Chapter 2

Introduction

Contents

Chapter 2
Introduction

This technical memorandum explores the major policy-related issues raised by the proposed private ownership of satellite-based civilian remote-sensing systems. It responds to requests from the Committee on Science and Technology of the U.S. House of Representatives to provide information that would help the committee fulfill its oversight and legislative responsibilities. Specifically, the committee requested that OTA "address the requirements or constraints relating to international and national security concerns. "[1]

This memorandum is designed to aid Congress in determining the appropriate requirements and conditions for private sector ownership and/or operation of the U.S. land remote-sensing systems. It also provides information and analysis that will be useful for Congress as it develops and considers legislation for transferring remote-sensing satellite systems to the private sector. It does not reach any explicit judgments about whether a transfer of remote-sensing services and data to private hands is either feasible or desirable, Rather, OTA's analysis discusses what a private owner and/or operator might be required to do in order to meet existing or projected U.S. obligations to the international community, to enhance national security, and to preserve the public benefits of civilian remote sensing from space.

Although the value of remote sensing must constitute part of the analysis of potential requirements, this memorandum neither analyzes the potential market for remote-sensing data, data products, and services, nor judges the benefits versus the costs of maintaining these services in the Federal Government as compared to transfer to the private sector. However, it enumerates many of the concerns that users of data from the system have expressed about transfer to the private sector. It leaves it to Congress to judge the relative importance of potential requirements that might be imposed on the private sector,

Shortly before this technical memorandum was completed, Congress voted to keep the meteorological satellite systems in the hands of the Government and directed the administration to cease preparation of a request for proposal to transfer these systems to the private sector. [2] However, because the issues the proposed sale of the meteorological satellites raises are typical of the movement of technology from the Government to private hands, and of the decisions that must be made vis-à-vis public and private goods, OTA has retained the analysis of meteorological satellite systems.

[1] Letter from U.S. House of Representatives Committee on Science and Technology, July 20, 1983; see also letter from Government operations Committee, September 1983.

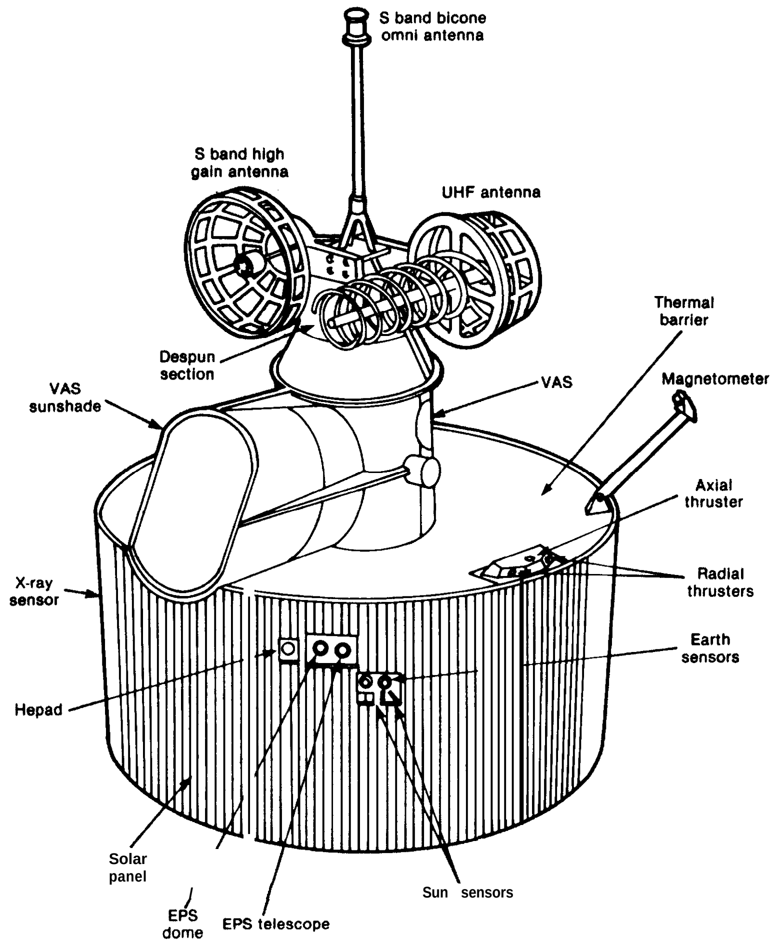
'Appropriations bill H.R. 3222, November 1983

DEVELOPMENT AND STATUS OF REMOTE SENSING FROM SPACE

The scientific and user community recognized early in the development of space technology the potential value of sensing Earth's atmosphere, land masses, and oceans from space for civilian purposes. The first civilian remote-sensing satellite was a polar-orbiting weather satellite called TIROS, launched by the United States in 1960. TIROS provided the first civilian images from space.

Subsequent improvements in the polar orbiters by the National Aeronautics and Space Administration (NASA), which until recently has conducted much of the research and development (R&D) on new sensors, and the National Oceanic and Atmospheric Administration (NOAA), which operates the meteorological satellite systems, have led to a powerful system of two orbiters that circle Earth every *102* minutes and provide complete

GOES Satellite



SOURCE: National Oceanic and Atmospheric Administration

MISSION: Repetitive observations of the earth disk and overlaying atmosphere in the field of view, measurements of solar x-rays and the proximate space environment, collection and relay of data from platforms at or near the earth's surface; broadcast of data and environmental information.

ORBIT. 35,800-km geosynchronous GOES East over equator at 75 W GOES West at 135 W

SENSORS AND FUNCTIONS:

- **Visible and Infrared Spin Scan Radiometer (VISSR) Atmospheric Sounder (VAS):** The VAS is a visible and infrared radiometer capable of providing both multi-spectral imaging and dwell sounding data. It possesses eight visible and six infrared detectors. Positioning a filter wheel allows selections from among 12 spectral bands with central wavelengths between 3.9 and 15 µm. VAS scans west to east in conjunction with spacecraft rotation at 100 rpm, a stepping mirror provides pole to pole scanning. Resolutions are 1-km in the visible and 7- or 14-km in the infrared, depending upon the selection of IR detectors. Visible imaging data are provided routinely every 30 minutes by each spacecraft during daylight and infrared (7-km) imaging data, on the same schedule, are provided day and night.

  Space Environment Monitor (SEM): Composed of 4 subsystems

  (1) X-Ray Sensor. Provides data on solar x-ray activity in two wavelength bands 0.5-3.0A and 1-8A

  (2) Energy Particle Sensor. Determines intensity of charged particle flux in the following ranges

  Protons - 0.8 to 500 MeV, 7 log ranges
  Alphas - 3.2 to 400 MeV, 6 log ranges
  Electrons >2 MeV, 1 range

  (3) High Energy Proton and Alpha Detector (HEPAD). Protons in the 379-keV range, alpha particles in the 850-keV range

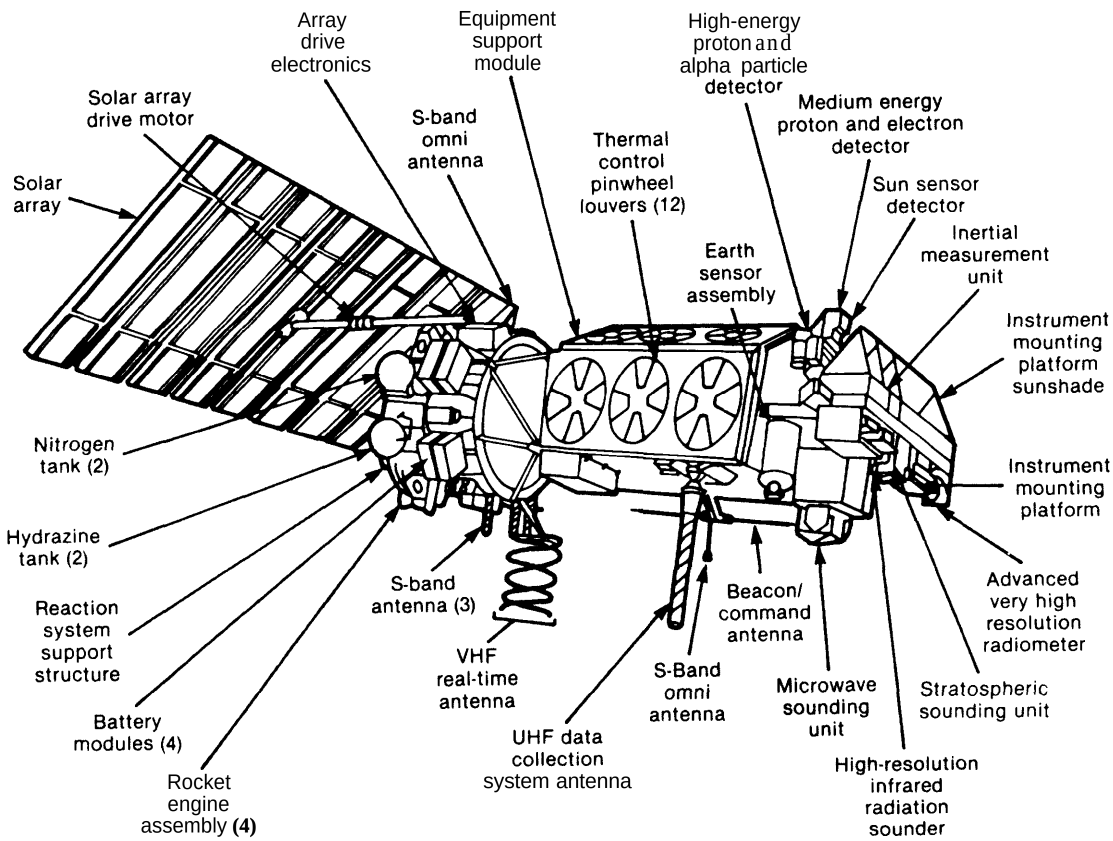
  (4) Magnetometer. Monitors magnitude and direction of ambient magnetic field, parallel field (± 1200γ), and transverse field in 4 selectable ranges (± 50γ, ± 100γ, ± 200γ, or ± 400γ)

- **Data Collection System (DCS):** Relays UHF interrogations to, and data from sensor platforms reporting environmental data

DIRECT BROADCAST: Broadcasts available to any ground station within range

- **WEFAX:** Retransmission of processed data at 1691.0 MHz. Along with meteorological charts, GOES imagery at 8-km resolution and NOAA imagery at 8- to 12-km resolution are transmitted. A daily operational message is transmitted that provides schedules and contents. A basic ground capability costs about $8,000 (U.S.) in 1981

- **Stretched Sensor Data:** A retransmission, at a reduced rate, of the data burst that occurs during the 20° angular sweep of VAS detectors across the earth. The transmission is on S-band at 1687.1 MHz. A basic ground station that includes a limited product capability costs about $150,000 (U.S.) in 1981



SOURCE: National Oceanic and Atmospheric Administration

MISSION: Collect global data on cloud cover. surface conditions such as ice and snow. surface and atmospheric temperatures. and atmospheric humidity; measure solar particle flux, collect and relay information from fixed and moving data platforms, provide continuous data broadcasts

ORBIT: 833- and 870-km circular. 98 89° inclination; 14-1 4 revs/day

SENSORS AND FUNCTIONS

- **Advanced Very High Resolution Radiometer (AVHRR/2)**
  1 1-km resolution, ·2600-km swath width

Channels	Wavelengths (μm)	Primary Uses
1	0 58 - 0 68	Daytime cloud surface mapping
2	0 725 - 1 10	Surface water delineation, ice and snow melt
3	3 55 - 3 93	Sea surface temperature, nighttime cloud mapping
4	10 30 - 11 30	Sea surface temperature, day and night cloud mapping
5	11 50 - 12 50	Sea surface temperature, day and night cloud mapping

- **TIROS Operational Vertical Sounder (TOVS):**
  A 3-sensor atmospheric sounding system

(1) **High Resolution Infrared Radiation Sounder (HIRS/2)** 17 4-km resolution

Channels	Wavelengths (μm)	Primary Uses
1-5	14 95 - 13 97	Temperature profiles, clouds
6-7	13 64 - 13 35	Carbon dioxide & water vapor bands
8	11 11	Surface temperature, clouds
9	9 71	Total O_3 concentration
10-12	8 16 - 6 72	Humidity profiles, detection of thin cirrus clouds
13-17	4 57 - 4 24	Temperature profiles
18-20	4 00 - 0 69	Clouds, surface temperatures under partly cloudy skies

(2) **Stratospheric Sounding Unit (SSU)**: 147 3-km resolution

Channels	Wavelengths (μm)	Primary Uses
1-3	15	Temperature profiles

(3) **Microwave Sounding Unit (MSU)**: 105-km resolution

Channels	Frequencies	Primary Uses
1	50 31 GHz	
2	53 73 GHz	Temperature soundings through clouds
3	54 96 GHz	
4	57 95 GHz	

- **Space Environment Monitor (SEM)**: Measures solar particle flux at spacecraft
  (1) **Total Energy Detector (TED)**: Solar particle intensity from 0 3- to 20-keV
  (2) **Medium Energy Proton and Electron Detector (MEPED)**: Protons, electrons, and ions in 30- to 60-keV range

- **ARGOS Data Collection System (DCS) (French)**: Collection and relay of data from fixed or moving automatic sensor platforms, determines location of moving platforms

DIRECT BROADCAST: Continuous data broadcasts available to any receiving station within range

- **Automatic Picture Transmission (APT)**: Visible and infrared imagery at 4-km resolution VHF broadcasts at 137 50 or 137 62 MHz. Basic ground equipment costs about $25,000 (U.S.) in 1981

- **High Resolution Picture Transmission (HRPT)**: Visible and infrared data at 1-km resolution S-band broadcasts at 1698 0 and 1707 0 MHz Basic ground equipment costs about $250 000 (U S) in 1981

- **Direct Sounder Broadcast (DSB)**: TOVS data transmitted for use in quantitative programs Broadcast at 136 77 or 137 77 MHz (Beacon Frequency) and in the HRPT data stream Conventional ground receiving station required but specialized data processing is necessary to produce environmental information coverage of Earth's atmospheric parameters every 6 hours. These NOAA N-Series satellites also carry the ARGOS Data Collection System provided by France, which collects and relays environmental and other data from ground-based automatic sensor platforms. The polar-orbiting meteorological satellite system is now augmented by two geostationary satellites (GOES) that provide low-resolution visible and infrared coverage of the western hemisphere every 30 minutes.

Both systems are integral parts of the U.S. weather and climatological systems and constitute a major source of timely weather data to the rest of the world. They also comprise a major source of data for studies of long-term weather trends and climatological studies.[3] By international agreement, weather data, including those gathered by satellite, are shared with the world community freely and at no cost. In return, the United States receives satellite and other weather data at no cost from other countries all over the world.

Aircraft-based experiments with multispectral land remote-sensing systems started before the Space Age, but were strengthened when NASA launched the first land remote-sensing satellite, Earth Resources Technology Satellite (ERTS), in 1972. This satellite was later renamed Landsat 1 and was followed by Landsats 2 and 3 in 1975 and 1978, respectively. In addition to other research devices, all three satellites carried a sensor called the multispectral scanner (MSS), having a spatial resolution at Earth's surface of about 80 meters and covering four spectral bands. The output of this sensor, transmitted to Earth, then corrected and stored, constitutes the primary archival library of Landsat data, extending back to 1972.

[3] *Civilian Space Policy and Applications* (Washington, D. C.: U.S. **Congress, Office of Technology Assessment,** OTA-STI-177, **June 1982), app. E.**

Landsat 4, which was launched in 1982, carries both an MSS sensor and an experimental thematic mapper (TM) sensor, having a nominal spatial resolution of 30 meters on Earth, and providing seven spectral bands of data. *

Developed and procured by NASA, the Landsat system (Landsat 4) is now operated by NOAA. At the present time, no data can be received directly from the TM because of a failed X-band transmitter aboard the satellite. Limited TM reception is possible through the Tracking Data and Relay Satellite System (TDRSS) when the latter is available for use. In addition, two of the four solar panels that provide power to the spacecraft have failed. Landsat 4 consequently has a highly limited lifetime. NOAA plans to launch the backup satellite to Landsat 4, Landsat D', this month. After launch it will then be named Landsat 5.

NASA's and NOAA's efforts with the Landsat system have demonstrated to a small but dedicated group of customers, both within and without the Government, that satellite data can be highly effective in meeting their resource information needs.[4]

In 1978, NASA launched the first dedicated ocean observation satellite, Seasat-A. Designed to last for at least 1 year, Seasat-A failed after only 3 months in orbit. During that period its active and passive microwave sensors (including a synthetic aperture radar) returned important new data on the characteristics of the oceans, sea ice, and a variety of terrestrial features. Despite Seasat's high degree of technical success, no follow-on civilian oceanographic satellite has been authorized.

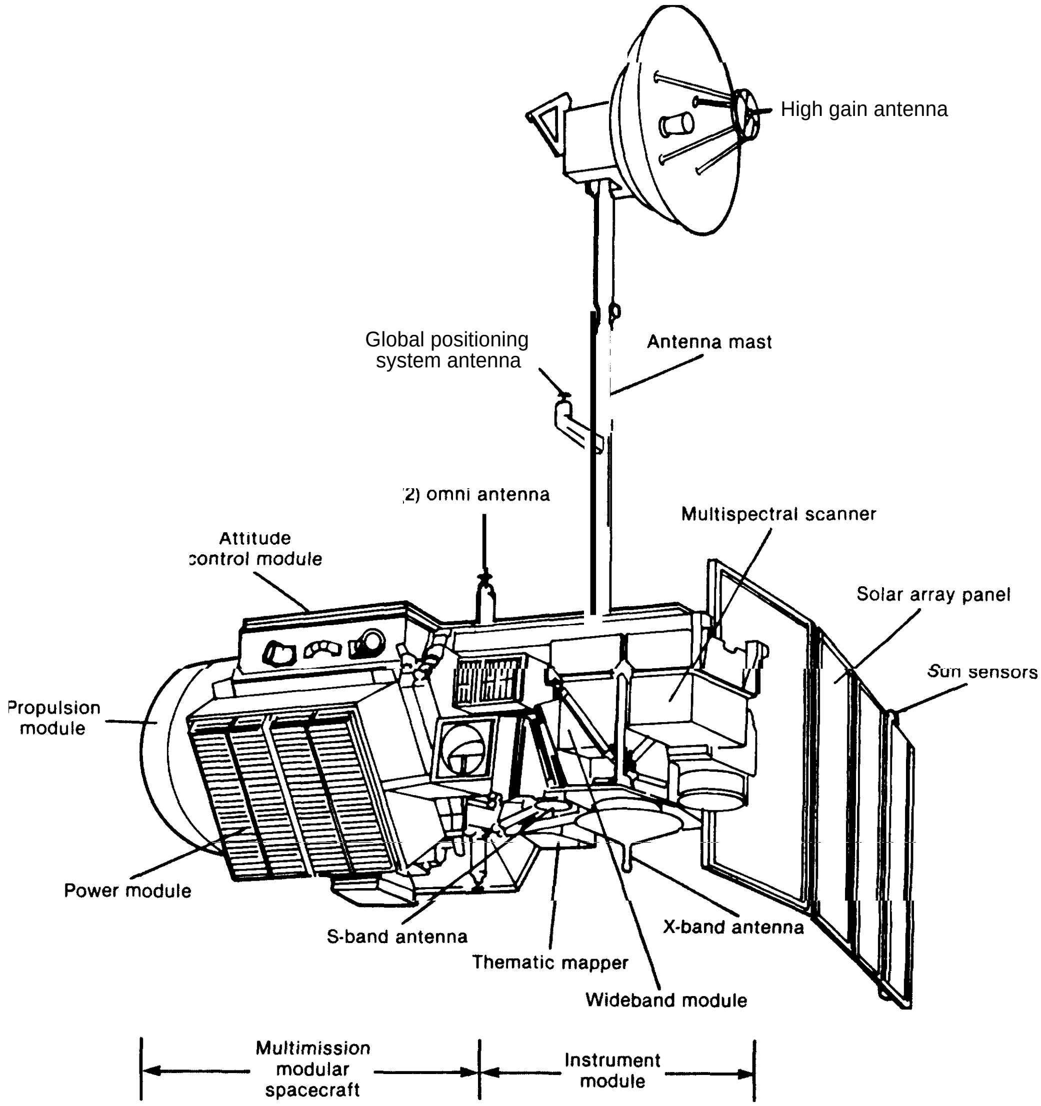
***The thermal band at** 10.40 to 12.5 microns has a spatial resolution of 120 meters.

[4] *Civilian Space Policy and Applications,* **op. cit., pp. 53-67.**

REMOTE-SENSING POLICY

Although the potential utility of images gathered by satellite of atmospheric conditions and of the surface of the land and ocean were recognized by those conceiving the systems, few considered operating the systems as commercial entities. However, as Federal, State, and local governments and universities and industrial firms began to work with the data from the Landsat system, they realized that these data were often a cost-effective substitute for older (aircraft) methods of

Landsat-5 Spacecraft



SOURCE: National Oceanic and Atmospheric Administration

MISSION: Collect remotely sensed, multispectral land data, broadcast data for receipt at ground stations operating under formal agreements

ORBIT: 705-km sun synchronous, 16 day repeat cycle

SENSORS **AND FUNCTIONS.**

Multi-spectral Scanner (MSS): The MSS is the specified operational sensor. Swath width is 185-km, resolution is 80-m

Sensor Wavelengths (μm)	Primary Uses
0.5 - 0.6	Movement of sediment laden water, delineation of shallow water areas
0.6 - 0.7	Cultural features
0.7 - 0.8	Vegetation, boundary between land and water, landforms
0.8 - 1.1	Penetration of atmospheric haze, vegetation, boundary between land and water, landforms

Thematic Mapper (TM): The TM is a NASA experimental sensor. It will come on-line operationally after it has been proven by NASA and an appropriate ground system has been constructed. It is designed to provide 30-m resolution except for 120-m resolution in the thermal infrared band

Sensor Wavelengths (μm)	Primary Uses
0.45 - 0.52	Coastal water mapping, soil vegetation differentiation deciduous coniferous differentiation
0.52 - 0.60	Green reflectance by healthy vegetation
0.63 - 0.69	Chlorophyll absorption for plant species differentiation
0.76 - 0.90	Biomass surveys, water body delineation
1.55 - 1.75	Vegetation moisture measurement
10.40 - 12.50	Plant heat stress management, other thermal mapping
2.08 - 2.35	Hydrothermal mapping

DIRECT BROADCAST: Broadcasts are provided for ground stations which have entered into formal agreements covering the receipt and distribution of these data gathering Earth resources data. The digital format, wide spatial coverage, and repeatability of the data make possible new applications that could eventually increase the value of the information these data provide. By the late 1970's, some observers postulated that the data might eventually have sufficient commercial value to attract private investment in a remote-sensing system. However, it was also clear that barriers of high cost, and technological and economic risk would have to be drastically reduced to interest private investors in providing a system comparable to the Landsat system.

Transfer of space-based land remote sensing to private hands was first considered seriously in the drafting of President Carter's 1979 policy statement on space, PD/NSC-54, which amplified the earlier policy statements, PD/NSC-37 and PD/NSC-42. According to the President's Policy Directive, "Our goal is the eventual operation by the private sector of our civil land remote-sensing activities. Commerce will budget for further work in FY 1981 to seek ways to enhance private sector opportunities. "[5] This statement left open the speed and the means of the transfer but, because it also committed the United States to provide continuity of the data flow from the Landsat system through the 1980's, most observers assumed that transfer to the private sector would take place about 1990. The first stage of that process was to transfer responsibility for operational management of the Landsat program to NOAA. Transfer of the meteorological satellite systems to private ownership was not envisioned by PD-54.

The Reagan administration decided early in its tenure to hasten the process of transfer, and announced "the intent of transferring the responsibility [of Landsat] to the private sector as soon as possible. "[6] That statement, too, made no mention of the meteorological systems. Later, in March 1983, the administration proposed to transfer both the Landsat and the metsat systems to private hands.[7] The Department of Commerce commissioned three studies to explore and examine the issues raised by transfer of remote sensing from space to the private sector.[8] Significantly, none of these reports concluded that rapid transfer was in the best interests of the United States.

In November 1983, Congress passed appropriations bill H.R. 3222, which contained a provision preventing sale of the Nation's meteorological satellite systems to private hands. President Reagan subsequently signed that bill into law (Public Law 98-166). The meteorological satellites will continue to be operated as a public service, On January 3, 1984, the Department of Commerce released a request for proposal (RFP) designed to solicit offers from private industry to own and operate the Landsat and any follow-on system. Proposals are due on March 19, 1984.

The eventual goal of the transfer of the results of Government R&D to the private sector is to create ultimately a self-sustaining business from all or part of the technology so transferred, with the private firm in full control (except for appropriate regulation) of further development and shaping of the system and products. Realization of such a goal would constitute full commercialization of the Government-developed technology. Intermediate steps along the way to this end could result in: 1) shared control of the technology; and / or 2) joint continued development of the technology and its products, through either subsidies, shared investment, or guaranteed Government purchase. The process of transferring to such an intermediate step, in which the system would receive significant Government subsidy, has often been called "privatization."

[5]"Presidential Directive NSC-54, " Nov. 16, 1979.

[6]Statement of Joseph Wright, Deputy Secretary, Department of Commerce, to the Subcommittee on Space Science and Applications of the House Committee on Science and Technology, and the Subcommittee on Science, Technology, and Space of the Senate Committee *on* Commerce, Science, and Transportation, July 22 and 23, 1981.

[7]Statement of Malcolm Baldrige, Secretary of Commerce, to the Subcommittee on Natural Resources, Agricultural Research, and Environment of the House Committee on Science and Technology, Apr. 14, 1983.

[8]"Space Remote Sensing and the Private Sector: An Essay, " National Academy of Public Administration, March 1983, Department of Commerce contract No. NA-83-SAC-066; "Commercialization of the Land Remote Sensing System: An Examination of Mechanisms and Issues, " ECON, Inc., April 1983, Department of Commerce contract No. NA-83-SAC-00658; "A Study to Examine the Mechanisms to Carry Out the Transfer of Civil Land Remote Sensing Systems to the Private Sector, " Earth Satellite Corp. and Abt Associates, Inc., Department of Commerce contract No. NA-83-SAC-O0679.

Depending on the terms and conditions agreed on, transfer of the Landsat system to the private sector could result in any one of several outcomes. As OTA recently testified:

Three principal alternatives seem plausible:

. Government contract with one or more firms, either to provide a direct subsidy or to purchase data at an agreed-upon high price;
- a **laissez-faire approach with competitive bidding to supply data for Government** needs; and
- a **mixed, phased strategy that would allow private vendors to build a market over time** while retaining partial Government ownership. "[9]

"'Landsat and Land Remote-Sensing Policy, " statement of Dr. John H, Gibbons, Director, Office of Technology Assessment, to the Subcommittee on Space Science and Applications and the Subcommittee on Natural Resources, Agricultural Research, and Environment of the House Committee on Science and Technology, June 21, 1983,

Whether such transfer would produce a commercially workable self-supporting system would depend on the interest of the private sector and the development of the market for data and data products (i.e., information) that is needed to sustain it. It would also depend on a national and international legal/political /security environment that permits the enterprise to seek success. Most of the debate over transfer centers on ideological, rather than practical, issues. Ultimately only the direct experience of the private sector can answer whether a self-supporting business will be the result, or whether such a goal is, at least for the time being, not feasible.

FOREIGN REMOTE= SENSING SYSTEMS

As the debate over the fate of the Landsat system continues, it is well to remember that as the United States deliberates, other countries are planning and building their own systems between now and 1990. These systems, particularly for land and ocean, present competitive challenges as well as opportunities for creative cooperative agreements.

Meteorological Satellite Systems

European Space Agency (ESA)—Meteosat-2 (1981). This geostationary satellite provides raw imagery of European weather conditions to Europe as well as relaying processed imagery from U.S. geostationary weather satellites. An improved Meteosat is planned for launch in 1985.

India—Insat-l (1982). This geostationary satellite provides both communications and limited meteorological data. Insat-lB, which replaced Insat-1, was launched successfully by space shuttle Mission 8 in August 1983.

Japan–Geostationary Meteorological Satellite, GMS-2. This was launched by Japan on a Japanese NII launcher in 1981 and is the second in a series of geostationary meteorological satellites. It has now failed and GMS-1 will be used until a third satellite, GMS-3, can replace it in August 1984.

Peoples Republic of China—The Chinese are working on a Sun-synchronous meteorological satellite whose launch date is presently uncertain.

U.S.S.R.—Meteor (4 satellites; a cluster of Meteor 2-7, 2-8, and 2-10, and a single newer version, 2-9). Meteor is a polar-orbiting satellite with sensors capable of determining global ice and snow cover in addition to sensing cloud cover. The Soviet Union currently plans to launch one geostationary meteorological satellite (1984), with visible and infrared sensors.

Land and Ocean Satellite Systems

Brazil-The Brazilians plan to launch a moderate-resolution land-sensing satellite in the late 1980's. Few details are available about this proposed satellite.

Canada–Radarsat (1990). This satellite will provide C-band Radar images of Earth to monitor the polar sea ice; other sensors are in the planning stages.

European Space Agency—Remote Sensing Satellite (ERS-1)—(1987/88). It is planned primarily for passive sensing of the coastal oceans and weather over the oceans. It will also carry a synthetic aperture radar for active sensing of land through cloud cover.

France—SPOT (1985). A land remote-sensing satellite capable of high-resolution, multispectral (3 band) stereo images. It will be the world's first commercial* remote-sensing satellite system.

West Germany—Modular Optoelectronic Multispectral Scanner (MOMS)—(1984/85). This instrument was flown on the Shuttle Pallet Satellite (SPAS) developed by Messerschmitt-Boelkow-Blohm GmbH (MBB) aboard shuttle flight 7. MBB has entered into an agreement with COMSAT, and with the Stenbeck Reassurance Co., Inc., to market land remote-sensing data collected on shuttle flights beginning in 1984 if agreement with NASA can be reached. The West Germans also tested a limited synthetic aperture radar aboard Spacelab on shuttle flight **9.**

* Although the SPOT system is organized **as a commercial system, it is, for the time being, heavily subsidized by the French Government.**

India—IRS-lA (1986). A low-resolution "semi-operational" land remote-sensing satellite to be built in India and launched by a Soviet launcher. A follow-on, IRS-lB, will be launched by an Indian-built launcher.

Japan–Marine Observation Satellite-1 (MOS-1)—(1986) and Japan Earth Resources Satellite-1 (JERS-1)–(1990). MOS-1 is being developed primarily for sensing various parameters of the ocean. It will also be useful for land remote sensing. JERS-1 is primarily a land remote-sensing satellite carrying a synthetic aperture radar that will also have some limited marine uses.

U.S.S.R.—Meteor Priroda (1980); Kosmos 1484 (1983). Both are experimental land remote-sensing satellites with low (170 m), moderate (80 m), and high (30 m) resolution electronic and mechanical scan sensors that operate in a variety of wavelengths. The Soviets consider the later satellite superior to Landsat 4, and have offered data from them to the Eastern bloc as well as the developing countries.

THIS TECHNICAL MEMORANDUM

The goal of the analysis of each of the following chapters is to present Congress with potential requirements the Government might wish to impose on private industry in supplying meteorological and land remote-sensing data. The third chapter, *International Relations and Foreign Policy,* describes the current international policy and practice of the United States in remote sensing from space and explores its international obligations as defined by treaties and agreements. It also examines the utility of remote-sensing data derived from space as an element of U.S. foreign policy, social and diplomatic outreach. The chapter explains requirements now demanded by law, and discusses other possible conditions that might be imposed for the specific benefit of the United States. Finally, the third chapter discusses the worries other countries have expressed about private ownership of U.S. remote-sensing systems.

Chapter 4, *Public Interest in Remote Sensing,* includes a short discussion of the civilian public good aspects of remote sensing as well as tables of uses of remote-sensing data by domestic and foreign non-Federal users. Short case studies show how State and local governments, private industry, and research and educational institutions integrate remote-sensing data into other information needs.

Chapter 5, U.S. Government Needs for Remote-Serzsing Data, summarizes projected future Federal needs for remote-sensing data, and shows where land remote-sensing data have been used to satisfy the requirements of congressionally mandated studies. A section of this chapter analyzes the sales of Landsat data.

Chapter 6, National Security Needs and issues analyzes the national security aspects of civilian remote sensing and discusses the feasibility of having private industry supply the data needs of the military and intelligence communities.

Preparation of the Technical Memorandum

In preparing this technical memorandum, OTA relied on personal interviews, contract studies from several individuals, and the results of two OTA workshops. In the first workshop, held July 26, 1983, participants drawn primarily from the private sector discussed those broad issues implicit in the transfer of remote-sensing systems related to international trade, foreign policy use of remote-sensing data, public-good aspects of land and meteorological remote sensing, and finally, national security issues. The second workshop, composed solely of participants from the executive agencies, discussed most of the same issues from the standpoint of Government policy and plans.

Throughout our discussions it was extremely difficult to separate the question of whether this country will continue to operate a land remote-sensing system from the question of what conditions and requirements a private firm should meet. **Customers of the data fear that the entire ability to gather and distribute useful land remote-sensing data might well be lost in the debate over transfer. They argue that uncertainties over the fate of land remote sensing have impeded the growth of a market for data and, consequently, the development of a strong value-added industry.**

OTA is grateful to the workshop participants and to the many others who provided information or reviewed portions of the draft of this technical memorandum. Their helpful and timely comments and suggestions made it possible to complete this report expeditiously.

25-357 O - 84 - 3 : QL 3