Earth Observation Systems/Sensors for Meeting Sustainable Development Needs*

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Executive Summary

Earth observation satellites were among the earliest space launches and were originally exploited for military and weather programs. Operational civil remote sensing was initiated in 1972 by the Landsat satellites and primarily used for scientific research. Since 1979, attempts to privatize or commercially operate government developed remote sensing satellites have only been marginally successful. Now, after many years of government funded research and development programs and space policy decisions, conditions have become favorable to stimulate the creation of private sector initiatives for the commercial exploitation of remote sensing. Buoyed by the potential applications demonstrated by many remote sensing satellite programs conducted by several nations, 20 or more nations now have plans to launch their own remote sensing satellites before the year 2005, and in late 1997, the first of as many as nine different privately financed satellite remote sensing systems is being launched for commercial purposes. Digital imaging sensors coupled with enabling technologies, primarily in communications, and with other technologic advancements such as the global positioning system (GPS), are facilitating the use of remote sensing applications. As a result, over 100 Earth observing satellites are proposed for launch by both governments and the private sector during the next decade, and a multi-billion dollar ($US) international geo-spatial information industry is being spawned. It is projected that the innumerable direct and spin-off applications available from Earth observation data will create a marketplace in which spatial information will become ubiquitous. To identify, study, address and monitor on a global basis the changes in the Earth's environment, numerous international scientific programs under the aegis or sponsorship of agencies of the United Nations have been established and collaboratively use remote sensing data. International cooperation to promote and coordinate remote sensing research, developments, applications, technology transfer and related issues is conducted by international groups such as ISPRS and the Committee on Earth Observation Satellites (CEOS). The major issues identified as currently facing the remote sensing community are the need for: education and training in the application of remote sensing data and geo-spatial information (especially in the developing countries); copyrights on remote sensing data and information; maintaining data/product quality; and avoidance of unfair sales practices.

Commercial Aspects of Space Remote Sensing Activities

History

The first space photograph of the Earth was transmitted by Explorer-6 in August of 1959. Remote sensing from space began in April 1960 with the USA launch of the Television and Infrared Observational Satellite (TIROS-1) as an experimental weather satellite. The USA military launched its first Earth observation satellite, Discoverer, in August 1960. During the 1960's a series of remote sensing satellites was launched for weather, intelligence and lunar landing programs by the USA and Soviet Union. In 1972 the first civil satellite designed specifically to collect data of the Earth's surface and resources was the Earth Resources Technology Satellite (ERTS-1, which was later renamed Landsat-1). Throughout the 1970's extensive research programs demonstrated a multitude of "public good" uses for Landsat imagery and the potential opportunity for a commercial market to evolve. However, differing responsibilities and management agendas at the USA government agencies of NASA, NOAA, DOD, USDA, and USGS plagued the Landsat program from its inception.

To resolve these problems relevant to varying agency responsibilities, the Carter Administration undertook an extensive review of both military and civilian space policies, and by 1979 new policies were formulated in which the civilian program was to be made operational, administered by NOAA, and eventually turned over to the private sector (U.S. Dept. of Commerce, 1980; White House, 1979). At about this same time the USA Congress merged land-, ocean-, and weather-sensing systems under the administration of NOAA.

Privatization/Commercialization

A crisis ensued (National Research Council, 1985). The major players in this crisis included: a burgeoning community of Landsat data users, among them the news media, who wanted inexpensive, publicly accessible data; an increasingly vociferous industrial sector concerned about pending international competition and who believed privatization would preserve America's niche in commercial Earth observations; and a federal establishment disinclined to commercialize all land, ocean, and weather satellite data systems.

In its effort to reduce the size of government, the first Reagan Administration moved quickly to move the Landsat program to the private sector. The result was Public Law 98-365, the Land Remote-Sensing Commercialization Act of 1984 (U.S. Congress, 1984). NOAA solicited bids to manage the existing Landsats and civilian meteorological satellites and, aided by large government subsidies, to build and operate future systems. In 1985, a contract was signed with EOSAT Corporation and the transfer was complete (U.S. Dept. of Commerce, 1985). A history of the debate leading up to and going beyond privatization is given by Morain and Thome (1990). It is interesting that the most compelling arguments made to the U.S. Congress for Landsat commercialization focused on data and program continuity--not spectral analyses and fine-resolution, time-sequential data.

In October 1992, the Land Remote Sensing Policy Act (U.S. Congress, 1992) was signed into law. This law reversed the 1984 decision to commercialize the Landsat system and recognized the scientific, national security, economic, and social utility of 'land remote sensing from space' (Sheffner, 1994). Hardly a year had passed before the Landsat program was evaluated for a third time which resulted in a May 1994 Presidential Decision Directive/NSTC-3 reconfirming the Administration's support for the program but giving NASA, NOAA, and the USGS joint management responsibility (White House, 1994). These three agencies negotiated with EOSAT for new Landsat-4 and -5 product prices for the U.S. government and its affiliated users, and are proceeding to develop Landsat-7.

Government policies designed to transfer the Landsat program from the public to the private sector were seriously flawed. These policies did not result in market growth, were more costly to the USA Government than if the system had been federally operated, did not significantly reduce operating costs, and significantly inhibited applications of the data (Lauer, 1990). Nevertheless, the program continued to provide a flow of high-quality, well-calibrated, synoptic imagery of the Earth.

Whether or not Landsat privatization was premature given existing and anticipated markets, it can be argued that an expanding global community of government, academic, and private sector users, particularly among developing nations in Africa, Latin America, and Asia, stimulated proliferation of international Landsat look-alike satellites (See Table I.). After 1986, with the development and launch of the SPOT-1 satellite by France, these systems augmented Landsat data around the world, further verifying proof-of-concept applications, and boosting overall space-based capabilities to a new level (Lauer, Morain, Salomonson, 1997).

Before the UNISPACE '82 Conference, only the USA and Soviet Union were conducting space remote sensing activities and the Landsat Program was the only operational system developed for civilian use. However, the international remote sensing community has grown significantly during the past 15 years. The French space agency, CNES, planned the SPOT program as a government developed, commercially operated system, and set up SPOT Image, S.A., to operate it and to develop a marketing strategy (R. A. Williamson, 1997). Since the launch in February 1986 of SPOT-1, France has successfully developed a global market for Earth observation data. Now in 1997, there are ten governmental bodies (See Table II.) which have successfully launched Earth observation satellites, and several of them have made their imagery available for commercial use. In addition, there are ten or more nations (Table II.) which have announced program plans to have their own Earth observation satellites. In looking at the future, we find that 6% of all civil and commercial satellite launches planned for the next decade are Earth observation satellites whereas civil and commercial communications satellites comprise about 75% of the planned launches.

Year	Platform (Country)	Sensor	Year	Platform (Country)	Sensor
1972	Landsat-1 (USA)	MSS; RBV	*1996*	*ADEOS (Japan)*	*AVNIR*
1975	Landsat-2 (USA)	MSS; RBV	1996	PRIRODA (Germany/Russia)	MOMS
1978	Landsat-3 (USA)	MSS; RBV	1997	CBERS (China/Brazil)	LCCD
1982	Landsat-4 (USA)	MSS; TM	1997	IRS-1D (India)	LISS-3
1984	Landsat-5 (USA)	MSS; TM	1998	SPOT-4 (France)	HRVIR
1986	SPOT-1 (France)	HRV	1998	Landsat-7 (USA)	ETM+
1988	RESURS-01 (Russia)	MSU-SK	1998	EOS AM-1 (USA/Japan)	ASTER
1988	IRS-1A (India)	LISS-1	1998	IRS-P5 (India)	LISS-4
1990	SPOT-2 (France)	HRV	2000	IRS-2A (India)	LISS-4
1991	IRS-1B (India)	LISS-2	2000	EOS PM-1 (USA/Japan)	MODIS
1992	JERS-1 (Japan)	OPS	2001	Resource 21 (USA)	Resource 21
1993	*Landsat-6 (USA)*	*ETM*	2001	XSTAR (France)	XSTAR
1993	SPOT-3 (France)	RV	2002	ALOS (Japan)	AVNIR-2
1993	*IRS-P1 (India)*	*LISS-2; MEOSS*	2002	SPOT-5A (France)	HRG
1994	IRS-P2 (India)	LISS-2; MOS	2004	IRS-2B (India)	LISS-4
1994	RESURS-02 (Russia)	MSU-E	2004	SPOT-5B (France)	HRG
1995	IRS-1C (India)	LISS-3	2004	ALOS-A1 (Japan)	AVNIR-3
			2007	ALOS-A2 (Japan)	AVNIR-4

Table I. Chronology of Landsat and Landsat-like Launches 1972-2007.
Italicized entries failed to achieve orbit, or did not function on orbit.
(updated from an excerpt from Morain and Budge, 1996; Stoney et al., 1996).

EOS Launched	EOS Planned
USA	Argentina
Russia	Australia
France	China
Japan	Republic of Korea
India	Pakistan
Canada	South Africa
Brazil	Spain
Israel	Ukraine
Germany	Italy
ESA	Spain

Table II. Earth Observation Satellites - Government Programs

Indirect Markets

Communications - the enabler

Our skies will soon be populated with a myriad of Earth orbiting satellites. Hundreds of low Earth orbiting satellites are being launched by a variety of consortia to globally support mobile voice and data communications. These satellites are in addition to the established communication satellites in geo-stationary and other orbits. It is predicted that the satellite industry's 2.5% share of the booming telecommunications market will grow to 5.5% by 2005, reaching $75 billion in annual revenues (Anselmo, 1997). These major initiatives in advancing satellite communications are paving the path for real growth in the spatial information sciences and technologies by enabling the widespread transmission of digital imagery acquired by remote sensing satellites.

The timeliness and economic benefits of digital satellite Earth observing systems have long been recognized by governments as an essential ingredient in addressing global resource and environmental issues as well as for reconnaissance activities. The end of cold war policies brought to fore "dual use" opportunities for commercial entities to enhance and leverage advanced technologies for development of commodities for the public and private sectors. Communications enhancements, such as the availability, increased capacity, improved methodologies (e.g. data compression algorithms) and lower cost per data transmission byte have brought to the commercial sector visions of innumerable new markets and consumers for products from imagery acquired from satellites. Dual use has spawned a commercial Earth observations industry with potentially as many as nine (and perhaps more) competitors to acquire imagery and to supply value-added derivative products.

Three decades of government research and development have created a significant segment of the aerospace industry to concentrate on the development of technology needed to acquire and transmit digital imagery. Except for high resolution reconnaissance activities, government sponsorships of R & D for applications have been concentrated in the scientific community with emphasis on identification of renewable and non-renewable resources. Governments recognized that satellite remote sensing has great commercial potential and since the early 1980's have tried through privatization policies to develop an opportunity for the creation of commercial enterprises. These policies have been marginally successful as exemplified by the EOSAT, SPOT Image, Soyuz Carta, etc. enterprises. Now, with recognition that Geo-spatial Information is a viable commercial market, the traditional aerial imaging and ground survey systems are starting to merge with satellite technology.

For the survey, mapping and remote sensing industry and the science community this merging has sparked the opportunity for a methodological rebirth. The availability of new tools and digital processes has prompted a reevaluation of the traditional paradigm established for exploitation of imagery. Having recognized the benefits of generating information in digital rather than analog form, many image processing organizations are already scanning and digitizing imagery and products produced from film imaging systems. This is only the precursor of a more comprehensive transition to all-digital data acquisition and all-digitally processed production streams. A geo-spatial information from imagery industry is being spawned.

Imaging Technology - the current state

Before the year 2000, four companies are planning to launch eight high resolution digital imaging sensors (See Table III.). These privately financed satellites are scheduled to be orbiting the Earth for the collection of scenes which will complement and enhance the coverage and interpretability of Landsat, SPOT, IRS-1C, AVHRR, RadarSat, Sovinformsputnik and other government financed imaging satellites. Both governments and industry have plans for development and launch of over 100 Earth observing satellites during the coming decade. The proposed government systems are being developed for the very low, low, medium, and high spatial resolutions[1] based on the intended application (weather, resources, reconnaissance). The proposed privately financed commercial systems are targeted at the high spatial resolution applications (QuickBird, IKONOS, OrbView, EROS) and at the medium spatial resolution applications (EarlyBird, Resource 21, GEROS, CIBSAT, XSTAR). A comprehensive summary of the salient technical characteristics of the proposed commercial high resolution and medium resolution digital imaging systems is given in Fritz (1997).

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[1] **Spatial Resolutions from satellites are classified as:**

Very Low	**≥ 300 m.**	**Medium**	**≥ 3 < 30 m.**	**Very High**	**< 0.5 m.**
Low	**≥ 30 < 300 m.**	**High**	**≥ 0.5 < 3 m.**		

The global infrastructure for reception of image data from the Landsat and SPOT programs has provided the basis for commercial opportunities to burgeon. Currently many additional fixed and portable receiving stations are being commissioned to provide reception capability for the new high resolution commercial Earth observing satellites.

Year	Company	Sensor	Year	Company	Sensor
1997	EarthWatch	EarlyBird-1	2000	Kodak	CIBSAT
1998	Space Imaging EOSAT	IKONOS-1	2000	Resource 21	Resource21-A, B
1998	West Indian Space	EROS-A	2001	West Indian Space	EROS-B4, B5
1998	EarthWatch	QuickBird-1	2001	Matra-Marconi	XSTAR A
1999	Space Imaging EOSAT	IKONOS-2	2001	ORBIMAGE	OrbView-3b
1999	ORBIMAGE	OrbView-3a	2001	GER Corp.	GEROS III, IV
1999	EarthWatch	QuickBird-2	2001	Resource 21	Resource21-C, D
1999	West Indian Space	EROS-B1	2002	West Indian Space	EROS-B6
2000	West Indian Space	EROS-B2, B3	2001	Matra-Marconi	XSTAR B
2000	GER Corp.	GEROS I, II	2002	GER Corp.	GEROS V, VI
2000	GDE	TBA	2003	West Indian Space	EROS-B6

Table III. Commercial Earth Observation Satellites - Private Sector Programs

New Technologies - the catalyst

Initially the GPS satellites have had the most visible impact on Earth remote sensing and survey activities. In review, we find that the development of several technologies has converged in this past decade to support expansion of the spatial information production community. These new technologies include GPS, digital photogrammetric workstations, high capacity broadband communications, efficient image compression algorithms, high speed microprocessor chips, light satellites, low orbiting satellites, RAID technology for storage and access of very large volumes of data, pan-sharpened multi-spectral data fusion, and, of course, availability of high resolution commercial satellite imaging systems, etc. The list is becoming endless. In 1999 spaceborne hyperspectral cameras will be added to the data acquisition end of the spatial information processing stream.

An awareness of the potential value for promoting a convergence of these technologies with high resolution satellite imaging systems has initiated a strong interest in the commercial satellite industry to integrate these disparate, yet complementary tools and processes, into a commercial spatial information systems industry. Venture capital has been committed and many companies have initiated satellite imaging system developments lured on by promising prospects for a viable, burgeoning and lucrative commercial market for image-based, spatial information products.

Commercial Alliances - a maturing of the spatial information industry

Since 1994, many alliances and collaborative agreements have been forged between the new, larger commercial satellite venture companies, international remote sensing ground stations, and the traditional small mapping, surveying and associated value-added GIS companies. The success of this new mix of large aerospace with small specialty companies is considered to be the key for commercial viability of a vast new array of new spatial information products.

Large aerospace companies have generated the investment capital of approximately US$350 million to US$600 million needed by each to initiate development, launch, promotion and operation of its spatial information from imagery system. The repetitive, synoptic surveillance capability of satellite imaging systems to provide "timely, quality spatial information" has not been economically viable from aircraft imaging. It is the ability of satellite imaging to repetitively capture temporal events which makes it so valuable for a vast new array of consumer interests. This repetitive capability of imaging satellites provides the opportunity for the acquisition of imagery to be both *applications driven and technology driven* whereas, aerial imagery is epochal and non-repetitive and uses methodologies and techniques which are primarily *applications driven*.

It is apparent that in the alliance of aerospace and the traditional value-added industries, the business success will be based on the provision of value-added, image-derived information. It is predicted that eventually the bulk of the spatial information products will not include images, even though the information products and services will be image-derived. However, it is the spatial, spectral and temporal quality of the Earth observation data which provides the key for the success of these industries. As the leadership and emphasis for image based production shift from governmental agencies to commercial GIS and spatial information companies, there must be vigilance to insure attention to product quality. It has been a primary role for governments to set standards and specifications for the quality of spatial products to protect public interests - "for public good". However, in the commercial arena spatial products become a commodity and the emphasis for quality assurance can sometimes be compromised by "for profit" motives.

Economic and Social Impact of Space Commercialization

The Future Marketplace - spatial information will become ubiquitous

The strategic goal for the Earth imaging industry is to provide spatial information for a sophisticated consumer market which does not care to know that the spatial information they are using came from images. Although the traditional markets for Earth observation imagery have been weather prediction and monitoring, as well as some surveying and mapping, the future market is for spatially attributed temporal information. A market niche in the transportation sector for real-time navigation has already been spawned from the use of map data from satellite imagery combined with GPS and inertial referencing systems. Another very promising market sector is precision farming which uses timely repetitive imagery. Precision farming is "the determination of precise field conditions for managing the dispensation of precise nutrients or remedies to precise locations for improvement of crop productivity." Many other promising niche and spin-off markets are envisioned for spatial information from Earth observation satellite systems. They include, but are surely not limited to:

disaster monitoring and assessment services;
emergency services;
tracking hazardous activities;
fire and hazards detection;
disease detection (agricultural);
disease monitoring (agricultural & human);
real estate appraisal, taxation and permitting;
city and urban planning;
financial and insurance services;
retail marketing;
facilities placement;
facilities monitoring;
peacekeeping and treaty monitoring;
law enforcement;
news services;
environmental protection;
global monitoring;
resource assessment (natural & renewable);
resource monitoring (natural & renewable);
archaeological & architectural site preservation;
cadastral survey and land registration;
trends analysis & prediction services;
navigation safety;
utilities management;
reconnaissance, detection and surveillance;
demographics;
tourism and recreation;
entertainment.

The ready availability of Earth observation products will provide the essential tools to enable humanity to manage growth and to control human impacts on this fragile planet.

Governments are the largest expected consumers in the initial marketplace. Properly integrated, and without unfair sales competition from new government imaging program developments, the new commercial alliances have the opportunity to rapidly exceed current industry assessments which project the year 2000 applications market value to range from $3 to $8 US billion (Miller & Walker, 1989). It should be expected that many of the hardware, software, developers and service providers will merge and align with the large image acquisition companies as the industry matures. The trend to all-digital value-added processes will accelerate these mergers.

International Cooperation

There are a number of international programs, systems and organizations which require and use data derived from remotely sensed imagery as a major part of their international collaboration activities.

Environmental Research Programs

IGBP The International Geosphere Biosphere Program established by the International Council of Scientific Unions (ICSU) in 1986 addresses the dynamic and complex nature of the Earth system, its past changes and its future development. IGBP core projects address priority scientific questions in which space data makes a significant contribution. As one of its main activities the IGBP Data and Information System (IGBP-DIS) has been established to encourage and facilitate a wider availability of data, including Earth observation data, which are useful for global change researchers.

WCRP The World Climate Research Program is jointly conducted by ICSU, the World Meteorological Organization (WMO) and the Intergovernmental Oceanographic Commission (IOC). WCRP projects are concerned with the characteristics of the oceans and the related water circulation, processes within the atmosphere, climate variability and predictability, and the Arctic climate system. Earth observation data contributes to many of the WCRP research questions.

IHDP The International Human Dimensions of Global Environmental Change Program recognizes that human activities on the planet have a link both with physical processes and institutional structures, social organization and cultural traditions. Accordingly, IHDP uses remote sensing data to address core research issues for analysis, including land use/cover change, industrial transformation, population growth, environmental security and sustainable development.

Global Monitoring Systems

GCOS The Global Climate Observing System is sponsored by IOC, ICSU, WMO, and United Nations Environment Program (UNEP). GCOS has developed a strategy which includes in-situ data, satellite imagery and derived information to address the main climate issues such as seasonal and inter-annual climate prediction, early detection of climate trends and climate change caused by human activity, and reduction in the major uncertainties in climate prediction.

GOOS The Global Ocean Observing System is sponsored by IOC, UNEP and WMO. GOOS uses Earth observation data and in situ data from the ocean surface and the ocean depths in order to respond to developing demands for ocean data. The Earth observation data are primarily from satellite altimeters, wind scatterometers, ocean color sensors and sea surface temperature instruments.

GTOS The Global Terrestrial Observing System was established in 1996 by the UN Food and Agriculture Organization (FAO), ICSU, UNESCO, UNEP and the WMO. GTOS is envisaged as a partnership of partnerships, formed largely by linking existing monitoring sites and observational networks, plus Earth observation systems to provide for hierarchical measurement of the land surface.

Collaboration and Coordination Organizations

CEOS The Committee on Earth Observation Satellites, created in 1984, works on a best-efforts basis and has the following three primary objectives.

- To optimize the benefits of spaceborne Earth observation through cooperation of its members in mission planning and in the development of compatible data products and services.
- To aid both its members and the international user community by serving as a focal point for international coordination of space-related Earth observation activities.
- To exchange policy and technical information to encourage complementarity and compatibility among spaceborne Earth observation systems.

The CEOS Strategic Implementation Team is leading the effort for an Integrated Global Observing Strategy to coordinate greater coherence of observing systems for GCOS, GOOS and GTOS.

ISPRS The International Society for Photogrammetry and Remote Sensing is an non-governmental organization comprised of member organizations representing the worldwide community of remote sensing, photogrammetry and GIS specialists in over 100 countries. ISPRS operates its activities on a four year cycle. Through its seven Commissions and 45 Working Groups, ISPRS: a) conducts and promotes high quality research and developments in photogrammetry, remote sensing, spatial information systems, related vision sciences and their applications; b) conducts regular forums for the dissemination of information on new developments; c) presents regular publications of activities and results of research, new developments and applications; and d) promotes and facilitates education and training programs in its areas of expertise. ISPRS provides the remote sensing, photogrammetric and GIS perspective in its coordination and collaboration activities with related international governmental and professional societies.

IEOS The International Earth Observing System is a smaller group of agencies which comprises the main public sector suppliers of Earth observation data. This group consists of the relevant Earth observation data supplier organizations of Europe, Japan and the United States which planned the original Polar Platforms. The IEOS comprises the following missions and organizations: Envisat-1 for ESA; EOS-AM1 for NASA, NOAA-N for NOAA, ADEOS for NASDA, and TRMM for NASDA/NASA.

Participation of Developing Countries

Some of the remote sensing organizations from developing countries do participate in these international programs and organizations, but they are seldom in a leading role. Brazil, India, China and Ukraine are members of CEOS where they have the opportunity to establish collaborative activities, exchange technical information and have some influence on policy issues. Many developing countries participate in ISPRS and countries such as Brazil, Nigeria, China, India, Indonesia have been elected for four year terms with responsibility for managing the technical and scientific activities of ISPRS Commissions. In most other organizations the participation of countries which are preparing Earth observation systems is limited mostly to international conferences. These countries include Pakistan, Korea and Argentina plus many developing countries which are establishing ground stations or facilities for using satellite imagery,

Education and training in photogrammetry, remote sensing and GIS is recognized as a major need by developing countries for implementation and beneficial use of satellite imagery.

Legal Aspects

The Principles Relating to Remote Sensing of the Earth from Space adopted by the United Nations on 3 December 1986 (UN/OOSA, 1994) has proven to be an insightful, judicious and even inspirational document for guiding the impending commercialization of remote sensing. Its comprehensive coverage has minimized the extent of legal issues regarding Earth observation, including open skies for high resolution systems. Some issues which could surface litigation include data rights, data pricing, data availability, data transmission bandwidth infringements, orbit allocations and data quality.

One of the main mechanisms for the protection of Earth observation data is copyright. There is no international law on copyright and so such protection is limited to national copyright laws. There are normally two definitions of copyright. First, when data are fixed in some form and second, where there is an element of creativity involved in the creation of the data. Copyright is an important issue in the long term to provide legal protection of Earth observation data and it is necessary to create clear guidelines for both users and suppliers on what constitutes copyright protection. However, there is a danger that some national laws may allow users to avoid copyright issues altogether. Under the US Freedom of Information Act it is stated that: *data in the physical possession of US Government employees or at US Government facilities must be made available to any requester under FOIA at the* *cost of reproduction regardless of whether the data are also available through a commercial distributor*. This condition could potentially create problems over the distribution of SPOT data and Meteosat data which are explicitly protected by CNES and EUMETSAT respectively.

In March 1996 the European Parliament and Council agreed a Directive on the legal protection of databases (R. Harris, 1997). The objective of the Directive is to: *afford an appropriate and uniform level of protection of databases as a means to secure the remuneration of the maker of the database.* In the preambles there are two items out of the 60 issues of justification which appear to be directly relevant to Earth observation data. The first notes that in Europe no clear legislation exists to protect databases: *Whereas databases are at present not sufficiently protected in all (European) Member States by existing legislation.* And the second relates directly to one of the major international tensions in Earth observation data policy: *Whereas the making of databases requires the investment of considerable human, technical and financial resources while such databases can be copied or accessed at a fraction of the cost needed to design them independently.* The Directive becomes European law on 1 January 1998.

The Directive proposes protection of databases by either copyright protection or by a sui generis protection. The core of the copyright protection in the Directive is the selection or arrangement of the database rather than protection of the contents of the database. Under the Directive copyright is used to protect an author's own intellectual creation of the organization of the database. Therefore the issue of copyright protection under the Directive revolves around the issue of who is responsible for the organization of the database. The Directive's provision for a sui generis right, that is a right *for the maker of a database which shows that there has been ... a substantial investment in either the obtaining, verification or presentation ... of the contents of that database.* This part of the Directive concentrates more on the financial investment in the construction of databases and in the acquisition of their content and so might be used to protect Earth observation data themselves. The term of protection foreseen for databases is 15 years, either from the creation of the database or from the date the database is made publicly available.

For both the copyright and the sui generis right there are exceptions. The Directive notes that Member States may agree to legislation to allow special conditions for scientific research which uses electronic databases as long as the source is indicated and there is a definition of the scope of non-commercial use. Thus for example, the United Kingdom law has reserved exception for *non-commercial research and for educational uses.* This exception directly relates to Earth observation data policy for scientific research. Other European Union countries may not have negotiated exceptions.

The issues of copyright of Earth observation data are also being addressed by the ICSU Group on Data and Information.

Conclusions

Long recognized as a potential commercial application of space technology, remote sensing is now maturing into a commercially viable industry. It is destined to play a prominent role in spatial information systems which are becoming pervasive in all human activities. It is essential that the cooperative collaborative environment between government and industry continue so that the many beneficial applications of remote sensing from space can be used to address the needs and wants of humanity in managing future growth and controlling human impact on this planet. As technological advancements in space sensors and processors continue, it can be expected that remote sensing and the spin-off benefits that it spawns will provide even greater benefits for servicing the spatial, spectral and temporal geo-information needs of Society.

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