mission to Planet Earth proposals - Science and Technology, Education and Applications - and to consider advisory panels for other areas of space activity.

SAFISY members also accepted the following principals, as outlined by the conference chairman in concluding remarks:

- The ISY should be constructed on a solid scientific basis, but it should also engage the widest possible range of beneficiaries of space and science technology.
- The ISY should pay special attention to the needs of developing countries, including the need for technical training; easy and rapid access to data from ISY programs should therefore be an important guideline.
- Educational activities should be a major ISY component. They should draw on the grandeur and inspiration of international cooperation in space and also increase public understanding of space as a new element of cultural development that will have ramifications on all aspects of life.
- SAFISY will not compete with other existing international bodies but will seek fruitful interaction with them, including private sector and other non-governmental organizations.

Mission to Planet Earth A major theme running through all the Earth science working group discussions, and the speeches, was the great opportunity offered by the ISY to initiate a long-term program of Earth observation mission coordination and worldwide data standardization. The increasing number, diversity, and sophistication of space agency Earth observation missions will accelerate during the next few years, highlighted by the recent and planned launching of ERS-1 (ESA), JERS-1 and ADEOS (Japan), TOPEX/Poseidon (U.S.-France), UARS (U.S.), IRS-1 (India), the U.S.S.R. RESOURCE system, Brazil's MECB system, complemented by improvements in existing weather satellite and SPOT and LANDSAT systems, and other activities. Those missions will be followed in the middle and late 1990's by a series of space agency polar platforms of even greater capability and complexity, and subsequently by a number of geostationary platforms. "This augmented capa-

bility," said NASA Administrator Fletcher, "would add up to a Mission to Planet Earth on a scale never before attempted to study any planet." But its success depends on the coordination of its components and the worldwide standardization and accessibility of their output.

The challenge is immense and extremely time-critical. The new fleets of Earth observing spacecraft can provide vital and otherwise inaccessible information on interconnected environmental issues of growing concern to political decisionmakers, such as the greenhouse effect, ozone depletion, and deforestation. On the other hand, as the global standards working group pointed out, "many of the potential benefits of those extremely important (and costly) missions will be lost unless steps are taken to standardize their output and make it available to the world at large." The problem will intensify with the unprecedented flow of information generated by the polar platforms scheduled for the mid-1990's.

The immediate decision by the senior officials group to inventory the capabilities of Earth observing spacecraft scheduled during the next decade, in preparation for specific ISY recommendations, reflected that sense of urgency. The inventory was recommended by the mission components working group and implemented by the senior officials group - not only to determine complementarities but also to discover gaps in coverage (and thus in needed information) that might be corrected. In a similar time-sensitive vein, the global change data objectives group recommended that agreement be sought from space agencies to carry instruments that measure pollution-causing atmospheric gases on their spacecraft at every opportunity.

There was a general agreement among the working groups that the ISY effort to strengthen coordination and standardization should emphasize global issues, as mentioned, and also regional initiatives of particular relevance to developing nations, such as crop management and technical training. The conference delegates further agreed that the best mechanisms for achieving their objectives were sharply-focused pilot projects that set standards for worldwide application. To that end, they accepted the concept of a Global Information System Test (GIST) and applied it to specific issues of immediate concern.

The GIST concept, as described by the global change data objectives group, would involve demonstration projects "limited in scope but truly end-to-end tests of the conversion of data to useful information." GIST activities would include developing globally accessible formats for data collected by national systems as well as combining data from several sources in order to produce information not available otherwise. GISTs would be interdisciplinary and international. "The experience gained in (these projects) would be of inestimable value in the development of the much more ambitious plans for the data and information systems associated with the polar platforms," the global standards group concluded.

A number of specific GIST proposals were presented. Two of them, originating in the environmental monitoring objectives group, were given priority. Both would establish globally applicable procedures for collecting and disseminating information while providing valuable new information on important environmental problems:

- **Greenhouse Effect Detection Project** This project would involve collecting and integrating data on temperature, pressure, wind velocity, and humidity near the surface and in the atmosphere and comparing it against other indicators of global change, such as rainfall patterns, oceanic cloud cover, permafrost, lake levels, etc.
- **Deforestation Pilot Study** This project would test the hypothesis that deforestation leads to desertification by using a combination of satellite and ground based data for Brazil and Africa.

The other promising GIST projects, in connection with the Tropical Ocean and Global Atmosphere Program (TOGA) and for measuring fields of ocean chlorophyll, presented by the global change objectives and global standards working groups, also received special attention.

The social and economic development objectives group, with strong support from the senior officials group, emphasized the importance of ISY Earth observation initiatives extending beyond research to include immediate and direct applications for social and economic development. The group stated: "The key is to be aware of the ultimate social and economic applications from the beginning...When end to end information systems are designed, the final terminals must not be in research laboratories. The flow of information must extend to the users in the general community, and it must be in a form they can use." In that context, the group joined its counterparts in recommending ISY pilot projects as a "most practical means of initially directing space assets toward social and economic development projects." Specific recommendations included:

- A multi-disciplinary atlas of Africa, integrating remote sensing information and other information useful for social and economic development.
- A global land use map for land management and policy development, showing precisely for what purposes all the land on the globe is used.
- A series of information projects designed to educate the public on the impact of global change.
- A directory of remote sensing activities and information sources for distribution and use in conjunction with the ISY, that would be expanded and updated in ensuing years.

Proposals for directories also came from the global change and mission components working groups. The global change group called for an ISY global change directory of

satellite and *in situ* data that could be accessed through a digital network. The mission components group proposed using the ISY to initiate an *Encyclopedia of the Earth*, consisting of remote sensing and applications data "collected systematically as part of the ISY" that would "provide a priceless baseline for future global change studies." The mission components group also proposed that the Earth encyclopedia be assembled so that information could be extracted from it for specialized studies in social and economic development and other objectives

In sum, the Mission to Planet Earth Conference accomplished a great deal in the 2 1/2 days it met. Seventeen

national space agencies or equivalent bodies endorsed the ISY and set up a mechanism for coordinating their participation. Terms of reference were drafted and adopted. Mission to Planet Earth was selected as a major ISY theme. A number of specific Mission to Planet Earth proposals were developed by specialized working groups. An ISY planning inquiry was telegraphed to all space agencies. A followup meeting was scheduled for within less than three months.

SAFISY REQUEST TO ALL AGENCIES OPERATING OR PLANNING TO OPERATE SPACE SYSTEMS OBSERVING THE EARTH AND SOLAR-TERRESTRIAL ENVIRONMENT

- **OBJECTIVE OF REQUEST:** To characterize for the scientific community the observational resources available for the ten-year period 1988-1998.
 - **SPACECRAFT AND GROUND STATION PARAMETERS NEEDED:**
 - Spacecraft Name
 - Expected or Actual Launch Date
 - Expected Lifetime
 - Orbit
 - On-board Recording Capability
 - Status: In-orbit, funded, or planned
 - Ground Station Locations and coverage
 - Spacecraft Transmission Frequencies and Data Rates per Frequency
 - **INSTRUMENT LIST AND PARAMETERS NEEDED:**
 - Name and Acronym
 - Spectral Coverage and Bands
 - IFOV in Each Band
 - Swath Width and Off-Nadir Coverage
 - Scanning Method: Mechanical or Electronic
 - Stereoscopic Coverage If Any
 - Data Rate (Average and Peak) per Instrument per Frequency
 - On-board Recording Capability per Instrument
 - Active or Passive
 - Primary and Secondary Scientific Measurement Objectives
 - Instrument Precision
 - **DATA AVAILABILITY AND ACCESS**
 - Real Time or Off Line
 - Any other Restrictions or Relevant Policies
 - **IDENTIFICATION OF POINTS OF CONTACT FOR CLARIFICATION OF INPUTS**
-

I. SPACE-BASED ISY MISSION COMPONENTS

Introduction

The working group focused its attention on the following areas:

- A review of information provided by ESA and NASDA of current and planned worldwide Earth observation systems;
- A means to develop an organized database of the parameters of those systems;
- An initial examination of the resources available at the beginning of the ISY time frame;
- The scientific areas that those initial resources may serve;
- The obviously absent capabilities that would extend the value of space-based Earth observations.

An Earth Observation Capabilities Database

Earth observation from space offers numerous opportunities for new scientific insights and for extending present applications with precision and to areas of the world that are currently underserved. Those opportunities rely upon present systems and future plans of spacefaring nations.

Descriptions of present, planned, and proposed systems are frequently published, but no organized database of the pertinent system and instrument parameters has been developed for the scientific and applications user community. Further, because no such database exists, users also have no means to be informed in a systematic manner of changes to system parameters.

It is therefore *recommended* that the spacefaring nations of the world that have or plan to deploy Earth observation systems provide the information for such a database for the ten-year period from 1988-1998.

The Earth Observing System in 1992

The information requested for the 1988-1998 period is obviously important for the overall objectives of the Global Change and ISY-proposed efforts. It is also important, however, to examine what can be done with space assets already in orbit that will continue to operate until the beginning of the ISY or that will be launched between now and then. While these assets will not be capable of measuring all desired parameters, they still represent a powerful resource that can be of great service to mankind if their data can be used both effectively and widely.

It is appropriate to recall the report of the Pacific ISY Conference held in Hawaii in 1987. In that report, it is observed (page 9 of conference report) that:

"... several factors unique to Earth observations and the ISY were identified:

Remote sensing satellites provide a unique perspective of the Earth, and data from their sensors can be used to derive information beneficial to the management of Earth resources for all mankind. Several sensors will be on orbit by the year 1992, and so data from these spacecraft could form important components of the ISY."

It is in keeping with that observation that the information shown on the next page was assembled. The left-hand column lists some of the scientific areas that might be addressed in a comprehensive study of Global Change and the objectives of ISY. The right-hand column is a list of the spacecraft or Space Shuttle payloads that will carry instruments addressing these areas:

SATELLITE-ACQUIRED DATA SETS AVAILABLE DURING THE ISY TIME FRAME

PARAMETER	SPACECRAFT SENSORS
• SOLAR CONSTANT	• UARS, Solar-A, Atlas-2
• SOLAR SPECTRAL IRRADIANCE	• UARS, Solar-A, Atlas-
• MAGNETIC/ELECTRIC FIELD STRUCTURE	• UARS, GOES, METEOSAT, GEOTAIL
• PARTIAL INPUTS TO ATMOSPHERE	• UARS, GOES, METEOSAT, GEOTAIL, GMS
• THERMOSPHERE WINDS	• UARS
• STRATOSPHERE/MESOSPHERE WINDS	• UARS
• STRATOSPHERE/MESOSPHERE COMPOSITION	• UARS, TIROS, Atlas-2
• STRATOSPHERE/MESOSPHERE TEMPERATURE	• UARS, TIROS
• TROPOSPHERIC TEMPERATURES	• TIROS, GOES, DMSP, ERS-1, TOPEX/Poseidon
• CLOUD IMAGES, TEMPERATURE, TYPE, MOTION, COVER	• TIROS, GOES, METEOSAT, GMS, INSAT, GOMS, Meteor
• AEROSOLS, HAZES	• TIROS, SeaWIFS
• SEA ICE FRACTION, TYPE, MOTION EDGE	• ERS-1, JERS-1, TIROS, DMSP TOPEX/Poseidon
• OCEAN COLOR	• LANDSAT-6
• SNOW COVER	• TIROS, GOES, GMS, METEOSAT, GOMS, INSAT, LANDSAT, MOS-1
• WETLAND EXTENT	• SIR-C, ERS-1, JERS-1, LANDSAT-6, SPOT
• VEGETATION, CLASSIFICATION, INDEX, SEASONAL CHANGES	• TIROS, SPOT, LANDSAT, MOS, JERS-1, IRS, COSMOS
• SURFACE MINERAL CLASSIFICATION	• SPOT, LANDSAT, JERS-1
• SURFACE TEMPERATURE	• TIROS, MOS, ERS-1, GOES, GMS
• SEA SURFACE WINDS, STATE, TOPOGRAPHY	• ERS-1, TOPEX/Poseidon
• OCEAN CIRCULATION	• ERS-1, TOPEX/Poseidon, SeaWIFS, TIROS
• LAND TOPOGRAPHY	• SPOT, SIR-C, JERS-1
• VOLCANOLOGY	• TIROS, GOES, GMS, GOMS, METEOSAT, INSAT, SPOT, LANDSAT
• CRUSTAL DYNAMICS	• LAGEOS, LAGEOS-II, TOPEX/ Poseidon, ERS-1, EGP

The obvious conclusion is that a rich and varied set of space-derived data will exist that can be of great value to research and applications. Whether it is available for effective use involves issues addressed at the Hawaii ISY meeting and by the other working groups of the New Hampshire ISY meeting, such as scientific understanding, data calibration, data availability, and the ability of the global user community to employ the information.

If the nations of the world are to effectively use this data set, a number of well-organized preparatory actions must be taken. This leads to the working group's *second recommendation*, that the Space Agency Forum on International Space Year (SAFISY) assign priority to planning and executing the actions needed to permit the widest possible utilization of the data by all nations.

A *third recommendation* also flows from this data set. Although geographically separated, it nevertheless forms a worldwide "encyclopedia" of Earth science and applications data, which if collected systematically as part of the ISY activities can provide a priceless baseline for future Global Change studies. Further, subsets of the total data set can be assembled for use in support of specialized studies and in educational, economic development, and societal advancement objectives. It is therefore recommended that the SAFISY assign to such working groups or panels that it may form the task of defining this "encyclopedia" and the means for its widest possible utilization.

Omissions from the Initial ISY Data

Although the initial set is rich and unparalleled in the Earth sciences and applications, there are evident missing capabilities that deserve attention for future space observational systems. The following list includes:

Parameters Not Covered by Current or Planned Observations

- Radiation budget
- Stratosphere/mesosphere composition (HO_x, HCL, total ozone, etc.)
- CO
- Tropospheric temperature 1-deg C., 1-km vertical resolution
- Tropospheric winds
- Precipitation
- Cloud liquid water and ice content
- Boundary layer height
- Aerosol profiles
- Phytoplankton groups
- Snow properties
- Lake biology
- Plant physiology
- Full surface spectra
- Soil and mineral identification
- Surface soil moisture
- Mesoscale geodynamics
- Solid Earth gravity field

This leads to the **fourth recommendation**, that the SAFISY task its subordinate panels with studying the feasibility of adding these capabilities to the initial observational capability.

Summary of Working Group Recommendations

The SAFISY should:

- Request that the spacefaring nations of the world provide comprehensive and timely data on their existing and planned Earth observational systems for the period 1988-1998, and provide for its periodic updating;
- Assign to its working groups and panels the task of developing a plan for the timely use of the Earth observations data collected during the ISY to all nations;
- Assign to its working groups and panels the task of defining a "global encyclopedia" of the data collected during the ISY period. The "encyclopedia" may be geographically distributed, but it should in any case be "indexed" in accordance with the Data Systems Working Group recommendation below. Consideration should be given to bringing together subsets of the total data in documents, electronically recorded media, or other forms for wide spread dissemination;
- Assign to its working groups and panels the task of examining the omissions from the basic ISY data set and determining the feasibility (both technologically and economically) of adding those capabilities to later missions.

II. ENVIRONMENTAL MONITORING OBJECTIVES

Introduction

A new and important objective of Earth Sciences is to obtain sufficient understanding of the causes and future course of global change so that it can be predicted and managed for the benefit of humanity. The task is immensely complex -- it may be the most challenging scientific initiative of the next 50 to 100 years. It is thus appropriate for the ISY to focus on a Mission to Planet Earth -- including extensive space-based and surface observations, careful analysis and verification of data, and the development of innovative models for assimilating data and placing them in a meaningful context.

The ISY is timed perfectly for initiation of a global commitment to such a Mission to Planet Earth. In 1992, the space agencies of the world will have in orbit, or under active preparation, an unprecedented number and variety of Earth science missions. Meanwhile, the international scientific community will be in the process of launching its most comprehensive activity ever - the International Geosphere-Biosphere Programme (IGBP), dedicated to the prediction and management of global change, which will extend into the 21st century. The ISY can unify the efforts of the IGBP just as they are taking shape and thus initiate a Mission to Planet Earth that would directly address global issues of immediate concern such as ozone depletion, the greenhouse effect, deforestation, and desertification. Careful and rigorous environmental monitoring is the key to detecting and understanding the evolution of planet Earth and the environmental changes and hazards yet to come. The IGBP can achieve its objectives of understanding global change only if the many disparate activities are coordinated worldwide. Thus the ISY can contribute significantly through:

- the initiation of prototype projects that establish standards and organizational mechanisms for eventual worldwide application; and
- through the development of long-term data sets, beginning with the organization of data accumulated through the last two decades, so that it can be applied in a focused manner to the problem of global change.

Scientific and Technological Challenges

Greenhouse and deforestation pilot projects, and a related data organization project, are proposed. Together, they will bring us much closer to diagnosing two major environmental problems. The first project will be to detect and verify, with environmental data taken from satellites and on the ground, the global and regional changes that have been predicted as a consequence of the intensified greenhouse effect of carbon dioxide and other gases being added to the atmosphere. The second prototype project will be to study, again using actual satellite and ground data, the climatic impacts of large-scale

deforestation in the tropics. Is the decreasing forest cover accelerating the process of desertification as many scientists have predicted? Can these predictions be checked by documenting the exact change?

Both these projects will require a third -- the assemblage and coherent organization of existing data from satellites of different nations and from surface observations around the globe that will make an excellent ISY project in its own right.

Together these three projects, two scientific and one technological, are the centerpieces of environmental monitoring activities we are recommending for ISY.

Greenhouse Effect Detection Project

An essential global experiment is to determine whether we can detect unambiguously the enduring effects of increasing greenhouse gases on the climatic regimes of the earth. The immediate task will be to ascertain changes in global and regional averages and compare with model predictions.

This task will require creating global data sets of temperature, pressure, wind velocity and humidity both near the surface and in the atmosphere. Any long-term trends thus established should be compared and checked against other indicators of global change. These include the changing rainfall patterns and their impact on the ecosystem, the changing oceanic cloud cover because of increasing sea surface temperatures, the heating of the poles and its manifestation on permafrost and on snow lines in the northern hemisphere, on the lake levels in the Antarctic and on the global sea ice volume. It had also been predicted that increased greenhouse effects should affect the intensity of spring-bloom in the North Atlantic and the stratospheric temperatures over the poles, and cause increased inundation of the coastal areas.

It is by studying these diverse signals that we will be able to determine whether a long term global change is really underway and if so whether an increased greenhouse effect is the cause.

Deforestation Pilot Study

Regional experiments to check on the hypothesis that deforestation leads to desertification are now feasible by using a combination of multi-satellite and ground based data over Brazil and Africa. Such experiments will involve measurements over large areas (1000 x 1000 km) from satellites, aircraft and surface networks, assimilation of the data into models and checks of model prediction by observations. Several such experiments are currently being planned by a

number of countries, including Brazil, China, France, FRG, and USA. The ISY initiative should single out one or two of those projects and make available to the scientists of developing countries, in a coordinated manner, necessary space observations required for such studies. These will include images and data from SPOT, LANDSAT, GOES, and METEOSAT, which already exist, and from those satellites which will be operational in 1992.

Global Data Set Production Project

Trends in global change can be determined only by collection of data over long periods. For greenhouse and deforestation trends, the determination process can be accelerated considerably by organizing data collected during the past two decades but not yet applied in a focused manner to those problems. It is recommended, therefore, that an effort be initiated for that purpose. Such reference data sets should include: vegetation state, extent and type, ocean and land surface temperatures, moisture at the surface and in the atmosphere, sea level, ice and snow cover, stratospheric characteristics, and ocean color.

A key variable which remains elusive to satellite technology is the rate and frequency of precipitation over the ocean. A new space mission to fill this gap in 1992 would be an excellent ISY project.

Conclusion

Success in meeting the three challenges outlined above would constitute a major contribution to the attempt to understand and manage global change. Pilot greenhouse and deforestation projects, complemented by a reference data set project, would provide government leaders with the information necessary to make decisions that will be vital to the future of all forms of life on planet Earth. We recommend that they be undertaken with vigor and resolve.

III. SOCIAL AND ECONOMIC DEVELOPMENT OBJECTIVES

Introduction

Earth observation from space has opened a new dimension for Earth science research. Already, the results have revolutionized the study of global change. Spaceborne sensors have provided Earth scientists with data that are essential for diagnosing long-term environmental problems.

However, Earth observation from space also has many immediate and direct applications for social and economic development, provided that space-generated data are translated into information that is relevant to social and economic concerns. The key is to be aware of the ultimate social and economic applications from the beginning. When end-to-end information systems are designed, the final terminals must not be in research laboratories. The flow of information must extend to users in the general community, and it must be in a form they can use.

Comments Related to Potential ISY Activities

Remotely sensed data, when applied at global, regional, and national levels, can be the basis for important information not only for scientific understanding but also for better economic and social development of the world's people. Economic and social application of remote sensing data and information can and must proceed before our scientific understanding is perfected. Humankind is now a major influence on the planetary environment and resources. These points should be recognized by the ISY program and by any Earth observation system.

The achievement of sustainable development is now an accepted goal for the world community; space derived data should play an important role in reaching this goal. Sustainable development, which is concerned with the maintenance of renewable natural resources yields while conserving the natural resource base, has important environmental, economic, and social implications. Consequently, it must be a factor in the planning and execution of the International Space Year, the Mission to Planet Earth, and the International Geosphere-Biosphere Programme. Thus it should be taken into account in the design of appropriate satellite sensors and systems for International Space Year activities and, most importantly, should push the development of end-to-end information systems as discussed below.

To be most useful, remotely sensed data must be considered in relation to other data, particularly social and economic data. It follows that there is an urgent need for the involvement of the applied social sciences (i.e., economists, sociologists, demographers, development planners) in the planning process of the International Space Year.

It is necessary to put information derived from remotely sensed data into forms that are readily understood by people

worldwide. This will involve different forms for policymakers (e.g., planners); specific users (e.g., fishermen's cooperatives); and the public (taxpayers, voters). For example, all these classes of users need to be able to understand how their local actions can effect other regions and vice versa. Also, it must be demonstrated clearly that space data enhance and complement traditional ground data systems.

We must begin now to train future decision makers and planners to think in terms of global systems. It is important that consideration be given to transforming space-derived information into forms suitable for inclusion in education programs. It is important to recognize and encourage the use of space technology in education and for education.

Additionally, specialized training in remote sensing technologies within the work force is needed to develop the unique skills required to merge remotely sensed and conventional information.

The working group felt that in general its priorities and recommendations are consistent with but go beyond both the Global Information System Test proposed in other working groups and similar scientific projects.

Priorities for action ought to be considered at global, regional and local levels. Possible areas include:

- Modifying the impacts of potential climate changes, e.g., sea level rise, changes in rainfall regimes.
- Measuring the depletion of stratospheric ozone. These measurements should be linked to a global study of potential hazards to human health, to other organisms, and to ecosystems.
- Land degradation including desertification and deforestation has been designated by many authorities (e.g. World Commission on Environment and Development, African Ministers Environment Conference) as being perhaps the major environmental problem facing the world in general and developing countries in particular. Better understanding of land degradation through regional or local studies would be a useful ISY outcome.
- Food security, including knowledge of supply, improvement of crop forecasts, and a better prediction of drought conditions is now a worldwide problem.
Information derived from the study of the global hydrological cycle can be applied usefully in this area.
- A global land-use survey with a baseline of 1991 is essential in view of rapidly growing world population and the growing pressure of that population on various ecological zones.
- Monitoring and measurement of sea state, sea surface

temperatures, and ocean production (ocean color) with a view to the wise use and management of renewable and non-renewable marine resources. Basin scale studies of physical and biological processes will contribute greatly to the management of resources in regional seas.

Recommended ISY Projects

Pilot projects offer a most practical means of initially directing space assets toward social and economic development objectives, and the ISY is an excellent vehicle for such projects.

- Develop a register of data bases and activities related to remote sensing that can be consulted by users, focussing initially on a selected theme. The objective would be to develop a product for distribution and use in conjunction with the ISY. This effort would eventually be updated and grow.
- Develop specific information products which demonstrate the impact of global change to the general public. They would include presentations showing the impact of humankind's activities on the environment (e.g. changes in global ice and forests) and presentations showing the environment affecting humankind (e.g. the social and economic effects of El Nino).
- Establish a centralized source for collecting and distributing information and guidelines for applications of space remote sensing technology as a teaching tool. Numerous applications have developed locally that might be applied internationally.
- Specific information mapping projects, such as:
 - (a) A multidisciplinary geographic-information-system atlas of Africa. This would include remote-sensing data and data from other sources including economic and social data. It would be developed for interactive use on personal computers perhaps using CD-ROM technology. The project should solicit feedback from users, and this feedback phase might occur during the ISY, in order to illustrate the benefits of such a space-derived atlas.
 - (b) A Pacific Basin ocean color map for use in managing fisheries, etc.
 - (c) A global land use map (perhaps by region) for use in land use management and policy development. A Domesday Book of the world.
 - (d) A working map of Pacific Rim vulcanism with provision for updating and for the generation of reports of impacts and, where possible, warnings.
 - (e) GIS-type products for use in schools. This might involve mass production of CD-ROM data bases or the provision of TV images through telecommunication networks. This would emphasize the combination of remote-sensing and other data.
 - (f) Specific projects in third world countries demon-

strating the delivery of information (originating in part from remotely sensed data) to ultimate end-users. Such end-users could be field offices, village elders, co-ops, etc. There should be an attempt to determine the cost-benefit ratio of such projects.

Costs and Benefits of Satellite Remote Sensing: Potential ISY Activity

Widespread application of satellite remote sensing technology depends upon making decisionmakers aware of its value. To that end, a project could be initiated to take 5-10 real case examples covering different uses of satellite-derived information in economic development in 20-25 randomly selected countries, between 1986-1991, and to document the social, economic, and possibly political benefits. The costs would be known, or collected and compared to the benefits. This would provide a clear comparison of costs and benefits of a representative set of large development activities. The results would be broadly disseminated during the ISY.

Conclusion

Remotely sensed data has the potential for contributing in a major way to the solution of many social and economic problems around the globe. For this potential to be realized fully, the data must be transformed into useful information and the appropriate people -- managers, officers, *et al* -- must be persuaded to use it.

Therefore, it is vital that end-to-end systems tests, and the permanent activities that grow out of them, have social and economic development as well as scientific objectives and that social scientists (economists, sociologists, demographers, planners, *et al*) join physical scientists in planning such activities. The ISY offers an excellent opportunity for developing that vital synthesis by means of projects such as those outlined above.

IV. GLOBAL CHANGE DATA OBJECTIVES

Introduction

The working group recommended that:

- A Global Information System Test be conducted, culminating in an assessment of global change parameters provided by the system in 1992;
- A global change directory of satellite and *in situ* data be compiled that can be accessed through a digital network, which will also be useful for the Information System Test, and as a general purpose E-mail system;
- An international agreement be sought from space agencies to carry instruments that measure atmospheric gases on spacecraft at every opportunity.

Global Information System Test

The report of the Earth Observation Panel in the report of the Pacific ISY Conference states: "Considerable work needs to be done in the coordination of collection, calibrations and distributions of Earth observations." We strongly agree and, to that end, we recommend a Global Information System Test (GIST) described below.

Earth observations from satellites will form a central part of programs relating to global change. In order for these programs to meet their objectives, the collected data (observations) upon which they depend must be translated into the information which is required for decisionmaking. The working group's primary concern is with the "end-to-end" management of these data handling processes. In particular, the panel was struck with the importance of the processes by which the original data (observations), from several sources, are combined to reveal useful information. The working group stresses that global change science objectives should drive information requirements, the information requirements should drive data processing, and so on, back to the design of the satellite sensor itself.

The working group endorses the efforts of the CEOS Working Group on Data. It also recognizes that one of the prerequisites for broad scientific application cooperation worldwide is that it is necessary that standardization of products is achieved not only in data format but also in terms of geophysical measurement algorithms and quality control procedures.

The working group recognizes the difficulties in translating the scientific objectives for global change monitoring into the requirements for data system management. These difficulties are related to:

- The *interdisciplinary* nature of the program;
- The *integration* of data sets;
- The *international* nature of this program – the requirements are for *global* data.

These three conditions require that a global change data handling system be tied to many agencies, scientific disciplines, and countries. The working group notes the great size of the undertaking, but looks to further ISY reviews to help define, test, execute, and evaluate the end-to-end data system.

The working group recommends that the focus be on projects which:

- Affect the public,
- Are international in scope,
- Involve more than one discipline, and
- Are doable/tractable.

Global Change Directory and Network

A directory of global change data sources would expedite the location of useful data for scientific research. Such a directory would contain a brief description of data sets, like a card catalog in a library. Information contained would include the data set name, source (i.e. satellite/sensor/program), archive location, author or science investigator, duration and geographic coverage, and other descriptive information. The directory would be in the form of an on-line computer data base that would accommodate rapid searches. Periodically, the directory would also be published in digital form for general distribution (e.g., on CD-ROM optical disk). The directory would contain those data sets of interest to global change and which are well documented and available through agency archives, but would not contain pricing information. The directory information would be exchanged internationally in common format so that each agency could maintain the common directory within its own catalog environment. An independent ISY-designated group would define the data sets which should be included in the directory, and ongoing efforts within the agencies would implement the directory.

The on-line directory should be acceptable and demonstrable over an electronic network. Such a network would serve a number of functions such as: (1) providing electronic mail services as a means for better ISY communications between space agencies, data centers, and relevant institutions and laboratories; (2) correcting the agencies' directories and providing user access to those directories in order to demonstrate and utilize their capabilities; (3) conducting portions of the Global Information System Test over the network where appropriate. Implementation of the network should take advantage of existing networks, should be low bandwidth at first but with high connectivity, and should be used to transmit high information content data. It should use international protocols and standards as they become available through such bodies as the International Standards Organization.

Global Information System Test

For NASA, 1992 will be a critical period in the development of the Earth Observing System to be launched aboard the polar platforms later in the 1990's as the centerpiece of an evolving international Earth system observing program. The TOPEX/Poseidon and Upper Atmosphere Research Satellite (UARS) should be ready for launch as a major contribution to the study of ocean dynamics and the ozone layer. The European Space Agency Earth Resources Satellite (ERS-1) and possibly the Japanese JERS-1 should be beginning to make major contributions to the study of the earth, in addition to the meteorological, land and ocean systems in various countries which are already in place and expected to continue.

The benefits of that already planned activity in space would be greatly enhanced if the International Space Year were dedicated to the Global Information System Test, that would make selected nationally available data streams truly accessible to scientists worldwide, and complete in-depth evaluations of the information content of the routinely available analyses and data products, including intercomparisons with *in situ* measurements and other satellite instruments. The experience gained in such a pilot program would be of inestimable value in the development of the much more ambitious plans for the data and information system associated with the Polar Platforms.

Demonstration projects for data access and evaluation should be carefully chosen for their probable utility to a broad group of international scientific users, and preferably in the context of established research projects expected to be then underway, such as Tropical Oceans Global Atmosphere Program (TOGA). They should be limited in scope but truly end-to-end tests of the conversion of data to useful information. They should draw upon developments in networking and electronic communications worldwide, starting in development mode but where appropriate building to near real time processing and distribution. Consideration should also be given to new techniques of digital publishing such as CD-ROM, and to providing proper attribution in scientific literature to creative contributions in the preparation and evaluation of data sets and derived information. It is important to establish patterns of interaction between the research community and data management and instrument professionals that develop the full potential of the entire ongoing observing system, both space and *in situ*.

The environment of the proposed GIST is shown in Figure 1 (see section V). A possible broad categorization of activities for the GIST itself would be:

- Data collection and distribution;
- Assembly, quality control, and analysis; and
- Independent validation and calibration.

The specifics in each category would vary greatly between the different foci.

Elements of the end-to-end system which can be tested include:

- Calibration (instrument physical input versus digital output, traceability of standards);
- Validation (instrument input versus quantity to be analyzed);
- Reduction algorithm (including ancillary data) coverage;
- Sampling (space and time);
- Quantity control and data acceptance criteria;
- Analysis algorithms and assimilation models;
- Independent measurements; and
- Documentation and access to information.

Possible candidates from which a short list of demonstration projects should be selected include:

- In the context of the TOGA program, fields of surface wind, sea level, sea surface temperature, surface solar radiation, cloudiness, atmospheric water vapor, and indices of precipitation

ERS-1 will feature a scatterometer and an altimeter for estimating surface wind stress and changes in sea level respectively, which should be compared with ongoing *in situ* surface wind and subsurface temperature measurements. TOPEX/Poseidon will feature more precise measurements of sea level. Improvements in cloud drift winds from geostationary satellites would also be very significant in this context. There have already been inter-comparisons of U.S. based techniques for satellite derived estimates of sea surface temperature, but much better documentation and validation is needed of their use in practice. The Along Track Scanning Radiometer (ATSR) aboard ERS-1 will provide a unique opportunity both to get better estimates of sea surface temperature and to validate the interpretations being placed on the ISCCP data on global cloudiness. Microwave radiometers aboard MOS and METEOSAT could provide the first synoptic global analyses of atmospheric water vapor, but only if we learn how to integrate this information effectively into assimilation models. Microwave and infrared indices of precipitation are currently being assembled under the World Precipitation Climatology Project, but still need to be put in the context of estimates of surface evaporation and atmospheric moisture.

- In the context of the proposed IGBP Joint Global Ocean Flux Study, fields of ocean chlorophyll.

In 1992 both MOS and LANDSAT-6 are expected to be flying instruments to measure ocean color, from which can be derived the distribution of chlorophyll in the surface layers. Knowledge of this distribution is a high priority requirement for the proposed international studies of nutrient cycling in the euphotic zone and transfer through the thermocline beneath. Effective mechanisms need to be established for making the data accessible to scientists in a timely manner and evaluating the relationships

between the satellite imagery and more extensive *in situ* sampling, both of biological variables and of the physical structure of eddies.

Agreement to Measure Atmospheric Gases

Agreement would be sought from national space agencies to carry instruments that measure atmospheric gases (CO₂, CH₄, N₂O, CFC, halons, CC1₄, and O₃), on the polar platforms and satellites whenever feasible. Data from these instruments would be calibrated internationally and made freely available to all interested parties.

V. GLOBAL STANDARDS FOR OBSERVING SYSTEMS

GLOBAL INFORMATION SYSTEM TEST (GIST)

Introduction

The year 1992 will occur in the midst of an extraordinary surge of Earth observation activity among spacefaring nations. For NASA, 1992 will be a critical time in the development of the Earth Observing System to be launched aboard polar platforms later in the 1990's as the centerpiece of an evolving international Earth System Observing Program. The TOPEX/Poseidon and Upper Atmosphere Research Satellite (UARS) should be ready for launch as a major contribution to the study of ocean dynamics and the ozone layer. Internationally, both the European Space Agency's Earth Resources Satellite (ERS-1) and possibly the Japanese JERS-1 should be starting to make major contributions to the study of the earth. In addition, various countries which already have satellites in place are expected to continue their meteorological, land, and ocean observations.

Many of the potential benefits of those extremely important (and costly) missions will be lost, however, unless steps are taken to standardize their output and make it available to the world at large. A critical first step, which could be a centerpiece of the ISY, would be a Global Information System Test, a so-called "end-to-end data system test," in which selected satellite data streams and *in situ* ground measurements would be organized, analyzed, and distributed in a manner opening them up to truly global usage. The experience gained in such a pilot program would be of inestimable value in the development of the much more ambitious plans for the data and information system associated with polar platforms.

Demonstration projects for data access and evaluation should be carefully chosen for their probable utility to a broad group of international scientific users, and preferably in the context of established research projects expected to be then underway, such as the detection of the greenhouse effect on climate and the Tropical Oceans Global Atmosphere Program (TOGA). They should be limited in scope, but truly end-to-end tests of the conversion of data to useful information. They should draw upon developments in networking and electronic communications worldwide, starting in the development mode but, where appropriate, building to near-real-time processing and distribution. Consideration should also be given to new techniques of digital publishing such as CD-ROM, and to providing proper attribution in scientific literature to creative contributions in the preparation and evaluation of data sets and derived information. However, most important is to establish patterns of interaction between the research community and data management and instrument professionals that develop the full potential of the entire ongoing observing system, both space-based and *in situ*.

GLOBAL STANDARDS FOR OBSERVING SYSTEMS

Documenting changes in our global environment requires sustained long-term measurements of established accuracy. The adequacy of present activities will be tested two or more decades from now by our successors as they attempt to decide whether these intervening apparent changes are real or an artifact of the way the measurements were taken. Establishing the accuracy of analyzed measurement products requires both *in situ* measurements from many different countries and oceans, and intercomparisons between satellite sensing systems. Many activities are already underway addressing aspects of these requirements.

A mechanism must be established to:

- Ensure the long-term accuracy of required global measurements;
- Facilitate exchange of data and data products between participating agencies/countries; and
- Coordinate the work of existing groups.

The accuracy of a global measurement depends on the following elements that lead to the analyzed product on a global scale:

• *Geophysical Parameters*

A clear difficulty has existed in relating e.m. quantities observed from space platforms to the actual geophysical parameter of interest. As a particular example, we cite the vegetation index derived from space sensors and its interpretation in terms of the specific nature of the vegetation which exists at the surface. Does the index relate to the mass of vegetation per square meter or to the density of forest canopy cover independent of the cover on the forest floor? Or is it too dependent upon seasonal variability (e.g., soil moisture and associated vegetation stress) or vegetation type to be useful as a direct monitor of vegetation? The scientific community needs to standardize definitions of how the geophysical parameter to be monitored may be measured or estimated from space. These definitions should not be instrument specific, but defined in terms of radiometric or electromagnetic variables. Such procedures are essential if we are to incorporate properly the *in situ* gathered information.

• *Sampling in Time and Space*

Addressing the requirements for temporal and spatial sampling of a geophysical parameter depends upon the characteristic lifetime and physical dimension of the phe-

nomenon or process involving the parameter. For example, adequate sampling of a minor constituent in the atmosphere whose lifetime is known to be years in length and which is uniformly mixed can be achieved by a very small number of sampling stations making monthly averaged measurements. If the constituent varies seasonally, the sampling frequency might be increased to weekly. On the other hand, if cloudiness is to be determined, measurements must be made globally with high spatial resolution and perhaps many times a day because of the transient nature and large variability of cloudiness.

For long-term, ongoing studies, low resolution observations might be quite adequate. However, special intensive, high resolution, high frequency measurements might be required from time to time to understand or model certain aspects of the behavior of a parameter. This intensive observation may be necessary to satisfy special requirements.

The sampling requirements for most significant geophysical parameters have been established over the years by individuals and teams studying the particular parameter/phenomenon/process in question. However, it would be very useful if these requirements were standardized in connection with the ISY, especially in the case of space-derived remote sensing data.

• *Data Format*

The crucial element in global standards is the development of common data formats applicable to remote sensing data as well as all additionally collected *in situ* and ancillary data. This request is based on the need to:

- exchange data between international teams of investigators;
- integrate remote sensing data in models of the ecosphere, the hydrological cycle, the global carbon cycle, etc.;
- integrate data collected at different scales in time and space; and
- be able to reinvestigate data collected at earlier times.

A common standard format(s) is essential for use in archiving space-derived and ancillary data sets. This will facilitate the free exchange and utilization of all geophysical data which is needed to study global change.

• *Algorithm Documentation*

Transforming raw satellite observations into analyzed fields of geophysical parameters is quite a complex procedure rarely satisfactorily described by instrument designers and/or agencies. From raw observations to analyzed fields, three major algorithmic steps may be identified:

- Conversion of raw data (for example, counting voltages, etc.) and housekeeping information into properly calibrated

and Earth-located observations. This step includes laboratory-derived information on the instrument;

- Conversion of calibrated/earth-located data into non-analyzed geophysical parameters through a "retrieval" procedure; and
- Re-imaging the data into a regular grid.

Having obvious impact on the quality of the final analyzed fields, each of these three steps must be completely documented. To that purpose, we recommend that all necessary information be reported in a "User's Guide" divided into three parts, each corresponding to one of the items above. The last major role of such a User's Guide should be to present an accurate and complete description of the instrument. It should be immediately updated after any modification of the procedure.

• *In Situ and Other Ancillary Data*

Remote sensing data sets need to be complemented by *in situ* measurements characterizing the investigated targets, their status and distribution by biophysical and biochemical data, as well as data describing the environmental conditions. The type of *in situ* parameters to be collected for the "physical calibration" depends strongly on the role of the anticipated goals. It may reach from parameters describing the canopy of a single agricultural field and its underlying soil to the classification of a whole area as an agricultural use area; it may characterize single forest stands by age classes, new diversity and types of trees, to a whole region as typical forest area. These characterization parameters are collected statistically such that whole test regions can be defined. The sets of *in situ* data are to be complemented by additional information such as digital terrain models, climatological charts, and soil and land use maps.

Furthermore, these data sets should be complemented by different types of models to:

- Relate remote sensing data with *in situ* parameters;
- Relate remote sensing data with the actual topographic and environmental target location; and
- Describe the growth stage and status of targets, for instance, by successional models.

• *Raw Data Archive*

History has shown the immense value of preserving data sets for long periods of time. This approach enables the review of previous data sets in the light of new information or unforeseen but emerging needs. Such a review requires that we archive the raw data and the calibration and housekeeping information which was employed in the production of geophysical and biological variables. We cite here the recent case of atmospheric ozone where we have recently discovered major short-term global change. We have no

information base against which we can gauge the significance of such an event. The ISY should actively encourage the major space agencies to ensure that:

- Long-term data sets are preserved and remain accessible to users;
- The utility of archived data be preserved to maximize the possibility of its use for purposes which may differ from those originally intended.

• *Geolocation and Spacecraft Position*

Of extreme importance in the application of remotely sensed data is the requirement for precise information which enables the geolocation of data. Geolocation of remotely sensed data is defined here as the attachment of Earth coordinates to the remotely sensed information.

The elements in this process include a knowledge of the spatial coordinates of the spacecraft, the spacecraft attitudinal information (yaw, pitch, and roll) if available, and the sensor directional information in spacecraft coordinates. Too frequently one or more of the above ingredients is absent or degraded, and data users have been required to resort to ground control information to improve the geolocation of data for particular purposes.

It would be far more satisfactory to be using ground information to provide the quality control of geolocation. The use of ocean data, for example, requires precision in geolocation since ground control features are not available.

CANDIDATES FOR DATA TESTING

Possible candidates from which a short list of demonstration projects should be selected include:

• *Detection of the Greenhouse Effect*

Considering future needs in the use of satellite data for studying and modelling global climate change, we propose for ISY a pathfinder test of the global information system. The program aimed at detecting the greenhouse effect is of international concern. It can also be designed to serve as a pathfinder experiment providing the basic model upon which future observing systems are designed. In addition, development of this data test requires that emphasis be given now to the design, preparation, and exchange of global data sets.

In general, space observations are used in conjunction with *in situ* data and other ancillary information to provide the best level of accuracy and resolution. Frequently, *in situ* observations are the only available technique. In all cases there are three basic requirements for the data which must be maintained: long-term stability, calibration, and validation. These three requirements are of extreme importance if one is to attempt to observe and study climate change.

A preliminary list of needed measurements includes the following: (a) climate change parameters - stratospheric temperature, tropospheric temperature, land and ocean surface temperature, global cloud cover, precipitation and soil moisture distributions, snow cover, ice sheet topography, and internal ocean temperature trends; and (b) climate forcing parameters- stratospheric and tropospheric trace gas trends including water vapor, solar irradiance, stratospheric aerosols, and surface albedo.

• *Tropical Ocean and Global Atmosphere Program*

In the context of the TOGA Program, fields of surface wind, sea level, sea surface temperature, surface solar radiation, cloudiness, atmospheric water vapor, and indices of precipitation could be studied.

ERS-1 will feature a scatterometer and an altimeter suitable for estimating the surface wind stress and sea level, respectively, which should be compared with ongoing *in situ* surface wind and subsurface temperature measurements. TOPEX/Poseidon will feature more precise measurements of sea level. Improvements in cloud drift winds from geostationary satellites would also be very significant in this context. There have already been intercomparisons of U.S. based techniques for satellite-derived estimates of sea surface temperature, but much better documentation and validation is needed of their use in practice. The Along Track Scanning Radiometer (ATSR) aboard ERS-1 will provide a unique opportunity to get better estimates of sea surface temperature and to validate the interpretations being placed on the International Satellites Cloud Climatology Program (ISCCP) data on global cloudiness.

Microwave radiometers aboard MOS and DMSP and the 6.7 micron channels aboard GOES and METEOSAT could provide the first synoptic global analyses of atmospheric water vapor, but only if we learn how to integrate this information effectively into assimilation models. Microwave and infrared indices of precipitation are currently being assembled under the World Precipitation Climatology Project, but still need to be put in the context of estimates of surface evaporation and atmospheric moisture.

• *Other Candidates*

In the context of the proposed IGBP initiative on terrestrial ecosystems, a global land survey suitable for estimating changes on a global scale over the next decades should be conducted. The LANDSAT Thematic Mapper and the Systeme Probatoire pour l'Observation de la Terre (SPOT) and the Japanese ERS-1 satellites all provide images of the land surface from which categories of present land use can be derived with varying degrees of precision. Combined with *in situ* measurements in selected areas, and subject to appropriate geographic sampling strategies, a baseline from which future changes can be estimated could be established

as part of the ISY. Such a project should also include establishment of procedures for long-term calibration and inter-comparison between the satellite sensors.

In the context of the proposed IGBP Joint Global Ocean Flux Study, fields of ocean chlorophyll should be measured. In 1992, both MOS and LANDSAT-6 are expected to be flying instruments to measure ocean color, from which can be derived the distribution of chlorophyll in the surface layers. Knowledge of this distribution is a high priority requirement for proposed international studies of nutrient cycling in the euphotic zone and transfer through the thermocline beneath. Effective mechanisms need to be established for making the data accessible to scientists in a timely manner and evaluat-

ing the relationships between the satellite imagery and more extensive *in situ* sampling, both of biological variables and of the physical structure of eddies.

CONCLUSION

The environment of the proposed GIST is shown in Figure 1. A broad categorization of activities for the GIST itself is shown in Figure 2, together with a possible organizational structure and milestones in Figures 3 and 4, respectively. As a first step, the task of the ISY is to define the organization that will state the requirements and suggest the means to create the GIST capability shown in Figure 1.

Global Information System Test

The Environment

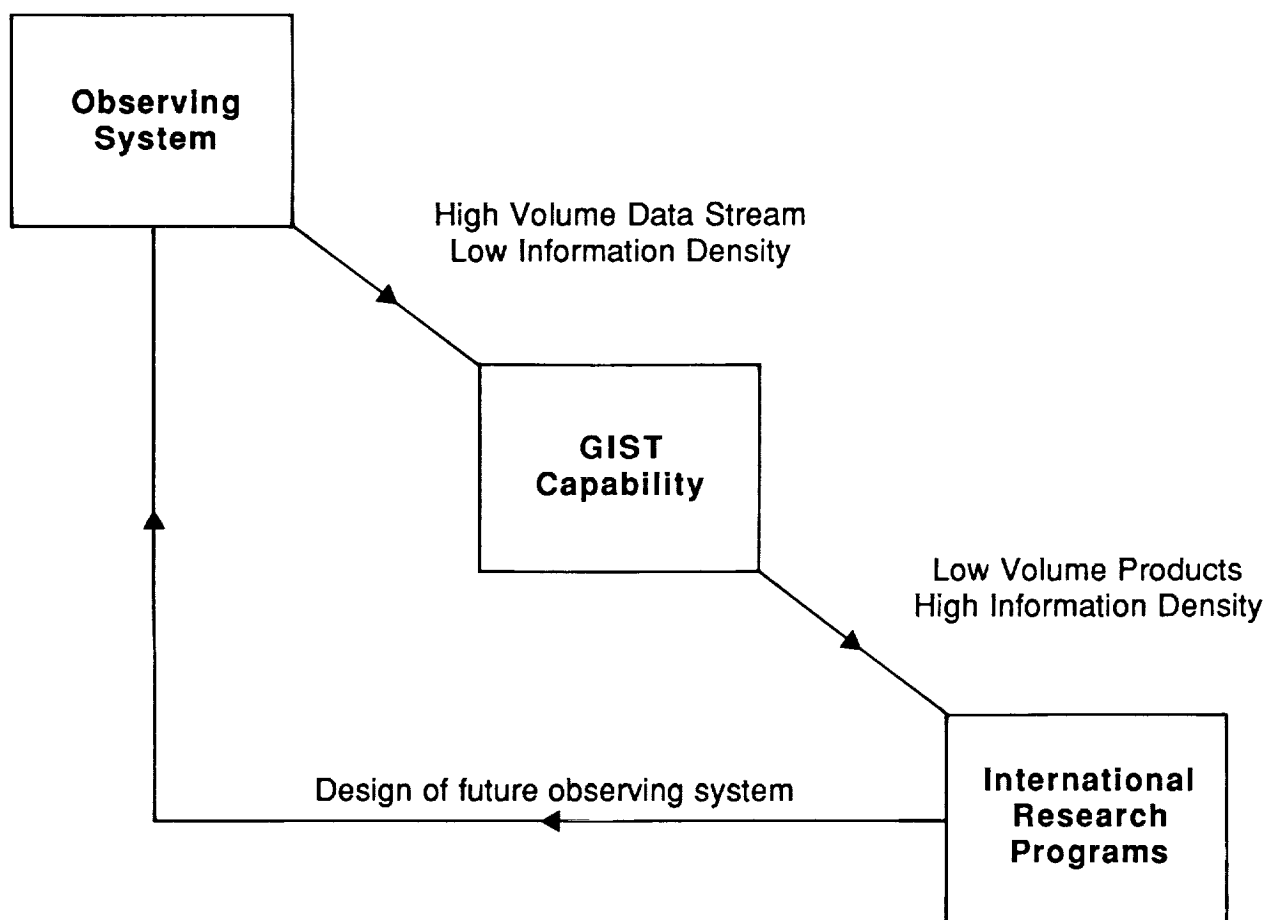


Figure 1. The GIST Environment

GIST Tasks for each variable

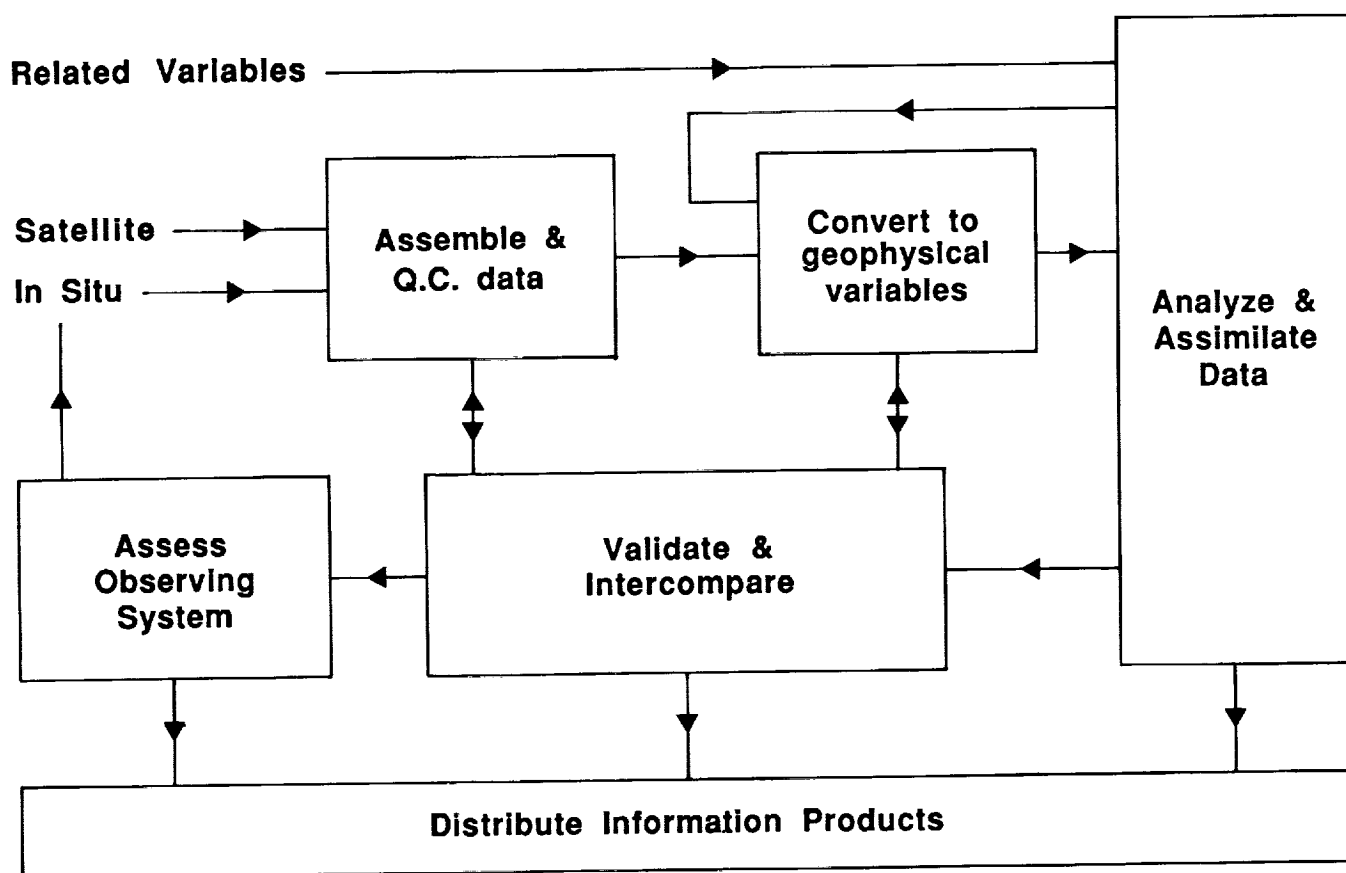


Figure 2. A Possible Definition of GIST Tasks

GIST Organization

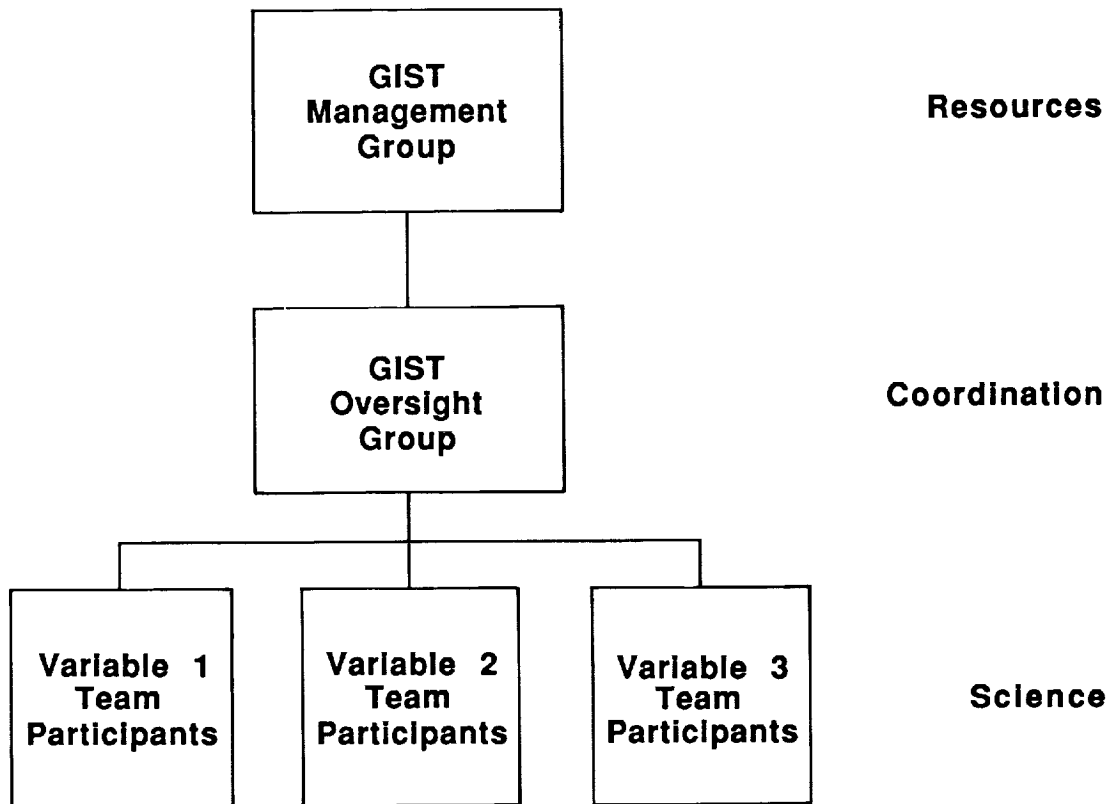


Figure 3. A Possible GIST Organization

GIST Milestones

Preparation Phase	1988-92
Subsystem Tests	1990-91
End to End Tests	1992
Evaluation of Observing/Information Systems	Initial 1993 Continuing -

Figure 4. A Possible GIST Schedule

VI. SPACE AGENCY SENIOR OFFICIALS

Senior management officials from seventeen national space agencies and equivalent organizations participated in the policies and planning working group that was established to discuss overall ISY coordination. The discussions were extremely fruitful. The working group focused on concrete actions and laid a foundation for future space agency coordination.

There was a general agreement to promote the ISY and to participate in and support the research activities needed to carry out ISY programs. Although the ISY will focus on the 1992-1994 time frame, the necessity for long-term continuity in ISY planning was recognized. Similarly, although a priority was accorded Mission to Planet Earth as an ISY activity, there was also clear recognition that other ISY programs will be considered, especially those which will promote broad international cooperation. The ISY should involve as many partners as possible, and it should look at the real needs of developing countries.

The ISY should be constructed on a solid scientific basis, but it should also engage the widest possible range of beneficiaries of space science and technology. Thus, easy and rapid access to data from ISY programs was accepted as an important guideline. We also agreed to make the best use of ground facilities, which many countries can afford.

Educational activities should be a major component of the ISY. For example, there should be emphasis on training of engineers from developing countries in the use of remote sensing. At the same time, public awareness of our cooperative efforts needs to be increased, especially in the field of space science and applications. There is grandeur and inspiration in the globally coordinated efforts of scientists that has not been sufficiently communicated. The ISY can also serve to increase understanding of space as a new element of cultural development that will have ramifications on all aspects of life. A meeting in Paris on these topics was proposed.

To achieve our goals there is a need for a flexible and informal operating network. It was therefore agreed to establish a Space Agency Forum on International Space Year (SAFISY) with membership from space agencies or equivalent bodies dealing with civilian space activities and receiving primary funding from public sources. Agencies will be represented in SAFISY by senior officials with broad management responsibilities who will meet periodically with member agencies serving alternately as hosts. SAFISY's primary objectives will be to enhance the activities of ISY and to exchange information on agency programs for ISY in order to encourage complementarity and compatibility.

SAFISY will not compete with other existing international bodies. It will seek interaction with the private sector and other non-governmental organizations, such as ICSU, COSPAR, IAF and IAA, as well as the United Nations and

other international organizations. Its goal is to complement their actions and to make ISY a successful scientific and popular event.

As an initial step, SAFISY will establish two panels of experts, one on Science and Technology and the other on Education and Applications, to carry out the recommendations resulting from the Earth sciences working groups which met as part of this conference. To assist the working groups, SAFISY has drafted a communication to all space agencies on the capabilities of all Earth observing missions currently in operation or scheduled during the next decade.

In remarks at the final plenary session, summarized above, Professor Curien urged the space agencies to respond positively to Dr. Fletcher's invitation in his keynote address to join together in planning for a 15-year program of long-term Earth observations, with the ISY serving as a catalyst. This mission "is at least as important as the big spectacular missions" that get most of the public's attention, Professor Curien said. He concluded:

"We are now sure of the success of the ISY and we will work for it. Two years to go from an idea to a reality is a very short time, and it is proof that the idea was a very good and timely one."

THE WHITE HOUSE
WASHINGTON

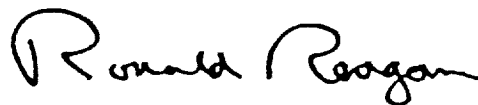
April 27, 1988

Greetings to everyone gathered with the US-ISK Association for the International Space Year Mission to Planet Earth Conference.

As you know, in 1986 I endorsed an International Space Year (ISK) for 1992, the quincenary of the discovery of America by Christopher Columbus; and I directed the National Aeronautics and Space Administration to organize an interagency effort to develop this idea. All of you can be proud that your spirit and hard work have created so much progress. As I said in 1986, the ISK should maximize, through international cooperation, the achievements and benefits of the world's current and prospective space programs and emphasize the involvement of both developed and developing countries in ways that show the benefits of space discoveries and the practical uses of space. That's exactly what you've been doing by reminding us all of how space cooperation can help us better understand and manage our surroundings and lead us to new horizons of human potential here and throughout God's universe.

Such cooperation can meet the challenges ahead; respond to humanity's deepest aspiration for peace, progress and freedom; preserve a healthful planet for generations yet unborn; and give us new realms to explore. That potential gives added meaning to your meeting, the first assembly of senior space agency officials from throughout the world to discuss ISK planning.

You have my best wishes for a truly productive conference and for the years to come. God bless you.

A handwritten signature in black ink, reading "Ronald Reagan". The signature is written in a cursive, flowing style with a large initial "R".

**EXCERPTS FROM REMARKS PREPARED FOR DELIVERY:
ISY MISSION TO PLANET EARTH CONFERENCE; APRIL 29, 1988
DR. JAMES C. FLETCHER, NASA ADMINISTRATOR**

Thank you very much, John (McLucas), President Haaland, Professor Curien, Dr. Malone, distinguished guests and ladies and gentlemen.

On behalf of NASA, it's a pleasure to welcome all of you to this most important conference. This is the first time that senior space agency officials from around the world are meeting to discuss how they might coordinate their activities during the International Space Year, or ISY, in 1992. As you know, the ISY will commemorate the 35th anniversary of the International Geophysical Year and the 500th anniversary of Columbus' voyage to the New World. Thus, it unites the universal themes of exploration, discovery and intellectual inquiry that have powered the human spirit in the past and continue to point to a future of unlimited horizons.

NASA is pleased that President Reagan directed the agency to lead an interagency effort to develop the ISY concept and international support for it. We view this conference as a major step forward in this effort, and are pleased that all of you could participate in the development of a major theme for ISY.

For thirty years, we humans have been opening new horizons in space and pushing back frontiers that limit our goals on this planet. As a spacefaring civilization, we have expanded our understanding of the solar system, the galaxies and the universe. In the process, we've seen new worlds as never before and, not surprisingly, have learned there's much more to know about our own world, planet Earth. So going into space has opened our eyes to what we know and don't know about Earth.

In fact, it would be no exaggeration to say that space exploration has spawned a revolution in humanity's perception and understanding of Earth. The Apollo program provided people around the world with a new perspective of this planet as "Spaceship Earth," a gleaming blue and white ball floating in the blackness of space. This image dramatically reshaped mankind's view of itself, and triggered an awareness of Earth as a fragile and most precious life support system, one made even more precious because, based on what we know today, it is the only body in our solar system to harbor and nourish life.

The scientific impact of spaceflight has been equally dramatic. In less than half the span of a human lifetime, largely through the findings of space-borne sensors, mankind has transformed its view of Earth's land masses, its oceans, its atmosphere, and its solar environment. Spaceflight provides the basis for improvements in our daily lives on Earth and will continue to do so in the future.

Geostationary satellite cloud pictures and data are now the basis for daily explanations of the weather worldwide. Multispectral images of land areas from space have become commonplace and have furthered our understanding of natural processes and the impact of human activities on our planet. The use of space observations together with vast improvements in computer power has enabled scientists throughout the world to develop global scale models of the atmosphere and of long-range weather and climate changes. And projects are under way to extend this approach to the stratosphere, the oceans, and Earth's land masses.

Witness the example of the Seasat 1 satellite NASA launched a decade ago. In its three-month lifetime, Seasat recorded more original information about Earth's ocean currents than had been accumulated during centuries of Earthbound navigation. By the same token, before the advent of spaceborne sensors, scientists barely had realized the global impact of isolated volcanic activity. We now have evidence that such activity causes substantial changes in climate patterns around the world over periods as long as several years.

Evidences of such interactions abound. Having seen and analyzed the Earth from space, we now know that it is a complex and dynamic world. As the sum of all its parts, it is also a fragile system in which disruptions at any point reverberate throughout the whole.

Many of these disruptions have been brought about by human activities. Thanks to our ability to observe the Earth from space and to the development of large-scale computer systems, we now know that economic and technological activities over the past few generations have contributed significantly to global change. Humankind is now a critical part of Earth's system. And it's clear we've still got a lot to learn about how to be a constructive part of that system.

Human activity has contributed, in large measure, to depletion of the ozone layer; to desertification of once-fertile lands; to deforestation in tropical and other forests; to acid rain and, perhaps, even to a "greenhouse effect", which some scientists believe is gradually warming the Earth's surface.

The good news, however, is that we are now in a position to understand the consequences of our actions; and, once understood, I trust, we'll be able to do something about them together. Every nation in the world will have a part to play in solving these problems, because global problems require global solutions carried out internationally. It is imperative that we join together to correlate and integrate measurements all over the globe. And this can involve every nation

on the face of the Earth -- large and small -- be it a space power or not.

Our goal is to obtain a scientific understanding of the entire Earth system on a global scale by describing how its component parts and their interactions have evolved, how they function, and how they may be expected to continue to evolve from decade to decade and even from century to century.

This is an enormous challenge. We must develop the capability to predict those changes that will occur in the next decade and well into the next century, from both natural causes and in response to human activity. This will require an integrated understanding of the entire Earth system where changes are likely to occur in periods of time spanning a decade or longer. And, as you know, that includes the land, the atmosphere, the oceans - i.e., the Earth's systems.

Therefore, global, synoptic and long-term measurements must be made. These measurements must involve simultaneous observations of the Earth's interactive natural and human processes, using spaceborne sensors to be complemented by Earth-based instruments and a new generation of information-processing systems.

Many nations of the world are already observing the Earth from space, or preparing to do so, to a degree we could hardly have imagined three decades ago.

In the United States, for example, NASA has long had an aggressive program of Global Earth Sciences. NASA developed the orbiting capabilities which form the basis of the United States' NOAA and GOES operational satellites and the LANDSAT land remote sensing satellites.

Geostationary weather satellite systems have been developed by Japan, Europe and India, with GMS, Meteosat and INSAT, respectively. The Soviet Union, France, Japan and India now have remote sensing spacecraft. ESA, Canada, Germany, Italy, Brazil, China and others are developing satellites or instruments.

NASA is now orbiting the Nimbus 7 and Earth Radiation Budget, or ERBS, research satellites. Nimbus is providing global data on stratospheric ozone, sea surface and sea ice variables. And ERBS is furthering our understanding of the balance of radiation input and output between the Earth and space - a balance which is key to improving our understanding of climate.

Beyond these ongoing missions, NASA will be doing much more in the area of Earth Science and Applications in the near future. And many of our activities will be cooperative efforts with other nations.

Three NASA missions to be launched in the early 1990's will address key aspects of the Earth as a system. Each will study a particular environment or region for a few years. Each will involve international cooperation. Thus, taken

together, these missions are the building blocks of a comprehensive understanding of Earth as a system and will provide the scientific foundation for future international cooperation.

The first program is the Upper Atmosphere Research Satellite, or UARS. UARS will provide the first comprehensive measurements of the interplay of and among dynamic, radiative and chemical processes in the stratosphere and mesosphere. As you know, recent research led by NASA in the Antarctic underlined the importance of these measurements, which determine the extent and durability of the ozone layer. The UARS instruments are from the U.S., the U.K., Canada, and France, and the data will be analyzed by an international team of scientists.

The second NASA program is a Scatterometer that we are developing for global measurement of sea surface wind velocity. We are now proposing to fly this instrument on a Japanese Advanced Earth Observing Satellite (ADEOS) in 1993.

The third near-term program is a joint U.S.-French ocean topography experiment called TOPEX/POSEIDON. This mission, to be launched aboard the European Ariane rocket, will provide the first detailed measurements of the ocean's global circulation patterns, including the manner by which strong poleward currents, such as the Gulf Stream, are balanced by equatorward flow. Thus, it will permit a fundamental breakthrough in understanding the overall oceanic system functions.

TOPEX/POSEIDON, as well as ESA's remote sensing satellite mission, ERS-1, are planned to be coordinated with extensive world-wide oceanographic field experiments scheduled to be conducted in the early 1990's by the World Climate Research Program of the World Meteorological Organization. Clearly, all of these efforts will lay the foundation for a continuing program to provide long-term observations of oceanic circulation and its variability.

The world user community will have access to data from the three future NASA missions I've just described, just as it has had access to data from NASA missions in the past. Similarly, all of us are benefiting from access to data from SPOT and from Japan's Marine Observations mission, MOS-1. And the user community looks forward to data from India's IRS-1 mission, from Soviet remote sensing instruments and from the many remote sensing missions being developed for flight in the early 1990's.

But the Earth is the sum of all its parts. And just as the Space Age has produced deeper understanding of the interconnections and interdependence of Earth's physical and biochemical processes, so, too, has it resulted in greater international cooperation in global change research, largely through observations in space. Examples are the World Ocean Circulation Experiment I've just described, the International Satellite Cloud Climatology Project and the Ocean Drilling program.

In addition, the International Council of Scientific Unions in 1986 initiated the definition of an International Geosphere-Biosphere Program, also known as "The Global Change" program. The program is designed to describe and understand the processes that regulate the total Earth system; the changes occurring in that system; and the manner by which those changes are influenced by human actions.

This is an immensely interactive and international program which will study the changes in the land, ocean and atmosphere simultaneously. It will cross the traditional boundaries of geophysics, geochemistry, and biology. Above all, it will promote the exchange of scientists and of data across national frontiers. And I believe its legacy will be an observational system that will continue to monitor global change for years to come.

These and other initiatives demonstrate the commitment of nations around the world to the study of Earth as a system and to the investigation of global change. The ISY offers the space agencies of the world the opportunity to highlight the key role of space in understanding the Earth.

As part of these international efforts, the United States is planning for a comprehensive approach to observing the full spectrum of processes which make up the Earth system through observations from space. This approach requires enlarged concentrations of orbiting remote sensing instrumentation and mission lifetimes of a decade or more.

The main thrust of this approach is the Earth Observing System, or EOS. Current plans call for its initiation in the early 1990's. EOS will use highly capable space platforms in polar orbit. Each of the platforms is designed to accommodate numbers of instruments for simultaneous observation of global variables. The mission eventually should involve at least four polar platforms in both morning and afternoon crossing time orbits.

The first two polar platforms will be part of the Space Station infrastructure, and can be supplemented by instruments on the Space Station to observe specific phenomena. The fact that we will be able to put specific scientific instruments on the Space Station will be one of the key scientific benefits of the Station, and one we expect will have a broad impact on scientific research through the end of the 1990's and well beyond.

The polar platform infrastructure in itself will be a magnificent example of international cooperation. Initially, NASA will provide one polar platform to be equipped with instruments provided by the National Oceanic and Atmospheric Administration. Plans call for a second U.S. polar platform later. Our Space Station partner, ESA, will provide a third platform, hopefully in the same time period as the first U.S. platform. Japan, another partner, is seriously considering developing its own platform, as well, in the late 1990's.

I'm pleased that ESA, Japan and the U.S. have been coor-

inating their respective efforts. Just this past January, NASA issued an Announcement of Opportunity for EOS instruments and investigations. The announcement was coordinated with similar announcements issued by ESA and Japan. Scientists from the United States, Europe, and Japan will work together to analyze the EOS data to establish an initial profile of Earth as a System.

In time, up to five geostationary platforms could complement the detailed data flow from the polar platforms to enrich our understanding of the Earth system with a continuous broad overview.

This augmented capability would add up to a Mission to Planet Earth on a scale never before attempted to study any planet. In fact, the ISY could, in effect, initiate activities to support a global study which could lead to a full-scale Mission to Planet Earth in the late 1990's.

To face this new and vital responsibility for our global future, the nations of the world must grasp the opportunity the ISY offers to ensure that the gifts of Planet Earth are passed on to future generations. I hope that the ISY will bring all nations into this effort in a coordinated way. There are many steps all of us can and must take in connection with ISY planning.

First, we must implement promptly a series of planned United States and international research programs that will provide those Earth science observations required over the next decade. Simultaneous measurements of the Planet Earth's interactive natural and human processes are required. Spaceborne sensors offer a unique global perspective. But they must be complemented by Earth-based measurements.

Second, we must resolve now to lay the foundations for the long-term program necessary to provide continuous global observations of the Earth from the mid-1990's and beyond. In developing our polar platforms for EOS, the United States is prepared to plan for a 15-year program of long-term Earth observations. Through Professor Luest, I have invited ESA to join with us all in this long-term commitment. And today, I extend this invitation to all of you and urge your respective space agencies to consider it seriously. By joining together in such a commitment, we can establish a truly global Earth Observation System.

Third, we must develop an advanced information system to process global data and to facilitate data analysis, data interpretation and quantitative modelling of Earth System processes by the scientific community. A new generation of data information systems will be essential to receive, process and store data, to distribute it to the research community for analysis.

Fourth, we must continue to strengthen the international agreements and coordination necessary for a truly worldwide study of Earth as a global system. A Mission to Planet Earth would rank among the most complex human enterprises ever undertaken.

I can think of no more appropriate summation of the challenge we can and will face together than some words from T.S. Elliot's "Four Quartets". So, let me quote them for you now:

"We shall not cease from exploration
And the end of all our exploring
Will be to arrive where we started
And know the place for the first time."

We have, indeed, started to know Earth for the first time. Most of all, we're learning that it belongs to all mankind; and thus, is ours to preserve or destroy. The ISY will give all of us an excellent opportunity to coordinate our efforts and to raise public awareness of the essential central role space activities will continue to play in understanding and maintaining our planet.

Humankind has but one Earth. Working together, there is no limit to what we can accomplish to ensure its survival so that future generations can enjoy it and live in safety and prosperity.

Thank you very much.

THE INTERNATIONAL SPACE YEAR (ISY) AND THE INTERNATIONAL GEOSPHERE-BIOSPHERE PROGRAM (IGBP)

DR. THOMAS F. MALONE

The message I am privileged to bring to you today is that we stand on the threshold of a renaissance in the sciences concerned with Planet Earth, including the fauna, flora and the humans who call it their home. A conceptual framework is emerging in which it is recognized that the terrestrial environment and the diverse forms of life inhabiting it constitute an integrated system of interacting parts. No single part – oceans, atmosphere, or biota – can be understood in isolation with sufficient depth to anticipate its changes. Nor can any geographic segment be analyzed satisfactorily as a sequestered entity. A deeper understanding of the structure and metabolism of the total Earth system is within reach.

This renaissance has its origins – in no small part – in the powerful observational capability provided by space science and technology. Its fulfillment is conditioned – in large measure – on the initiative, imagination, and active involvement of the international community of space agencies. This involvement is more than merely supplying the promising new technology of "remote sensing". It will require intensive participation in the birth of a sweeping new science, one that promises to illuminate over the next few decades the intimate interaction of the geosphere and biosphere and the role of human activity in inducing global change. It is especially appropriate and timely that ISY address the role of space science in deepening our understanding of Planet Earth. You are acting with verve and imagination in raising public consciousness concerning the role of science and space in societal affairs. IGBP and ISY uniquely complement each other. IGBP is concerned with science, society and space. It will reach a critical stage in 1992, coinciding with a peak in your efforts. IGBP needs ISY. ISY needs IGBP.

As you consider the set of issues before your working groups, do so with the conviction that this exciting adventure of the human mind and spirit is an integral part of the destiny of space science and technology. We in the Earth sciences look forward to a true partnership of effort with the space sciences. Your contribution to the human habitability and sustainable development of Planet Earth is vital. Your role in Mission to Planet Earth will constitute a splendid record of accomplishment that will provide popular support for your exploration of the solar system and the universe beyond.

The roots of IGBP go back to the writing earlier in this century of the Soviet geochemist, Academician Vernadsky, who recognized the inextricable link between life and its surrounding energetic and material structure through photosynthesis, transpiration and nutrition. The philosophical basis for the IGBP was set forth with admirable clarity by Dr. Herbert Friedman in 1983 in these words:

The real connections that link the geosphere and biosphere to each other are subtle, complex, and often synergistic; their study transcends the bounds of specialized scientific disciplines and the scope of limited, national scientific endeavors. For these reasons progress in fundamental areas of ocean-atmosphere interactions, biogeochemical cycles, and solar-terrestrial relationships has come far more slowly than in specialized fields, in spite of the obvious practical importance of such studies. If, however, we could launch a cooperative interdisciplinary program in the earth sciences, on an international scale, we might hope to take a major step toward revealing the physical, chemical, and biological workings of the Sun-Earth system and the mysteries of the origins and survival of life in the biosphere. The concept of an International Geosphere-Biosphere Program (IGBP) ... calls for this sort of bold, 'holistic' venture in organized research – the study of whole systems of interdisciplinary science in an effort to understand global change in the terrestrial environment and its living systems.

He went on to say:

... the power of new technologies for remote sensing of atmospheric, geological, biological, and oceanographic conditions promises to revolutionize our grasp of global conditions and our understanding of global change.

The deep involvement of the space science community in this revolution is captured by the masterly report of NASA's Earth Systems Sciences Committee. Sixteen years ago, in prophetic words, Dr. James Fletcher, (then, as now, Administrator of NASA) in an address to the 13th Meeting of the Panel on Science and Technology of the Committee on Science and Astronautics in the U.S. House of Representatives remarked:

Now, I have lumped together disciplines which are apparently separate – oceanography, hydrology, meteorology, agriculture, forestry, cartography, geodesy, and environmental quality. This is deliberate. In fact, I foresee a time when these individual disciplines will be regarded as what they really are – parts of a whole new structure of knowledge, understanding, and action.

That time has now arrived, Dr. Fletcher!

Preliminary meetings around the world in 1984 culminated in a symposium on global change in September, in Ottawa, Canada, sponsored by the International Council of Scientific Unions (ICSU). The recognition evolving from that meeting that "a deepened understanding of anthropogenically induced global change is becoming an impera-

tive of contemporary society" led ICSU to commission a two-year study leading to the establishment of *The International Geosphere-Biosphere Program: A Study in Global Change* in 1986. The objective of the program is:

To describe and understand the interactive physical, chemical, and biological processes that regulate the total Earth system, the unique environment it provides for life, the changes that are occurring in that system, and the manner by which these changes are influenced by human actions.

The ultimate intellectual scope of IGBP links conditions in the interior of the Earth with those in the interior of the sun. The hallmark of IGBP is integration – breaking down the barriers that have traditionally compartmentalized the study of the atmosphere, oceans, the solid Earth, solar terrestrial interaction, fauna and flora, and humankind.

Both observational and analytical, the nature of the program will require observations of parameters not now being measured and will necessitate an innovative style of interdisciplinary analysis. The most challenging aspect of the proposal is the intent to illuminate the intimate linkage between the physical sciences and the life sciences. The viewpoint is holistic and global.

The rationale for IGBP is fourfold:

- Maturation in understanding the processes in the several domains of geophysics – atmosphere, oceans, lithosphere, solar-terrestrial physics – and in the study of ecological systems has brought us to the point at which it is possible to cast these processes in quantitative form -- mathematical models. An array of international programs over the past two decades have made it abundantly clear that interactions among the several domains are so important that issues in geophysics and ecology must be addressed in a uniform manner.
- It turns out that a vital part of the linkage is found in the biogeochemical cycling of both major and trace chemicals. These cycles have been elucidated during the last decade or so and are now the object of intensive study. New dimensions of global observations combining *in situ* and remote-sensing measurement are required.
- Major advances in sensor and detector technology have been made since TIROS was launched in April 1980. Active remote-sensing techniques are under development to add to the current passive remote-sensing capabilities. These techniques promise to provide three-dimensional measurements of the dynamic, thermodynamic, chemical, and biological processes in the Earth system. Explosive growth in the processing power of computers is making possible mathematical modeling that was only a dream a decade ago. Advances in telecommunications, data-archiving function into a sophisticated information system that is an integral part of research, permitting real-time interaction by individual researchers.

- A powerful motivating force is the realization that the agricultural and industry activity in our generation that transforms natural resources into the goods and services to meet the human needs of a growing world population is altering the environment of our small and tightly knit planet in unprecedented ways. These changes have consequences for future generations that we cannot as yet comprehend. The greenhouse gas issue, depletion of the stratospheric ozone layer, desertification, deforestation, and species extinction are issues that have rocketed in public consciousness. The unity of ecology and economics has now been generally accepted, following publication of the Brundtland Report. The concept of sustainable development (living off the yield of natural resources without depleting the resource capital itself) is looming ever larger in the thinking within developing countries, where population pressure will be greatest as we cross the threshold into the twenty-first century. *Apprehension* over the traumatic consequences of anthropogenically induced global change combined with *hope* that wise measures will make our global environment comfortably habitable for future generations provide powerful motivation for action. Rational action, however, must be based on precisely the kind of understanding that is the goal of IGBP.

The structure of the program is now being developed by the Special Committee of ICSU chaired by professor James McCarthy of Harvard University. It has a secretariat headed by Professor Thomas Roswall of the Royal Swedish Academy of Sciences in Stockholm. Close consultation is maintained with national IGBP committees and with the groups overseeing international programs such as the world climate research program and programs addressed to the study of the oceans, the solid Earth, and solar-terrestrial physics. The Special Committee will hold a major consultative conference in Stockholm in late October. That occasion will provide a superb opportunity to develop further the linkage between the space and the Earth sciences.

Intensive planning and program design will continue for the balance of this decade. The observational mode will commence in the 1990's, with full-scale operations probably coinciding with the planned initiation of the Earth Observing System in the mid-1990's. The timing of The International Space Year is thus both fortuitous and important.

Initial program activities will include:

- Process studies – The flux of energy, water, and chemicals at the ocean-atmosphere and the land-atmosphere interfaces – the response of the atmosphere to fluctuations in the several spectral domains of the solar radiance – the biological processes that influence biogenic missions from the vegetation and from the euphotic zone of the ocean.
- Observations – An internationally sponsored Earth observing system is required. It will include standardized and calibrated remote-sensed observations from geosta-

tionary and polar-orbiting satellites as well as an Earth-based network to provide spatial resolution and validation for the satellite measurements. New ground must be broken in measuring biological and chemical processes. An integral part of this observational program and of the study of processes will be the design and development of a sophisticated scientific information system responsive to the needs of research while fulfilling an archival function. Intimate interaction is necessary between a dynamic research program and data collection.

Modelling – Theory, as well as information gained from process studies and the observational system, will guide the development of conceptual and quantitative representation of those processes and their interactions. The models, in turn, will feed back to the design of observational systems and the elucidation of processes. Models are the principal tools for anticipating natural change and discriminating between it and anthropogenic perturbations. A hierarchy of models is envisioned that reaches across domains and links the relevant physical, chemical, and biological processes.

- Recovery of environmental records – "Proxy" indicators, or records, of prehistoric environmental changes – such as global ice volume, tree-ring widths, ice cores, isotope and chemical ratios in lake and ocean sediments, ice caps, and coral deposits. The stage is now set for a more intensive study of the dynamic content of these indicators within the context of a set of highly interactive processes that make up the total Earth system.

Priority is being given to key interactions that may lead to significant global change on time scales of decades to centuries; that most affect the biosphere; that are most susceptible to human activity; and that will most likely lead to a useful predictive capability.

Prominent among the issues that must be addressed over the next two years are:

1. Specific program elements must be thoughtfully planned and internationally coherent. Smooth integration of the IGBP initiative with related programs such as the World Climate Research Program, the International Solar-Terrestrial Physics Program, the World Ocean Circulation Experiment, and studies of the solid earth will be required. The sharp focus in the initial stages of IGBP will be broadened over the years to embrace the full scope of the term "global change". Early attention will be directed toward establishing a knowledge base adequate to anticipate and to deal rationally with the disturbing, recurring sequence of surprise, problem identification, and response, that is to say with stratospheric ozone depletion, greenhouse gas/climate change, acid deposition, etc. This will be succeeded by attention to the understanding required for prudent management of the Earth's planetary life support system to assure the general health and stability of human life on Planet Earth.

2. Appropriate institutional arrangements that recognize the autonomy of agencies and national efforts while insuring coherence globally needs to be explored. Space agencies have developed an effective array of mechanisms for international cooperation; multilateral governmental cooperation is traditionally implemented through the specialized agencies of the United Nations; the world scientific community is comfortable with cooperation through the International Council of Scientific Unions. An institution for exchange of program plans may have to be invented that will avoid the undue concentration of authority and bureaucratic paralysis. The design and operation of an international data system may focus attention on institutional issues.
3. Sooner rather than later, social and behavioral scientists should join the natural scientists in assessing the human response to – and responsibility for – global change. This has already begun in the initiative of the International Federation of Institutes of Advanced Study. Sharp focus will be required on (a) the characteristics, causes, and local and regional manifestations of global change; (b) the societal impact of global change; and (c) the policy options for dealing with global change.
4. Significant and sustained financial support will be required for the capital investment in technology and the continuing research effort that insures an adequate return on that capital investment. The longevity of the program and the need to match funding and firm program milestones will challenge the political processes that provide support. The political will required for that support rests on public understanding of objectives and awareness of accomplishments.

Can a productive partnership be forged between earth scientists and space scientists? Between the nongovernmental scientific community and the intergovernmental organizations? I believe it can. Twenty-five years ago last month, I participated in the Dryden-Blagonravov discussions in Rome to explore US/Soviet cooperation in the application of space science and technology to meteorology. That seminal meeting was the precursor of a literal explosion of knowledge concerning the global atmosphere. The problem of a total earth science program is far more complex. The means for addressing it, however, are at hand. This particular ISY conference is a good augury. It may be hazardous to label the Conference a seminal event – especially during the first plenary session – but I am willing to risk it.

The scientific challenge is clear. The response of the scientific community and those planning the International Space Year bodes well for exciting prospects in science and technology with profound societal benefits. Involvement in international scientific matters over a quarter of a century left me unprepared for the powerful support this program is receiving. Thirty years ago, IGY lifted the eyes of a war-weary people everywhere to the vision of a better and more livable world. ISY has an upward and outward vision of its own to share with people everywhere.

Is it possible that science and technology can develop the knowledge base upon which the power of world opinion operating through governments will demand a path with attractive vistas instead of one that places in jeopardy so many of the values that humankind treasures? Cannot the coming together of scientists from many disciplines and many nations offer an example of a mode of thinking that might well be reflected by diverse national governments as they address the management of world affairs?

The potential contribution of ISY is dazzling. Your dedicated efforts and the vision of a better Planet Earth you inspire among the world's people can generate a kind of global change that will be the most precious heritage of the International Space Year.

TERMS OF REFERENCE OF THE SPACE AGENCY FORUM ON INTERNATIONAL SPACE YEAR

I. PREAMBLE

- 1.1 The Space Agency Forum on International Space Year (SAFISY) was established by assembled representatives of national space agencies throughout the world:
UNDERSTANDING the utility of space research for mankind;
ACKNOWLEDGING that nations in all stages of development can contribute to and benefit from space science and its applications;
CONSIDERING the autonomy of national agencies responsible for space activities;
REALIZING the advantages of ongoing communication and cooperation among governmental space agencies;
APPRECIATING the high priority attached by space agencies to the study of global changes of the planet Earth; and
RECOGNIZING the need to provide a forum for expression of views and informal coordination of projects by national civil space agencies in support of International Space Year (ISY), so as to enable the agencies to take these views and projects into account while planning their individual programs for ISY.
SAFISY will not supersede current or potential agreements by members. Participation in activities of SAFISY shall not be construed as being binding upon governments, or as restricting their right to develop and manage programs according to their needs and resources.
- 1.2 These terms of Reference were considered by representatives of national space agencies at the ISY Mission to Planet Earth Conference in Durham, New Hampshire, April 29-May 1, 1988.

II. MEMBERSHIP

- 2.1 Members of SAFISY are employees with broad management responsibilities of national agencies or organizations conducting civil space activities which receive their primary funding from public sources.
- 2.2 The status of Affiliate is open to representatives from national and international organizations which declare an intent to participate in the observance of International Space Year through production or sponsorship of a related program or event. Affiliates will periodically report on the progress of their plans for ISY.
- 2.3 Addition of new Members and Affiliates will be by consensus of existing Members of SAFISY.

III. OBJECTIVES

- 3.1 SAFISY will seek to enhance the observance of International Space Year.
- 3.2 SAFISY will serve as a forum for the exchange of information and ideas to encourage complementarity and compatibility among space agency programs for ISY, either in operation or development.
- 3.3 SAFISY will seek appropriate interaction with private sector and other non-governmental organizations planning ISY activities.
- 3.4 SAFISY will seek opportunities to coordinate its work with that of the United Nations and other international organizations involved in ISY.
- 3.5 SAFISY Members will present their plans for ISY and will discuss appropriate approaches for the coordination of ISY activities.
- 3.6 SAFISY encourages its Members to maintain communications as appropriate with other groups and organizations involved in ISY through the relevant channels within their respective governments.

IV. ORGANIZATION AND PROCEDURES

- 4.1 SAFISY will convene at least once per year in plenary session. Additional meetings may be convened at the request of any Member, provided that written notification is provided at least two months in advance and a majority of the Members agree to such a meeting.
- 4.2 SAFISY meetings will be organized and chaired by the host organization, which shall provide an agenda to Members at least once a month in advance of the scheduled meeting. The host organization will provide and distribute minutes of the meeting and will report on any follow-on activities at the next regular meeting. At each SAFISY meeting, the time, place, and host for the next meeting will be established.
- 4.3 SAFISY will seek to schedule its meetings to be contiguous with other meetings involving a plurality of Members, when appropriate.
- 4.4 SAFISY may establish ad hoc Panels of Experts and Working Groups to advise SAFISY and its member organizations on specific aspects of carrying out ISY activities.
- 4.5 Conclusions resulting from SAFISY plenary sessions, or the findings and recommendations of Panels of Experts and Working Groups, are non-binding and will be acted upon at the discretion of each SAFISY Member.

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