Earth Observation System
Discussion Paper on a Framework
Prepared for the *Ad Hoc* Inter-governmental Group on Earth Observations (GEO)
(Formerly referred to as the Intergovernmental Ad Hoc Working Group)

Purpose:	To provide the GEO Members with a working document, which offers suggestions for key constructs that may aid in developing an Integrated Earth Observation System.
Audience:	GEO Members
Expectations:	The Discussion Paper on a Framework may provide the GEO with a preliminary foundation, a set of possible constructs, and related suggestions, which the GEO may wish to consider in the development of the Framework Document and the more comprehensive 10-Year Full Implementation Plan for an Integrated Earth Observation System.

Discussion Paper on a Framework
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I. Purpose of and Vision for the Integrated Earth Observation System

A. Purpose. The Earth Observation Summit will call on all participating countries to support:

- the exchange of observations recorded from *in situ*, aircraft, and satellite networks, dedicated to the purposes enumerated in the Declaration, in a full and open manner with minimum time delay and minimum cost;
- a comprehensive, coordinated, and sustained Earth observation system that will meet collective requirements for observations, minimize data gaps, and optimize the utility of the system;
- preparation of a 10-year plan for the implementation of a comprehensive, coordinated and sustained Earth observation system, building on existing systems, with the Framework being available by next spring's Tokyo ministerial conference and the full plan available within one year for discussion and subsequent adoption; and
- a coordinated effort to work with developing countries to improve and sustain their contribution to observing systems, as well as their access to observations, thereby building local scientific and technical expertise; and,
- the establishment of an *ad hoc* inter-governmental Group on Earth Observations (GEO) to effect the above objectives and the commissioning of the Group to proceed, taking into account the existing activities aimed at developing a global observing strategy in addressing the above, in particular specific actions of the participants for coordination of observing systems.

This international, comprehensive, integrated, and sustained Earth observation system will be referred to here as the Integrated Earth Observation System (IEOS). One definition of "comprehensive, integrated and sustained" is:

- comprehensive in terms of meeting the needs and requirements of a wide variety of science and applications disciplines and providing system support solutions for decision makers worldwide;
- integrated, meaning combining and strengthening country and multinational organization assets through the appropriate exchange of satellite, aircraft, and *in situ* data in the development of applications, through development of networks and agreed standards, and through better coordination among countries and international organizations; and
- sustained, meaning long-term, continued financial and in-kind support from funding authorities.

The purpose of the IEOS is to help address the environmental challenges of the 21st century, which will have profound global economic and social impacts on our world. The purpose of the GEO is to develop a 10-year full implementation plan for this integrated system.

B. Vision. Humanity has entered a new era where human ingenuity must now be applied to developing a deeper understanding of the Earth's complex systems—an understanding that should begin with Earth observations. The forces of global development and change present serious challenges to world leaders, decision makers, and institutions—challenges that require advancing our existing Earth observation systems to a new level. That new level is an international, comprehensive, integrated, and sustained Earth observation system that provides the tools to "take the pulse of the planet."

These advanced tools (analogous to the medical community's diagnostic tools) would potentially allow for a continuous Earth system diagnosis to address the interrelated processes of weather, climate, ecosystems, and cycles of water, energy, and carbon. These advanced tools could also identify potential symptoms that, if left uncorrected, would impair the health of the Earth. An effective IEOS would provide information that enables decision makers to take proactive measures. Thus, an IEOS, with combined observations of atmospheric, terrestrial, ocean, and other phenomena, will form the basis for sound science for sound decision-making.

The social, economic, and scientific benefits of an IEOS are recognized internationally. However, so are the challenges associated with the international coordination of planning, developing, and implementing such a system.

This document briefly addresses: the impetus for the IEOS; the barriers to establishing the IEOS; the current state of Earth observation system integration; an initial framework for initiating the planning process; and a possible profile of initial IEOS implementation steps.

II. Impetus for an Integrated Earth Observation System

This section addresses the need for immediate action to develop the IEOS, recognizing the potential short- and long-term economic, social, and scientific benefits the IEOS would produce.

A. Need for Immediate Action. Every day without the IEOS is a lost opportunity and limits our ability to properly address recognized global environmental problems. Every day that an observation is not taken impacts the integrity of the scientific record and the observation can never be recovered. Having access to existing longer-term records addresses some of our environmental problems, but the lack of critical observations is significantly retarding the environmental understanding we seek and require.

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B. Short-term Benefits to All Countries. All countries would benefit in the near term from exchanging Earth observations recorded from *in situ*, aircraft, and satellite networks, dedicated to the purposes enumerated in the Declaration, in a full and open manner with minimum time delay and minimum cost. Earlier this year, the World Meteorological Organization (WMO) reported that from 1950-1999, loss of lives from natural catastrophes had been reduced in countries with good weather observation systems. Access to all existing and relevant Earth observation data today will provide a foundation to improve global response to weather hazards, fires and seismic events—thereby reducing loss of lives and minimizing loss of property. The return on investment for current Earth observation systems has brought great benefit to the world populace. The benefits resulting from an international, comprehensive, and sustained IEOS and analysis of observations into useful products could be monumental. Table 1 provides a sample of potential near term socioeconomic benefits that might result from the IEOS.

APPLICATION	POTENTIAL SOCIOECONOMIC BENEFITS
Water Management	•Cost savings through improved drought forecasting and water supply
Agricultural Efficiencies	•Improved crop productivity based on better forecasting
Aviation Safety	•Improved airport capacity and reduced delays
Coastal Management	•Reduced economic impacts from harmful algal blooms affecting public health, fisheries, recreation and tourism
Disaster Management	•More lives saved through improved early warning systems •Reduced property losses

Table 1. Potential Short-Term Socioeconomic Benefits of IEOS

C. Long-term Benefits of an Integrated Earth Observation System

1. Understanding the Earth system. For decades, nations have supported observations of the Earth's atmosphere, land, and ocean. Routine *in situ* observations have been complemented in recent years by remote sensing observations from aircraft, and from space. In addition, new observational capabilities have been developed within basic research programs.

Advances in scientific theory, when combined with improvements in observing systems and major increases in computing and communications capacity, are increasing our ability to model the Earth's atmosphere, land, and ocean processes on regional and global scales with steadily improving reliability. Comprehensive regional and global databases of geophysical parameters are required to support this Earth system modeling. Improved and expanded Earth observation systems are required to provide measurements of the key geophysical parameters of the planet. In addition to the need for continuity of existing measurements, needs exist for improved geographic and temporal coverage, as well as for systems with the capacity to provide monitoring and measurements of additional types of geophysical parameters.

2. Reducing Disaster Loss. Disaster management support would greatly benefit from an integrated observations approach. For example, we must integrate *in situ* information with space imagery, other Earth observations, and the associated model predictions of hurricanes, earthquakes, and other disaster events that span the four "pillars" of all-hazards disaster management: preparedness, response, recovery, and mitigation. Integrating these observations and predictions would facilitate timely delivery of decision support to aid communities in preparing for disasters, as well as in their response, recovery, and mitigation efforts.

3. Supporting Sustainable Development. Overarching challenges of capacity building and sustainable development still remain. Sustainable development has three principal dimensions: economic growth, social equity, and protection of the environment. The ability of a country to progress towards sustainable development is largely determined by the capacity of its people and institutions. An increase in capacity improves community skills and abilities to address crucial questions, evaluate policy options and implementation approaches, and appreciate constraints and limitations.

A cadre of trained people, communication systems, information access and availability, and the support for science and technology are all elements of a country's institutional capacity. Science and technology represent avenues for improving sustainable development decision-making through better understanding of ecological processes, enhanced efficiency of resource utilization, and systematic assessments of current conditions and future prospects. IEOS would

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contribute to national and international decision-making, as well as increasing the knowledge of our Earth and its dynamic processes.

III. Overcoming Barriers to Establish an Integrated Earth Observation System.

A. General. The Earth's dynamic environment, including physical climate and ecosystems, affects every aspect of society and economy. Within this context of an ever-changing Earth system, the environment provides both resources and risks. Minimizing risks while maximizing resources requires comprehensive understanding of the key processes that govern the Earth system. The diversity and complexity of the Earth system has led to the development of a diverse set of observing systems. Current observing systems are focused on specific needs for a range of applications and scientific disciplines. Examples include: meteorology and climatology; atmospheric chemistry; oceanography; hydrology; geography, geology and geophysics; marine and terrestrial ecology and biodiversity; and human health.

At present, data from these systems are not collected in consistent formats, which makes integration of data from multiple systems much more difficult. Each of these systems was built to respond to a specific scientific application and, thus, each produces data in a format specific to that system. Earth observation systems are often not consistently calibrated in either space or time. Additionally, calibration data and system performance data are not universally captured. These system shortcomings make long-term analysis of long-term processes difficult. The variety of formats and calibration schemes will be a challenge for developers of the IEOS.

B. Specific Examples of IEOS Barriers. The concept of an integrated Earth observation system is not new. There are a number of barriers, however, that have precluded development of such a system in the past.

Some of those barriers are:

- Insufficient data sharing;
- Inadequate observations (spatial, temporal, and/or quality limitations);
- Inconsistent data formats;
- Costs;
- Agreement on and development of mechanisms to maintain appropriate security, and in particular, to ensure that systems and/or data are used only for peaceful purposes; and
- Complexity of global environmental problems.

The Earth Observation Summit presents a superb opportunity to overcome these barriers. The potential partnership of over 30 countries in the Summit and the GEO (with the prospect of additional countries in the future) enables us to mount a realistic attempt to develop this IEOS. No single country could do so within its own resources. The substantial political support demonstrated by the Earth Observation Summit, however, bodes well for overcoming these barriers through the efforts of the GEO.

IV. Current State of Integration

A comprehensive and sustained IEOS currently does not exist, but some essential components are already in place. Several new Earth observing satellites, global *in situ* networks and reference sites, and Earth science modeling processes currently produce unprecedented high-quality observations and predictions that are leading to major new insights about the Earth system.

We also have several examples of integration "success stories" that can be used as examples. The WMO World Weather Watch, supported by the nations that contribute to the network, has put in place a system for nations around the world to receive daily weather observations, analyses, and forecasts. The WMO has also played a pioneering role in the global coordination of geophysical and meteorological experiments, thus providing operational foundations for the worldwide monitoring of atmospheric chemical composition, climate variability, and hydrology. The Global Observing System of the World Weather Watch and the ongoing "Redesign the Global Observing System" are examples of building blocks for an IEOS.

Over the past decade, several national, regional, and international efforts have been initiated and may provide additional opportunities. Some international examples include:

- Global Climate Observing System (GCOS);
- Global Ocean Observing System (GOOS);
- Global Terrestrial Observing System (GTOS);
- Committee on Earth Observation Satellites (CEOS); and
- Integrated Global Observing Strategy (IGOS).

As described by their respective websites, these examples offer considerable potential as building blocks for IEOS. GCOS is a long-term, user-driven operational system capable of providing comprehensive observations for monitoring the climate system, detecting and attributing climate change, assessing the impacts of climate variability, and supporting climate system research. GOOS is a permanent global system for observations, modeling and analysis of marine and ocean variables to support worldwide operational ocean services. GTOS is a program for observations, modeling, and analysis of terrestrial ecosystems to support sustainable development. CEOS coordinates and communicates the plans and operational status of satellite systems. IGOS is a strategic planning process that seeks to link research, long-term monitoring and operational programs into a framework to deliver maximum benefit and effectiveness.

None of these examples are both comprehensive and sufficiently supported (politically, fiscally, and technically) to accomplish the purpose of the IEOS. For example, there is no structured mechanism for establishing priorities for an integrated suite of Earth observation platforms and for identifying the respective countries (or organizations) that agree to fund and maintain specific Earth observation capabilities. However, with the recent G-8 call for action and the worldwide political support engendered by the Earth Observation Summit, we may be poised, as never before, to develop an IEOS.

V. Framework Dimensions for an Integrated Earth Observation System

A. General. The development of a 10-year IEOS implementation plan requires a framework that all contributing participants can use as a common basis for discussion and coordination. That framework includes, at a minimum, two dimensions: an architectural dimension and an organizational dimension. The architectural dimension includes the requirements process. The organizational dimension includes a description of the "team members" contributing to the effort, as well as the formation of an international coordination mechanism necessary to orchestrate the IEOS development activities.

B. Architectural dimension. What should IEOS look like? One view of IEOS is as a network of independently owned and operated elements with common rules and purpose and collaborative relationships. What are the unifying, organizing structures (or enabling mechanisms) that will allow the IEOS to be effective? Determining those appropriate enabling mechanisms is at the heart of our IEOS development effort. Within the architectural dimension, the GEO should determine the required components (many of which exist) and a structured building (i.e., architectural development) process to ensure the IEOS can address the right problems for the right people at the right time, in terms of both cost and risk.

1. Components of IEOS. Figure 1 illustrates recommended focus of IEOS. The figure is analogous to the "knowledge ladder" of knowledge management theory (bits, data, information, knowledge, wisdom) and visualizes societal benefit as the expected consequence of IEOS. Earth observation data obtained from existing systems constitute the building blocks of information. The data provides early detection and enables Earth system science models to predict consequences of human-induced and naturally occurring changes to the Earth system.

Information from those models is provided to decision-makers at all levels who use knowledge-based decision support strategies and systems. Information generation and decision making rely on Earth observations and are fundamental to achieving societal benefit, but are not the focus of IEOS. The key components of IEOS are existing Earth observation systems and data integration enabling mechanisms.

a. Earth observation systems. Observations are the foundation of our activity. To be most efficient, IEOS should begin with and incorporate data from the existing Earth observation systems dedicated to the purposes enumerated in the Declaration. These systems include research and operational instruments and observing networks with sensors on fixed or moving platforms and communication links among the observation sources. The GEO should consider integrating existing Earth observation system capacity to ensure pertinent Earth observation system solutions are effectively funded, deployed, and maintained. The data from these observing systems need to be integrated to provide the foundational data that are converted into the information (through application domain models) that supports sound science for our decision-makers.

b. Data integration. It is essential to agree on: the required geophysical parameters to be measured with IEOS and the necessary data protocols, policy, format, standards, metadata, etc., to ensure global data are useful to all IEOS participants. These data mechanisms are essential to facilitate an integrated approach and to achieve continuity for key geophysical variables for appropriate geographic and temporal coverage. These data mechanisms will also allow the development of multi-dimensional and multi-scale data models to evaluate system effectiveness.

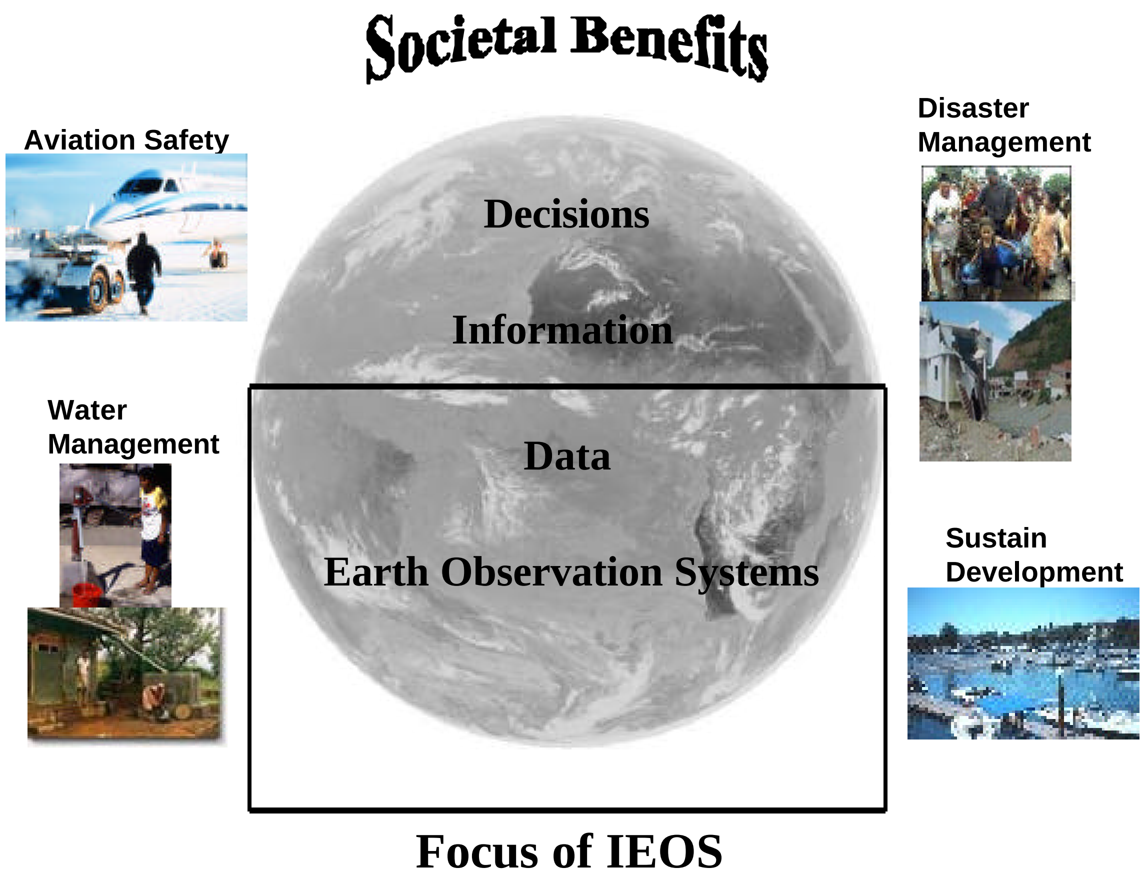

Figure 1. Earth Observations as the Foundation of an Integrated Earth Observation System

2. Information Components Outside Scope of IEOS. The following components are beyond the scope of IEOS, but will be directly impacted by IEOS development actions and will be essential to realizing societal benefits.

a. Information Product Generation. This component includes such capabilities as science modeling laboratories, application development centers, computing and communications capacity, and the methods to combine observations from multiple sources for predictions. The users of Earth observation data may need the direct geophysical measurements from the observation systems or output from predictive models initialized by the basic data. These needs call for an integrated approach for sharing multi-scale data sets and model output and for establishing continuity of data sets and model output in scales ranging from global to regional to national to local.

b. Information Integration. Appropriate mechanisms are necessary to ensure proper interfaces between Earth observation information models and the decision support tools used by decision makers. However, several questions arise. How will we make our Earth observation information products (observations and predictions) available, to enable effective decisions using decision support tools owned and operated by various countries around the world? What are the crucial information protocols necessary for integrating our diverse Earth observation model output to provide the more robust inputs often required by decision makers?

c. Decision Support Systems and Decision Making. Knowledge-based decision support strategies will likely embrace questions of economic, environmental, and social sustainability and create the opportunity for people to share information to address emerging issues in many venues of Earth science. The ability to obtain and analyze Earth observation information from diverse Earth observation elements creates new opportunities for international dialogue, learning, and decision building.

d. Societal Benefits. The rapidly growing world population will increase the demand for clean water, plentiful food, and other resources. The world's scientists should improve their understanding of the complex workings of Earth systems in order for decision makers to manage resources efficiently in the face of these growing Earth system challenges. Realizing societal benefits will require systematic assimilation of Earth observations and information into knowledge bases, climate record portals, decision support tools, and education tools. Additionally, this assimilation must be done through collaboration with the public sector, the private sector, and international communities.

3. Structured building process. To accomplish a task of this magnitude, the GEO will need to consider a number of significant issues and evaluate several alternative developmental processes. However, all have similar foundational elements. The GEO will be expected to evaluate and select the structured building process most appropriate for developing a feasible Implementation Plan.

C. Organizational Dimension. The GEO will designate participants to develop the IEOS. The initial team will include the governmental representatives from the GEO, and likely will expand to ensure participation from appropriate international institutions, professional societies, industry, and academia.

Earth observations are crosscutting, not issue-specific or specific to any single existing organization. In any event, many international organization partners will need to be involved. It will be up to the Members of the GEO to determine the most appropriate approach.

VI. Implementation

A. Early Actions. The GEO faces a challenging timetable to provide a Framework Document and develop a full implementation plan by the proposed delivery dates. The GEO has eight months to develop a Framework Document to be presented in Japan in Spring 2004. Subsequently, the GEO may have only three months after delivering the Framework Document to complete the initial version of a 10-Year Full Implementation Plan per the Declaration.

B. Related GEO Objectives. The draft GEO Outline Paper for the Inaugural Meeting lists the following elements for possible inclusion:

- evaluate system requirements to maximize intended benefits and to maintain security and other protections;
- establish an inventory of relevant Earth observing systems;
- develop a data model;
- perform a gap analysis (comparing required geophysical data to observed Earth observation parameters to identify data voids);
- address those observation deficiencies;
- assess the costs of alternatives to address the identified requirements; and
- mobilize resources to establish and maintain the integrity of an end-to-end geospatial information system.

C. Subgroups. The draft GEO Terms of Reference allows the GEO to establish subgroups. Subgroups may be considered for: organization (international coordination mechanisms); architecture (including requirements and inventory of existing Earth observation systems); gap analyses; security; cost analysis; and capacity building.

D. Phased Analysis and Focus. The GEO may find value in prioritizing and phasing the effort with initial focus of the plan on selected observation elements (e.g., climate, water, weather, oceans, ecologies, solid earth, global carbon) during the implementation period (August 2004-July 2013).

E. Immediate Opportunities. The GEO may find it essential to conduct an initial inventory of existing Earth observation systems and perform analyses to determine immediate opportunities for improvements, new Earth observation systems, or system elements that participating countries may wish to pursue. Early, continuous feedback from the GEO to the participating countries would facilitate progress toward identified opportunities.

VII. Summary

Organizing for, developing, and building this IEOS will be enormously challenging and will provide an opportunity for leveraging individual system elements into an integrated effort that would better address the global environmental challenges of the 21st century. It is hoped the entire team (government delegations with support from professional societies, international institutions, industry, and academia) will work together in harmony and close collaboration to build our past “building block” successes into an improved global capacity for the benefit of all.

Appendix

International Calls for Greater Integration

APPENDIX

INTERNATIONAL CALLS FOR GREATER INTEGRATION

The Earth Summit, Agenda 21 (1992)

- "Support development of new user-friendly technologies and systems that facilitate the integration of multidisciplinary, physical, chemical, biological, and social/human processes which, in turn, provide information and knowledge for decision makers and the general public."
- "In order to understand the Earth as a system, develop Earth observation systems from space which will provide integrated, continuous and long-term measurements of the interactions of the atmosphere, hydrosphere and lithosphere, and develop a distribution system for data which will facilitate the utilization of data obtained through observations."
- "Develop and apply systems and technology that automatically collect, record, and transmit data and information to data and analysis centers, in order to monitor marine, terrestrial and atmospheric processes and provide advance warning of natural disasters."
- "Develop, strengthen and forge new partnerships among national, regional and global capacities to promote the full and open exchange of scientific and technological data and information."

UN Framework Convention on Climate Change Subsidiary Body on Scientific and Technological Advice:

- "noted the importance of an integrated international effort on research and systematic observation"

UN Commission on Sustainable Development (April 2001)

- "Encourage relevant international organizations to plan and implement a joint strategy for integrated global observations to monitor the Earth's atmosphere"

National Academies' National Research Council (2001)

- "A major limitation of these model forecasts for use around the world is the paucity of data available to evaluate the ability of coupled models to simulate important aspects of past climate... Therefore, above all, it is essential to ensure the existence of a long-term observing system that provides a more definitive observational foundation to evaluate decadal-to-century scale variability and change."

World Summit on Sustainable Development (September 2002) – Actions are required to:

- "Promote the systematic observation of the Earth's atmosphere, land, and oceans by improving monitoring stations, increasing the use of satellites, and appropriate integration of these observations to produce high-quality data that could be disseminated for the use of all countries."

On June 2, 2003, the G-8 Partners agreed to Cooperative Action on Science and Technology for Sustainable Development. One of the three specified actions is that the G-8 Partners "develop close coordination of our respective global observation strategies for the next ten years; identify new observations to minimize data gaps; …develop an implementation plan to achieve these objectives by next spring's Tokyo ministerial conference." "The work will be initiated at the Earth Observation Summit."