Earth observations: the view from the ground

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Introduction

Late twentieth century and early twenty-first century civil remote sensing missions are increasingly being defined by data distribution and access as well as on-orbit operations. Circumstances exist where more obstacles to successful missions are generated on Earth than in space. In general, most satellite operating nations have mastered the space segment and can reasonably expect routine technological advancement to be an ongoing norm. However, the remote sensing ground segment – defined here as an aggregate entity consisting of legal, political, and technological agreements, facilities, and organizations considered as a whole – fails to reflect the same degree of success.

This is so, in large part, because the attention of remote sensing decisionmakers has been overwhelmingly centered on the space-based portion of remote sensing activities. Satellites, like most space technologies, were born in, and of, the Cold War and its necessities. As such, their development, operations, and use were dominated by issues of national sovereignty and prestige. Technology, the ultimate manifestation of Cold War superiority, was more often used to achieve these goals than to develop its likely applications. In the USA, this is evidenced by the fact that historically, while Earth observation satellites tend to be funded and continue to be the focus of high-level governmental policies and politics, the data generated by them has been little cared for. Only recently, with the advent of the Earth Observing System Data and Information System (EOSDIS) has the ground segment taken on political proportions approaching the magnitude of the satellites. Even so, the relative lack of priority for ground segment activities is indicated by decisions that continue to reduce the proportion of EOSDIS funding from its original 60% of the entire Earth Observing System mission to approximately 33%.

Additional impediments to ground segment evolution lie in the difficulty of merging highly complex, technical questions like data and media standards with equally complex international politics and economics. Incompatible national policies, ambiguous laws, nonenforceable agreements, and resource and expertise disparities have also hampered the evolution of terrestrial networks necessary for long-term data collection and processing.

However, the ever-increasing economic and scientific value of data is rapidly transforming attitudes about the relative value of the
remote sensing ground segment. What has been neglected is now being recognized as perhaps the most important part of remote sensing. It is on the ground that data are received, relayed, distributed, interpreted, and turned into information. It is on the ground where people are employed, set policy, operate facilities, and run businesses to handle the satellites' product: data. It is data, therefore, and the capability of locating and accessing it, that ought to serve as the criteria for determining the success of a particular ground segment or network. An additional criterion is whether the collected database encompasses the intended satellite coverage area, be it local, regional, or global.

This paper examines some of the ground segment entities that have, or are, emerging. While the number and scope of such entities continue to change rapidly and continuously only four will be discussed in some detail. They are, the Landsat Ground Station Operations Working Group (LGSOWG), the Committee on Earth Observation Satellites (CEOS), the Global Land 1-KM AVHRR Project (1-KM Project), and the Multi-Resolution Land Characteristics Consortium (MRLC). LGSOWG is examined because it was the first, and continuing, attempt to establish a ground network to support the mission of an Earth observation satellite. CEOS is considered because it is comprised primarily of governmental organizations currently responsible for operating the world's civil space-based Earth observations programs. The 1-KM Project and the MRLC are included because they are producing, and continue to produce, regional and global data products valued by government and commercial users across political boundaries.

Consideration of these groups together suggests that at least two major categories of ground segments have emerged: those that are satellite-driven and which have top-down organizations and those that are data-driven and organized from the bottom up. Or put differently, the former are generally data providers and the latter, generally data users. LGSOWG and CEOS are in the first category and the MRLC is in the second category. The 1-KM Project has elements of both with its main partners operating in a satellite-driven, top-down organization and its network participants operating in a data-driven, bottom-up manner.

The paper concludes with brief look at other some other ground segment organizations involving the remote sensing industry, the scientific community, and multilateral commercial and public partnerships. They are GOSS, GEOSAT, Inc., NARSIA and ESA/ESRIN/EARTHSAT.

Top-down, satellite-driven ground segments

*LGSOWG*

LGSOWG, The Landsat Ground Station Operations Working Group is the oldest organization created specifically to acquire, distribute and archive satellite data and to address issues raised by an Earth observation satellite. The first meeting was held in 1975. LGSOWG participation was a condition of receiving Landsat data and it was created as a forum to exchange information on problems and opportunities among nations operating LANDSAT data acquisition and processing facilities. LGSOWG's legal status is contained in a series of bilateral memoranda of understanding (MOUs) executed from the
mid-1970s between the USA and nations with Landsat ground stations. NASA was the US signatory to the earliest agreements, with NOAA subsequently assuming that role in the early 1980s. All of the signatories of the participating nations are government agencies.

MOUs through Landsat 5 were negotiated by the US Government. The now-repealed Land Remote Sensing Commercialization Act allowed a contractor to become the government’s agent in these agreements. This introduced the then quasi-private Earth Satellite Observation Company (EOSAT) to LGSOWG in 1985 as a NOAA contractor. For the now defunct Landsat 6, initially the MOUs would continue to be signed by NOAA but eventually negotiations were conducted ‘directly between the individual foreign ground stations and EOSAT.’ At least one of these agreements omitted any mention of LGSOWG entirely which had raised questions about its continued existence. However, the failure of Landsat 6, the repeal of the Commercialization Act, and the return of the Landsat program to the public sector precluded EOSAT from participating in future ground station agreements on behalf of the USA. Absent this authority, EOSAT’s continued participation in LGSOWG terminates after the official demise of Landsats 4 and 5.

NOAA has resumed responsibility for the Landsat ground segment, beginning with Landsat 7 and is the new US signatory for the MOUs it is renegotiating with the foreign ground stations. MOU obligations are ‘subject to the national laws and regulations of each party.’ In exchange for Landsat 7 data, each international ground station agrees to fund its own operations including communications links with NOAA and the USGS/EROS Data Center (EDC). Each ground station will pay an annual access fee, on a quarterly basis, of $600,000. Nonpayment can result in data transmission curtailment or termination.

Individual stations ensure that all data from all Landsats acquired under the new and previous MOUs are ‘available for sale or distribution on a public, non-discriminatory basis.’ NOAA may request copies of Landsat 7 data distribution agreements made by a station and the copies must be provided. Ground stations must also maintain a current inventory of holdings and provide the EDC with monthly metadata to be ‘made available publicly through U.S. data facilities.’ NOAA can also request limited data acquisition to support key US Government programs and individual stations may request data from one another. All data must be archived for at least 10 years, and a ground station must give the US National Satellite Land Remote Sensing Data Archive (NSLRSDA) first right of refusal for any data it plans to purge. Data must be given to NSLRSDA at cost of reproduction and transmission.

NOAA ‘will endeavor to avoid competition’ with each ground station within its area of coverage. Therefore, if a data request is made from within a particular station’s area and EDC metadata indicates the station has the data, the requestor will be referred to that station. If the requestor is from outside of the coverage area and EDC does not have the data, then it will tell the requestor that the station may have ‘more complete data’ available. To make these referrals possible, the station must make ‘complete and current information’ to NOAA and EDC.

Downlink resources will be scheduled ‘to meet requests from all participating [ground stations] in an equitable and balanced manner.’ Conflicts will be resolved by conflict resolution and interpretation disputes will settled by the NOAA Assistant Administrator for Satellite
and Information Services and an appointed representative from the participating ground station.

LGSOWG membership currently includes Australia, Brazil, Canada, Ecuador, ESA, India, Indonesia, Japan, Pakistan, the People's Republic of China, Saudi Arabia, South Africa, Thailand, and the USA. Taiwan has observer status. The 1995 meeting was also attended by Singapore. CNES, the French space agency, was invited to participate in the second meeting. Over the years representatives from Argentina, Chile, Ecuador, Iran, Italy, New Zealand, Zaire, EARTHNET, Telespazio, and the Swedish Space Corporation have attended intermittently.

LGSOWG has two primary working groups, the Landsat Technical Working Group (LTWG) and the Data Distribution and Marketing Working Group (DDMWG). The DDMWG had previously been the Data Distribution Working Group (DDWG) begun in 1981, but was rechartered in 1983 to consider ways to expand the Landsat data products and services market, support system cost-recovery objectives, and to assess collectively commercial trends and the impacts of policies and practices on the Landsat market. The LTWG and the DDMWG meet at approximate one year intervals.

Regular meetings and discussions are arranged to 'maximize [operators'] responsiveness to the user community.' Meetings were originally held twice a year but were changed to approximately one year intervals due to the travel budget constraints of a number of the members. Meeting sites rotate among participating nations near actual operations facilities. Landsat applications reports, education and training opportunities, and information about new programs are also exchanged. Each country gives a presentation regarding its operations and plans. Early topics included a regional approach to remote sensing in Africa; a cost-sharing plan; standardized data cataloging; and, disaster assessment. Issues that continue to arise are user access to data, data price, cost recovery, commercialization, regionalization, and technological compatibility of various system components. Recent topics include global change research, impact of human activity on the environment, and the US commitment to data continuity.

A recurring issue is the state of the Landsat International Data Base maintained at EDC. In concept, the entire database consists of all data held by the EDC and each of the participating ground stations. The database is intended to provide users with scene identification, acquisition dates, location, cloud cover, and quality. As of June 1991, it held approximately one million US archived scenes and two million scenes archived by non-US stations. Proposals for standardizing data catalogs were discussed at the very first LGSOWG meeting in 1975.

Stations were encouraged to list all other ground stations in their own catalogs and to provide the catalogs to the other stations, EDC was willing to list the data holdings of other ground stations with its own data so that users requesting information on available data could be told where in the combined LGSOWG holdings it could be located. Participation in database sharing was voluntary with each station being responsible for making their listings compatible with the receiving databanks. The USA distributed reports on each country's archiving and cataloging methods in 1981.

The need for a plan and schedule for 'a total Landsat holding update from each participating country' was raised in 1986. Although a preliminary schedule was outlined, updating information was still an
outstanding business item in 1989 and 1990. Providing catalog data from the international ground stations to EDC for the Landsat International Data Base, was made an ongoing LGSOWG item in 1991 and it was emphasized that in order to optimize for global data coverage determination the international data base should include holdings of all LGSOWG members, with members improving frequency and timeliness of their updates. It was estimated that there were one-half million scenes archived by stations that had yet to make them available to EDC. This was still the case in 1992.

CEOS

In 1984, the Economic Summit of Industrialized Nations Working Group on Growth, Technology and Employment’s Panel of Experts on Satellite Remote Sensing recognized the ‘multidisciplinary nature’ of Earth observations missions and the inability of a single agency to afford the full range of Earth observations measurements. It recommended that a coordinating body for these missions be formed. The result was the Committee on Earth Observation Satellites (CEOS) which has three categories of participation: members, observers, and affiliates. Members include governmental organizations that are international or national ‘by nature’ with responsibility for operating a civil space-based Earth observations program. Observers are governmental organizations developing spaceborne systems or with significant ground-segment activity that supports CEOS objectives. Affiliates are other satellite coordination groups, scientific or governmental bodies that are ‘international in nature’ with significant programmatic activity that also support CEOS objectives. Views of all three participant groups are considered in the decision-making process but only the members’ opinions are required to form consensus. CEOS may make recommendations and agree on actions to promote coordination across satellite coordination groups and national and international satellite programs. Individual CEOS members will use their best efforts to implement CEOS recommendations in their respective Earth observations programs.

Taking action based on conclusions and recommendations of Plenary sessions and ad hoc working groups is at the discretion of each member. Standing working groups are established to ensure long-term continuity of work and continue without requiring specific confirmation by the Plenary unless consensus is reached to discontinue the group. CEOS holds a yearly Plenary session and meetings are organized and chaired by designated host organizations. A standing Secretariat is maintained by ESA, NASA/NOAA, and STA/NASDA and is chaired by the CEOS Plenary host organization.

One of the first two standing bodies created by CEOS was the ad hoc Working Group on Data (WGD). Its original function was to serve as a control authority for Earth observation digital data formats. It was made permanent in 1988 and had its original Terms of Reference modified to include an emphasis on networking. In 1990, the WGD recommended that an ad hoc Working Group on Space-to-Ground Networks (WGSN) be formed to address the requirements and coordination of space-to-space and space-to-ground networks. Japan offered to become its first chair. In 1991, the ad hoc WGSN was made a subgroup of the WGD. In 1992, a satellite mission dossier was introduced which contained additional sections on the ground segment.
and an initiative to strengthen network coordination was proposed by
UK Prime Minister John Major.\textsuperscript{33}

The 1991 WGSN meeting was held in Tsukuba, Japan and was
attended by 12 space agencies.\textsuperscript{34} Meeting objectives were to:

- assess user requirements for space networks, especially as they
  relate to Earth observations satellites;
- evaluate the roles and responsibilities of existing groups that
  coordinate and recommend international standards related to
  space networks; and
- review a draft Terms of Reference for CEOS WGSN.\textsuperscript{35}

The participants found that ‘all of the major issues related to space
networks were covered by existing standards or coordination groups’
some, outside of CEOS. However, regarding terrestrial networks the
participants found a very different situation and recommended the
following.

- A group should be identified to collect and coordinate end-user
  requirements for real-time and near-real-time Earth observations
  data acquisition, and for delivery of these data to terrestrial
  networks.
- A group should be identified to coordinate Earth observation
  satellite data acquisition among CEOS members.
- The CEOS WGD Network Subgroup should be activated under a
  permanent chair to coordinate data exchange among CEOS
  members, to recommend exchange standards, and to evaluate
  requirements for space network interfaces to ground networks.\textsuperscript{36}

The WGSN’s oversight group, the WGD, stated that network activities, as
addressed by the first two recommendations, ‘would be treated on a case-by-
case basis and that [it] could not take overall responsibility for overall
coordination.’ This position was endorsed by the fifth CEOS Plenary and
the Secretariat offered to address the recommendations regarding user
requirements and ground infrastructure as part of the next Plenary. The
WGSN was dissolved\textsuperscript{37} and an ad hoc Working Group on Networks co-
chaired by Japan and Europe was established at the 1993 Plenary.\textsuperscript{38} At the
1994 Plenary, the ad hoc group was dissolved and an interim Working
Group on Network Services (WIGNS) was created.\textsuperscript{39} Unlike the ad hoc
group whose representation was limited to ESA, NASA, and NASA/
NOAA, membership in WIGNS is unlimited and available to all three
categories of CEOS membership. The group’s first meeting was set for
December 1994 to draft formal terms of reference and a decision to establish
the interim group on a permanent basis was on the agenda for the 1995
Plenary. However, the US proposed that the WGD and WIGNS be merged
into a single group, the Working Group on Information Systems and
Services (WGISS). At the May 1995 meeting of WDG and WIGNS, the
proposal was discussed and adopted and was accepted at the 1995 Plenary.

The first WGISS meeting was held in November 1995 after which a
5-year plan, incorporating an initial list of tasks, was developed.
WGISS meets twice a year and has a Chair and two Vice-Chairs that
are designated by the CEOS Plenary. These positions rotate among
WGISS members every 2 years. The current Chair position is held by
NOAA of the USA, the User Vice-Chair by a representative from the
IGBP-DIS, and the General Vice-Chair by STA/NASDA of Japan.
WGISS intends to ‘develop the means by which clear, stable and
reliable infrastructure and standards can be defined for earth
observations providers and users.’\textsuperscript{40}
The 5-year plan has six main themes which outline the activities to be undertaken: user consultation, data and information management, user services, data standards, CEOS information services, and promotion of WGISS' work in the data user and provider community. In all of these themes, WGISS will pay particular attention to the needs of developing countries and assist them in using and making Earth science data and metadata available. Specific WGISS work areas are access, data, and networks, each with a corresponding sub-group. There are 25 specific tasks which have deadlines linked to major mission and program milestones of CEOS members. The plan is updated annually and will bring WGISS into 2000.41

Bottom-up and data-driven ground segments

The MRLC consortium

When six different government environmental monitoring programs with complementary missions and remote sensing needs found that commercial data prices and acquisition delays were unable to accommodate their individual budgets and research schedules, they came together in 1993 to form the Multi-Resolution Land Characteristics Consortium to produce the Multi-Resolution Land Characteristics Data Base.42 Members of the multi-agency partnership are the US Environmental Protection Agency – Environmental Monitoring and Assessment Program (EMAP); the US Geological Survey – National Water-Quality Assessment Program (NAWQA); the North American Landscape Characterization (NALC), a joint venture between the EPA and USGS; the USGS Biological Resources Division (BRD) (formerly the National Biological Survey (NBS), the original Consortium member) – Gap Analysis Program (GAP); the EROS Data Center (EDC); and the National Oceanic and Atmospheric Administration – Coastal Ocean Program, Coastal Change Analysis Program (C-CAP).

Intra-agency areas of interest range from ecosystem monitoring, biological diversity, Earth resources information management, water quality, and coastal change, to land cover detection. Intra-agency research objectives served by the consortium include prevention of additional species being listed as threatened or endangered; correlation of land use changes and drinking water quality; detection of uplands and emergent wetlands change; comparison of distribution of vegetation and all vertebrate species with land ownership and management; and, large area bioregion vegetation and habitat mapping, among many others.

The MRLC Consortium’s ‘seminal goal’ is the ‘joint acquisition of Thematic Mapper (TM) imagery for the coterminous US’.43 For the first time, the Consortium created a complete land characteristics database of the entire lower 48 United States for ‘broad-based research on existing and future conditions of physical and biological resources of the United States.’44 Consisting of 53745 scenes at $3256 per scene, totalling $1 400 080,46 the consortium’s purchase was the largest single civilian purchase of satellite imagery from one source since Landsat data were privatized in 1984.47 The interagency purchase resulted in a short-term savings to the government of $20–30 million and long-term benefits unable to be calculated at this stage.48

Use of the original raw data is limited to EDC and its Affiliates
defined as 'any person conducting MRLC research within the scope of a relationship with EDC which is defined by contract, employment, financial support arrangement, or written cooperative research agreement.' Affiliates must designate in writing 'the nature, scope, and requirements' of their research; must agree to publish research results in open literature; and, refrain from using data and unenhanced products for commercial purposes. Data acquired jointly is archived and distributed by EDC to any MRLC participant at the cost of reproduction plus preprocessing if previously unpaid for by the consortium. The land characteristics database, the MRLC itself, can be used by the Consortium and other federal, state, and local organizations. The right to market a commercial version of the value-added database as 'The Best of the U.S.' was given to the data seller as part of the data purchase agreement.

The purchased images are the founding data set for the MRLC. The MRLC objective is to develop regional and national land characteristic spatial data bases. Large land cover data sets being produced include an interpreted land cover map at 1:100,000 scale; indexed derivatives of AVHRR images; an archive of ground sample points and digital ground photos; an index of airborne video transects; a land cover change data set from MSS images over the last 30 years; a public domain spectrally clustered data set available for user interpretation; a data set of marine and estuarine features. The processed database has consistent resolution and a uniform set of corrections. An MRLC Information System is available over the Internet.

An example of the dramatic growth in MRLC product generation and bottom-up cooperative efforts flowing from the original founding data set is the experience of one of the Consortium's members, the BRD's GAP Project, which seeks to identify conservation gaps. That is, flora and fauna unrepresented in current conservation lands. The standardized method and format provided by the MRLC has enabled 36 states to edge-match their data to reveal large-scale biodiversity patterns. The number of cooperating organizations has grown to over 200 and includes private corporations, non-profit groups, research institutions, schools, universities, and state and local government agencies. Cooperative efforts are supported by participants through sharing money, in-kind contributions, and services.

Having successfully evolved through its first stage of growth, the Consortium is now faced with a different set of challenges generated by its success. As it is preparing to execute another joint data purchase the Consortium is being tested by the changing needs of the participants. The changes are due, in part, to the results obtained from using the jointly acquired data. Needs and requirements of individual participants are being reviewed in light of the research conducted thus far. The ability of the consortium to stay intact will depend, in some measure, on participants being able find common use of common data sets while continuing to define and carry out individual monitoring missions.

Combination satellite and data driven with elements of top-down and bottom-up organization

The 1-KM project

The object of the 1-KM Project is the acquisition and compilation of a global land 1-km resolution multi-temporal AVHRR data set. In
1991, the four original major project partners were NASA, NOAA, USGS/EDC, and the European Space Agency/European Space Research Institute (ESA/ESRIN). They were joined shortly thereafter by the Commonwealth Scientific and Industrial Research Organization of Australia (CSIRO). Combining NOAA’s High Resolution Picture Transmission (HRPT) stations and its Local Area Coverage Recorder (LAC), ESA/ESRIN’s AVHRR HRPT ground station network, the USGS/EDC ground station network, and key CSIRO Australian HRPT stations, the partners created a global data receiving network – in fact, a network of networks – consisting of approximately 29 active ground stations. The first data was received and ingested by EDC 1 April 1992.

USGS/NASA responsibilities include daily data acquisition directly from NOAA satellites and NOAA ground stations; establishment of agreements and technical plans with ESA and CSIRO to acquire and transfer data to EDC; and to obtain commitments from the core network of ground stations and NOAA to acquire and transfer data to EDC. USGS/NASA is also responsible for processing and archiving raw data received; populating, maintaining and providing worldwide access to an information system containing metadata and digital browse data; making microimage browse distribution available by subscription; and, providing a basic data set and derived global data product preparation, generation, and distribution.

ESA’s responsibilities include obtaining commitments from its ground stations to acquire and transfer data to ESA/ESRIN/Earthnet; processing and archiving raw data received; establishing a letter of agreement with USGS/NASA to transfer data to EDC; populating, maintaining, and providing worldwide access to a metadata and digital browse data system; and providing a basic set of data products and derived global data product/set preparation, generation, and distribution. As of August 1994, one-third of all collected data by the ESA network had been archived.

NOAA’s responsibilities include making its best effort to schedule daily data acquisition for areas uncovered by the AVHRR network or where individual ground stations are unable to meet project requirements; ensure satellite and ground station transfer of data to its operations control center; processing and archiving raw data received; serving as a backup archive to EDC for data acquired by its satellites and stations; authorizing EDC to distribute raw data; populating, maintaining, and providing access to a metadata system; and, providing preparation, generation and distribution capabilities for a basic set of data products.

CSIRO Australia’s responsibilities include obtaining commitments from the Australian network of key ground receiving stations, archiving raw data acquired by or transferred to CSIRO; establishing an agreement and technical plan with USGS/NASA to transfer data to EDC; populating, maintaining, and providing access to a metadata system; investigating product preparation, generation and distribution capabilities for a basic set of data products.

The ground stations in the ESA and USGS networks are responsible for daily data acquisition; establishing agreements with ESA or USGS/NASA to acquire and transfer data to ESA or EDC; and, to transfer raw data to the project. Data is gathered centrally for the ESA network by ESA/ESRIN in Frascati, Italy and sent to EDC. In turn, EDC centrally gathers the data from its network and sends it to ESA.
All four primary partners – ESA, NOAA, USGS/NASA, and CSIRO – have agreed to ‘provide/distribute the raw and data derived products on a nondiscriminatory basis, at the marginal cost of processing the specific user request.’\textsuperscript{65} ESA, NOAA, and CSIRO are also bound by their own data distribution and policy guidelines.\textsuperscript{64}

The project was originally intended to continue for 18 months. However, satisfied that they were producing results, project participants agreed in April 1993 to extend the project for an additional 12 months until September 1994.\textsuperscript{65} At that time, the participants again decided to continue their efforts, this time until at least 1998. Project products include seven composite global images and a total of 42,000 scenes acquired through 1994.\textsuperscript{66}

In the USA, the 1-KM Project has operated under the auspices of the Land Processes Distributed Active Archive Center (LP-DAAC), an EOSDIS node, through EDC and has been funded in large part by NASA though an EOSDIS line item. From fiscal year 1992 through 1994, the total amount was approximately $2 million.\textsuperscript{67} ESA has also contributed funds.\textsuperscript{68} There has been no exchange of funds between the LP-DAAC/EDC and ESA. Contributed funds have been used to begin and coordinate project activities, including data processing at EDC. Partners and participating ground stations are expected to fund local operations. The basic form of exchange among network participants is data on a \textit{quid pro quo} basis. That is, for each scene contributed to the project’s data pool, a participant may receive a scene in return. The largest exchange was 2000 scenes between the Chinese stations and EDC.\textsuperscript{69} Supplemental forms of exchange include hardware, expertise, and software. These require additional negotiation on a case-by-case basis between the ground station and a major partner. Cash exchange is kept to a minimum for practical and political reasons. Funds are exchanged only between NASA and USGS/EDC with USGS/EDC directing NASA money to the ground stations, if and where necessary.\textsuperscript{70} Increase in funds beyond a first-time basis requires strong justification and is atypical.

Additional stations have continued to be added since the Project’s inception raising the total number of participating ground stations. Each of the major partners is responsible for determining which stations to add or delete from their network. Using the concept of a 'core network,' a partner determines which stations ought to be included or excluded. ‘Core’ is defined as any station or group of stations that presents the only available capability in a particular area and which is necessary in obtaining the project’s goal: a complete global data set.\textsuperscript{71} Redundancy is an important criterion in determining if a station is ‘core.’ But alone, redundancy itself is inconclusive. For example, a second Japanese ground station which provided the same coverage as the first one to be included in the network was deemed redundant and outside of the ‘core.’ However, stations at Maspalomas and Niamey, while both providing coverage of the African Sahel, are considered ‘core’ because the Niamey station has a high degree of unreliability and the Maspalomas station has a high degree of reliability. When taken together, Niamey’s local position and Maspalomas reliability create a joint capability that provides coverage of an area critical to the global data base.

The addition of new stations is anticipated. With NASA assistance, Ulaan Baatar, Mongolia became operational providing Siberian coverage. A Costa Rican station and additional Asian and European stations would also be welcomed.
Industry ground segment organizations

Ground segment organizations are transforming in mission, size, and composition as quickly as politics and technology change. The end of the Cold War has increased the number of nations seeking remote sensing technology and has added an entirely new dimension to its use. Technologies like portable ground stations and direct broadcast receiving facilities also serve dramatically to reconfigure ground segment organizations. This section will briefly mention just a few of ground segment entities that are representative of different industry groups with an interest in remote sensing activities.

As an industry, remote sensing participants have long sought to establish an organization to represent its interests. This need has taken on added importance as the public sector proceeds with organizations like CEOS. From the private sector’s point of view, some type of organization is necessary to ensure its interests are represented in the larger remote sensing community and to have these interests considered by the developing public sector groups. The remote sensing industry, however, is multifaceted and is comprised of different groups within the overall industry: satellite manufacturers, data producers, and data users. All have different, although related, interests. Three organizations, Ground Operating Segment Support (GOSS), the GEOSAT Committee Inc., and The North American Remote Sensing Industries’ Association (NARSIA) have been formed to meet the needs of some of these interests.

GOSS

This organization is analogous to LGSOWG for the French SPOT system. It was instituted around 1984. Each ground station agreement is negotiated by SPOT headquarters in Toulouse, France and the ground station operator. Given the French government’s substantial financial support of SPOT, and headquarters’ participation in negotiations, GOSS is really a hybrid institution with both public and private sector elements. GOSS meetings are closed to the public with participation limited to SPOT ground system operators. Documentation, such as meeting minutes and ground station agreements, are also private. GOSS is considered by its leadership to be less ‘unwieldy’ than the LGSOWG structure.72 GOSS was, however, initially modeled after LGSOWG. CNES requested to have representatives participate in a number of LGSOWG meetings. CNES observers briefed LGSOWG participants on SPOT development and operation plans.73 The original plans were to ‘hold [SPOT ground station working group] meetings back-to-back’ with the LGSOWG meetings.74

The GEOSAT committee

The Geosat Committee, Inc. dates back to 1977, and has individual and corporate members. Membership includes academic representatives who have joined as individuals. Federal employees have participated in Geosat cooperative research projects. It was founded to promote the continuation of satellite remote sensing technology programs, the Landsat commercialization process, and ‘non-discriminatory commercial access to [remote sensing] technology’,75 an industrial version of the original nondiscriminatory access policy for data. Geosat worked to influence the Japanese in their decision to make data from the Japanese Earth Remote Sensing satellite available on a
nondiscriminatory basis. It provides representatives to testify before
the national legislatures of various countries, including the USA.
Geosat also engages in research and has worked with NASA and the
USGS, the governments of Canada, Germany, UK, France, Australia,
and Japan.

A major institutional change occurred within Geosat in the late 1980s
as the group focused primarily on lobbying and shifted away from data
user issues. At that time, Geosat memberships fees were up to $15,000
per year with only the largest corporate members paying them. A
number of Geosat members reorganized in the early 1990s, the group’s
president was discharged, and focus was redirected to data user
concerns. The four goals of the reorganized Geosat are to sponsor
remote sensing research, disseminate remote sensing information, act as
a center for utilization of data through cooperation with other
organizations and societies, and provide public education on remote
sensing technology.

NARSIA

A more recent industry group, the North American Remote Sensing
Industry Association, (NARSIA) was formed during 1993 and 1994.
Initially, efforts were aimed at forming a new collection of land remote
sensing data users associations around the world. The first
organizational meeting was convened by EOSAT in Geneva,
Switzerland on 10 December 1993. Logistical assistance was provided
by the Cantonal Government of Geneva and the US Embassy in Bern.
A second meeting was held in Melbourne, Australia in February
1994, and a third meeting was held in Washington, DC on 8 August
1994. A group met at the National Press Building in Washington, DC
on 9 September 1994 to frame the initial terms of reference.

Initially, NARSIA’s main supporter was EOSAT. At the Washington
organizational meeting it was decided that not-for-profit industries were
eligible for NARSIA membership but ‘federal government
organizations, universities, and their employees’ and ‘the aircraft remote
sensing business’ were ineligible. The exclusion of academics and the
planned expressed absence ... of both congressional staffers and
federal employees’ at the meeting was arranged because it was felt
that their remote sensing interests are met by grants. Aircraft remote
sensing industries were deemed unacceptable because NARSIA’s
‘emphasis was in the area of space.’ Participation of federal employees
and academics was later permitted through auxiliary memberships.
NARSIA promotional materials list annual dues ranging from $50 for
individuals to $2,500 for corporations with $10 million in annual sales
in areas ‘related to NARSIA.’

EOSAT stated that it was ‘busy consolidating its business with
potential partners’ and anticipated that NARSIA ‘may well emerge as
the US counterpart for international users in a future remote sensing or
cooperative council, with attributions similar to COMSAT in
INTELSAT or INMARSAT.’

Geneva meeting participants agreed to draft terms of reference for
the association and the focus of discussion in Geneva was ‘the
usefulness of creating a form of association with the purpose of
supporting the development of the remote sensing market in general, for
the benefit of the overall commercial sector and for creating a forum for
discussion of the interests of commercial users in order to articulate
these interests to data providers, governments and international entities, such as CEOS.87

The European, Australian, and North American groups developed into separate, unconnected entities.88 The European group, consisting of commercial remote sensing data users, extended membership to include 'other possible users with similar interests.'89 The European group eventually decided to deny membership to space segment data providers and became the European Trade Association for Earth Observation Commercial Exploitation. The Australian group invited participation of space segment data providers but limited membership to Australia and New Zealand. Plans were contemplated for Asia, the western Pacific countries, South America.90 A NARSIA Congress is planned for 1998 near Washington, DC.

Multilateral, commercial and public combination

ESA/ESRIN/Earthnet
The Earthnet Program was adopted by the European Space Agency at its Council level (ESA) in 1977. Its original objective was to provide European access to Landsat and other NASA satellites by centralizing data reception, preprocessing, distribution, and storage facilities. It began with Telespazio's data reception and preprocessing site at Fucino, Italy and ESA's computerized data center at Frascati, Italy. In 1980, Earthnet was changed from an optional to a mandatory ESA program, meaning that ESA member nations were required to financially support it as a condition of membership. Since then the program has evolved into a complex series of programs, relationships, and data distribution agreements among ESA, the European Space Research Institute (ESRIN), the European Space Operations Center (ESOC), non-ESA, and non-European ground stations.

ESRIN, an ESA establishment in Frascati, operates the ground segment and serves as ESA's point of contact for the European data user community. The current ESRIN/Earthnet Earth observation infrastructure includes a central facility for ground segment coordination, development, and technical monitoring; a set of 10 national stations; the Tiros coordinated network; facilities for payload data handling activities; and, national points of contact or consortia for data distribution and promotion through agreements.91 ESRIN/Earthnet also coordinates with other ground stations in Europe and non-ESA nations and offers training facilities and a variety of online and data catalog services.

ESRIN/Earthnet handles data from many international geostationary and polar-orbiting weather and land remote sensing satellites. However, Europe's largest and most complex Earth observation satellite ERS-1, launched in 1991, required a major expansion of ESA's ground data handling facilities resulting in an equally complex ground network which became operational in 1992. The ERS ground segment is comprised of three ESA centers; five ESA ground stations in Europe and Canada; four processing and archiving centers in the UK, France, Germany and Italy; and 17 non-European ground stations who have signed, or are planning to sign, MOUs.92 An ERS data processing facility was established in Kenya which is operated in partnership between ESA and the multinational African Regional Center for Services in Surveying, Mapping, and Remote Sensing (RCSSMRS).93
The Earthnet ERS Central Facility (EECF) serves as the core of the ERS network. A special ERS-1 users' data office was established at ESRIN and a three-company consortium was formed to commercialize ERS-1 data products. Data from ERS-2, launched in April 1995, is received by the ESA stations and, if requested, is available for test purposes to non-ESA stations that have signed MOUs.

Conclusion

The proliferation of ground segment groups indicate two important trends. First, data have become as strong a force in ground segment organization as satellites have been; and second, in some cases, organizational impetus is coming from the bottom up, creating transpolitical structures, rather than coming from the top down, in national structures. Satellite-driven decisions and data-driven decisions generate different kinds of results. Satellites are considered important national assets and are therefore subject to major political forces. Data, on the other hand, has never been afforded the status of a national asset and, until recently, has been less subject to these forces. Data are more available through nonbureaucratic channels than actual satellite access, and therefore more susceptible to widespread use with a relatively small amount of bureaucratic activity.

Satellite-driven, top-down organizations provide top-level coordination that can assist establishment and administration. They also allow data providers accountable for the satellites to meet their domestic or shared responsibilities. However, they also are vulnerable to the high-level politics that surround the satellites. LGSOWG history demonstrates how ground organization has to adapt to an individual member's domestic satellite policy change. The most obvious example was when the US national policy changed to allow Landsat commercialization, changes in intramember LGSOWG agreements became necessary. Basic issues like defining the appropriate contractual relationship between nation-states and corporations had to be addressed.

WGISS demonstrates that even with an emphasis on the 'capture, description, processing, access, retrieval, utilization, maintenance and exchange' of data, satellite-driven organizations must carry out their work aware of "the need for more 'top-down' direction, driven by needs associated with agency mission and program plans." Therefore, WGISS' "structure facilitates 'top-down' strategic planning and coordination as well as 'bottom-up' dissemination of task results" and its Chair must "ensure that WGISS takes account of the direction and requirements of the [CEOS] Plenary, planning and co-ordinating appropriately to ensure that 'top-down' guidance of WGISS activities occurs." 95

Changes in non-satellite owning members' domestic environments can also affect a group. Following the US lead in commercialization, LGSOWG members established domestic commercialization policies and expanded their ground facilities to accommodate other commercial satellites. So even though the USA returned Landsat to the public sector it became necessary, in the most recent MOU negotiations, to acknowledge members' right to continue to set commercial data prices within their own nations pursuant to their domestic policies.

Contending with high-level political necessities and responsibilities extends the time required to develop insitutions and practices for data
distribution. This is evidenced by LGSOWG’s on-going need to seek better access to collected data even after 20 years of existence; CEOS’ prolonged efforts at establishing data retention and purging guidelines; and its multi-year formal process to establish WGISS before beginning network services. Contrast this with a bottom-up, data-driven organization like MRLC where data acquisition, frenetic distribution, and spontaneous use was occurring for 2 years before the official memorandum of understanding was even signed.

Whether top-down or bottom-up, all of the groups described in this paper depend heavily on volunteerism, although a hierarchy of official approval is apparent. LGSOWG and CEOS have the highest degree of official approval, which is heavily dependent on formal agreements, national policies and operates within the sovereignty principle. However, although driven by high-level national satellite policies, both CEOS and LGSOWG activities are carried out by middle- and lower-level officials and many critical decisions are made without upper level awareness and oversight.

The most intriguing implication from considering the ground segment is that data flows create institutions. Data, and their flow, are very democratic, going to whomever has the desire to access it. To identify nascent institutional structure, follow the data.

Even with these trends, to say that the ground segment is more important than the space segment is to oversate the case. For in the final analysis, the remote sensing ground segment will always need the raw material – data – produced by the space segment. Saying that the ground segment is more important than the space segment is also simply reversing the earlier mistake of stressing the importance of the space segment to the detriment of the ground segment. In reality, the space and ground segments are interdependent and, together, constitute a whole system. They must be considered together for the long term.


\[5^{5}\] Letter from EOSAT General Counsel to NOAA/NESDIS Chief, Landsat Commercialization Division, 6 April 1993.


\[8^{8}\] The EOSAT–government contract terminates when EOSAT officially notifies the government of the ‘practical demise’ of the satellites. As of this writing, formal notification had not been given.

\[9^{9}\] As of this writing, the draft agreement is still evolving. However, the basic principles identified here have appeared in previous drafts in varying forms and can be expected to be retained in the final agreement.

\[10^{10}\] Draft Memorandum of Understanding Between the International Ground Station (IGS) and the US Department of Commerce National Oceanic and Atmospheric Administration, February 1997. [Hereinafter, Draft MOU].

\[11^{11}\] Draft MOU. This draft omits a phrase contained in a 1996 draft which states that data are to be distributed consistent with the J.N. Remote Sensing Principles.

\[12^{12}\] Technically, the data is to be made to the EDC-DAAC. That is, the Eros Data Center-Distributed Active Archive. This is an internal organization that was established to serve as a node in NASA’s Earth Observations Data and Information System. For the sake of simplicity, it will only be referred to as ‘EDC’ here.

\[13^{13}\] Draft MOU.

\[14^{14}\] Draft MOU.


\[16^{16}\] Minutes of the Landsat Ground Station Operations Working Group Meeting, Telespazio Headquarters, Rome, Italy, 24–26 March 1978, p. 1. [Hereinafter, all LGSOWG minutes will be referred as LGSOWG followed by the number of the meeting. For example, LGSOWG 1.]

\[17^{17}\] LGSOWG 13, 14–16 November 1983, Minutes, 27 February 1984, p. 16.


\[19^{19}\] LGSOWG 1, 1 June 1995, Minutes undated, pp. 4–6.

Earth observations: J. I. Gabrynowicz

24LSOWG 11, 1 June 1975, Minutes, undated, p. 6.
24LSOWG 4, 12–14 April 1977, Minutes, undated, p. 6.
25LSOWG 22, 23–26 June 1992, Minutes, undated, p. 3.
241994 Report, CEOS Terms of Reference, pp. 5–6.
2The 12 were the European Space Agency (ESA), the National Space Development Agency of Japan (NASDA), the Centre National d'Etudes Spatiales of France (CNES), the Instituto Nacional de Pesquisas Espaciais of Brazil (INPE), the National Aeronautics and Space Agency of the USA (NASA), the National Oceanographic and Atmospheric Administration of the US (NOAA), the British National Space Centre (BNSC), the Swedish National Space Board (SNSB), the Norwegian Space Centre (NSC), the Canada Centre for Remote Sensing (CCRS), the World Meteorological Organization (WMO), and the Deutsche Agentur fur Raumfahrtarzenganheiten of Germany (DARA).
2CEOS 1993 Report, p. 57.
23CEOS 1993 Report, p. 58.
2Moodie, L., Senior International Relations Specialist, NOAA, interview, 20 October 1994.
24http://pooh.esrin.esa.it:8888/geo/rgt/0x006af0c3d_0x00071a18#INTRO
24http://pooh.esrin.esa.it:8888/geo/rgt/0x006af0c3d_0x00071a18#INTRO
2Jennings, M., National Coordinator for GAP Analysis, Idaho Cooperative Fish and Wildlife Research Unit, University of Idaho, interview, 29 June 1995. [Hereinafter, Jennings interview.]
24Letter from D. T. Lauer, Chief, EROS Data Center to Arturo Silvestrini, President, EOSAT, 19 August 1993.
24This includes the original purchase of 430 scenes, options for additional scenes and authorized use of previously purchased scenes.
24Letter from D. T. Lauer, Chief, EROS Data Center to Arturo Silvestrini, President, EOSAT, 24 September 1993.
25MRLC MOU.
25Jennings interview.
25Documentation Notebook.
25Documentation Notebook.
25Jennings interview.
25Ops Plan.
25Ops Plan.
25However, ESA began to address archiving the "stitched" orbit data products for which there was no capacity. Giancarlo Pitella, ESA/ESRIN Earth Observation Division, Head of Third Party Missions Section, project review, EROS Data Center, Sioux Falls, SD, USA 30 September 1994.
25Ops Plan.
25Eidenshink et al.
25Ops Plan.
251-KM UPDATE!, EROS Data Center, July 1993, p. 2.
24Pita, op. cit., Ref 60.
24Holm & Eidenshink, telephone interview, 27 September 1994. [Hereinafter, Holm et al.]
24Holm et al., Fund limits are determined by a variety of complex factors beyond simple amounts available. They include procurement regulations, exchange rates, foreign economic and political institutions, and available communication systems.
24Vanz, T., President, SPOTImage, Reston, VA, Interview, 14 July 1995.
25LSOWG 10, 16–18 June 1980, Minutes, p. 11.
25GEOSAT Secretariat, interview, 6 July 1995.
25GEOSAT Secretariat, interview, 6 July 1995.
25NARSA Writing Group Meeting, 9 September 1994, Meeting Notes, p. 1.
25Pelcher, M., public address, 11th National Space Symposium, 5 April 1995, Colorado Springs, CO.
25Wilhee, G. W., Deputy Assistant Administrator for Satellite and Information Services, NOAA, Interview, 29 July 1994.
24http://pooh.esrin.esa.it:8888/geo/fr/ceos-news/0x006af0c3d_0x00071a18