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EARTH VIEW: A Business Guide to Orbital Remote Sensing

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Research Institute for Computing and Information Systems
University of Houston - Clear Lake

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The RICIS Concept

The University of Houston-Clear Lake established the Research Institute for Computing and Information systems in 1986 to encourage NASA Johnson Space Center and local industry to actively support research in the computing and information sciences. As part of this endeavor, UH-Clear Lake proposed a partnership with JSC to jointly define and manage an integrated program of research in advanced data processing technology needed for JSC's main missions, including administrative, engineering and science responsibilities. JSC agreed and entered into a three-year cooperative agreement with UH-Clear Lake beginning in May, 1986, to jointly plan and execute such research through RICIS. Additionally, under Cooperative Agreement NCC 9-16, computing and educational facilities are shared by the two institutions to conduct the research.

The mission of RICIS is to conduct, coordinate and disseminate research on computing and information systems among researchers, sponsors and users from UH-Clear Lake, NASA/JSC, and other research organizations. Within UH-Clear Lake, the mission is being implemented through interdisciplinary involvement of faculty and students from each of the four schools: Business, Education, Human Sciences and Humanities, and Natural and Applied Sciences.

Other research organizations are involved via the "gateway" concept. UH-Clear Lake establishes relationships with other universities and research organizations, having common research interests, to provide additional sources of expertise to conduct needed research.

A major role of RICIS is to find the best match of sponsors, researchers and research objectives to advance knowledge in the computing and information sciences. Working jointly with NASA/JSC, RICIS advises on research needs, recommends principals for conducting the research, provides technical and administrative support to coordinate the research, and integrates technical results into the cooperative goals of UH-Clear Lake and NASA/JSC.

Earth View:

A Business Guide to Orbital Remote Sensing

Space Business Research Center

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Preface

The observation of the Earth from space has been one of the unquestioned benefits of the space program. Data from weather satellites became critical to weather forecasting in the 1960s almost from the day they were available. Televised pictures of the cloud cover motions also added a nice graphic to the nightly weather broadcast.

Begining in 1972, observation of land area was also an instant success because of the need to discover new oil fields following the run-up in oil prices. Finally, satellites trained on the oceans not only mapped global ocean currents, but discovered the now famous El Nino temperature variation in the Pacific Ocean that has a tremendous effect on global weather patterns.

With all of this benefit, it is surprising that orbital remote sensing is not a bigger business than it is today. For 1987, the Space Business Research Center reported revenues of $75.2 million in the remote sensing market. That figure was recently confirmed by Department of Commerce sponsored studies projecting $91 million in 1988 revenues. In any case, the market is small compared to its acknowledged potential. Among the many reasons for this disappointing performance may be the lack of suitable information about the business aspects of the remote sensing market.

The University of Houston-Clear Lake established the Space Business Research Center to gather and distribute information on the emerging space industry. With the assistance of NASA's Office of Commercial Programs and the Space Station Utilization Office, the Center has been serving the business, government, and academic communities with commercial information about space for two years while investigating the information which those communities need to increase their participation in the industry.

Earth View: A Business Guide To Orbital Remote Sensing is one of a series of Center publications designed to disseminate that information to the widest possible audience. The series began with Space Business '88, an economic profile of the space industry, published in August 1988. The series will continue with planned publications of business guides in space transportation and microgravity materials processing.

Earth View contains a wide assortment of information for new and existing businesses in the orbital remote sensing of land areas. The guide opens with an introduction to the technology of orbital remote sensing for those new to the industry.

Earth View also contains specific business information about orbital remote sensing--an overall description of the remote sensing market place, including market statistics, detailed descriptions of the primary products and services, and their prices and availability. A table of all remote sensing satellites launched and a history of recent developments in U.S. remote sensing policy is also included.

Finally, Earth View contains reference materials, such as a list of commonly used acronyms in the remote sensing field and a directory of firms and other organizations currently participating in the market.

Such an effort is always the collaboration of many hardworking and talented people. Consultants and graduate research assistants working at the Space Business Research Center conducted the primary research for this guidebook. Gary Hamel, Manager of the Space Business Research Center, performed supplementary research. James Cumming of the Space Business Research Center produced the textual format and graphics design. The text was reviewed by scientists and business people in the remote sensing industry. All material, however, is the sole responsibility of the Space Business Research Center.

Since the Center is also a research program on the business information required by the space industry, all comments about this publication are welcome. Please address your comments to:

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Part I: *A Guide To Orbital Remote Sensing*

Introduction

Remote sensing devices are carried on a variety of transportation platforms, but generally are flown aboard aircraft or satellites. Aerial and orbital remote sensing platforms each offer distinct advantages and drawbacks.

Since aircraft fly closer than satellites to the target object, aerial remote sensors can obtain more spatial detail with less atmospheric distortion than their orbital counterparts can. Small areas can be targeted and viewed more easily, and aerial remote sensing is relatively inexpensive since it costs less to fly airplanes than to build and launch satellites.

Satellite remote sensors, however, provide extensive coverage at comparatively low cost-per-area. Orbital sensors can not only scan more area at a time because of their greater distance from the target, but can observe virtually any spot on Earth. Satellite remote sensing is the method generally used to scan large or inaccessible land areas.

Background

Military agencies pioneered orbital as well as airborne remote sensing for reconnaissance. The first remote sensing satellite was launched by the United States in February 1959. Since then, many countries have orbited remote sensing satellites.

The military background of remote sensing led to two key legal concepts about satellite operations and data applications. The first viewpoint, the "Open Skies Doctrine" introduced by the U.S. in the 1950s, considers space, like the oceans, as international territory, and that all parts of the earth are opened for orbital viewing. Western countries generally accept this doctrine, but Russia, the People's Republic of China and Japan do not. Consequently, Soviet and Japanese marketing programs are somewhat restricted. The Russians, for example, do not sell imagery from a Warsaw Pact country to buyers outside that country.

The second concept, of nondiscriminatory access to remote sensing data, holds that satellite-acquired images cannot be proprietary and must be available for sale to all buyers. The U.S. also introduced this policy but is its sole adherent. The European Space Agency (ESA), Russia and Japan will acquire and sell data on an exclusive basis, giving them commercial advantages over the U.S.

Table 1: Remote Sensing Satellites Launched 1959 to 1988

Russia	430
USA	130
France	6
Japan	4
India	4
China	4
ESA	2
Total	580

Source: Space Business Research Center

Non-military government agencies initially used satellites to sense the atmosphere, and worldwide coverage of weather patterns is now an essential component of weather forecasting. The U.S. and other major nations currently maintain large and effective weather monitoring systems.

Non-military orbital sensing of land areas began in 1972 when the National Aeronautics and Space Administration (NASA) launched the first Landsat satellite. Landsat data has since been used to locate oil and mineral deposits in geological formations, measure and forecast food and renewable resource production, and make more accurate maps of Earth's physical features.

Earth's oceans have not yet been scrutinized as closely as the atmosphere and land. Although the oceans affect weather and are commercially critical to many countries, governments and businesses have been slow in developing orbital systems to continuously monitor the seas. However Japan launched its Marine Observation Satellite (MOS-1) in February 1987. In addition, EOSAT, which now operates the Landsat system, will install an ocean color-scanner on the Landsat 6 satellite scheduled for launch in June 1991.

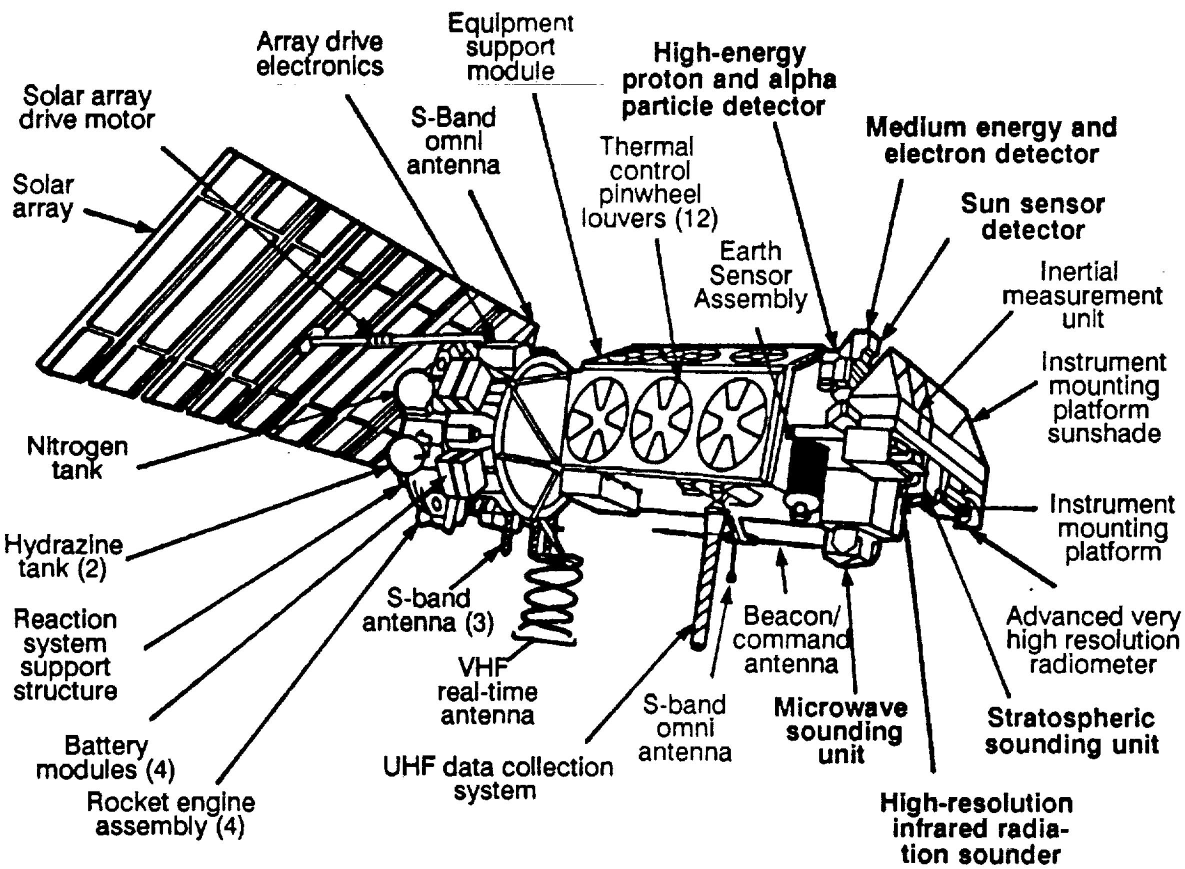
Orbital Remote Sensing Equipment

A remote sensing satellite contains two major components -- sensors and the platform that carries them. The platform is a mechanical structure that houses the sensors and provides their operational systems: power, attitude control, data processing, communications, etc. The platform is also called a "bus," a communications term, since it can carry many different types of sensors.

The platform generally used for commercial remote sensing is the TIROS (Television and Infrared Observation Satellite), shown in Figure 1. The platform consists of everything except the instruments (listed in bold) on the Earth Sensor Assembly on the right side of the spacecraft. The current Landsat 5 satellite is represented in Figure 2, which also shows sensor systems in bold.

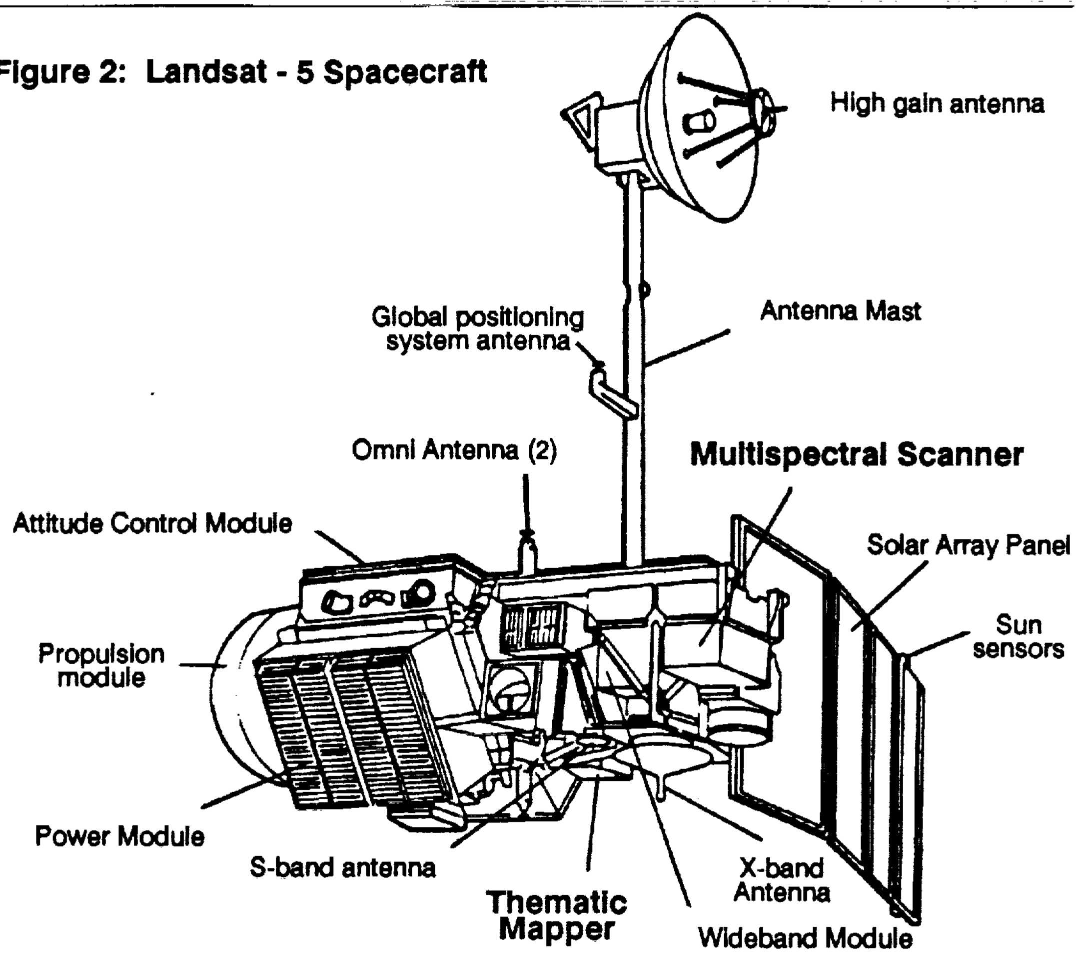
Satellites circle the Earth in well-defined orbits of varying altitude and inclination, the angle an orbit makes relative to the Equator. Remote sensing satellites generally are placed in moderately high orbits 500 to 1000 miles above Earth. These paths escape the drag of the residual atmosphere remaining in the 200- to 300-mile-high orbits typically used by manned missions. Weather satellites are inserted in a 22,500-mile-high

Figure 1: TIROS Bus (NOAA-N Spacecraft)



Source: National Oceanic and Atmospheric Administration.

Figure 2: Landsat - 5 Spacecraft



Adapted from: NESDIS Programs / NOAA Satellite Operations, NOAA, U.S. Dept of Commerce, March 1985, p. 211

geosynchronous orbit to give full views of Earth's hemispheres. Since the ability to gather fine detail decreases with altitude, while transportation costs increase, most remote sensing satellites are placed where they can maintain long-term, stable orbits just above the atmosphere.

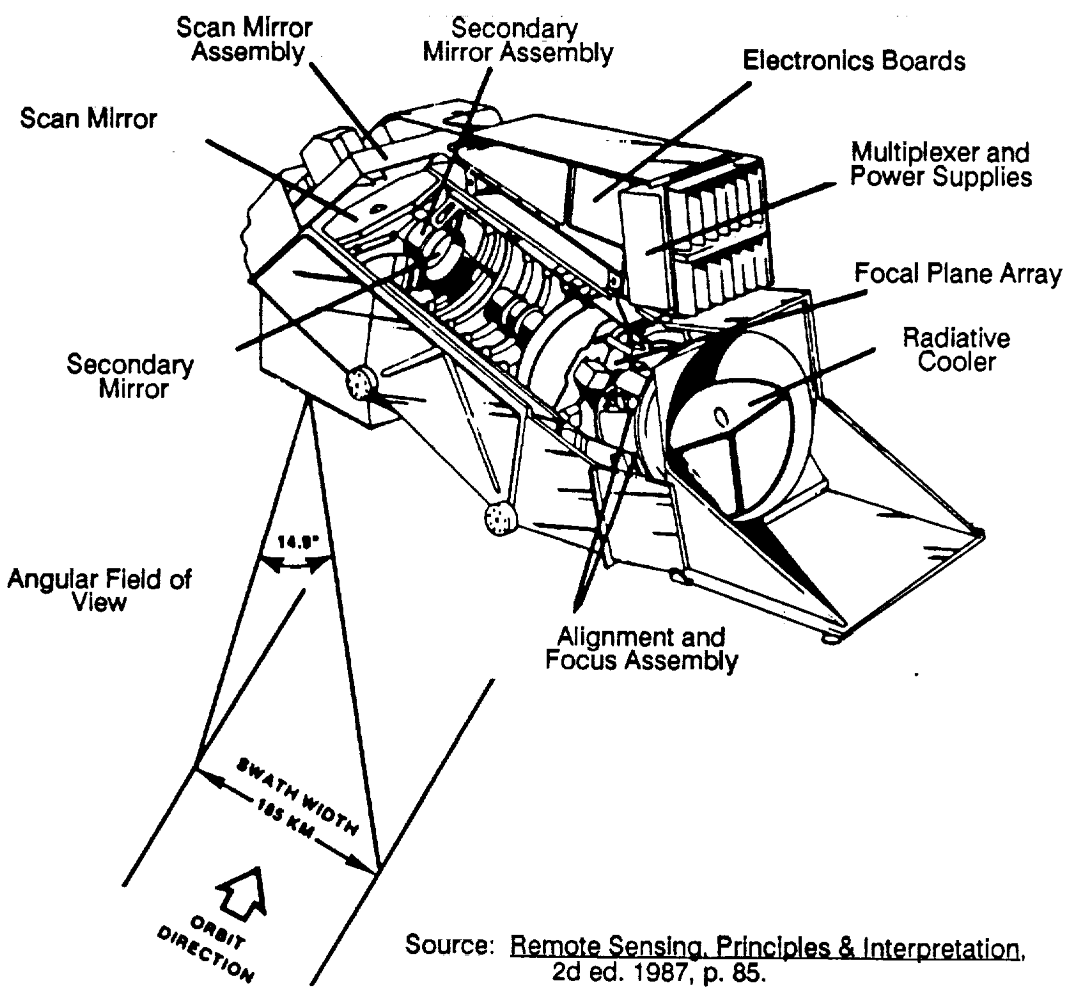
Remote sensing satellites travel in a roughly north-south path called a near-polar orbit. They pass within 10 degrees of the poles and cross the Equator at almost a right angle. The polar orbit is used because it crosses all latitudes -- as the Earth rotates, the satellite eventually passes over every point on the planet's surface.

Sensor Systems

Early satellites used the principles of photography and television to observe the earth. High-resolution cameras and film were placed on satellite platforms which automatically jettisoned film canisters when they were full. The containers were retrieved after landing for film processing and interpretation. U.S. military satellites used this technique into the 1970s, and the U.S.S.R. still uses film for many remote sensing applications. The amount of film onboard a satellite at launch, however, severely limits its useful life. Commercial remote sensing satellites, accordingly, rely primarily on scanners rather than cameras to observe the Earth.

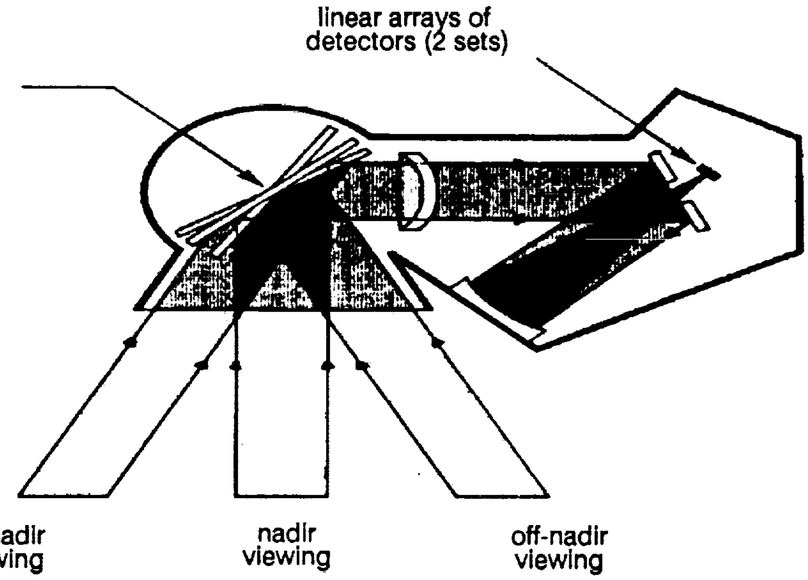
In place of light-sensitive film, scanners use photometers, devices that electronically measure the number of photons in narrow frequency bands. However, each photometer can sense light in just a single portion of the electromagnetic spectrum. Since objects emit light at various frequencies, sensor systems include numerous photometers individually tuned to different frequencies, making the system "multispectral." By using the information gathered by a range of photometers, which are also called channels or bands, analysts can discern the details of atmospheric phenomena and aquatic, natural, and man-made objects. The differences between varying kinds of trees or crops can also be distinguished.

Figure 3: Landsat Thematic Mapper Sensor



Source: Remote Sensing, Principles & Interpretation, 2d ed. 1987, p. 85.

Figure 4: SPOT Imaging System



Adapted From: G. Weill, SPOT Image Corporation, in Remote Sensing: Principles & Interpretation, 2d ed. 1987, p. 120

Spectral Resolution

A sensor system's quality and capabilities depend on two key performance factors. Spectral resolution, a system's visual range, is determined by the number of photometers or channels that comprise the system. The American Landsat 5 satellite operated by EOSAT, carries a Thematic Mapper (TM) system(Figure 3) containing seven channels and a Multispectral Scanner (MSS) that has four.

The French SPOT satellite, currently the world's other major commercial remote sensing spacecraft, holds two sensors systems. The first contains three channels, while the second -- a panchromatic system -- measures all visible light as shades of gray.

As the number of channels in a sensor system increases, its spectral resolution improves. EOSAT's TM system has better spectral resolution than its companion MSS system, and both have higher spectral resolution than either SPOT system.

Spatial Resolution

The other key characteristic of a sensor is its spatial resolution, the sharpness of its vision. Images with high spatial resolution are crisp and clear, showing more small objects and greater detail on large ones. Landsat 5's MSS scanners have an 80-meter spatial resolution: the smallest unit in an MSS image -- a "dot" or pixel -- represents a ground area 80 meters square, about 265 feet on each side. Objects within that area are not visible as discrete entities. Landsat's newer TM system can resolve objects 30 meters or 100 feet in size. The two SPOT systems have better spatial resolution: 20 meters or 65 feet with the three-channel system, and 10 meters or 34 feet for the panchromatic.

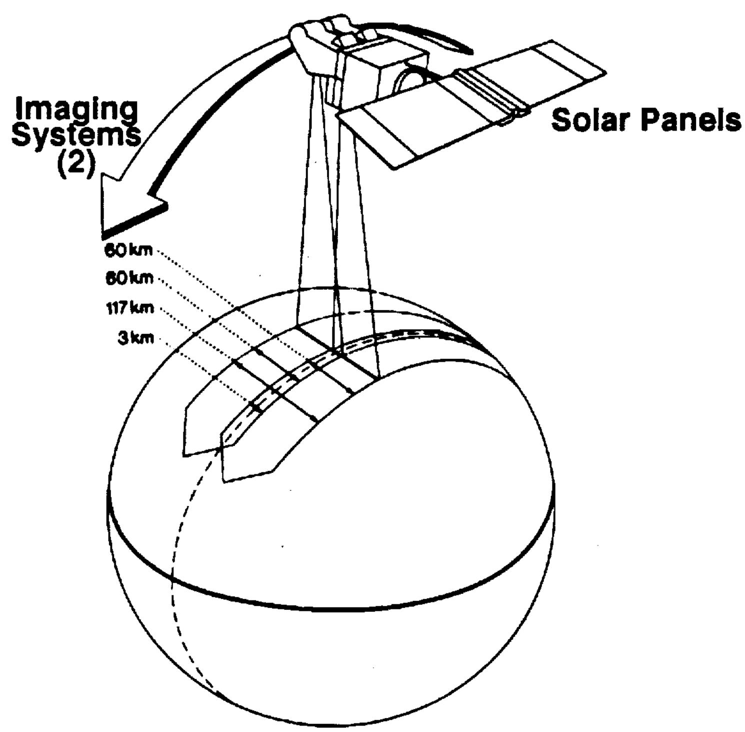
Remote Sensing Systems - Development

The era of civilian remote sensing began in 1972 when NASA launched the Earth Resources Technology Satellite 1 (ERTS-1), later renamed Landsat 1. NASA has launched four additional Landsats since then, the last two of which are still in orbit. However, Landsat 4 can only use its MSS and TM scanners alternately, not simultaneously. Landsat 5, which can use both systems at once, is expected to remain nominally operational through 1989 and perhaps into 1990. Landsat 4, which could fail at any time, remains nominally operational.

In 1985, the Landsat system was transferred to the private sector. The Earth Observation Satellite Company (EOSAT), a consortium formed by RCA and Hughes Aircraft, became the system's operator following a long and difficult federal bidding process.

The resulting agreement with the government specifies that EOSAT will operate the Landsat satellite and its data acquisition system, and build the next two satellites in the series, Landsats 6 and 7. In return, EOSAT has the exclusive right to sell the data, and receives funding for development of Landsat 6. Because of the delays in producing Landsat 6, however, Landsat 7 probably will not be built. The U.S. will instead be working on the Earth Observing System (EOS) by then.

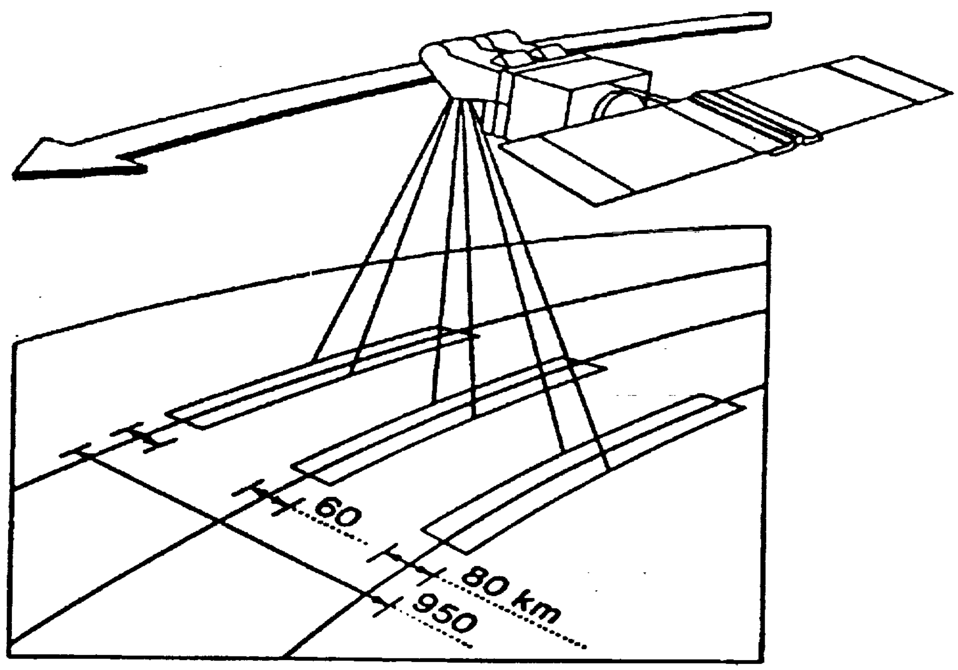
Figure 5: SPOT Satellite Platform and Image swaths in nadir viewing mode.



Adapted From: G. Weill, SPOT Image Corporation, In Remote Sensing: Principles & Interpretation, 2d ed. 1987, p. 120

EOSAT's monopoly on U.S. remote sensing ended the following year when the French entered the domestic market with their SPOT-1 (Satellite Pour l'Observation de la Terre) satellite. The spacecraft was built by the French space agency CNES and transferred to the private firm Spot Image which operates the system and markets its data. Spot Image is represented domestically by Spot Image Corporation, a U.S. corporation wholly owned by Spot Image of Toulouse, France.

Figure 6: Off-nadir viewing capability of SPOT using tiltable mirror



Adapted From: G. Weill, SPOT Image Corporation, in Remote Sensing: Principles & Interpretation, 2d ed. 1987, p. 121.

EOSAT - SPOT: Capabilities Comparison

In addition to the spectral and spatial resolution differences between the Landsat and SPOT satellites, SPOT's two sensors can rotate to view objects not directly below the spacecraft (Figure 4). This gives the SPOT system greater scope and frequency of coverage.

Any satellite returns to a given point in its orbit once in a cycle of days called the revisit period. Landsat, which has a revisit time of 16 days at the equator, can reexamine an area approximately that often, at best. Rescanning may take longer, however, because of cloud cover and technical or scheduling problems.

SPOT's revisit time is 26 days. Since the sensors are tiltable, however, the French satellite can reexamine the same area from slightly different angles several times during that period. Figures 5-7 show the coverage, or swathing patterns, of Landsat and SPOT satellites.

The ability to record images from different angles enables remote sensing data analysts to create stereoscopic, three-dimensional images of locations. Such images substantially improve accuracy in measuring land elevations and contours.

Data Acquisition

Satellite sensing of an object or area is only the first step in a long chain of communication and data processing that together produce usable materials. Information is transmitted from remote sensing satellites by electrical signals sent directly through receiving stations on the ground or to relay satellites. Since remote sensing spacecraft use a relatively low orbit, they are not always within range of a receiving station.

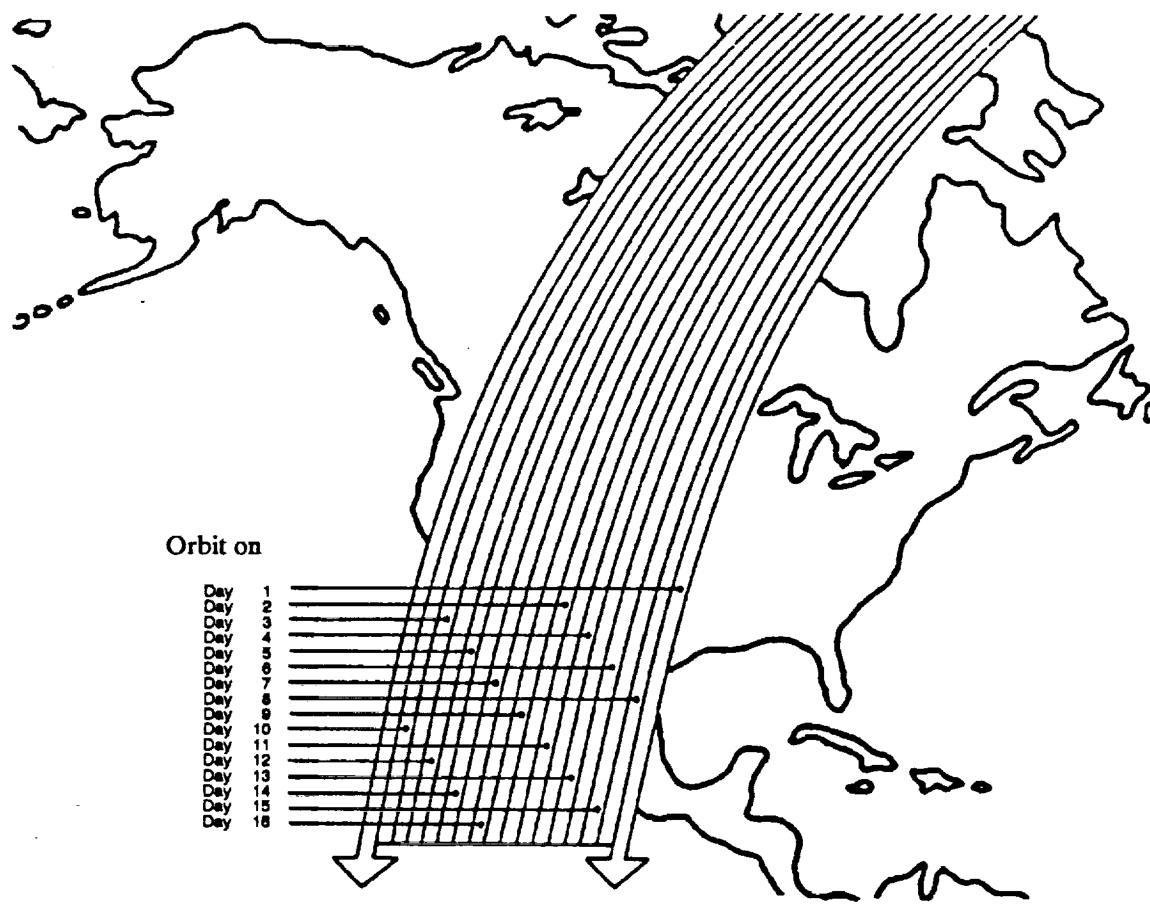
To extend the coverage area, two technical means are used. The SPOT satellite carries a tape recorder to store information until a signal can be sent to a receiving station. The tape recorder, however, increases the spacecraft's weight and cost, and is subject to mechanical failure.

The first three Landsat satellites also relied on tape recorders. Beginning with Landsat 4, the system has relayed data through the Tracking Data Relay Satellite (TDRS), a geosynchronous communications spacecraft owned and operated by NASA. EOSAT has used a TDRS currently positioned over the Atlantic just east of Brazil to receive Landsat signals covering 40% of the earth's surface and transmit them to a processing facility. The September 1988 shuttle launch of a second TDRS, positioned over the Pacific south of Hawaii, gave EOSAT full coverage of the Earth. A third TDRS, deployed from a shuttle in March 1989, replaced the partially dysfunctional TDRS-1 over the Atlantic. TDRS-1 will now be moved to a location between the other two serve as an on-orbit spare.

Whether ground stations or relay satellites are used, the signal is routed to a processing center. EOSAT uses the Goddard Space Flight Center and the U.S. Geological Survey's EROS Data Center in Sioux Falls, South Dakota, to process, store and distribute data. SPOT data for the U.S. and Canada are received by two Canadian ground stations and processed at Spot Image headquarters in Reston, VA. SPOT data for other countries are processed at the parent company's headquarters in Toulouse, France.

In all cases, the remotely sensed information is filtered through computer programs specially designed to correct spatial and spectral distortions that occur during data acquisition and transmission. After this, the information is converted into digital, computer-compatible tapes (CCT's) or photographic images. These products are then sold to customers who either use the information as supplied or apply additional processing before analyzing the data.

Figure 7: Landsat - 4 Swathing Pattern



Source: NOAA

Analysis and Interpretation

Useful information is extracted from basic remote sensing data through the process of interpretation. This identifies objects in remotely sensed images -- whether in water or on bare, cultivated or developed land -- and discerns their characteristics, including elevation, stage of crop or resource growth, or degree of pollution.

The analysis of raw, remotely sensed data requires a complex combination of computer processing and human judgment. Some interpreters prefer data in photographic form and rely primarily on their experience of objects' appearance. Other analysts, working with digital data, use computer algorithms to reveal patterns in the images. No interpretation is possible without using some portion of both analytical techniques.

Remote Sensing Applications

Remote sensing has current or potential applications in virtually all activities involving land: agriculture, cartography, construction, geology, metals and minerals exploration, petroleum development, renewable resource production and so forth. Techniques to interpret remote sensing data are continually developed and refined, then disseminated through the market's technical publications.

The practical applications of these techniques, however, have not fulfilled early expectations. Several things have contributed to the shortfall. Remotely sensed data have been more difficult to obtain than anticipated, and the required processing is often perceived as too technically demanding and expensive to be cost-effective. In addition, prospective users sometimes do not clearly understand the data's benefits, requirements and limitations. Whatever reasons account for its underdevelopment, the remote sensing market has substantially greater prospective utility and profits than have yet been realized.

The most extensive use of remote sensing data to date has been in geology, particularly for oil exploration. The initial availability of remote sensing data for large areas of Earth coincided with the oil price increases of the 1970s and resulting surge in oil exploration. Petroleum companies developed extensive in-house capabilities to analyze remotely sensed data about prospective sites worldwide.

The steep decline in oil prices in the early 1980s and again in 1986 considerably reduced the demand for remote sensing data. The market's data analysts, including those laid-off by oil companies, are trying to apply this specialty to metals and minerals exploration. Mining companies have been slow to adopt the technology, however, because they do not consider it cost-effective.

Remote sensing has also been applied successfully in agriculture and forestry. The renewable resources industries have maintained a comparably small but constant demand for remote sensing data. Although numerous studies by the U.S. and other governments have demonstrated the exceptional accuracy of satellite data for measuring crop status, projected yields and resource production, only a few U.S. companies have adopted the technology. Crops develop too rapidly for EOSAT data -- available once or twice monthly -- to be useful. Agricultural applications may increase in the future since SPOT can revisit an area once or twice each week using off-nadir viewing capabilities. Satellite imagery has gained more widespread use in the forestry industry where, due to longer growing times, frequent data is not required.

Geology, agriculture and forestry represent the major applications of remote sensing. The market's other significant service sectors are listed below:

- **Cartography**
  - Mapping remote areas
  - Measuring land-use patterns
- **Hydrology**
  - Locating water sources
  - Modelling water usage over large areas
  - Mapping sedimentation patterns
- **Civil engineering**
  - Construction site planning for roads or pipelines
- **Environmental Science**
  - Environmental impact assessments
  - Pollution monitoring

Future Activities, Prospects

SPOT 2, the successor to SPOT 1 and an identical copy of it, has already been built. SPOT Image has delayed launch because SPOT-1 has exceeded its anticipated operational lifespan.

Landsat 6, the replacement for the present EOSAT satellite, has not yet been manufactured. EOSAT's difficulties with government contract negotiations and payments have delayed production.

The next Landsat will be quite similar to the current one. The spacecraft will not include an MSS sensor. Instead, the satellite will carry an enhanced TM sensor with seven spectral bands, and a panchromatic sensor with 15-meter spatial resolution.

Launch is tentatively scheduled for 1991. Landsat 5, which has already exceeded its three-year life expectancy, is expected to stop functioning before then. The ensuing "data gap" will hamper EOSAT's marketing efforts even though the company has a 15-year archive available to clients, principally geologists, who can use historical images.

Additional satellites can be anticipated for SPOT, but not for Landsat. SPOT Image has announced plans for four satellites, including significantly enhanced capabilities for SPOT 4.

Increased use of radar and rapid expansion of satellite sensor capacity could substantially affect data acquisition and interpretation. Since radar can accurately measure objects' elevations, the applicability of satellite data to geology as well as cartography would be substantially increased. Japan's MOS-1 satellite carries a single radar sensor and a Canadian satellite bearing two types of radar sensors is scheduled for launch in June 1994.

Proposed use of Multiple Linear Arrays -- scores to hundreds of sensors aboard a single satellite -- would also affect the entire remote sensing market. MLA's, like radar, would exponentially increase satellite data and its telemetry control, processing, and analysis requirements as well as potential applications.

America's remote sensing market share depends on various U.S. government plans. These include Earth Observing System (EOS), an international polar platform to be launched from Vandenberg Air Force Base in late 1995. The platform, nominally part of the space station program, was designed to be a large, multi-purpose, remote sensing facility. The platform would need to be launched by a Titan 4 rocket and serviced by the space shuttle. Now that the shuttle facility at Vandenberg has been closed, the serviceability of the polar platform is in doubt.

The platform program would include two satellites -- one crossing the Equator 16 times daily in the morning, and the other crossing in the afternoon. The European Space Agency would supply the first, to carry instruments for weather, air, land, ocean, and polar observations, and possibly for solar and astronomical sensing as well. The U.S. would supply the second satellite, intended mainly for atmospheric monitoring. It also would carry instruments to measure a wide range of atmospheric, terrestrial and aquatic data.

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Part II: *Current Orbital Remote Sensing Systems*

Introduction:

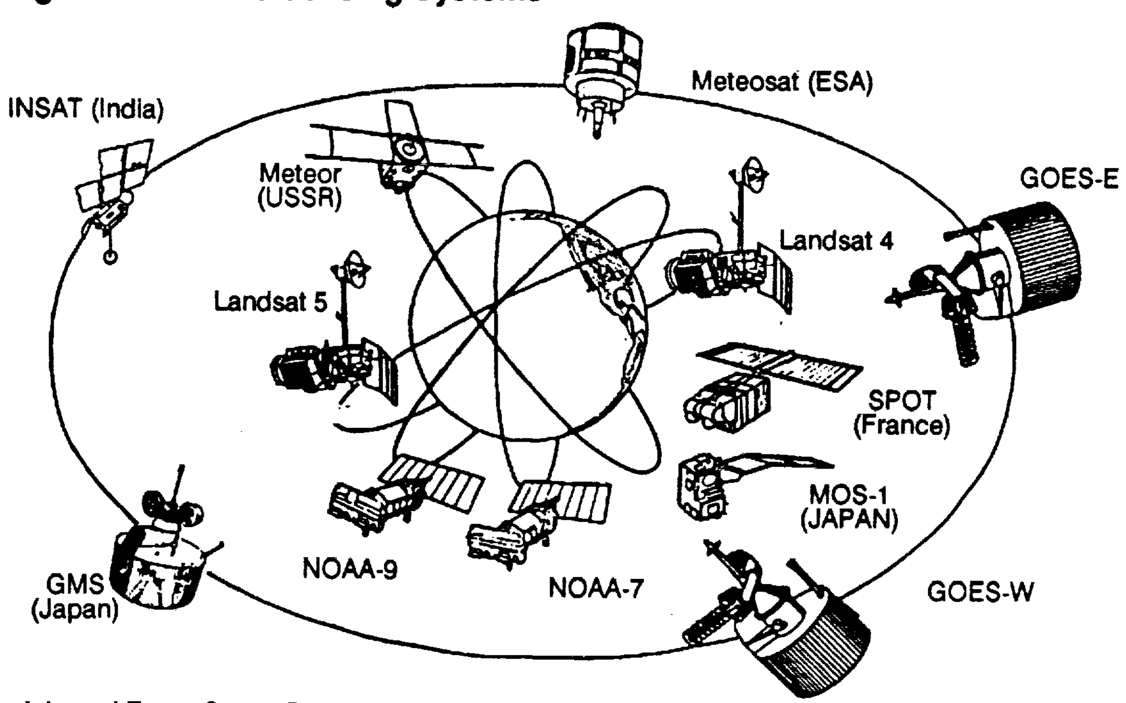
This portion of the guidebook contains detailed descriptions of each of the major, civilian remote sensing systems now operating, and information about systems planned or under development.

A chapter is devoted to each of the two key systems operating domestically, Landsat and SPOT. The following topics are covered in each portion:

- *History of the system*
- *Satellite platform and sensors information*
- *Current surface area coverage*
- *Data products and prices*

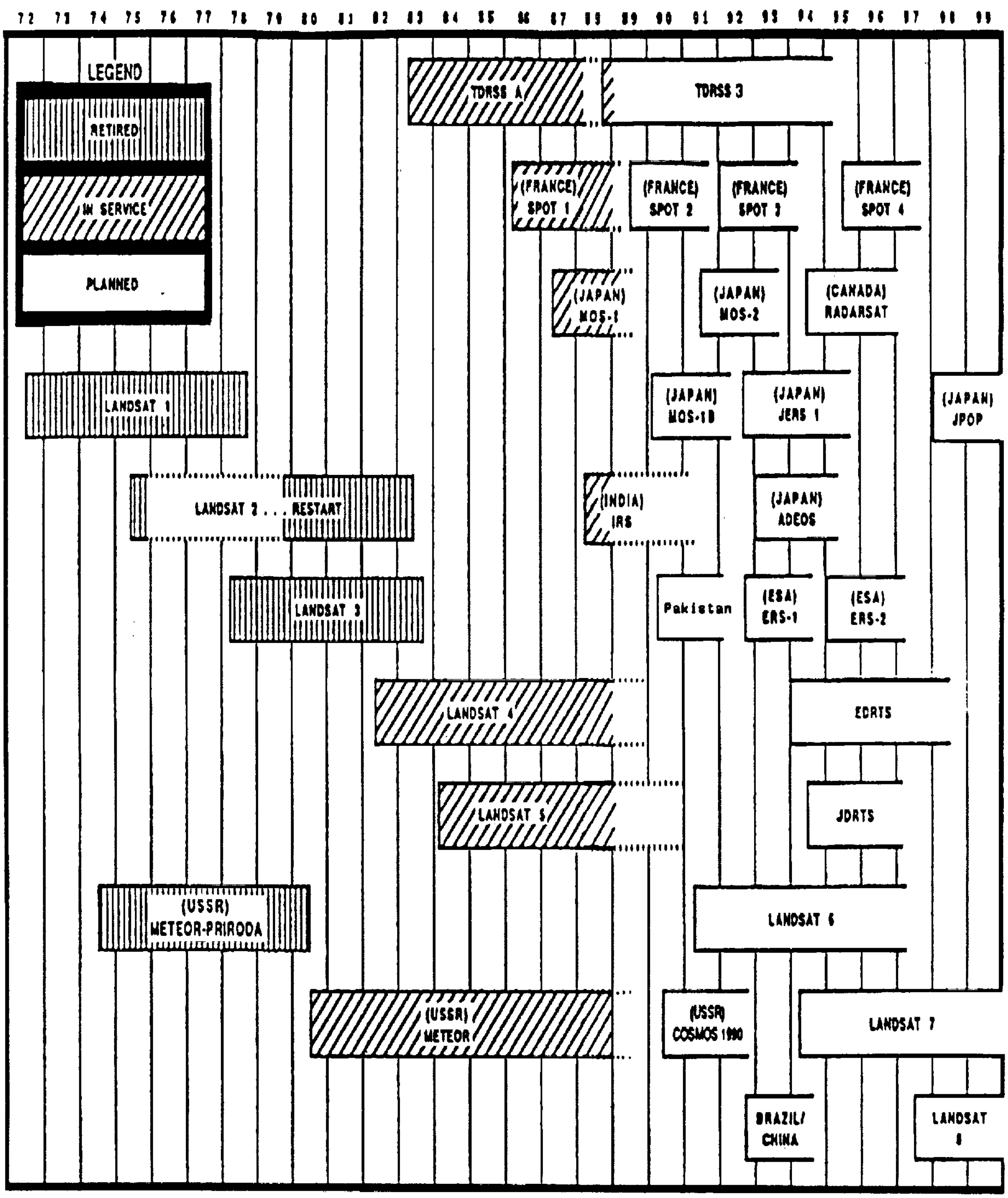
Additional chapters are devoted to two emerging systems, Japan's MOS-1 and the Soviet Union's Soyuzkarta.

Figure 8: Remote Sensing Systems



Adapted From: Space-Based Remote Sensing of the Earth from Space: A Report to Congress, NOAA & US Dept. of Commerce Sept. 1987, p.3

Figure 9: International Remote Sensing Systems



Adapted from: EOSAT Landsat Data User Notes, Vol 3, #2 June 1988, p. 5. Copyright 1988 Earth Observation Satellite Company. Landsat data distributed by Earth Observation Satellite Company, Lanham, MD, USA. Used with permission.

Chapter I: *Landsat*

Overview and History

The following historical summary of the Landsat satellite system is adapted from LANDSAT (Lanham Md: EOSAT, July 1987).

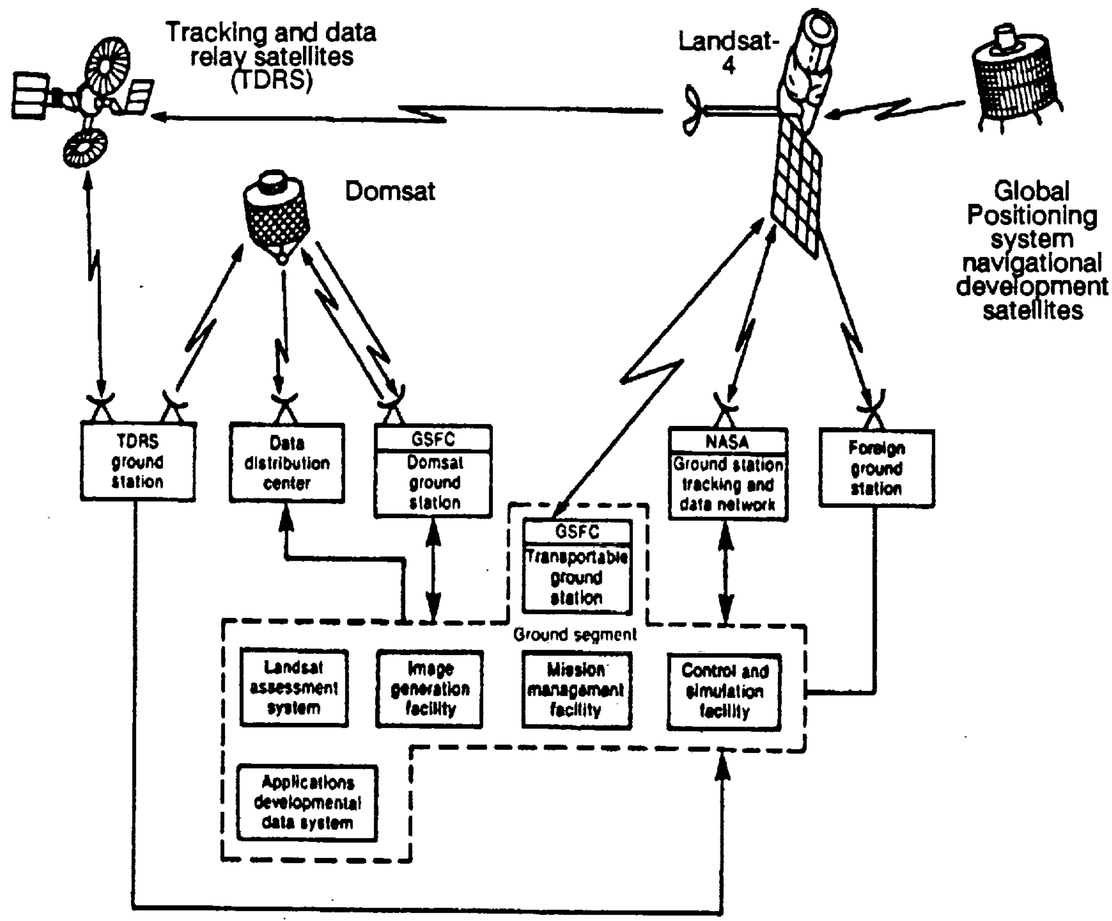
Launching the Program.

During the 1960s, following successful Earth photography by Gemini and Apollo astronauts, proposals for an Earth Resources Observation Satellite (EROS) were made by various federal agencies. The U.S. Department of Agriculture saw the potential use of such a satellite to survey crops, timberland and other vegetation. The Interior Department's U.S. Geological Survey (USGS) perceived numerous potential uses for the program.

The Interior Department asked the Office of Management and Budget (OMB, then called the Bureau of the Budget) for funding for an EROS program in 1968. OMB delayed approval until they could find a way to operate the system. NASA was the obvious choice, but they were proscribed by law from offering products and services for sale.

An agreement was finally reached whereby NASA would develop, launch and collect data from the satellite which the Interior Department would then sell to users, or "investigators" -- the people who would analyze and interpret the satellite data.

Figure 10: Landsat Ground Segment



Adapted From: National Oceanic and Atmospheric Administration

Congress approved funds for the program in 1969. Responsibility for civilian use was later transferred to the Commerce Department's National Oceanic and Atmospheric Administration (NOAA) as the program progressed from development to operation.

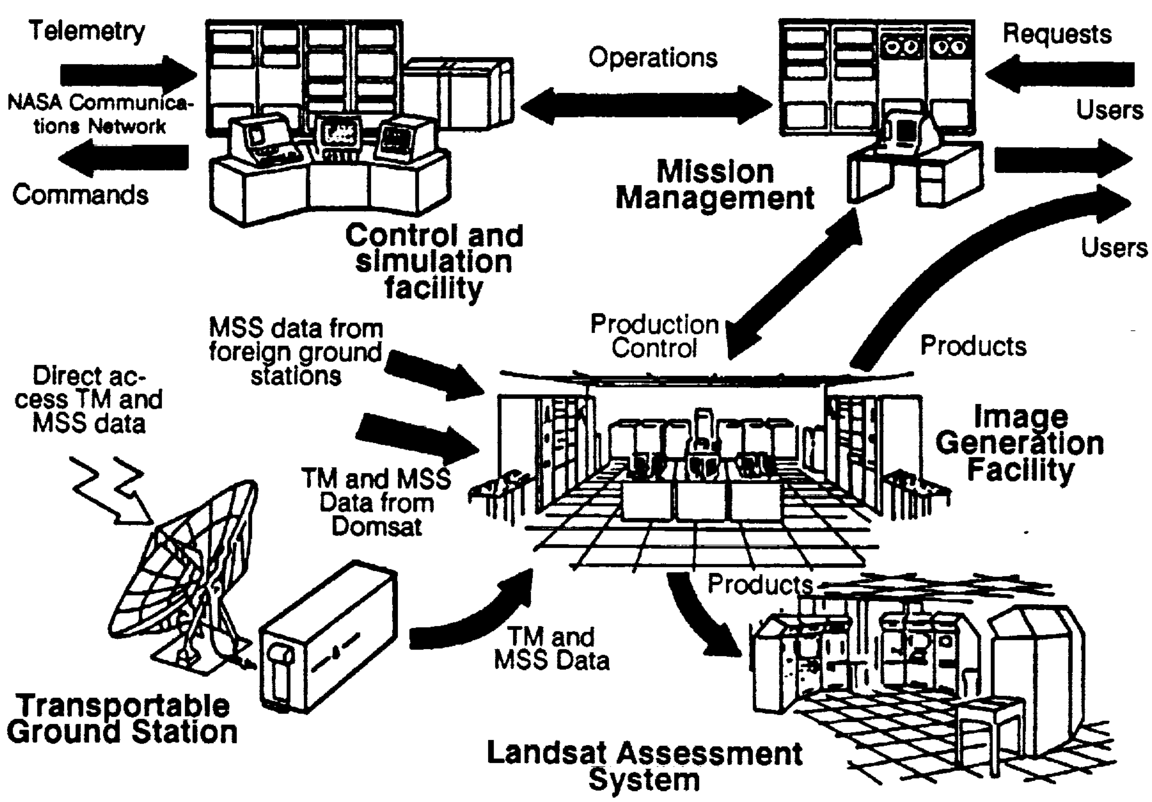
Contractors -- principally the Space Division of General Electric at Valley Forge, Pennsylvania -- were chosen in 1970 to build and equip the spacecraft, and the first Landsat was launched on July 23, 1972. Landsat 1, expected to function for a year, provided more than five years of nearly continuous service, then ceased operating early in 1978. During its life, it returned data for some 300,000 images of Earth's surface.

Early Success

Landsat 1 was programmed to acquire and transmit information designed to help investigators in such fields as geology, agriculture, environmental study, geography, cartography, urban and social studies, and oceanography. Its design was similar to Nimbus, a highly successful series of weather satellites launched by the United States since the early 1960s. The first three Landsats used Return Beam Vidicon (RBV) television cameras to record earth images, while the Multispectral Scanner (MSS) sent signals to be decoded at ground stations. The initial receiving stations were located at the Goddard Space Flight Center in Greenbelt, Md., Goldstone, Ca., Fairbanks, Ak., and Prince Albert, Sask., Canada.

The federal agencies which had first believed in the program's usefulness were now joined by state and local officials. States could use the satellite data in land management, water resources, agriculture, coastal zone management, resource development, wetlands mapping, wildlife habitat analysis, forest mapping and geological analysis. Agencies seven-fold cost savings by using Landsat instead of traditional methods of data collections.

Figure 11: Major Elements of the Landsat System



Adapted From: EOSAT chartCopyright 1988 Earth Observation Satellite Company. Landsat data distributed by Earth Observation Satellite Company, Lanham, MD, USA. Used with permission.

Foreign governments responded as well. The project's international participation, a feature from the beginning, escalated dramatically. The experiments undertaken by the satellite included surveys to determine spring flooding hazards from melting snow in Norway, land use and soil erosion in Guatemala, crop inventories in the Sudan, the hydrologic cycle of the Santa River basin in Peru, winter monsoon clouds and snow cover in Japan, and a sweeping analysis of natural resources in India. In the program's early stages, scientists from Australia, Brazil, Canada, Chile, Colombia, Ecuador, France, West Germany, Greece, Guatemala, India, Indonesia, Israel, Japan, South Korea, Mexico, Norway, Peru, Switzerland and Venezuela participated in studies funded by their governments.

Investigators from more than 50 foreign countries are now involved in Landsat surveys. Receiving stations are currently operating in Canada, Brazil, Italy, Saudi Arabia, the People's Republic of China, Argentina, Australia, India, Japan, Sweden, Indonesia, Thailand, South Africa and the Canary Islands. Pakistan opens a French-built receiving station in mid-1989, and Canada recently built a station in Ecuador. Other pending or proposed receiving stations are under consideration for western China, Mexico, the Philippines, Rumania and the African countries of Kenya, Nigeria, and Burkina Faso.

The United Nations has actively encouraged the international use of remotely sensed data since the beginning. In 1969, the U.N. Committee on the Peaceful Uses of Outer Space established a Space Applications Program to foster cooperation among nations to share such information for scientific research, mineral exploration, international development, disaster relief activities and other areas of global interest. During the 1970s, the U.N. established remote sensing centers at its Center for Natural Resources and Department of Technical Cooperation for Development in New York, and at its Food and Agriculture Organization in Rome.

The World Bank, the international economic development agency, quickly adopted remotely sensed data for use in agriculture resources management, rural development and cartography.

Commercial interests also were attracted. The forest industry uses Landsat to help site mills and hauling roads, and to survey the health of timber stands. Oil and gas companies soon became consistent Landsat customers who use the data to survey remote areas and acquire geological overviews of regions.

Public utilities have used the data to survey regional population growth trends and to help plan the placement of pipelines, power lines and substations.

Federal Agency Roles and the Commercialization of Landsat

Initially, the U.S. Department of Agriculture (USDA) distributed Landsat data through the Stabilization and Conservation Services Aerial Photography Field Office in Salt Lake City, Utah. The Department of the Interior provided data to researchers through the U.S. Geological Survey (USGS) Earth Resources Observation System (EROS) Data Center, now the EROS Data Center, in Sioux Falls, South Dakota. Data was also available through the USDA Stabilization and Conservation Services Aerial Photography Field Office in Salt Lake City, Utah, and through the NASA Goddard Space Flight Center.

President Carter transferred responsibility for Landsat from NASA to NOAA in November, 1979. NOAA was chosen to receive the program partly because of the agency's ten years' experience managing the weather satellite program.

The presidential directive also established commercialization as a goal for the system. In response, NOAA developed a phased plan to commercialize the Landsat program by the early 1990s. In February 1983, President Reagan accelerated the commercialization process by authorizing formal proceedings to locate a private operator. Just before the launch of Landsat 5 in March 1984, the Department of Commerce solicited proposals for Landsat commercialization. Legislation authorizing the transfer (the Land Remote Sensing Commercialization Act of 1984) was passed by Congress and signed by the president in July 1984. Negotiations with a private firm, the Earth Observation Satellite Company (EOSAT) formed by RCA and Hughes Aircraft, culminated in a contract on September 27, 1985, to design, construct and launch the next generation of Landsat spacecraft and sensors, and build ground processing systems.

Landsat data is distributed by the EROS Data Center. The facility is required to maintain a national archive of all space-acquired data -- more than six million images from all space programs, including Gemini, Skylab and Apollo.

The Landsat Commercialization Process

The following excerpt was adapted from Congressional testimony was given by Anthony J. Calio, Deputy Administrator, NOAA, on June 13, 1985, before a joint meeting of the Natural Resources, Agriculture Research and Environment Subcommittee, and the Space Science and Applications Subcommittee of the House Space, Science, and Technology Committee. The testimony was reproduced in the November 1985 issue of NOAA's Landsat Data Users Notes (Issue No. 54). It presents a concise overview of the Landsat commercialization process from 1983 through 1985. It also summarizes the contract terms and conditions negotiated by EOSAT and the Department of Commerce.

After the White House memorandum authorizing Landsat Commercialization was issued in February 1983, the Department of Commerce established the Source Evaluation Board for Civil Space Remote Sensing to issue a formal Request for Proposals (RFP), evaluate them and report findings. The Source Evaluation Board included representatives from the Departments of Agriculture, Defense, Interior, State, and Commerce, and from NASA. Additional staff and logistical support were provided by NOAA, NASA, the National Bureau of Standards, and the Departments of Defense, State and Interior.

The RFP provided that no proposal could be considered if it were not acceptable with respect to national security, foreign policy, requirements of the RFP, and particular stipulations of the RFP.

Seven proposals were received by the official closing date for the RFP, March 19, 1984. After initial evaluation, the Board found three proposals to be within the competitive range, those of the Earth Observation Satellite Company, Eastman Kodak Company and Space America Corporation.

On May 29, 1984, the proposals of Eastman Kodak and EOSAT were selected as the most qualified, and negotiations began with both companies to define firm contractual agreements. Both firms were informed that their technical approaches were acceptable but their financial proposals were not.

The OMB decided that its support should be limited to the remaining costs to operate Landsats 4 and 5; and a maximum of $250 million of new budget authority for the commercial follow-on system. Both offerors were notified of this decision July 20, 1984 and requested to revise their proposals accordingly. EOSAT did, but Eastman Kodak declined to do so.

EOSAT is a joint-venture partnership formed by Hughes Aircraft Company and RCA Corporation, now GE Aeronautics Division, in accordance with the provisions of the Uniform Partnership Law of the State of Delaware. Hughes and RCA have an equal interest in the venture.

In June 1984, Congress passed the Land Remote Sensing Commercialization Act of 1984. The Act was signed into law by the president on July 17. In addition to providing a framework for the transfer to the private sector of both the current Landsat 4/5 system and the follow-on commercial system, the Act dealt with licensing, R&D roles of Federal agencies, data archiving and several other matters.

The Land Remote Sensing Commercialization Act of 1984 provides for the construction, launch, and operation of additional Landsat satellites; the development of a supporting ground system; and the worldwide sale and distribution of remotely sensed data.

Shortly thereafter, the White House reported that financial arrangements would not meet the goal of having the contractor accept the majority of long-term risks. In March 1985, EOSAT submitted a revised proposal including the following key points: Two satellites and a new ground station would be provided by EOSAT for a fixed price of $250 million. EOSAT would fund all capital costs over $250 million except for required launches, to be funded by the government. EOSAT would market all unenhanced Landsat data and retain all revenues from data sales, including a pro-rata share of access fees and royalty fees paid by foreign ground stations under an existing Memorandum of Understanding with the government. If cumulative revenues fall below 65 percent of projected revenues before the launch of Landsat 6, or 60 percent thereafter, EOSAT could terminate marketing at any time and terminate operations four months after the launch. However EOSAT would still be required to build, launch and check-out Landsat 6 and 7, and would provide the ground station for a fixed price of $250 million.

In November 1985, five months after this testimony was given, the Office of Management and Budget zeroed Landsat out of the 1987 budget. No funds were forthcoming, and in December 1986, EOSAT stopped construction on Landsat 6. The next month, EOSAT and its subcontractors laid-off or transferred 400 people.

No agreement could be reached between EOSAT and the Government on funding until October 1987, when a Revised Landsat Commercialization Plan was released by the Department of Commerce.

The revised plan included (for FY 1988) $26.4 million for Landsat 4 and 5 operations (including $35 million reprogrammed from the polar-orbiting satellite program), $34.2 million for development and launch costs of Landsat 6, and $2 million for the study of the advanced Landsat 7 systems.

The total ten-year EOSAT commercialization effort with only one satellite can now cost no more than $209.2 million, less than half the $500 million originally requested by Hughes and GE to commercialize Landsat in 1984, and also less than $250 million the U.S. government promised EOSAT when the contract was signed in 1985. [Excerpted from "EOSAT Senses a Future," Frank Colucci, SPACE, Jan-Feb, 1988.]

Landsat - Current Status, Future Plans

Current Landsat capabilities will be continued when Landsat 6 becomes operational. The satellite is scheduled to enter a 705 km.-high, sun-synchronous orbit in June 1991. One thousand pounds heavier than the current Landsat 5, the satellite will carry an enhanced TM sensor with the same seven spectral bands used by Landsat 5. The satellite will cover a 185 km. imaging swath but, unlike the SPOT 1 now in orbit, have no off-nadir viewing capability. The high-resolution revisit cycle will continue to be approximately 16 days at the equator.

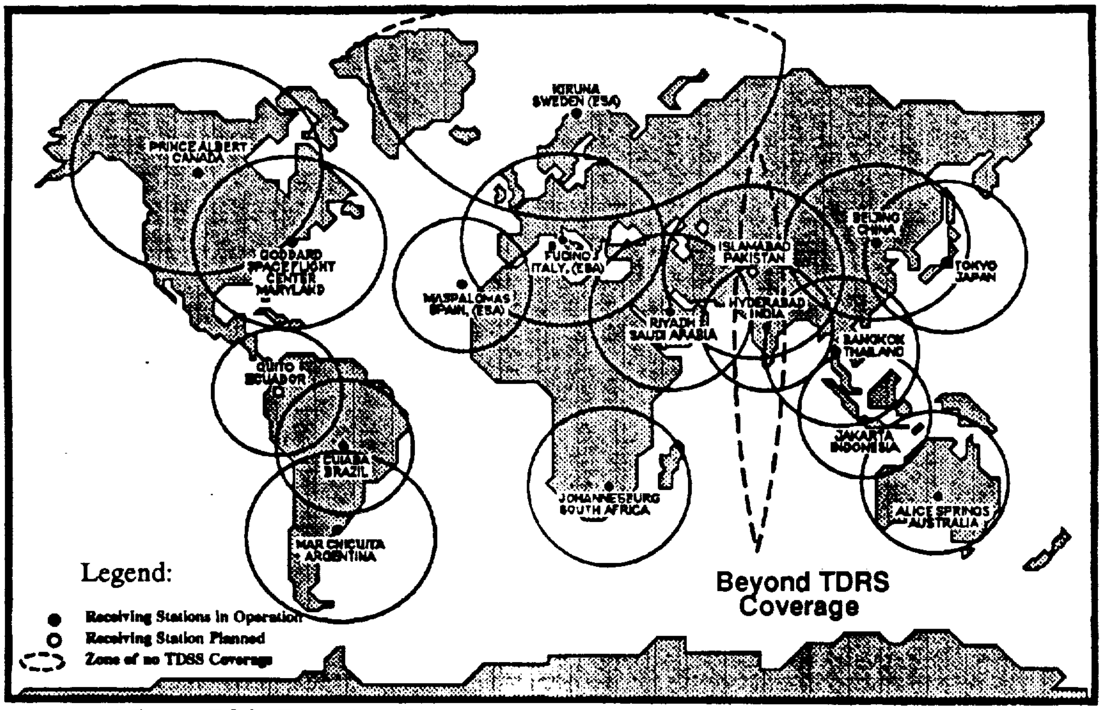
Products and Services

Landsat data are divided into scenes listed in the EOSAT product catalog by their type of coverage and geographic location. Location is further specified through Landsat's numbering system of satellite paths and rows, or by standard latitude and longitude coordinates.

Products derived from the scene data can be either MSS or TM images in black-and-white or color on film or paper, or digital data on computer compatible tapes. In general, the following principles apply to product prices:

- TM data (with higher spatial, spectral, and radiometric resolution) costs more than MSS data
- Digital tape is more costly than images
- Color images are more expensive than black-and-white ones
- Full-scale images cost more than wider views
- Film is slightly more expensive than paper
- Prices range from $50 for a 1:1,000,000 scale, black-and-white, MSS scene on paper; to $4,900 for a full-scale scene in TM digital data format.

Figure 12: Landsat TM Data Coverage via the TDRS System



Adapted From: EOSAT Landsat Technical User Notes

Coverage

Landsat data is transmitted either directly to any of 15 receiving stations worldwide (Table 1) when the satellite is within range, or via the TDRS network to a station in the U.S. Most stations can receive MSS data, and all but two can receive TM data. Table 2 lists EOSAT receiving stations, their MSS and TM reception and processing capabilities. Table 3 lists EOSAT price lists for various remote sensing products.

Contact Address

EOSAT
4300 Forbes Blvd.
Lanham, MD, 20706
Telephone: (301) 552-0500

Landsats 4 & 5 System Specifications

Orbit and Coverage:

- Orbit Altitude: 705 km (438 miles)
- Type: Circular, sun-synchronous
- Equatorial crossing time: 9:45 a.m.
- One orbit every 98.9 minutes, 14 orbits per day
- Repeat Coverage: 16 days at Equator
- Inclination: 98.22 degrees
- Ground track separation at Equator: 172.0 km

Spacecraft Dimensions:

- Weight: 2200 kg. (4800 lbs.)
- Length: 4 meters (14 ft.)
- Width: 2 meters (7 ft.)
- Height of high gain antenna: 3.7 meters (12.5 ft.)

Launch Dates & Satellite Life:

- Landsat 4: July 16, 1982 (still operating)
- Landsat 5: March 1, 1984 (still operating)

Sensor Package:

- Multi-Spectral Scanner (MSS) -- 79 meters resolution -- Continuity with Landsats 1, 2, and 3
- Thematic Mapper (TM) -- 30 meters resolution -- 7 bands of Visible, Near-, Shortwave-, and Thermal-Infrared Data

The Landsat - 6 Satellite

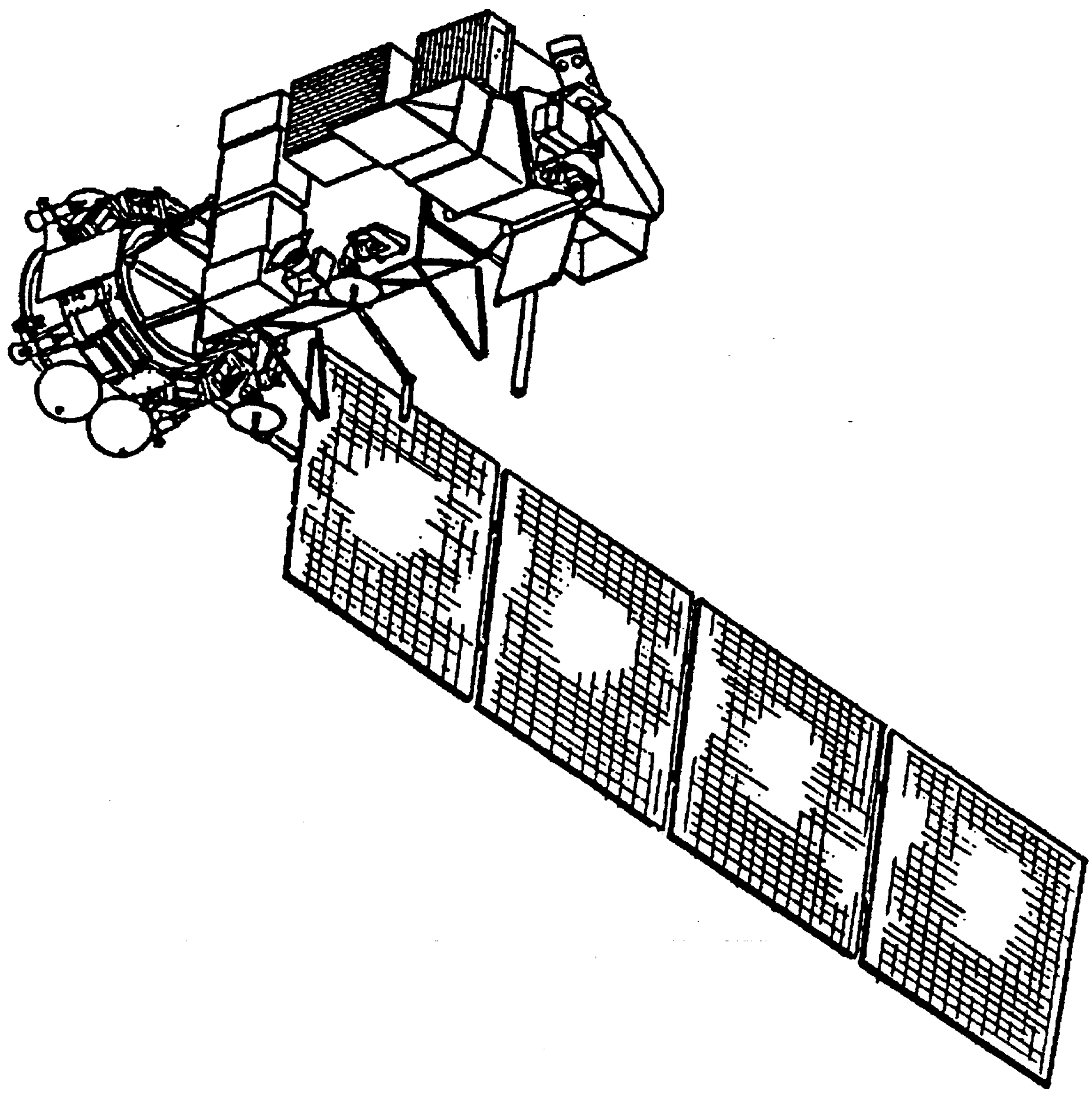


Table 2: Landsat Receiving Stations' Capabilities

Station	Date Established	Reception and Processing MSS	Reception and Processing TM	Status
Argentina	Dec. 1980	X		Off-Line
Australia	Nov. 1980	X		Operational
Brazil	May 1974	X	X	Operational
Canada	Aug. 1972	X	X	Operational
People's Republic of China	Dec. 1986	X	X	Operational
Ecuador	Aug. 1989		X	Operational
European Space Agency (3)	Nov. 1982			
Fucino, Italy	Apr. 1975	X	X	Operational
Kiruna, Sweden	Mar. 1983	X	X	Operational
Maspalomas, Spain	Spring 1984	X	X	Seasonal operation
India	Jan. 1980	X	X	Operational
Indonesia	July 1982	X	X	Off-Line TM Upgrade Announced
Japan	Jan. 1979	X	X	Operational
Pakistan	Summer 1989	X	X	Operational
Saudi Arabia	Jan. 1987	X	X	Operational
South Africa	Dec. 1980	X		Operational
Thailand	Nov. 1981	X	X	Operational
United States	July 1972	X	X	Operational

Adapted from : EOSAT data, Copyright 1989, Earth Observation Satellite Company, Lanham, MD, USA. Used with permission.

Table 3: EOSAT Prices

TM Digital		Price
	Standard Full Scene (185x170km)	$3,600
	Quarter Scene (92.5x85km)	1,800
	Sample	200
	Geocoded	
	Full Scene	4,900
	Quarter Scene	2,900
	Map Sheet	2,300
	Floppy Disks	
	Scene (15x15km)	600
	Sample	250
	Movable Scene	
	Subscene (100x100km)	2,600
	Miniscene (50x100km)	2,000
TM Photo		
	Black & White (1:1,000,000 - 1:250,000)	$300-500
	Standard Color " "	660-800
	EFP Color	
	Full Scene	700-1000
	Quarter Scene	750-850
MSS Digital		
	Full Scene	$660
	Sample	50
MSS Photo		
	Black & White	$ 50-150
	Color	300-550

Adapted From: EOSAT Landsat Products and Services, Price Schedule.

Chapter II: *SPOT IMAGE*

Overview

The French government formed the Earth Observation Satellite Program (Satellte Pour l'Observation de la Terre, or SPOT,) in February 1978. The French Space Agency (Centre National d'Etude Spatiales, or CNES,) with the assistance of the French space industry, was given responsibility for program development and satellite operation. Belgium and Sweden became co-founders of the SPOT program. The French government chartered the SPOT IMAGE Company on July 1, 1982 to distribute data and products acquired by SPOT remote sensing satellites.

The SPOT satellite program is administered by a private French company, SPOT IMAGE S.A., formed in 1982. The French Space agency CNES builds the SPOT satellite and pays for its launch while SPOT IMAGE is responsible for operating the system and marketing the data.

The SPOT satellite was launched on an Ariane rocket from Kourou, French Guiana in February 1986. Following on-orbit tests, the satellite began commercial operation in May of that year, and the full data processing and distribution network was in place by that October.

SPOT IMAGE operates in the U.S. through a wholly owned subsidiary, Spot Image Corp. of Reston Va. Data for the continental U.S. is received through two Canadian receiving stations and processed at the center in Reston. Data from all other countries is processed in the central facility in Toulouse, France.

Products and Services

SPOT Image maintains a computerized catalog, electronically accessible at any time, of data and value-added products available from the company. For each scene, the catalog contains the following information:

- Location (geographical coordinates, orientation, etc.)
- Operating conditions (spectral mode viewing configuration angle, stereopairs, etc.)
- Scene identification (SPOT Reference Grid number, date)
- Image quality (cloud cover extent, if any)
- Related archived products available

Operations and Production

The basic elements of the SPOT System are listed below.

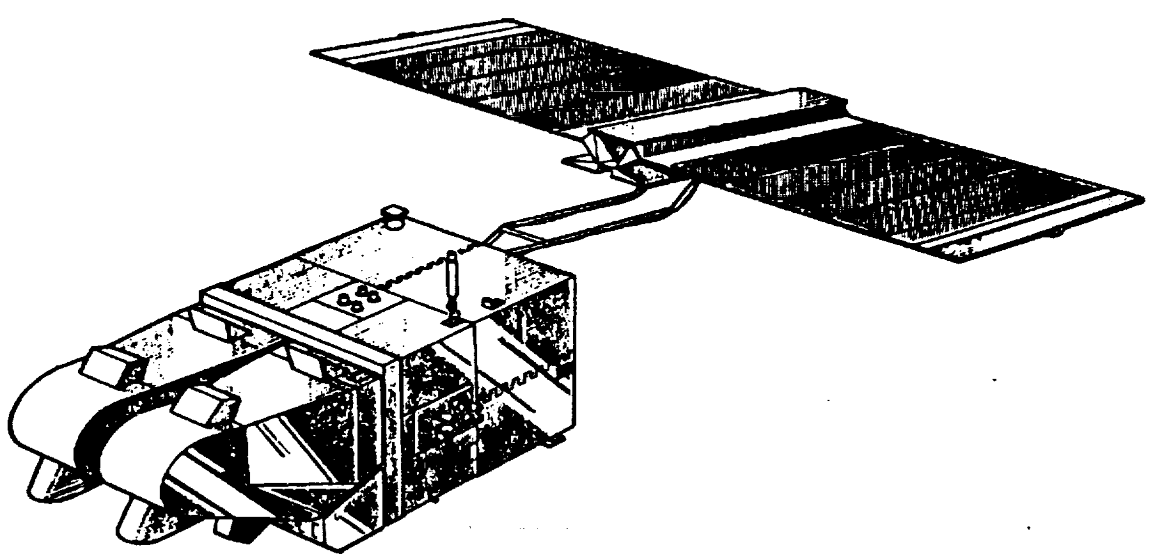
Headquarters

SPOT Image Corporation
1897 Preston White Drive
Reston, Va. 22091

Mission & Operations Control Center

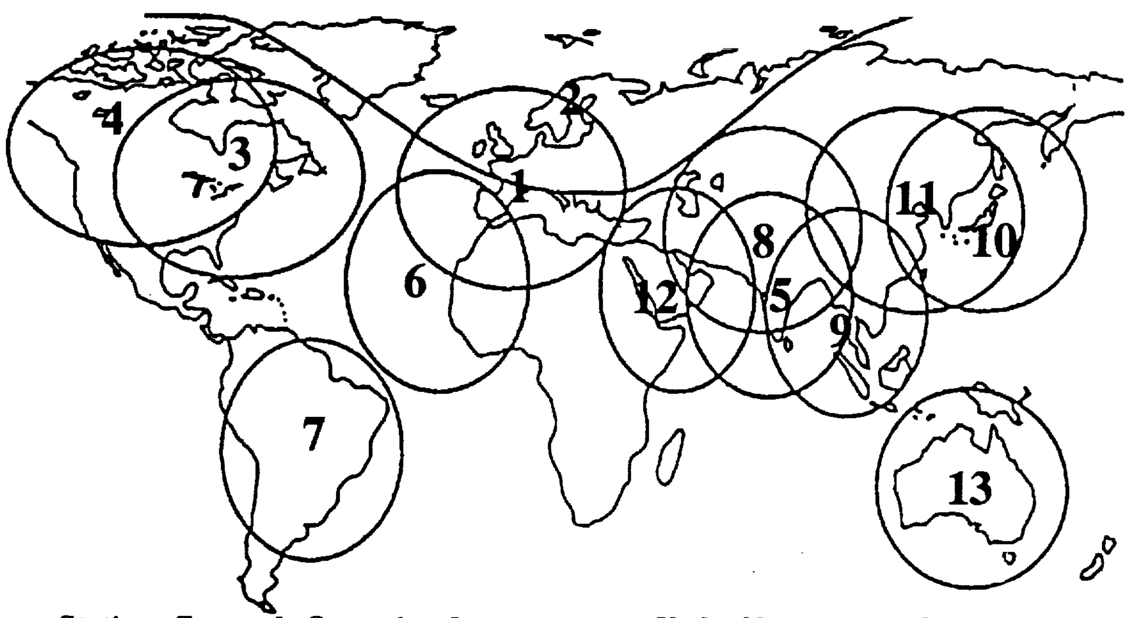
This CNES-operated center in Toulouse, France programs the SPOT satellite to acquire images requested by users.

Figure 13: SPOT Satellite



Source: SPOT Image Corporation

Figure 14: SPOT Receiving Station Network



Stations Currently Operational

1. Toulouse, France
2. Kiruna, Sweden
3. Gatineau, Canada
4. Prince Albert, Canada
5. Hyderabad, India
6. Maspalomas, Canary Is.

Under Negotiation / Construction

7. Cuiaba, Brazil
8. Islamabad, Pakistan
9. Lad Krabang, Thailand
10. Hatoyama, Japan
11. Beijing, China
12. Riyadh, Saudi Arabia
13. Alice Springs, Australia

Adapted from: SPOT Image Corporation data

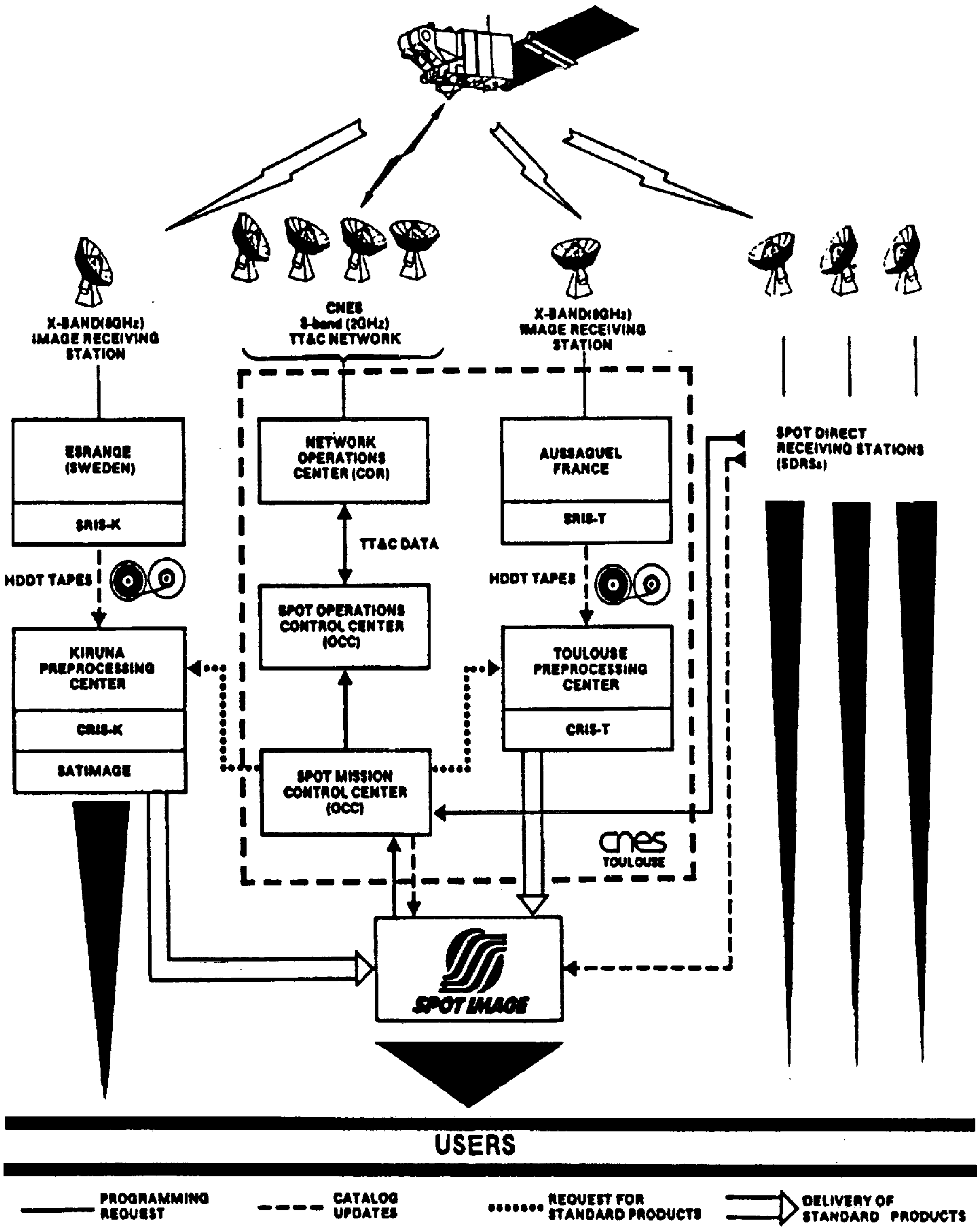
Primary SPOT receiving stations

The two main receiving stations are located at Aussaguel near Toulouse, France and Esrange near Kiruna, Sweden. Each station has an associated SPOT data processing center. Both stations receive data transmitted by the spacecraft as it passes over the north polar region, Europe and North Africa; and data acquired over other areas and stored on the two onboard recorders. Each station can receive 250,000 scenes a year.

Distribution network

The network, operated under commercial agreements signed with SPOT IMAGE, distributes both standard and value-added products in different areas. More than three dozen distribution centers represent SPOT IMAGE worldwide.

Figure 15: SPOT Data Network



Source: SPOT Image Corporation

Production facilities

The SPOT Satellite transmits raw data covering the U.S. to two Canadian Direct Receiving Stations. SPOT Image Corporation's production unit in Reston, Va. converts telemetry from HDDTs (High Density Data Tapes) received from Canada, and CCTs (Computer Compatible Tapes) from European stations into SPOT products. Photographic production facilities for high-quality B/W and color products are also located in Virginia.

SPOT Satellite - Technical Specifications

Unlike Landsat, the SPOT satellite offers both vertical and oblique viewing, as well as higher spatial resolution. The basic characteristics of the SPOT Satellite follow.

- 60 km-wide scenes, viewed vertically or obliquely (for objects not directly below the satellite's ground track), with a spatial resolution of 10 to 20 meters.
- Mean revisit interval of 2.5 days using oblique viewing.
- Stereoscopic images available through oblique viewing from different angles during satellite passes over the same area.
- 10-meter resolution, permitting map work at a scale of 1:50,000 or even 1:25,000 in some instances.

SPOT 1 Satellite System Specifications

SPOT 1 dimensions

- Body: 2m. x 2m. x 4.7m.
- Solar panels: 15.6m.
- Weight: 1806 kg.

Orbit

- Sun-synchronous, near polar
- Altitude: 832 km.
- Inclination: 98.7 degrees
- Orbital Cycle: 26 days for complete Earth coverage
- Equatorial Crossing: 10:30 A.M. mean local solar time

Ground resolution (pixel size)

- Panchromatic: 10m. x 10m.
- Multispectral: 20m. x 20m.

Sensors

- Two high-resolution visible (HRV) instruments.
- Adjustable viewing angle: 27-degree range east and west of orbital path
- Ground imaging swath: 60km./instrument, 117 km. (3 km. overlap) when combined (vertical viewing)

Spectral Resolution (wavelength bands)

- Panchromatic: .50 to .73 microns
- Multispectral: .50 to .59 microns (green band)
- .61 to .68 microns (red band)
- .79 to .89 microns (near infrared band)

Source: SPOT Image Corp.

Table 4: SPOT Products

Computer Compatible Tapes (CCT)	**Panchromatic**	**Multispectral**
Level 1A, 1B		
6250 or 1600 bpi	$ 1,900	$ 1,700
Level 2		
6250 or 1600 bpi	3,500	3,200

Film		
Level 1A, 1B		
1:400,000 (Full Scene)	$ 990	$ 850
1:200,000 (Full Scene)	1,500	1,400
1:200,000 (1/4 Scene)	550	500
1:100,000 (1/4 Scene)	1,500	1,400
Level 2		
1:400,000 (Full Scene)	2,500	2,000

Promotional Data Sets	*Digital*	*Photographic*
SPOT Education and Evaluation Data Set (S.E.E.D.S.) (33 subscene set - slides)	$ 600	$ 60
Special Offer Images (Full U.S. Scenes, 1:400,000 Film)	600	400

Adapted From: Spot Image Corp. data

Table 5: SPOT Prints and Services

SPOT Prints - Photographic prints are not available as a separate standard product. However, if placed with original order for a Level 1 standard data product (CCT or film), a print of the same scene and processing level is supplied for a $250 service fee.

The following print scales are available:

With CCT:	a 1:100,000 print
With 1:400,000 Film (Full Scene):	a 1:200,000 or 1:100,000 print
With 1:200,000 Film (Full Scene):	a 1:200,000 print
With 1:200,000 Film (Quarter Scene):	a 1:100,000 or 1:50,000 print
With 1:100,000 Film (Quarter Scene):	a 1:100,000 print

Nonstandard Processing Options

Certain nonstandard processing options are available as listed below.

Scene Shifting:

U.S. Scenes (CCT or Film)	$100/scene (Most U.S. scenes, except Hawaii and parts of Alaska)
Non U.S. Scenes (CCT only)	Add 50% of license fee/scene cost
EBCDIC coding of CCTs	$100/scene
Split record size on 1600 bpi CCT	$100/scene

If both EDCDIC coding and split-recorded size are desired, a single $100/scene payment is required.

SPOT Services

Satellite Aquisition Program

Registration	$100/scene
Completion	$400/scene
Prints (concurrent with CCT or Film)	$250

Rush service, scene shifting, and EBCIDIC coding are also available for additional fees.

Adapted From: Spot Image Corp. data

Chapter III: *MOS-1*

Overview

The Japanese Marine Observation Satellite 1 (MOS-1) is the first remote sensing satellite dedicated mainly to ocean observation in order to establish the fundamental technology of the observation satellite. In addition to its primary mission, MOS-1 is used to monitor crops, forests and the environment.

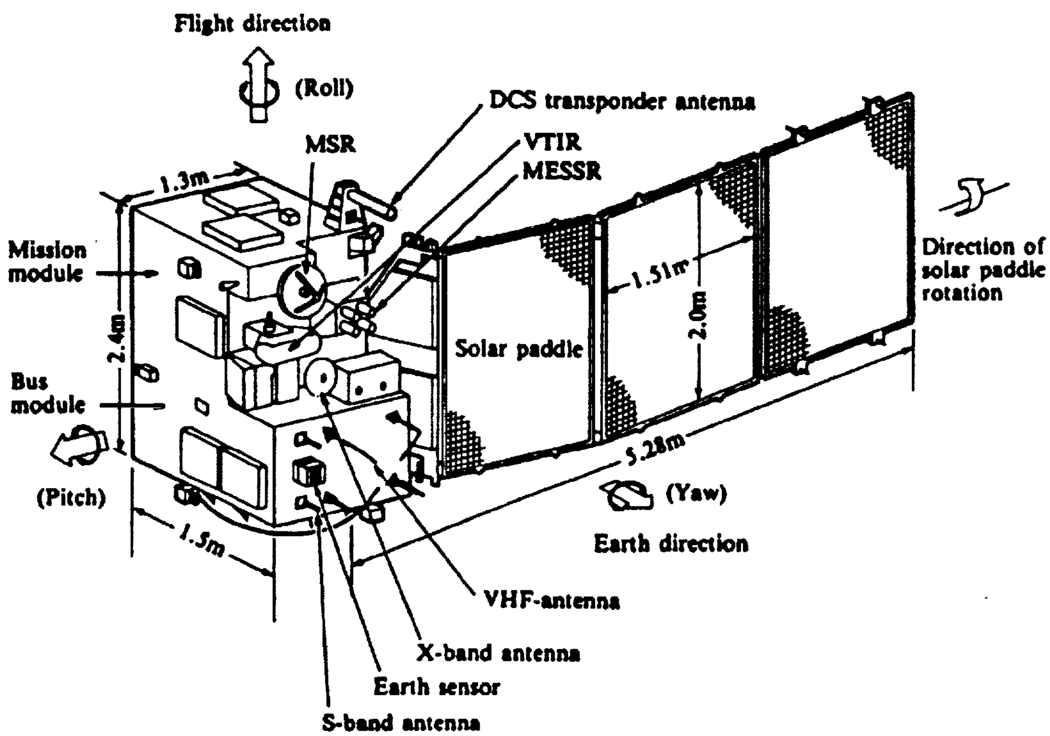
The 740-kg. satellite was launched February 19, 1987 from the Tanegashima Space Center and placed in a 909 km.-high, near-polar orbit. The satellite, which had an expected two-year lifespan, orbits the Earth every 103 minutes. The spacecraft's revisit time is 17 days.

MOS-1b, the specifications for which are the same as MOS-1, is scheduled to be launched on February 1, 1990 from the Tanegashima Space Center. It will continue to observe using similar sensors to MOS-1.

MOS-1 has three sensors designed to acquire data about the atmosphere and its water vapor content, clouds, seas and their surface temperatures, and snow. Through its Data Collection System (DCS), the satellite also can collect information from instruments on the ground and transmit the data to teh ground station.

The spacecraft carries a Multispectral Electronic Self-Scanning Radiometer (MESSR), an electronic scanner using two visible bands and two near-infrared ones. The scanner's spatial resolution is ap-

Figure 16: MOS-1 Satellite



Source: National Space Development Agency of Japan (NASDA)

proximately 50 meters for areas within its 100 km.-wide swath.

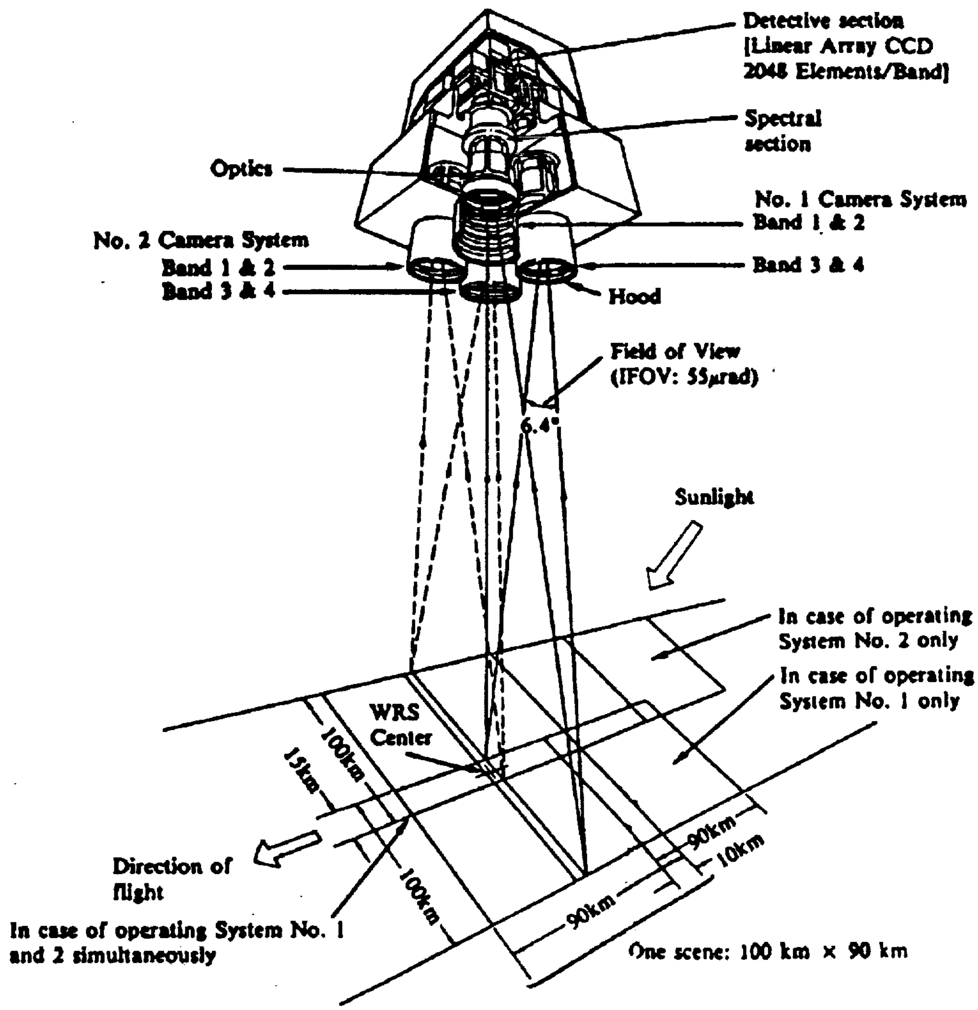
An onboard Visible and Thermal Infrared Radiometer (VTIR) can observe the clouds and ocean surface temperatures with one visible and three thermal infrared bands. The instrument's resolution is 900 meters in the visible band region, and 2700 meters in the thermal infrared bands. The sensor's swath-width is 1500 km.

The spacecraft's Microwave Scanning Radiometer (MSR) employs two microwave frequencies to observe the sea surface and record atmospheric water vapor content and snowfall amounts. The sensor's resolution is 23 or 32 km., depending on the frequency used, in a swath-width of 317 km.

MOS-1 data products are available in black-and-white or color prints or film, and on floppy disks and computer-compatible tapes. Prices range from approximately $30 for a black-and-white print from any sensor, to about $425 for a MESSR CCT. Data products are distributed by the Remote Sensing Technology Center (RESTEC), Uni-Roppongi Bldg. 7-15-17, Roppongi, Minato-ku, Tokyo, Japan.

The MOS-1 satellite's technical specifications, coverage capabilities and patterns, and data acquisition-processing systems are depicted on the following pages. The information and graphics were excerpted from MOS-1 publications.

Figure 17: MESSR Swath and Characteristics

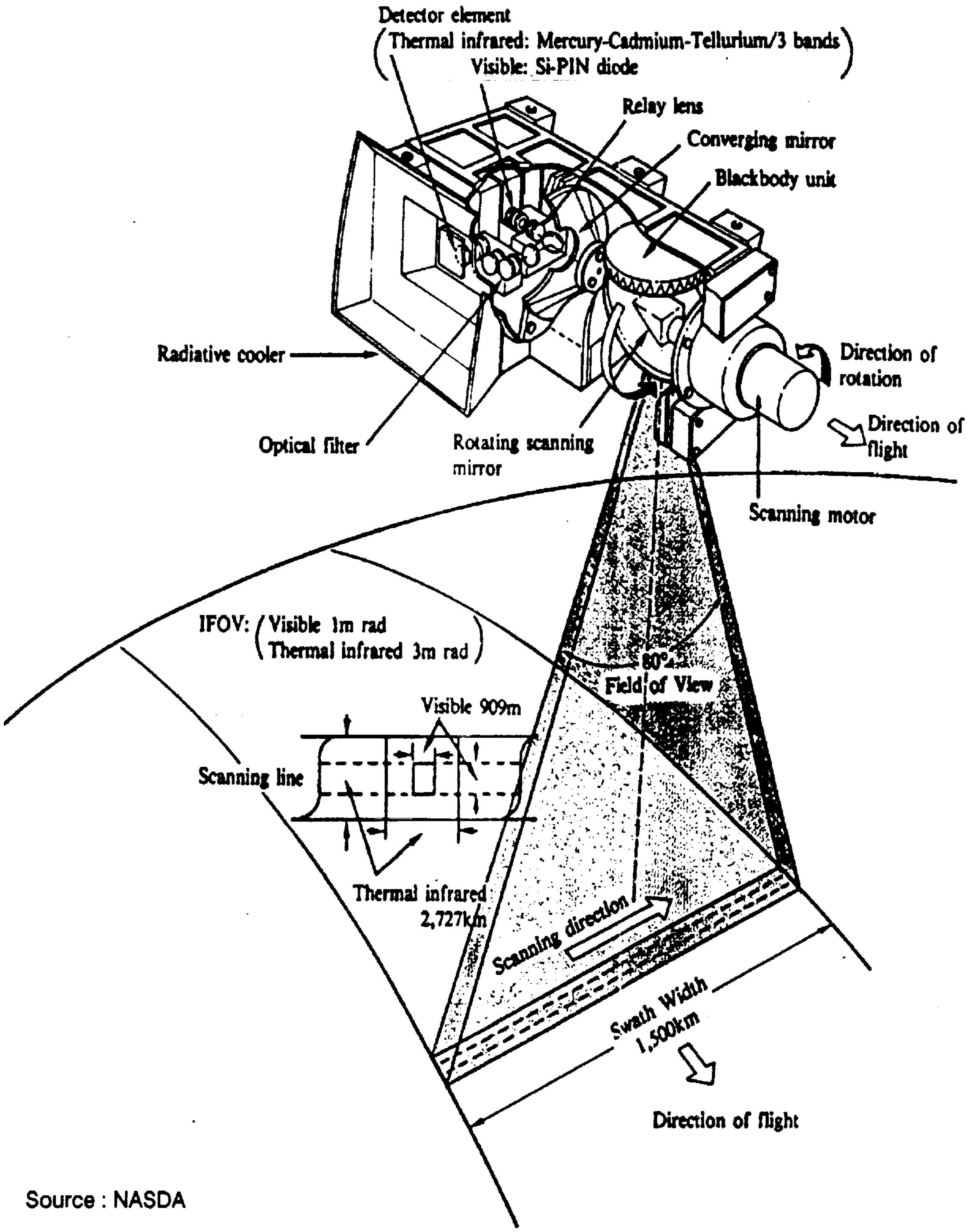


MESSR characteristics

	Spectral band	Application
Observation Wavelength	Band 1 (green): 0.51 ~ 0.59μm	Reflection from suspended matter in water or from the bottom of the shallows
	Band 2 (red): 0.61 ~ 0.69μm	Distinction between green growth and bare ground, classification land usage
	Band 3 (near infrared): 0.73 ~ 0.80μm	Distinction between land and water
	Band 4 (near infrared): 0.80 ~ 1.10μm	Determining topography, geological features and water systems

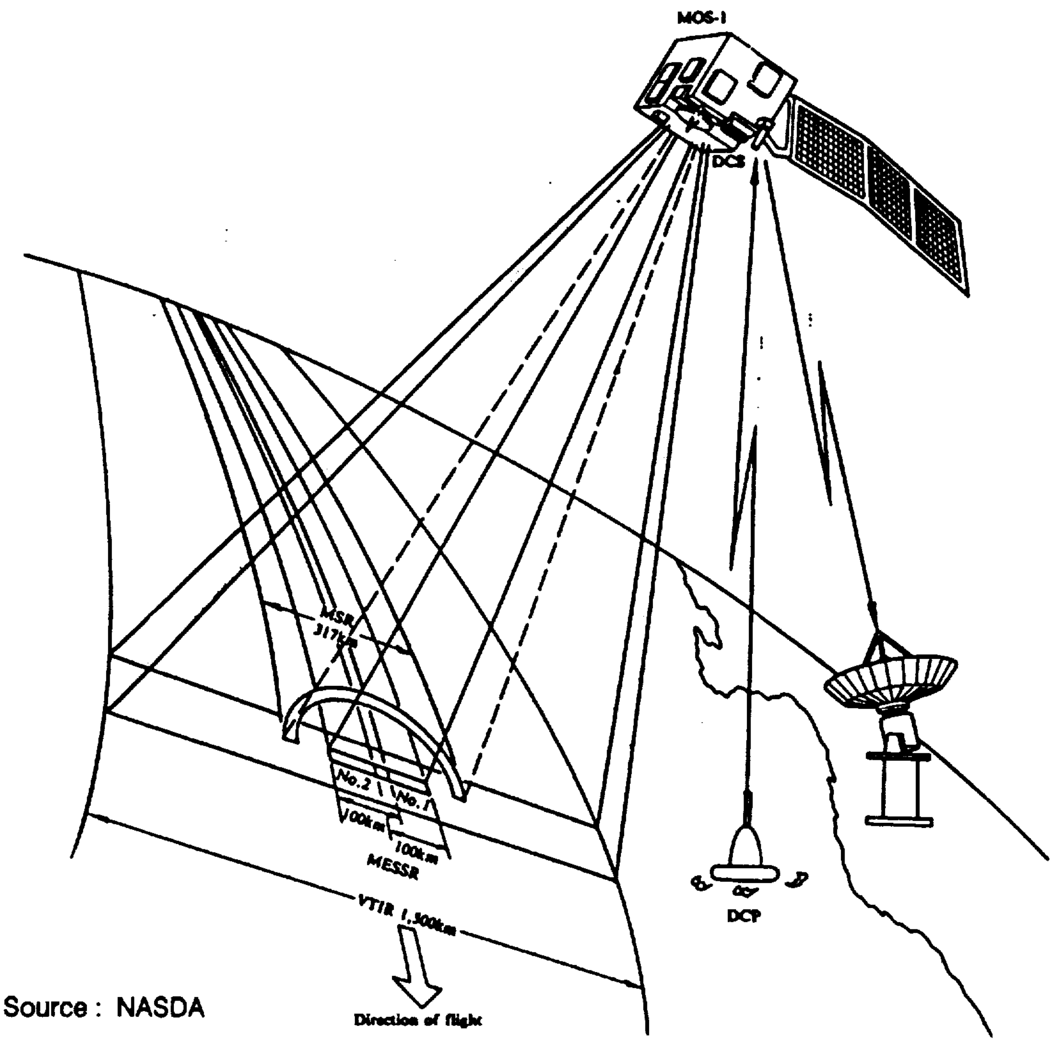
Source: NASDA

Figure 18: VTIR



Source : NASDA

Figure 19: MOS-1 Observation Pattern



Source : NASDA

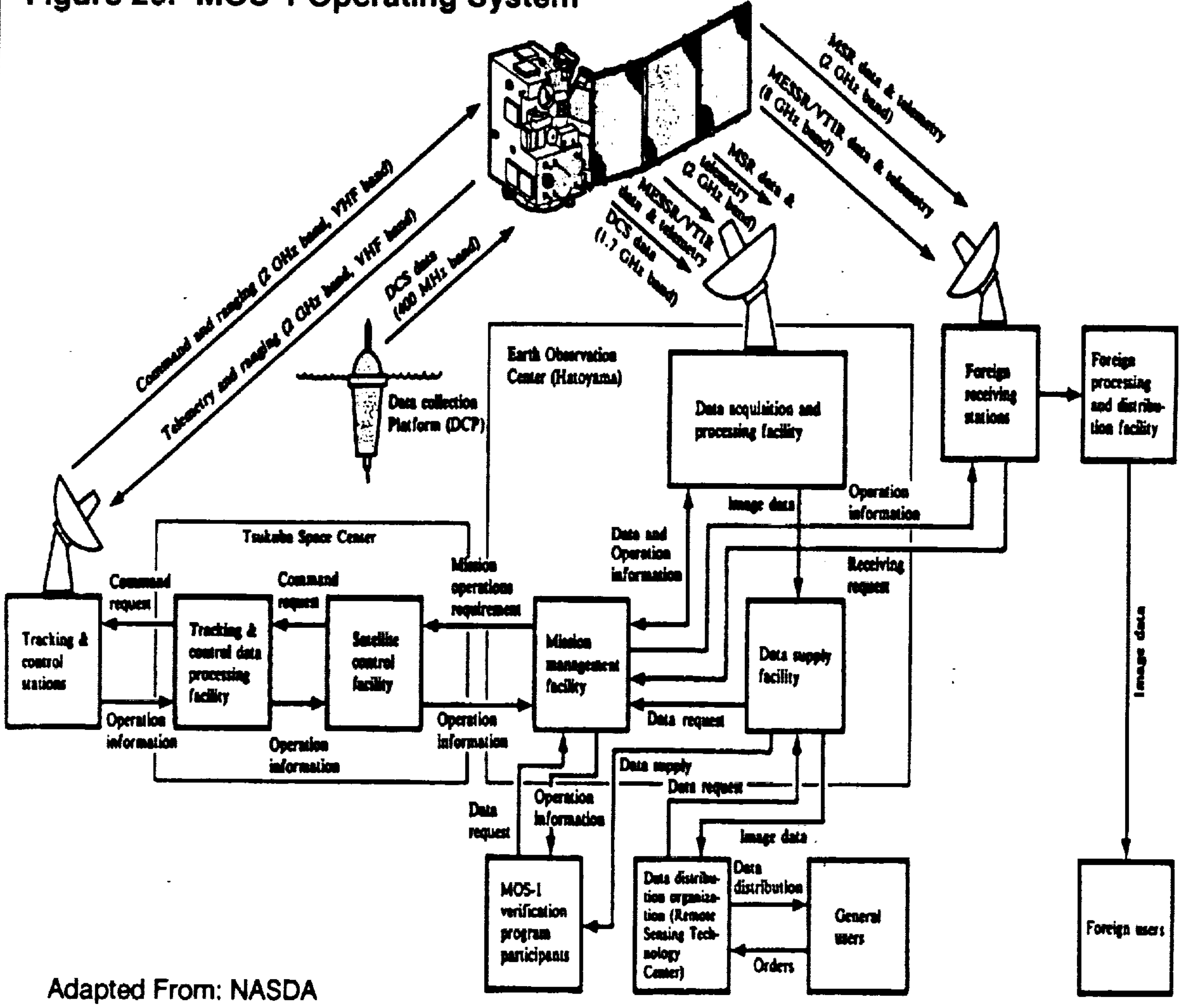
Orbit and Ground Track

MOS-1 occupies a sun-synchronous, subrecurrent orbit at an altitude of about 909 km. and an inclination of 99.1 degrees. The local mean solar time of the descending node, in which the satellite crosses the Equator from north to south, is between 10:00 and 11:00 A.M.

Since MOS-1 completes one orbit every 103 minutes, it circles the Earth about 14 times each day. Because of the Earth's rotation, the next day the satellite's ground track moves about 169 km. westward along the Equator.

After making 237 orbits in 17 days, the satellite returns to its original ground track on the 18th day (238th orbit). In this way, it passes over almost all parts of the Earth's surface in a 17-day period.

Figure 20: MOS-1 Operating System



Adapted From: NASDA

Date Reference System

The orbit's of MOS-1 are numbered 1 to 237 from east to west, starting at Long. 159 degrees 40 minutes East (equator). The satellite completes the ground tracks of 237 orbits in one recurrent cycle of 17 days.

Each orbit around the earth is divided into 496 equal parts, which are given row numbers starting near the northernmost point of a descending orbit. The path numbers and row numbers constitute a worldwide reference system (WRS).

MESSR data processing uses this WRS pathrow. VTIR and MSR data references relate to the unit of the continuous zonal scene within the coverage in each WRS path.

Data Acquisition, Processing Network

The MOS-1 operation system includes two basic components: (1) satellite tracking and control, and (2) mission management.

The satellite is tracked and controlled primarily by the Tracking and Control Center at NASDA's Tsukuba Space Center, along with tracking and data acquisition stations at Katsuura, Masuda and Okinawa.

Mission management and acquisition, and processing of observation data on Japan and its environs is handled by NASDA's Earth Observation Center.

Processed data is offered to general users for a fee by the Remote Sensing Technology Center (RESTEC). NASDA accepts foreign requests for direct reception of data from MOS-1.

Contact Addresses:

Remote Sensing Technology Center (RESTEC),
Uni-Roppongi Bldg. 7-15-17,
Roppongi, Minato-ku, Tokyo, Japan
Phone: 03-403-1761

National Space Development Agency of Japan (NASDA)
World Trade Center Building
4-1, Hamamatsu-cho 2-chrome
Minato-ku, Tokyo 105 Japan
Phone: 81-3-435-6111
Fax: 81-3-433-0796
Telex: J28424(AAB:NASDA J28424)

Figure 21: MOS-1 Configuration

Shape	Box type with expanding type solar cell paddle (one wing)
Size	Bus unit L127 × W140 × T148 cm Solar cell paddle, total length 528 cm × W200 cm (Triple panel configuration 151 × 200 cm)
Weight	Approx. 740 kg
Satellite orbit	Sun synchronous subrecurrent orbit Altitude about 909 km, inclination about 99 degrees, period about 103 min.
Attitude control	Three axes control Pointing accuracy (3σ) Roll, Pitch: ±0.6° Yaw: 1.0° Stability accuracy (3σ) Roll, Pitch: ±0.016°/sec Yaw: 0.05°/sec
Mission devices	MESSR, VTIR, MSR, DCST
Data down link	MESSR, VTIR, TLM data: 8 GHz band MSR, TLM, R&R data: 2.2 GHz band DCS data: 1.7 GHz band
Power	Generated power over 640W (BOL), over 540W (EOL) Power consumption: Max. about 400W during sunlight (in H mode) Max. about 440W during eclipse (in I mode)

Source: NASDA

Figure 22: MSR Characteristics

Item	Performance	
Frequency (GHz) Beam width Integrating time (msec) Surface resolution (km)	23.8 ±0.2 1.89° ±0.19 10&47 32	31.4 ±0.25 1.31° ±0.13 10&47 23
Swath width Scanning system Dynamic range Antenna	317 km Mechanical (conical scan) 30 ~ 330K Offset Cassegrain	
Radiometer type Polarization Receiving sensitivity	Dicke Horizontal < 1K (target at 300K, integration time 47ms, 1 σ value)	Dicke Vertical < 1K (target at 300K, integrating time 47ms, 1 σ value)
Scanning period Quantization level Data rate Power consumption Weight	3.2 sec 1024 (10 bits) 2 Kbits/sec 45 W 48 Kg	

Source : NASDA

Chapter IV: SOVIET REMOTE SENSING SYSTEMS

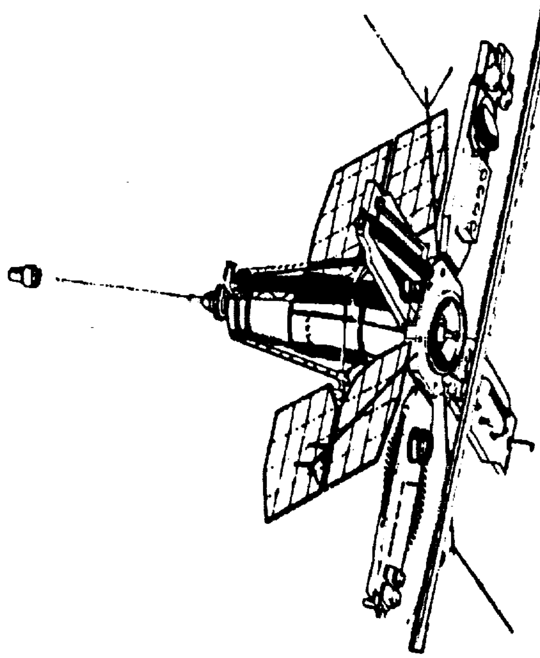
Overview

A late entrant into the international remote sensing commercial market in October 1987, the Soviet Union's five different but related Earth Resources systems constitute a comprehensive remote sensing program to monitor land resources, land use, environmental conditions, and oceanography.

The Resurs ("Resource") network consists of three spacecraft capable of transmitting data directly to Earth receiving stations: Resurs-O, a polar orbiting satellite utilizing multi-spectral instruments; Okean, an oceanographic satellite in high-inclination orbit; and Prognoz, a geosynchronous satellite. Resurs-F complements the more advanced spacecraft with a system of short-duration photographic reconnaissance satellites. A separate system launched in July 1987, Radarsat (not to be confused with the Canadian satellite) ushered in a new era of radar remote sensing.

The Soviet space remote sensing system is operated by the U.S.S.R. Research Center for Earth Resource Exploration (URCERE) under the State Committee for Hydrometerology (SCHM). URCERE works with other Soviet organizations to develop remote sensing systems specifications as well as data processing and value-added applications. Receiving, processing and distribution of data to users is managed

Figure 23: Okean-0



Source: Soyuzkarta

also served as forerunners to the Resurs-O system.

Similar to the Landsat system, Resurs-O incorporates multi-spectral data digitally transmitted from sun-synchronous satellites with orbits of 600 kilometers inclined to 98 degrees. Kosmos-1939 carries two primary scanning systems. One is a five-channel visible-infrared scanner with a 600 kilometer swath width and resolutions of 150 meters (4 channels) and 600 meters (1 channel). The second scanner spans four channels with a narrower 80 kilometer swath and accordingly finer 45 meter resolution.

by the Main Data Receiving and Processing Center (MDRPC), under URCERE, and the Main Computer Center for SCHM, both located in Moscow. Regional Computer Centers at Novosibirsk, Khabarovsk and Tashkent also process and distribute data.

Resurs-O

The first operational Resurs-O satellite (also called Kosmos-1939) was launched in April 1988. It was preceded by the Meteor-Priroda ("Nature") series, first launched in 1974 and each designed to last one to two years. The Meteor-Priroda satellites carried two primary multi-spectral imaging instruments with resolutions of 1000 to 1700 meters and 140 to 240 meters. In 1980, a more advanced Meteor 1-30 was launched. A series of experimental Kosmos satellites

The Meteor-Priroda and newer Resurs-O satellites are estimated to save the Soviet economy 500-600 million rubles (approximately $800-900 million U.S. dollars) annually through agriculture and forestry monitoring, geological and mineral surveys, water and resources management, cartography and oceanography applications. Because of their high-inclination orbits, Soviet satellites are particularly useful in monitoring ice conditions for commercial shipping interests. Satellite data can help guide transport ships through treacherous ice conditions, saving the cost of sending an icebreaker. For the first time in 1986, satellites, through the Khabarovsk processing center, could transmit charts on ice conditions directly to ships in the Oxotsk and Bering Seas. Satellites also are advantageous in monitoring the vast Russian land area for forest fires and for locating potential oil and gas reserves.

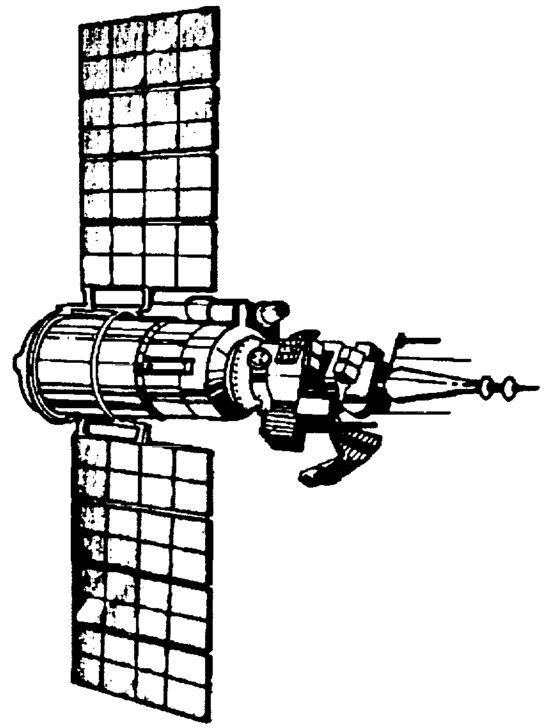
Okean

After years of experimental Kosmos satellites, operational Soviet ocean remote sensing began in July 1988 with the launching of Okean-1, the first in a planned oceanographic series. Weighing 4000 kilograms, Okean-1 was placed in a 650 kilometer-orbit inclined to 82.5 degrees by a Cyclone (SL-14) launch vehicle.

Okean-1 carries a scanning high-frequency radiometer (SHF) with 600-kilometer swath width and 200-meter resolution, a MSU-M multi-spectral scanner covering a 2000 kilometer swath at a 1500 meter resolution as well as an X-band side-looking radar (SLR) which covers a swath of 460 kilometer with a 1.5-kilometer resolution at a wavelength of 3.15 centimeters.

The SLR provides high-quality photographs at any time of day in all weather conditions. SLR imagery can measure wind speed and direction at the ocean surface. SLR radar and its ability to determine ice conditions is particularly helpful in northern regions where cloud cover may prevent regular observations at visual wavelengths. Maps, from information received by three receiving stations, can be readied in 10 days, while ice forecasts can be directly sent to ships via Ekran communications satellites. Up to two Okean satellites are expected to be launched each year.

Figure 24: Resurs-0



Source: Soyuzkarta

Prognoz

Kosmos-1940 (Prognoz), the first in a possible series of seven geosynchronous Soviet earth resource satellites, was launched in April 1988. A complement to the Soviet's planned Geostationary Operational Meteorological Satellite Network (GOMS), Prognoz satellites monitor natural resources, oceans and atmospheric processes. Kosmos-1940 was initially placed in a its designated Western Hemisphere location at 336 degrees east. However, it was later moved to 12 degrees east geosynchronous orbit until early September 1988, when it drifted slowly eastward again, remaining in a non-geosynchronous orbit for the rest of the year.

Unlike the other spacefaring nations, the Soviet Union has made slow progress in developing both remote sensing and communications geosynchronous satellites. They are virtually useless in the polar and near polar regions of the U.S.S.R. A party to the Global Atmospheric Research Program, the U.S.S.R. does plan three GOMS satellites to collect meteorological, oceanographic and geophysical information.

Resurs-F

In the past, the Soviet remote sensing satellites relied heavily on photographic images taken from Kosmos satellites, aircraft or manned space stations. Because such film must be processed in a timely manner, U.S.S.R. photographic remote sensing satellites generally remained in orbit for about two weeks, and required frequent launches to replace used systems.

Soviet photographic spatial resolution far exceeds those of other systems. The KFA-1000 camera carried on Resurs-F satellites is reportedly capable of recording areas of 40,000 square meters at resolutions of 5 to 10 meters. However, several studies show the Soviet photographs have resolutions better than 5 meters, and have reportedly been good enough to determine the centerline of airport runways at a 30-centimeter accuracy. The Soviet's entry into the international remote sensing market was one reason that forced the U.S. government to discard its security policy of prohibiting domestic satellite companies from selling photos with spatial resolutions of better than 10 meters.

Remote sensing imagery is also taken from the manned MIR space station using multi-spectral MKF-6 and MKF-6M cameras from an attitude of 350 kilometers. Each frame covers an area of 155 by 200 kilometers with a resolution approximating 15 meters. Black-and-white or color photographs are available.

Radarsat

The Soviet high-resolution radar sensor satellite series Radarsat has no equivalent in other civilian remote sensing systems. The first Radarsat, launched in 1987 as Kosmos-1870, was sent into a self-destructive reentry on July 29, 1989 due to age. Little was known about Kosmos-1870 until 1988, and at one time it was thought to be a military reconnaissance satellite.

As big as a school bus and the most advanced U.S.S.R. spacecraft, Radarsat offers resolutions of 10 to 30 meters under all lighting and weather conditions 24 hours a day. The Soviets emphasize its ability to determine precise sea states and "the presence of underwater formations," probably including submarines. Radarsat data can be used for scientific research in various applications including hydrology, cartography, geology, agriculture and environmental monitoring.

The first Radarsat orbited at a 270-kilometer altitude inclined to 72 degrees. It carried a 10-centimeter microwave radar remote sensing instrument capable of at least 25-meter resolution. Because of its low altitude, the spacecraft had to be periodically boosted to a higher altitude and was on a 24-day decay and reboost cycle before it reentered.

The Soviets are said to be planning to launch another Radarsat sometime in 1990 and hope to have a fully operational system later in the decade.

Data Sales

Data from Soviet remote sensing systems is exclusively marketed worldwide by a U.S. firm, Space Commerce Corporation of Houston, Texas. Through a January 1989 joint agreement with GLAVKOSMOS, the central

Soviet space agency, Space Commerce offers licenses to receive and use Soviet remote sensing data directly. Real-time access is possible and photographs, data tapes and value-added products are available. However, photographic data from the Resurs-F satellites are sold through Soyuzkarta, the Soviet's cartography agency.

Space Commerce, working with GLAVKOSMOS, can integrate and launch sensors on Soviet spacecraft, providing confidential results to customers. For example, the company sells digital tapes from the Resurs-O spacecraft for $2,500 or, in an arrangement with the Soviet government, will sell an entire spacecraft for $100 million. Space Commerce also hopes to build a radar data user base for the new Radarsat satellites. Space Commerce has a guarantee of commercial access to Soviet remote sensing data at least through the end of the century.

While the Soviets are progressing with sophisticated high-resolution remote sensing instrumentation on spacecraft and integrated networks, the lack of Earth-based modern high-speed computers and analytical software for value-added applications could hamper marketing efforts in the near-term future.

Limited Access Policies Changes

In the past, all Soviet remote sensing data was not available for purchase. The Soviets previously did not support the open data policies of the U.S. or France which sell remotely sensed data of all countries to any customer. The Soviets did not provide data of Warsaw Pact nations and supplied some remote sensing data on exclusive basis to the country sensed. Previously, U.S.S.R. proposed policies that no remote sensing data of 50 meter or better resolution be sold without the sensed country's consent.

Soyuzkarta officials now say its agency's remote sensing data sales policy is a political matter but "will be led by the decisions of the United Nations in this regard." However, images of 6-meter or better resolution of Socialist countries still may not routinely be purchased.

Remotely sensed images furnished from GLAVKOMOS are a different story. The cooperative agreement between GLAVKOSMOS and Space Commerce state that the Soviet remote sensing system will image the entire Earth based on United Nations agreements. Therefore, no restrictions apply to the availability or sale of commercial remote sensing data from any part of Earth.

Table 6: Sensors on the Okean Satellites

Instrument	*Operating wavelength*	*Resolution*	*Minimum swathwidth (km)*	*Additional sensor characteristics*
SLR - - Side - looking radar	3.1cm	1.3-2.5 km	450	Dynamic range of received signals, not less than 30 dB
Scanning microwave radiometer	0.8 cm	25 km	550	Temperature measurement range, 110-330°K
MSU-L low-resolution spectrometer	0.5-0.6 μm 0.6-0.7 0.7-0.8 0.8-1.1	2 km	1900	
MSU-M medium resolution spectrometer	0.55-0.8 μm 0.7-1.0	410 m	1100	
MSU-K medium resolution con-field scanner	0.55-0.8 μm	500 m	950	
Trasser polarization spectrometer	430-800 nm	25 km		62 spectral channels

Adapted from: Soyuzkarta data.

Table 7: USSR Current and Planned Remote Sensing Systems

Name	*Type*	*Orbit*	*Primary Attributes*
Geostationary Operational Meteorological Satellite (GOMS)	Environmental/ weather	Geostationary	Continuous weather observation, tracking fast moving storms
Resurs-0	Earth Resources	Altitude, 650 km Sun synchronous; inclination, 98°	Land surface observation
Okean	Ocean state, resources	Altitude, 650 km; inclination, 82.5°	Oceans, water Surface, ice observation
Radarsat	Earth, ocean resources	Geostationary inclination, 72° Reentry July 1989	Continuous viewing observations of surface of land, oceans
Prognoz	Earth, ocean resources	Geostationary	Continuous viewing
Resurs-F	Earth, ocean resources	Altitude, 260x275 km; inclination, 82.3°-82.3°	Photographic data output

Adapted from: Soyuzkarta data

Appendix A: *Remote Sensing Satellite Systems*

Introduction:

This appendix, in three different sections, contains lists and characteristics of past and future remote sensing satellites.

Appendix A.1 lists all remote sensing satellites ever launched. The list shows that while the U.S. pioneered remote sensing technology in the 1960s, the Soviet Union quickly overtook the U.S. in the number of satellites launched. This was because Soviet reconnaissance satellites, until recently, used photography rather than spectral scanning. Since the film was expended in a matter of weeks, their satellites had considerably shorter lifetimes and required replacement satellites more often than the longer-lived U.S. systems.

Appendices A.2 and A.3 describe the characteristics and instruments of currently operating systems and those planned for the future.

There are two important trends in orbital remote sensing emerging in the 1990s. The U.S. and other Free World nations are moving to a more integrated, cooperative approach to remote sensing. Rather than launching separate systems for the atmosphere, land and oceans, the new Earth Observing Systems (EOS) described in Table 34 of Appendix A.3 contains a diverse list of potential onboard instruments. While all of these instruments are not expected to fly simultaneously, some 10 to 15 will be incorporated on the first version of the spacecraft.

The second major trend in remote sensing is that many more nations will participate than have in the past. Most of the industrial nations will have remote sensing systems by the end of the 1990s. Although not reflected in these tables, most developing countries also plan for their own remote sensing systems to be launched during the next 10 to 20 years. Joint international programs, like EOS, will become more common in the future as the cost of space technology continues to mount.

These tables in Appendices A.2 & A.3 reflect therefore both the history and future of remote sensing technology.

The Space Business Research Center gratefully acknowledges the tremendous work of the many U.S. government agencies which contributed to NOAA and NASA's "Spaced-Based Remote Sensing of the Earth: A Report to the Congress, September, 1987," in which these tables originally appeared.

Appendix A.1: Chronology of Remote Sensing Satellites

Table 8: Launch Information and Orbital Parameters

Name/Identification	Launch Information Date	Site	Vehicle	Period (min)	Orbital Parameters Perigee (km)	Apogee (km)	Inclin (degrees)	Weight (kg)
EUROPEAN SPACE AGENCY								
Meteosat 1	Nov 23, 77	ETR	Delta	1435.8	34738.0	36822.0	1.8	697.0
GEOS 2	July 14, 78	ETR	Delta	1436.0	35768.0	35802.0	1.7	573.0
FRANCE								
D 1A	Feb 17, 66	Hammaguir	Diamant	117.2	505.0	2601.0	34.1	44.0
D 1C	Feb 8, 67	Hammaguir	Diamant	102.9	561.0	1231.0	40.0	50.0
EOLE 1	Aug 16, 71	WI	Scout	100.3	668.0	877.0	50.1	
Starlette	Feb 6, 75	Kourou	Diamant B-P4	104.2	805.0	1108.0	49.8	47.0
SPOT 1	Feb 22, 86	Kourou	Ariane 1	101.4	824.0	828.0	98.7	1830.0
INDIA								
Bhaskara	June 7, 79	Kapustin Yar	C-1	94.2	473.0	484.0	50.7	360.0
Rohini 2	May 31, 81	Srihari-Kota	SLV-3	90.5	186.0	418.0	46.3	38.0
Bhaskara 2	Nov 20, 81	Kapustin Yar	C-1	95.3	519.0	541.0	50.6	444.0
Insat 1C	Jul 21, 88	Kourou	Ariane 3	1436.2	35763.0	35812.0	0.2	550.0
JAPAN								
Himawari (GMS-1)	July 14, 77	ETR	Delta	1433.9	35691.0	35793.0	0.7	281.0
GMS 2	Aug 10, 81	Tanegashima	N-2	1438.1	35606.0	36047.0	1.0	670 Full
Himawari 3(GMS-3,N)	Aug 2, 84	Tanegashima	N-2		303.0			
MOS - 1	Feb 19, 87	Tanegashima	N-11	103.2	907.0	909.0	99.2	
Ajisai (EGS)	Aug 12, 86	Tanegashima	H-1	115.7	1479.0	1497.0	50.0	685.0

Name/Identification	Launch Information Date	Site	Vehicle	Orbital Parameters Period (min)	Perigee (km)	Apogee (km)	Inclin (degrees)	Weight (kg)
PEOPLE'S REPUBLIC OF CHINA								
China 13	Aug 19, 83	Shuang Cheng-Tse	Long March 2	90.1	171.0	388.0	63.3	
China 16	Sept 12, 84	Shuang Cheng-Tse	Long March 2	90.3	174.0	400.0	67.9	3600.0
China 17 (PRC 17)	Oct 21, 85	Shuang Cheng-Tse	Long March 2	90.2	171.0	393.0	63.0	2000.0
China 19 (PRC 19)	Oct 6, 86	Shuang Cheng-Tse	Long March 2	90.0	172.0	375.0	56.9	
UNITED STATES								
Vanguard 1	Mar. 17, 58	ETR	Vanguard	133.6	653.0	3905.0	34.2	3.0
Explorer 6	Aug 7, 59	ETR	Thor-Able	768.0	157.0	26366.0	47.0	143.0
Tiros 1	Apr 1, 60	ETR	Thor-Able	98.8	677.0	722.0	48.4	263.0
Transit 2A	June 22, 60	ETR	Thor-Able Star	101.2	609.0	1020.0	66.7	223.0
Tiros 2	Nov 23, 60	ETR	Delta	97.4	591.0	681.0	48.5	278.0
Tiros 3	July 12, 61	ETR	Delta	100.2	732.0	802.0	47.9	285.0
Tiros 4	Feb 8, 62	ETR	Delta	100.1	702.0	827.0	48.3	287.0
Tiros 5	June 12, 62	ETR	Delta	99.9	582.0	929.0	58.1	286.0
Tiros 6	Sept 18, 62	ETR	Delta	98.2	660.0	684.0	58.3	281.0
Tiros 7	June 19, 63	ETR	Delta	96.2	566.0	589.0	58.2	297.0
Tiros 8	Dec 21, 63	ETR	Delta	98.9	681.0	734.0	58.5	265.0
Secor 1	Jan 11, 64	WTR	TAT-Agena D	103.3	906.0	924.0	69.9	40.0
Nimbus 1	Aug 28, 64	WTR	Thor-Agena B	98.3	263.0	579.0	98.6	830.0
Explorer 22	Oct 10, 64	WTR	Scout	104.5	877.0	1065.0	79.7	116.0
Tiros 9	Jan 22, 65	ETR	Delta	119.0	703.0	2569.0	96.4	305.0
Secor 3	Mar 9, 65	WTR	Thor-Agena D	103.3	901.0	931.0	70.1	40.0
Secor 2	Mar 11, 65	WTR	Thor-Able Star	98.0	206.0	624.0	89.9	40.0
Secor 4	Apr 3, 65	WTR	Atlas-Agena D	111.4	1265.0	1312.0	90.3	40.0
Explorer 27	Apr 29, 65	WI	Scout	107.8	941.0	1309.0	41.2	132.0
Secor 5	Aug 10, 65	WI	Scout	122.2	1137.0	2417.0	69.2	45.0
OGO 2	Oct 14, 65	WTR	TAT-Agena D	95.4	358.0	713.0	87.3	1118.0
Explorer 29	Nov 6, 65	ETR	TAD	120.3	1113.0	2275.0	59.4	385.0

	Launch Information			Orbital Parameters				
Name/Identification	Date	Site	Vehicle	Period (min)	Perigee (km)	Apogee (km)	Inclin (degrees)	Weight (kg)
ESSA 1	Feb 3, 66	ETR	Delta	100.0	692.0	820.0	97.9	305.0
ESSA 2	Feb 28, 66	ETR	TAD	113.4	1352.0	1412.0	101.2	290.0
Nimbus 2	May 15, 66	WTR	TAT-Agena B	108.0	1092.0	1176.0	100.4	912.0
OGO 3	June 6, 66	ETR	Atlas-Agena B		1135.0			
Secor 6	June 9, 66	WTR	Atlas-Agena D	125.1	104.0	2266.0	90.1	38.0
Pageos	June 23, 66	WTR	TAT-Agena D	180.5	2772.0	5627.0	85.0	125.0
EGRS 7	Aug 19, 66	WTR	Atlas-Agena D	167.5	3672.0	3698.0	89.8	38.0
ESSA 3	Oct 2, 66	WTR	TAD	114.5	1384.0	1484.0	100.9	320.0
EGRS 8	Oct 5, 66	WTR	Atlas-Agena D	167.6	3685.0	3696.0	90.3	38.0
ATS 1	Dec 6, 66	ETR	Atlas-Agena D	1436.1	35760.0	35817.0	10.5	775.0
ESSA 5	Apr 20, 67	WTR	TAD	113.5	1353.0	1419.0	102.0	320.0
EGRS 9	June 29, 67	WTR	Thor-Burner II	172.1	3798.0	3940.0	89.8	45.0
ATS 3	Nov 5, 67	ETR	Atlas-Agena D	1436.1	35720.0	35854.0	9.2	805.0
ESSA 6	Nov 10, 67	WTR	TAD	114.8	1407.0	1483.0	102.1	290.0
Explorer 36	Jan 11, 68	WTR	TAID	112.2	1082.0	1570.0	105.8	460.0
ESSA 7	Aug 16, 68	WTR	Long-Tank Delta	114.9	1429.0	1471.0	101.8	320.0
Secor 11	Aug 16, 68	WTR	Atlas-Burner II					
Secor 12	Aug 16, 68	WTR	Atlas-Burner II					
Lidos	Aug 16, 68	WTR	Atlas-Burner II		117.0			
RM 18	Aug 16, 68	WTR	Atlas-Burner II					
ESSA 8	Dec 15, 68	WTR	Long-Tank Delta	114.6	1411.0	1461.0	101.2	290.0
ESSA 9	Feb 26, 69	ETR	TAID	115.2	1423.0	1502.0	102.0	320.0
Nimbus 3	Apr 14, 69	WTR	Thorad-Agena D	107.3	1070.0	1130.0	99.6	1269.0
Secor 13	Apr 14, 69	WTR	Thorad-Agena D	107.2	1068.0	1128.0	99.6	45.0
ITOS-1 (Tiros M)	Jan 23, 70	WTR	TAT-Delta M	115.0	1432.0	1477.0	101.8	682.0
Nimbus 4	Apr 8, 70	WTR	Thorad-Agena D	107.1	1087.0	1097.0	99.5	1488.0
NOAA-1	Dec 11, 70	WTR	Long Tank Delta	114.8	1422.0	1471.0	101.8	675.0

	Launch Information			Orbital Parameters				
Name/Identification	Date	Site	Vehicle	Period (min)	Perigee (km)	Apogee (km)	Inclin (degrees)	Weight (kg)
ERTS-1, Landsat 1	July 23, 72	WTR	Delta	103.1	899.0	911.0	98.8	816.4
NOAA-2 (ITOS-D)	Oct 15, 72	WTR	Delta	114.9	1447.0	1453.0	101.4	344.0
Nimbus 5	Dec 11, 72	WTR	Delta	107.1	1087.0	1100.0	99.7	772.0
NOAA 3	Nov 6, 73	WTR	Delta	116.1	1499.0	1508.0	101.7	345.0
N, 1974 15A	Mar 16, 74	WTR	Thor-Burner 11A	101.2	768.0	863.0	99.2	195.0
SMS-1	May 17, 74	ETR	Thorad Delta	2266.7	50781.0	50781.0	5.6	243.0
N, 1974 63A	Aug 9, 74	WTR	Thor-Burner IIA	101.5	792.0	862.0	98.7	195.0
NOAA4-ITOS-G	Nov 15, 74	WTR	Thorad Delta	114.9	1443.0	1457.0	101.4	340.0
Landsat 2	Jan 22, 75	WTR	Delta	103.2	901.0	914.0	99.2	953.0
SMS 2	Feb 6, 75	WTR	Delta	1436.7	35752.0	35844.0	1.8	627.0
GEOS 3	Apr 9, 75	WTR	Delta	101.7	818.0	858.0	115.0	341.0
DMSP	May 24, 75	WTR	Thor-Burner	101.7	797.0	881.0	98.7	194.0
Nimbus 6	Jun 12, 75	WTR	Delta	107.4	1100.0	1112.0	99.8	829.0
GOES 1	Oct 16, 75	ETR	Delta	1436.1	35777.0	35797.0	2.3	295.0
DMSP	Feb 18, 76	Failed to launch						
NOSS-1	Apr 30, 76	WTR	Atlas	107.4	976.0	1240.0	63.4	
SSU-1	Apr 30, 76	WTR	Atlas	107.5	971.0	1246.0	63.4	
SSU-2	Apr 30, 76	WTR	Atlas	107.5	971.0	1246.0	63.4	
SSU-3	Apr 30, 76	WTR	Atlas	107.5	975.0	1242.0	63.4	
LAGEOS-1	May 4, 76	WTR	Delta	225.4	5837.0	5946.0	109.8	411.0
NOAA 5 (ITOS H)	July 29, 76	WTR	Delta	116.2	1503.0	1519.0	101.9	340.0
AMS 1	Sept 11, 76	WTR	Thor Burner 2	101.3	806.0	834.0	98.6	450.0
DMSP	June 5, 77	WTR	Thor Burner 2	101.3	789.0	853.0	99.0	450.0
GOES 2	June 16, 77	ETR	Delta	1436.2	35778.0	35797.0	0.2	627.0
NOSS-2	Dec 8, 77	WTR	Atlas F	107.4	1058.0	1158.0	63.4	
Landsat 3	Mar 5, 78	WTR	Delta	103.2	897.0	919.0	99.9	960.0
HCMM	Apr 26, 78	WTR	Scout	97.1	618.0	627.0	97.6	134.0

	Launch Information			Orbital Parameters				
Name/Identification	Date	Site	Vehicle	Period (min)	Perigee (km)	Apogee (km)	Inclin (degrees)	Weight (kg)
DMSP-F3	May 1, 78	WTR	Thor Burner 2	101.1	804.0	817.0	98.6	513.0
GOES 3	Jun 16, 78	ETR	Delta	1435.4	35762.0	35784.0	0.8	627.0
Seasat 1	June 27, 78	WTR	Atlas-Agena D	100.5	778.0	783.0	108.0	2300.0
Tiros-N	Oct 13, 78	WTR	Atlas F	101.8	854.0	838.0	99.1	734.0
Nimbus 7	Oct 24, 78	WTR	Delta	104.1	944.0	958.0	99.3	907.0
DMSP F-4	June 6, 79	WTR	Thor Burner 2	101.2	806.0	828.0	98.7	513.0
NOAA 6	June 27, 79	WTR	Atlas F	101.1	800.0	817.0	98.7	723.0
MAGSAT	Oct 30, 79	WTR	Scout G	93.1	341.0	510.0	96.8	181.0
NOAA B (7)	May 29, 80	WTR	Atlas F	97.5	250.0	1028.0	92.2	1405.0
GOES-4	Sept 9, 80	ETR	Delta	1436.1	35771.0	35802.0	0.0	627.0
GOES-5	May 22, 81	ETR	Delta	1436.2	35783.0	35792.0	0.1	836 Full
NOAA 7	June 23, 81	WTR	Atlas F	101.9	838.0	858.0	98.9	1405 Full
OPS-2849	Jan 21, 82	WTR	Titan 3B	96.8	560.0	644.0	97.3	
Landsat-4	July 16, 82	WTR	Delta	98.6	680.0	700.0	98.3	
OPS-9845	Dec 21, 82	WTR	Thor-Burner 2	101.4	816.0	826.0	98.7	
OPS-0252	Feb 9, 83	WTR	Atlas F	107.5	1050.0	1170.0	63.4	
NOAA-8	Mar 28, 83	WTR	Atlas F	101.3	808.0	830.0	98.8	
KH-9	Apr 15, 83	WTR	Titan 3B/Agena D	88.9	135.0	298.0	96.5	
GOES-6	Apr 28, 83	ETR	Delta					
NOSS-5	June 10, 83	WTR	Atlas F	107.4	1045.0	1165.0	63.3	
GB-1	June 10, 83	WTR	Atlas F	107.4	1045.0	1165.0	63.3	
GB-2	June 10, 83	WTR	Atlas F	107.4	1045.0	1165.0	63.3	
GB-3	June 10, 83	WTR	Atlas F	107.4	1045.0	1165.0	63.3	
Big Bird (OPS-0721)	June 20, 83	WTR	Titan 3D	88.8	159.0	259.0	96.5	
DMSP 2-02	Nov 18, 83	WTR	Atlas F	101.4	814.0	831.0	98.7	
NOSS-6	Feb 5, 84	WTR	Atlas F	107.5	1072.0	1147.0	63.4	
JD-1	Feb 5, 84	WTR	Atlas F	107.5	1072.0	1147.0	63.4	

	Launch Information			Orbital Parameters				
Name/Identification	Date	Site	Vehicle	Period (min)	Perigee (km)	Apogee (km)	Inclin (degrees)	Weight (kg)
JD-2	Feb 5, 84	WTR	Atlas F	107.5	1072.0	1147.0	63.4	
JD-3	FEb 5, 84	WTR	Atlas F	107.5	1072.0	1147.0	63.4	
Landsat-5	Mar 1, 84	WTR	Delta	98.6	683.0	698.0	98.3	1938.0
UOSAT 2	Mar 1, 84	WTR	Delta	98.6	678.0	696.0	98.3	52.0
USAF (OPS 8424)	Apr 17, 84	WTR	Titan 3B/Agena D	88.9	127.0	311.0	96.4	
USA-2	June 25, 84	WTR	Titan 34D	88.5	170.0	230.0	96.5	
ERBS	Oct 5, 84	ETR	Challenger	96.7	599.0	608.0	56.0	226.0
USA-6	Dec 4, 84	WTR	Titan 3D	92.2	300.0	650.0	97.0	
NOAA-9	Dec 12, 84	WTR	Atlas F	102.1	844.0	865.0	98.9	1712.0
Geosat	Mar 13, 85	WTR	Atlas F	100.7	760.0	817.0	108.1	635.0
USA 15-18 (NOSS)	Feb 9, 86	WTR	Atlas F					
NOAA 10	Sept 17, 86	WTR	Atlas F	101.2	808.0	826.0	98.7	1700.0
GOES - 7	Feb 26, 87	Kennedy	Delta	1439.4	35763.0	35823.0	0.1	397.0
USA 22-25	May 15, 87	Canaveral AFS	Atlas H	107.5	1050.0	1170.0	63.4	
USA 26	Jun 20, 87	Vandenberg	Atlas E	102.0	834.0	857.0	98.8	700.0
USA 27	Oct 26, 87	Vandenberg	Titan 34D	92.2	265.0	500.0	97.0	
USA 29	Feb 3, 88	Vandenberg	Atlas	101.3	815.0	826.0	98.7	700.0

SOVIET UNION

Kosmos 44	Aug 28, 64	Tyuratam	A-1/2	99.0	608.0	817.0	65.1	
Kosmos 45	Sept 13, 64	Tyuratam	A-1/2	89.7	128.0	203.0	64.9	
Kosmos 65	Apr 17, 65	Tyuratam	A-1/2	89.9	130.0	213.0	65.0	
Kosmos 92	Oct 16, 65	Tyuratam	A-1/2	89.9	132.0	219.0	65.0	
Kosmos 100	Dec 17, 65	Tyuratam	A-1/2	76.7	540.0	660.0		
Molniya 1C	Apr 25, 66	Tyuratam	A-2-e	710.0	310.0	24544.0	64.5	710.0
Kosmos 118	May 11, 66	Tyuratam	A-1/2	94.8	501.0	518.0	65.0	
Kosmos 122	June 25, 66	Tyuratam	A-1/2	95.2	507.0	547.0	65.0	

	Launch Information			Orbital Parameters				
Name/Identification	Date	Site	Vehicle	Period (min)	Perigee (km)	Apogee (km)	Inclin (degrees)	Weight (kg)
Kosmos 144	Feb 28, 67	Plesetsk	A-1/2	93.2	419.0	442.0	81.2	
Kosmos 149	Mar 21, 67	Kapustin Yar	B-1	89.8	154.0	185.0	48.4	
Kosmos 156	Apr 27, 67	Plesetsk	A-1/2	95.1	511.0	537.0	81.2	
Kosmos 184	Oct 25, 67	Plesetsk	A-1/2	95.0	503.0	534.0	81.2	
Kosmos 185	Oct 27, 67	Tyuratam	F-1-m	98.7	324.0	552.0	64.1	
Kosmos 206	Mar 14, 68	Plesetsk	A-1/2	95.0	507.0	530.0	81.2	
Kosmos 226	June 12, 68	Plesetsk	A-1/2	94.1	457.0	487.0	81.2	
Meteor 1	Mar 26, 69	Plesetsk	A-1/2	97.1	600.0	639.0	81.2	
Meteor 2	Oct 6, 69	Plesetsk	A-1	96.8	582.0	627.0	81.2	
Kosmos 304	Oct 21, 69	Plesetsk	C-1	99.7	734.0	754.0	74.0	
Kosmos 312	Nov 24, 69	Plesetsk	C-1					
Kosmos 315	Dec 20, 69	Plesetsk	C-1	95.3	324.0	346.0	74.1	
Meteor 3	Mar 17, 70	Plesetsk	A-1	93.4	419.0	457.0	81.1	
Meteor 4	Apr 28, 70	Plesetsk	A-1	97.3	595.0	661.0	81.2	
Meteor 5	June 23, 70	Plesetsk	A-1	101.9	821.0	879.0	81.2	
Meteor 6	Oct 15, 70	Plesetsk	A-1	96.4	579.0	593.0	81.2	
Meteor 8	Apr 17, 71	Plesetsk	A-1	95.8	550.0	564.0	81.2	
Meteor 9	July 16, 71	Plesetsk	A-1	96.0	560.0	577.0	81.2	
Meteor 12	June 30, 72	Plesetsk	A-1	102.8	880.0	898.0	81.2	
Meteor 13	Oct 26, 72	Plesetsk	A-1	102.4	858.0	883.0	81.2	
Meteor 14	Mar 20, 73	Plesetsk	A-1	102.5	866.0	883.0	81.2	2000.0
Kosmos 555	Apr 25, 73	Plesetsk	A-2	89.0	216.0	233.0	81.3	4000.0
Kosmos 556	May 5, 73	Plesetsk	A-2	89.0	218.0	225.0	81.3	4000.0
Meteor 15	May 29, 73	Plesetsk	A-1	102.3	842.0	891.0	81.2	2000.0
Meteor 16	Mar 5, 74	Plesetsk	A-1	102.0	825.0	885.0	81.2	
Kosmos 639	Apr 4, 74	Plesetsk	A-2	89.0	209.0	238.0	81.3	4000.0
Kosmos 640	Apr 11, 74	Plesetsk	A-2	88.9	205.0	236.0	81.3	4000.0

	Launch Information			Orbital Parameters				
Name/Identification	Date	Site	Vehicle	Period (min)	Perigee (km)	Apogee (km)	Inclin (degrees)	Weight (kg)
Meteor 17	Apr 24, 74	Plesetsk	A-1	102.4	855.0	887.0	81.2	
Kosmos 650	Apr 29, 74	Plesetsk	C-1	113.4	1365.0	1399.0	74.0	
Kosmos 651	May 15, 74	Tyuratam	F-1-m	103.4	892.0	947.0	65.0	
Kosmos 654	May 17, 74	Tyuratam	F-1-m	104.4	931.0	1000.0	65.0	
Meteor 18	July 9, 74	Plesetsk	A-1	103.0	887.0	911.0	81.2	
Kosmos 675	Aug 29, 74	Plesetsk	C-1	113.6	1362.0	1421.0	74.1	
Meteor 19	Oct 28, 74	Plesetsk	A-1	102.3	834.0	899.0	81.2	
Meteor 20	Dec 17, 74	Plesetsk	A-2	102.2	841.0	882.0	81.2	
Kosmos 699	Dec 24, 74	Tyuratam	F-1-m	93.3	429.0	443.0	65.0	
Kosmos 708	Feb 12, 75	Plesetsk	C-1	113.5	1369.0	1406.0	69.2	650.0
Kosmos 721	Mar 26, 75	Plesetsk	A-2	88.9	208.0	228.0	81.3	4000.0
Meteor 21	Apr 1, 75	Plesetsk	A-1	102.4	858.0	887.0	81.2	2200.0
Kosmos 723	Apr 2, 75	Tyuratam	F-1-m	103.7	905.0	958.0	64.7	4500.0
Kosmos 724	Apr 7, 75	Tyuratam	F-1-m	103.0	865.0	935.0	65.6	4500.0
Kosmos 730	Apr 24, 75	Plesetsk	A-2	90.0	210.0	234.0	81.3	4000.0
Meteor 21	Jul 11, 75	Plesetsk	A-1	102.3	847.0	885.0	81.3	2800.0
Meteor 22	Sept 18, 75	Plesetsk	A-1	102.2	801.0	920.0	81.3	2200.0
Kosmos 770	Sept 24, 75	Plesetsk	C-1	109.1	1163.0	1205.0	83.0	650.0
Kosmos 771	Sept 25, 75	Plesetsk	A-2	88.7	203.0	219.0	81.3	4000.0
Kosmos 784	Dec 3, 75	Plesetsk	A-2	89.0	216.0	252.0	81.3	4000.0
Kosmos 785	Dec 12, 75	Tyuratam	F-1-m	104.2	901.0	1012.0	65.1	4500.0
Meteor 23	Dec 25, 75	Plesetsk	A-1	102.2	842.0	885.0	81.3	2200.0
Meteor 24	Apr 7, 76	Plesetsk	A-1	102.1	831.0	888.0	81.3	2200.0
Meteor 25	May 15, 76	Plesetsk	A-1	102.1	832.0	884.0	81.3	2200.0
Kosmos 838	July 2, 76	Tyuratam	F-1-m	93.3	428.0	448.0	65.0	4500.0
Meteor 26	Oct 15, 76	Plesetsk	A-1	102.3	848.0	885.0	81.3	2200.0
Kosmos 860	Oct 17, 76	Tyuratam	F-1-m	104.3	904.0	1017.0	64.7	4500.0

	Launch Information			Orbital Parameters				
Name/Identification	Date	Site	Vehicle	Period (min)	Perigee (km)	Apogee (km)	Inclin (degrees)	Weight (kg)
Kosmos 861	Oct 21, 76	Tyuratam	F-1-m	104.3	924.0	995.0	64.9	4500.0
Kosmos 868	Nov 26, 76	Tyuratam	F-1-m	93.2	429.0	443.0	65.0	4500.0
Meteor 2	Jan 6, 77	Plesetsk	A-1	102.8	881.0	898.0	81.3	2750.0
Meteor 1-27	Apr 5, 77	Plesetsk	A-1	102.3	846.0	892.0	81.3	2200.0
Kosmos 912	May 26, 77	Plesetsk	A-2	89.0	219.0	257.0	81.4	4000.0
Meteor 1-28	June 29, 77	Tyuratam	A-1	96.3	556.0	608.0	97.7	2200.0
Kosmos 937	Aug 24, 77	Tyuratam	F-1-m	93.3	428.0	444.0	65.0	4500.0
Kosmos 948	Sept 2, 77	Plesetsk	A-2	89.0	217.0	265.0	81.4	5900.0
Kosmos 952	Sept 16, 77	Tyuratam	F-1-m	104.1	923.0	979.0	64.9	4500.0
Kosmos 954	Sept 18, 77	Tyuratam	F-1-m	89.6	251.0	264.0	64.9	4500.0
Kosmos 1025	June 28, 78	Plesetsk	F-2	97.2	611.0	640.0	82.5	4375.0
Prognos 7	Oct 30, 78	Tyuratam	A-2-e	5888.0	483.0	202465.0	64.9	950.0
Kosmos 1066	Dec 23, 78	Plesetsk	A-1	102.1	822.0	896.0	81.2	3800.0
Kosmos 1067	Dec 26, 78	Plesetsk	C-1	109.1	1154.0	1211.0	83.0	880.0
Meteor 1-29	Jan 25, 79	Tyuratam	A-1	96.6	583.0	606.0	97.9	3800.0
Kosmos 1076	Feb 12, 79	Plesetsk	F-2	97.1	606.0	634.0	82.5	4500.0
Meteor 2-4	Mar 1, 79	Plesetsk	A-1	102.1	831.0	888.0	81.2	3800.0
Kosmos 1094	Apr 18, 79	Tyuratam	F-1-m	93.3	427.0	446.0	65.0	4000.0
Kosmos 1096	Apr 25, 79	Tyuratam	F-1-m	93.2	429.0	443.0	65.0	4000.0
Kosmos 1122	Aug 17, 79	Plesetsk	A-2	88.9	208.0	227.0	81.3	5500.0
Meteor 2-5	Oct 31, 79	Plesetsk	A-1	102.5	866.0	882.0	81.2	3800.0
Kosmos 1151	Jan 23, 80	Plesetsk	F-2	97.4	618.0	650.0	82.5	6320.0
Kosmos 1176	Apr 29, 80	Tyuratam	F-1-m	103.4	898.0	940.0	64.8	4450.0
Kosmos 1180	May 15, 80	Plesetsk	A-2	89.8	238.0	290.0	62.8	5900.0
Kosmos 1182	May 23, 80	Plesetsk	F-2	89.1	210.0	250.0	82.3	7420.0
Kosmos 1185	June 6, 80	Plesetsk	F-2	89.9	259.0	283.0	82.4	7420.0
Meteor 1-30	June 18, 80	Tyuratam	A-1	96.6	561.0	630.0	97.9	3475.0

	Launch Information			Orbital Parameters				
Name/Identification	Date	Site	Vehicle	Period (min)	Perigee (km)	Apogee (km)	Inclin (degrees)	Weight (kg)
Kosmos 1201	July 15, 80	Plesetsk	A-2	89.1	211.0	246.0	82.3	7220.0
Kosmos 1203	July 31, 80	Plesetsk	F-2	89.8	259.0	273.0	82.3	7420.0
Kosmos 1209	Sept 3, 80	Plesetsk	A-2	89.8	259.0	272.0	82.3	7420.0
Meteor 2 (6)	Sept 9, 80	Plesetsk	A-1	102.2	840.0	889.0	81.2	3300.0
Kosmos 1211	Sept 23, 80	Plesetsk	F-2	89.0	215.0	240.0	82.3	7220.0
Kosmos 1212	Sept 26, 80	Plesetsk	F-2	89.1	208.0	247.0	82.3	7220.0
Kosmos 1220	Nov 4, 80	Tyuratam	A-2	99.4	581.0	878.0	65.0	4150.0
Kosmos 1237	Jan 6, 81	Plesetsk	A-2	92.2	355.0	415.0	72.9	600.0
Kosmos 1239	Jan 16, 81	Plesetsk	A-2 (F-2)	89.0	213.0	234.0	82.3	5700.0
Kosmos 1240	Jan 20, 81	Tyuratam	A-2	89.7	167.0	361.0	64.9	6700.0
Interkosmos 21	Feb 6, 81	Plesetsk	C-1	92.8	397.0	427.0	74.0	550.0
Kosmos 1245	Feb 13, 81	Plesetsk	A-2	92.2	346.0	423.0	72.8	6300.0
Kosmos 1246	Feb 18, 81	Tyuratam	A-2	89.1	197.0	271.0	64.9	6700.0
Kosmos 1248	Mar 5, 81	Plesetsk	A-2	89.6	171.0	345.0	67.1	6700.0
Kosmos 1249	Mar 5, 81	Tyuratam	F-1-m	103.9	258.0	975.0	65.0	
Kosmos 1259	Mar 17, 81	Tyuratam	A-2	92.1	350.0	414.0	70.3	6300.0
Kosmos 1260	Mar 20, 81	Tyuratam	A-2	96.8	463.0	749.0	65.0	
Kosmos 1262	Apr 7, 81	Plesetsk	A-2	90.3	196.0	392.0	72.8	6300.0
Kosmos 1264	Apr 15, 81	Tyuratam	A-2	92.3	361.0	416.0	70.3	6300.0
Kosmos 1265	Apr 16, 81	Plesetsk	A-2	89.6	226.0	289.0	72.8	6300.0
Kosmos 1266	Apr 21, 81	Tyuratam	F-1-m	89.6	248.0	267.0	64.9	
Kosmos 1268	Apr 28, 81	Tyuratam	A-2	90.6	241.0	366.0	70.3	6300.0
Meteor 2-7	May 14, 81	Plesetsk	A-1	102.3	849.0	887.0	81.3	2750.0
Kosmos 1270	May 18, 81	Tyuratam	A-2	89.7	173.0	348.0	64.8	6700.0
Kosmos 1272	May 21, 81	Tyuratam	A-2	92.3	361.0	416.0	70.3	6300.0
Kosmos 1273	May 22, 81	Plesetsk	F-2	89.1	211.0	249.0	82.3	5900.0
Kosmos 1274	June 3, 81	Plesetsk	A-2	89.7	170.0	353.0	67.1	6700.0

	Launch Information			Orbital Parameters				
Name/Identification	Date	Site	Vehicle	Period (min)	Perigee (km)	Apogee (km)	Inclin (degrees)	Weight (kg)
Kosmos 1276	June 16, 81	Plesetsk	A-2	89.0	214.0	237.0	82.3	5900.0
Kosmos 1277	June 17, 81	Tyuratam	A-2	92.3	360.0	416.0	70.4	6300.0
Kosmos 1279	July 1, 81	Tyuratam	A-2	92.3	358.0	418.0	70.4	6300.0
Kosmos 1280	July 2, 81	Plesetsk	A-2	89.8	258.0	273.0	82.3	6300.0
Kosmos 1281	July 7, 81	Plesetsk	A-2	92.2	357.0	414.0	72.8	6300.0
Meteor 1-31	July 10, 81	Plesetsk	A-1	97.5	610.0	664.0	97.9	2200.0
Kosmos 1282	July 15, 81	Tyuratam	A-2	89.5	172.0	336.0	64.9	6700.0
Kosmos 1283	July 17, 81	Plesetsk	F-2	91.5	325.0	371.0	82.3	6300.0
Kosmos 1284	July 29, 81	Plesetsk	F-2	91.4	325.0	370.0	82.3	6300.0
Kosmos 1286	Aug 4, 81	Tyuratam	F-1-m	93.4	433.0	447.0	65.0	
Interkosmos 22	Aug 7, 81	Plesetsk	A-1	101.8	795.0	890.0	81.2	1500.0
Bulgaria 1300	Aug 7, 81	Plesetsk	A-1	101.8	795.0	890.0	81.2	1500.0
Kosmos 1296	Aug 13, 81	Plesetsk	A-2	89.7	169.0	357.0	67.1	6700.0
Kosmos 1297	Aug 18, 81	Plesetsk	A-2	89.8	225.0	304.0	72.8	6300.0
Kosmos 1298	Aug 21, 81	Tyuratam	A-2	89.5	173.0	330.0	64.9	6700.0
Kosmos 1299	Aug 24, 81	Tyuratam	F-1-m	104.0	914.0	977.0	65.1	
Kosmos 1300	Aug 24, 81	Plesetsk	F-2	97.6	630.0	658.0	82.5	
Kosmos 1301	Aug 27, 81	Plesetsk	F-2	89.8	259.0	272.0	82.3	6300.0
Kosmos 1303	Sept 4, 81	Tyuratam	A-2	92.3	360.0	415.0	70.4	6300.0
Kosmos 1306	Sept 4, 81	Tyuratam	F-1-m	93.3	427.0	441.0	64.9	
Kosmos 1307	Sept 15, 81	Plesetsk	A-2	92.2	354.0	417.0	72.8	6300.0
Kosmos 1309	Sept 18, 81	Plesetsk	F-2	89.1	214.0	253.0	82.3	5700.0
Oreol 3	Sept 21, 81	Plesetsk	A-2	109.2	402.0	1977.0	82.5	1000.0
Kosmos 1313	Oct 1, 81	Tyuratam	A-2	89.6	231.0	279.0	70.3	6300.0
Kosmos 1314	Oct 9, 81	Plesetsk	F-2	88.9	212.0	235.0	82.3	6300.0
Kosmos 1316	Oct 15, 81	Tyuratam	A-2	89.6	232.0	278.0	70.3	6300.0
Kosmos 1318	Nov 3, 81	Plesetsk	A-2	89.7	171.0	352.0	67.1	6700.0

	Launch Information			Orbital Parameters				
Name/Identification	Date	Site	Vehicle	Period (min)	Perigee (km)	Apogee (km)	Inclin (degrees)	Weight (kg)
Kosmos 1319	Nov 13, 81	Tyuratam	A-2	92.1	350.0	413.0	70.3	6300.0
Kosmos 1328	Dec 3, 81	Plesetsk	F-2	97.6	631.0	660.0	82.5	
Kosmos 1329	Dec 4, 81	Tyuratam	A-2	89.4	233.0	261.0	65.0	6300.0
Kosmos 1330	Dec 19, 81	Tyuratam	A-2	89.6	160.0	348.0	70.4	6700.0
Kosmos 1332	Jan 12, 82	Plesetsk	C-1	89.1	210.0	248.0	82.3	
Kosmos 1334	Jan 20, 82	Plesetsk	A-2	89.7	226.0	288.0	72.9	
Kosmos 1336	Jan 30, 82	Tyuratam	A-2	89.8	169.0	356.0	70.3	
Kosmos 1337	Feb 11, 82	Tyuratam	F-1	93.3	428.0	446.0	65.1	
Kosmos 1338	Feb 16, 82	Plesetsk	A-2	92.3	357.0	414.0	72.9	
Kosmos 1342	Mar 5, 82	Plesetsk	A-2	89.7	227.0	288.0	72.9	
Kosmos 1343	Mar 17, 82	Plesetsk	A-2	89.6	225.0	282.0	72.8	
Meteor 2-8	Mar 25, 82	Plesetsk	F-1	104.1	941.0	961.0	82.5	
Kosmos 1347	Apr 2, 82	Tyuratam	A-2	89.7	172.0	340.0	70.4	
Kosmos 1350	Apr 15, 82	Plesetsk	A-2	89.8	171.0	357.0	67.2	
Kosmos 1352	Apr 21, 82	Tyuratam	A-2	92.2	349.0	415.0	70.4	
Kosmos 1353	Apr 23, 82	Plesetsk	A-2	89.1	211.0	241.0	82.3	
Kosmos 1355	Apr 29, 82	Tyuratam	F-1	93.3	428.0	446.0	65.1	
Kosmos 1365	May 14, 82	Tyuratam	F-1	89.7	248.0	265.0	65.0	
Kosmos 1368	May 21, 82	Tyuratam	A-2	89.5	233.0	260.0	70.4	
Kosmos 1369	May 25, 82	Plesetsk	A-2	90.0	261.0	283.0	82.3	
Kosmos 1370	May 28, 82	Tyuratam	A-2	89.2	197.0	275.0	64.9	
Kosmos 1372	June 1, 82	Tyuratam	F-1	89.7	250.0	264.0	65.0	
Kosmos 1373	June 2, 82	Tyuratam	A-2	92.7	365.0	448.0	70.4	
Kosmos 1376	June 8, 82	Plesetsk	A-2	89.9	253.0	278.0	82.4	
Kosmos 1377	June 8, 82	Tyuratam	A-2	89.7	172.0	343.0	64.9	
Kosmos 1378	June 10, 82	Plesetsk	F-1	97.8	634.0	663.0	82.5	
Kosmos 1381	June 18, 81	Tyuratam	A-2	92.7	376.0	436.0	70.4	

Name/Identification	Launch Information Date	Site	Vehicle	Orbital Parameters Period (min)	Perigee (km)	Apogee (km)	Inclin (degrees)	Weight (kg)
Kosmos 1384	June 30, 82	Plesetsk	A-2	89.8	170.0	354.0	67.2	
Kosmos 1385	July 6, 82	Plesetsk	A-2	88.8	186.0	236.0	82.3	
Kosmos 1387	July 13, 82	Plesetsk	A-2	89.1	212.0	234.0	82.3	
Kosmos 1396	July 27, 82	Plesetsk	A-2	89.8	229.0	292.0	72.9	
Kosmos 1398	Aug 3, 82	Plesetsk	A-2	89.0	216.0	234.0	82.4	
Kosmos 1399	Aug 4, 82	Tyuratam	A-2	89.7	170.0	345.0	64.9	
Kosmos 1401	Aug 20, 82	Plesetsk	A-2	89.9	261.0	274.0	82.3	
Kosmos 1402	Aug 30, 82	Tyuratam	F-1	89.6	251.0	264.0	65.0	
Kosmos 1403	Sept 1, 82	Tyuratam	A-2	92.3	354.0	416.0	70.4	
Kosmos 1404	Sept 1, 82	Plesetsk	A-2	92.3	358.0	414.0	72.9	
Kosmos 1405	Sept 4, 82	Tyuratam	F-1	93.3	430.0	444.0	65.0	
Kosmos 1406	Sept 8, 82	Plesetsk	A-2	88.8	212.0	220.0	82.3	
Kosmos 1407	Sept 15, 82	Plesetsk	A-2	89.6	174.0	340.0	67.2	
Kosmos 1408	Sept 16, 82	Plesetsk	F-1	97.8	635.0	669.0	82.6	
Kosmos 1411	Sept 30, 82	Plesetsk	A-2	92.3	357.0	414.0	72.9	
Kosmos 1416	Oct 14, 82	Tyuratam	A-2	89.6	231.0	278.0	70.4	
Kosmos 1419	Nov 2, 82	Tyuratam	A-2	89.6	228.0	285.0	70.3	
Kosmos 1421	Nov 18, 82	Tyuratam	A-2	89.6	230.0	280.0	70.3	
Kosmos 1422	Dec 3, 82	Plesetsk	A-2	89.7	228.0	287.0	72.9	
Meteor 2-9	Dec 14, 82	Plesetsk	A-1	102.0	810.0	895.0	81.3	
Kosmos 1424	Dec 16, 82	Tyuratam	A-2	89.7	170.0	350.0	64.9	
Kosmos 1438	Jan 27, 83	Tyuratam	A-2	89.2	175.0	293.0	70.4	
Kosmos 1439	Feb 6, 83	Tyuratam	A-2	89.1	160.0	295.0	70.4	
Kosmos 1440	Feb 10, 83	Plesetsk	A-2	89.9	260.0	275.0	82.3	
Kosmos 1442	Feb 25, 83	Plesetsk	A-2	89.8	169.0	360.0	67.2	
Kosmos 1444	Mar 2, 83	Plesetsk	A-2	92.3	358.0	416.0	72.8	
Kosmos 1446	Mar 16, 83	Tyuratam	A-2	89.1	222.0	241.0	69.9	

	Launch Information			Orbital Parameters				
Name/Identification	Date	Site	Vehicle	Period (min)	Perigee (km)	Apogee (km)	Inclin (degrees)	Weight (kg)
Kosmos 1449	Mar 31, 83	Plesetsk	A-2	92.3	356.0	417.0	72.9	
Kosmos 1451	Apr 8, 83	Plesetsk	A-2	90.0	227.0	323.0	82.4	
Kosmos 1454	Apr 22, 83	Plesetsk	A-2	89.6	170.0	343.0	67.1	
Kosmos 1455	Apr 23, 83	Plesetsk	F-1	97.8	635.0	665.0	82.5	
Kosmos 1457	Apr 26, 83	Tyuratam	A-2	89.7	171.0	350.0	70.4	
Kosmos 1458	Apr 28, 83	Plesetsk	A-2	89.1	212.0	245.0	82.3	
Kosmos 1460	May 6, 83	Tyuratam	A-2	92.2	350.0	417.0	70.3	
Kosmos 1462	May 17, 83	Plesetsk	A-2	89.9	259.0	277.0	82.3	
Kosmos 1466	May 26, 83	Tyuratam	A-2	89.7	174.0	345.0	64.9	
Kosmos 1467	May 31, 83	Plesetsk	A-2	92.3	357.0	417.0	72.9	
Kosmos 1468	June 7, 83	Plesetsk	A-2	89.9	252.0	277.0	82.3	
Kosmos 1469	June 14, 83	Plesetsk	A-2	90.3	231.0	342.0	72.8	
Kosmos 1471	June 28, 83	Plesetsk	A-2	89.7	122.0	345.0	67.1	
Kosmos 1472	July 5, 83	Plesetsk	A-2	91.6	336.0	360.0	82.4	
Kosmos 1482	July 13, 83	Tyuratam	A-2	92.2	351.0	411.0	70.0	
Kosmos 1483	July 20, 83	Plesetsk	A-2	89.9	258.0	273.0	82.3	
Kosmos 1484	July 24, 83	Tyuratam	A-1	97.3	592.0	661.0	98.0	
Kosmos 1485	July 26, 83	Plesetsk	A-2	92.3	356.0	414.0	72.9	
Kosmos 1487	Aug 5, 83	Plesetsk	A-2	89.9	258.0	273.0	82.3	
Kosmos 1488	Aug 9, 83	Plesetsk	A-2	92.3	355.0	415.0	72.9	
Kosmos 1489	Aug 10, 83	Tyuratam	A-2	89.3	175.0	301.0	64.7	
Kosmos 1493	Aug 23, 83	Plesetsk	A-2	92.3	358.0	412.0	72.8	
Kosmos 1495	Sept 3, 83	Plesetsk	A-2	89.0	213.0	235.0	82.3	
Kosmos 1496	Sept 7, 83	Tyuratam	A-2	89.6	168.0	340.0	67.2	
Kosmos 1497	Sept 9, 83	Plesetsk	A-2	92.3	356.0	413.0	72.9	
Kosmos 1498	Sept 14, 83	Plesetsk	A-2	89.9	259.0	272.0	82.3	
Kosmos 1499	Sept 17, 83	Plesetsk	A-2	92.3	356.0	414.0	72.9	

	Launch Information			Orbital Parameters				
Name/Identification	Date	Site	Vehicle	Period (min)	Perigee (km)	Apogee (km)	Inclin (degrees)	Weight (kg)
Kosmos 1500	Sept 28, 83	Plesetsk	F-1	97.8	633.0	665.0	82.5	
Kosmos 1504	Oct 14, 83	Tyuratam	A-2	89.3	171.0	306.0	64.9	
Kosmos 1505	Oct 21, 83	Plesetsk	A-2	92.3	356.0	414.0	72.9	
Meteor 2-10	Oct 28, 83	Plesetsk	A-1	101.4	752.0	888.0	81.2	
Kosmos 1507	Oct 29, 83	Tyuratam	F-1	93.4	433.0	442.0	65.1	
Kosmos 1509	Nov 17, 83	Plesetsk	A-2	89.7	225.0	290.0	72.9	
Kosmos 1511	Nov 30, 83	Plesetsk	A-2	89.6	167.0	338.0	67.1	
Kosmos 1512	Dec 7, 83	Plesetsk	A-2	92.3	355.0	416.0	72.9	
Kosmos 1516	Dec 27, 83	Tyuratam	A-2	89.3	205.0	270.0	64.9	
Kosmos 1530	Jan 11, 84	Plesetsk	A-2	92.3	356.0	415.0	72.8	6300.0
Kosmos 1532	Jan 13, 84	Plesetsk	A-2	89.8	167.0	355.0	67.1	6700.0
Kosmos 1533	Jan 26, 84	Tyuratam	A-2	92.2	348.0	414.0	70.4	6300.0
Kosmos 1537	Feb 16, 84	Plesetsk	A-2	89.9	259.0	273.0	82.4	6300.0
Kosmos 1539	Feb 28, 84	Plesetsk	A-2	89.6	169.0	241.0	67.2	6700.0
Kosmos 1542	Mar 7, 84	Tyuratam	A-2	92.2	348.0	414.0	70.4	6300.0
Kosmos 1543	Mar 10, 84	Plesetsk	A-2	90.6	216.0	394.0	62.8	5700.0
Kosmos 1545	Mar 21, 84	Plesetsk	A-2	92.3	356.0	415.0	72.8	6300.0
Kosmos 1548	Apr 10, 84	Plesetsk	A-2	89.5	167.0	334.0	67.1	6700.0
Kosmos 1549	Apr 19, 84	Plesetsk	A-2	92.3	356.0	415.0	72.9	6300.0
Kosmos 1551	May 11, 84	Plesetsk	A-2	89.3	196.0	279.0	72.9	6300.0
Kosmos 1552	May 14, 84	Tyuratam	A-2	89.5	182.0	332.0	64.9	6700.0
Kosmos 1557	May 22, 84	Plesetsk	A-2	89.2	211.0	247.0	82.3	6300.0
Kosmos 1558	May 25, 84	Plesetsk	A-2	89.1	168.0	294.0	67.2	6700.0
Kosmos 1567	May 30, 84	Tyuratam	F-1	93.3	432.0	442.0	65.0	93.3
Kosmos 1568	June 1, 84	Plesetsk	A-2	92.3	356.0	415.0	72.8	6300.0
Kosmos 1571	June 11, 84	Tyuratam	A-2	92.2	349.0	412.0	70.2	6300.0
Kosmos 1572	June 15, 84	Plesetsk	A-2	89.9	258.0	272.0	82.4	6300.0

Name/Identification	Launch Information Date	Site	Vehicle	Orbital Parameters Period (min)	Perigee (km)	Apogee (km)	Inclin (degrees)	Weight (kg)
Kosmos 1573	June 19, 84	Plesetsk	A-2	90.0	231.0	309.0	72.9	6300.0
Kosmos 1575	June 22, 84	Plesetsk	A-2	90.0	258.0	274.0	82.3	6300.0
Kosmos 1576	June 26, 84	Plesetsk	A-2	90.9	178.0	368.0	67.1	6700.0
Kosmos 1579	June 29, 84	Tyuratam	F-1	89.7	250.0	264.0	65.0	
Kosmos 1580	June 29, 84	Plesetsk	A-2	89.5	228.0	271.0	62.8	6300.0
Meteor 2-11	July 5, 84	Plesetsk	F-2	104.2	943.0	960.0	82.5	2750.0
Kosmos 1582	July 19, 84	Plesetsk	A-2	89.5	213.0	279.0	82.4	6300.0
Kosmos 1583	July 24, 84	Plesetsk	A-2	92.3	356.0	416.0	72.9	6300.0
Kosmos 1584	July 27, 84	Plesetsk	A-2	90.0	180.0	265.0	82.4	6300.0
Kosmos 1585	July 31, 84	Tyuratam	A-2	89.3	174.0	302.0	64.7	6700.0
Kosmos 1587	Aug 6, 84	Plesetsk	A-2	90.2	197.0	368.0	72.9	6300.0
Kosmos 1588	Aug 7, 84	Tyuratam	F-1	93.3	426.0	446.0	65.0	
Kosmos 1589	Aug 8, 84	Plesetsk	F-2	116.0	1494.0	1502.0	82.6	
Kosmos 1590	Aug 16, 84	Plesetsk	A-2	89.9	263.0	273.0	82.4	6300.0
Kosmos 1591	Aug 30, 84	Plesetsk	A-2	89.3	209.0	293.0	82.3	6300.0
Kosmos 1592	Sept 4, 84	Plesetsk	A-2	89.7	225.0	287.0	72.9	6000.0
Kosmos 1597	Sept 13, 84	Plesetsk	A-2	89.1	211.0	244.0	82.3	5900.0
Kosmos 1600	Sept 27, 84	Tyuratam	A-2	92.2	349.0	416.0	70.0	6300.0
Kosmos 1599	Sept 28, 84	Plesetsk	A-2	89.6	180.0	327.0	67.1	6700.0
Kosmos 1602	Sept 28, 84	Plesetsk	F-2	97.8	634.0	667.0	82.5	2000.0
Kosmos 1607	Oct 31, 84	Tyuratam	F-1	89.7	250.0	264.0	65.0	
Kosmos 1608	Nov 14, 84	Tyuratam	A-2	89.0	195.0	250.0	70.0	6700.0
Kosmos 1609	Nov 14, 84	Plesetsk	A-2	92.3	358.0	414.0	72.9	6300.0
Kosmos 1611	Nov 21, 84	Tyuratam	A-2	89.8	173.0	351.0	64.8	6700.0
Kosmos 1613	Nov 29, 84	Plesetsk	A-2	92.3	356.0	414.0	72.8	6300.0
Kosmos 1616	Jan 9, 85	Tyuratam	A-2	89.8	173.0	358.0	64.9	6700.0
Kosmos 1623	Jan 16, 85	Tyuratam	A-2	92.2	349.0	415.0	70.0	6300.0

	Launch Information			Orbital Parameters				
Name/Identification	Date	Site	Vehicle	Period (min)	Perigee (km)	Apogee (km)	Inclin (degrees)	Weight (kg)
Kosmos 1625	Jan 23, 85	Tyuratam	F-1	89.4	116.0	370.0	65.0	
Kosmos 1628	Feb 6, 85	Plesetsk	A-2	92.3	355.0	415.0	72.9	6300.0
Meteor 2-12	Feb 6, 85	Plesetsk	F-2	104.1	939.0	959.0	82.5	2200.0
Kosmos 1630	Feb 28, 85	Tyuratam	A-2	89.6	174.0	334.0	64.9	6700.0
Kosmos 1632	Mar 1, 85	Plesetsk	A-2	89.3	209.0	267.0	72.9	6300.0
Kosmos 1643	Mar 25, 85	Tyuratam	A-2	89.1	183.0	276.0	64.8	6700.0
Kosmos 1644	Apr 3, 85	Tyuratam	A-2	92.2	349.0	415.0	70.3	6300.0
Kosmos 1646	Apr 18, 85	Tyuratam	F-1	93.3	429.0	443.0	65.1	
Kosmos 1647	Apr 19, 85	Plesetsk	A-2	89.4	169.0	323.0	67.1	6700.0
Kosmos 1648	Apr 25, 85	Plesetsk	A-2	90.1	229.0	327.0	82.3	6300.0
Kosmos 1649	May 15, 85	Plesetsk	A-2	92.3	356.0	415.0	72.9	6300.0
Kosmos 1653	May 22, 85	Plesetsk	A-2	89.9	259.0	273.0	82.3	6300.0
Kosmos 1654	May 23, 85	Tyuratam	A-2	89.7	172.0	343.0	64.9	6700.0
Kosmos 1657	June 7, 85	Plesetsk	A-2	89.2	182.0	284.0	82.3	6300.0
Kosmos 1659	June 13, 86	Plesetsk	A-2	92.3	357.0	415.0	72.9	6300.0
Kosmos 1660	June 14, 85	Plesetsk	F-2?	116.1	1482.0	1526.0	73.6	600.0
Kosmos 1663	June 21, 85	Plesetsk	A-2	89.9	258.0	274.0	82.3	6300.0
Kosmos 1664	June 26, 85	Plesetsk	A-2	90.6	224.0	379.0	72.8	6300.0
Kosmos 1665	July 3, 85	Plesetsk	A-2	89.7	225.0	290.0	72.8	6300.0
Kosmos 1672	Aug 7, 85	Plesetsk	A-2	89.9	258.0	273.0	82.3	6300.0
Kosmos 1673	Aug 8, 85	Tyuratam	A-2	89.2	198.0	272.0	64.8	6700.0
Kosmos 1676	Aug 16, 85	Plesetsk	A-2	89.6	167.0	345.0	67.2	6300.0
Kosmos 1677	Aug 23, 85	Tyuratam	F-1	89.7	251.0	264.0	65.0	
Kosmos 1678	Aug 29, 85	Plesetsk	A-2	89.9	258.0	272.0	82.3	6300.0
Kosmos 1679	Aug 29, 85	Tyuratam	A-2	89.7	172.0	342.0	64.9	6300.0
Kosmos 1681	Sept 6, 85	Plesetsk	A-2	89.0	219.0	227.0	82.3	6300.0

Name/Identification	Launch Information Date	Site	Vehicle	Orbital Parameters Period (min)	Perigee (km)	Apogee (km)	Inclin (degrees)	Weight (kg)
Kosmos 1683	Sept 19, 85	Plesetsk	A-2	92.3	356.0	414.0	72.9	6300.0
Kosmos 1685	Sept 27, 85	Plesetsk	A-2	92.3	356.0	414.0	72.9	6300.0
Kosmos 1689	Oct 3, 85	Tyuratam	A-2	97.1	573.0	657.0	98.0	1500.0
Kosmos 1696	Oct 16, 85	Tyuratam	A-2	89.7	230.0	281.0	70.4	
Meteor 3-1	Oct 24, 85	Plesetsk	F-2	110.3	1227.0	1251.0	82.6	
Kosmos 1699	Oct 25, 85	Plesetsk	A-2	89.6	168.0	338.0	67.2	6700.0
Kosmos 1702	Nov 13, 85	Plesetsk	A-2	92.3	356.0	414.0	72.9	6300.0
Kosmos 1705	Dec 3, 85	Plesetsk	A-2	92.3	356.0	415.0	72.9	6300.0
Kosmos 1706	Dec 11, 85	Plesetsk	A-2	89.6	162.0	340.0	67.2	6700.0
Kosmos 1708	Dec 13, 85	Plesetsk	A-2	89.9	257.0	273.0	82.2	6300.0
Meteor 2-13	Dec 26, 85	Plesetsk	F-2	104.1	939.0	962.0	82.5	2000.0
Kosmos 1713	Dec 27, 85	Plesetsk	A-2	90.7	216.0	398.0	62.8	
Kosmos 1715	Jan 8, 86	Plesetsk	A-2	89.4	226.0	263.0	72.8	6000.0
Kosmos 1724	Jan 15, 86	Plesetsk	A-2	89.2	168.0	334.0	67.1	6000.0
Kosmos 1728	Jan 28, 86	Tyuratam	A-2	89.4	223.0	270.0	70.0	6000.0
Kosmos 1730	Feb 4, 86	Plesetsk	A-2	89.6	224.0	280.0	72.9	6000.0
Kosmos 1731	Feb 7, 86	Tyuratam	A-2	89.9	183.0	269.0	64.8	2500.0
Kosmos 1732	Feb 11, 86	Plesetsk	F-2?	116.0	1477.0	1524.0	73.6	
Kosmos 1734	Feb 26, 86	Plesetsk	A-2	89.1	163.0	348.0	67.1	6000.0
Kosmos 1735	Feb 27, 86	Tyuratam	F-1	92.7	401.0	416.0	65.0	
Kosmos 1736	Mar 21, 86	Tyuratam	F-1	104.4	922.0	1010.0	65.0	5000.0
Kosmos 1737	Mar 25, 86	Tyuratam	F-1	91.0	213.0	436.0	73.3	
Kosmos 1739	Apr 9, 86	Tyuratam	A-2	89.5	173.0	329.0	64.8	6000.0
Kosmos 1740	Apr 15, 86	Plesetsk	A-2	92.2	352.0	413.0	72.9	6000.0
Kosmos 1742	May 14, 86	Plesetsk	A-2	92.2	351.0	416.0	72.9	6000.0
Meteor 2-14	May 27, 86	Plesetsk	F-2?	104.1	941.0	960.0	82.5	2000.0
Kosmos 1746	May 28, 86	Plesetsk	A-2	89.8	255.0	269.0	82.3	6000.0

Name/Identification	Launch Information Date	Site	Vehicle	Orbital Parameters Period (min)	Perigee (km)	Apogee (km)	Inclin (degrees)	Weight (kg)
Kosmos 1747	May 29, 86	Tyuratam	A-2	89.1	248.0	252.0	70.4	600.0
Kosmos 1756	June 6, 86	Tyuratam	A-2	89.4	169.0	323.0	64.9	6000.0
Kosmos 1757	June 11, 86	Plesetsk	A-2	90.0	165.0	384.0	82.3	6000.0
Kosmos 1760	June 19, 86	Tyuratam	A-2	92.2	350.0	415.0	70.0	6000.0
Kosmos 1762	July 10, 86	Plesetsk	A-2	89.8	255.0	269.0	82.5	6300.0
Kosmos 1764	JUly 17, 86	Tyuratam	A-2	89.5	170.0	327.0	64.9	7000.0
Kosmos 1765	July 24, 86	Plesetsk	A-2	92.2	353.0	412.0	72.9	6300.0
Kosmos 1766	July 28, 86	Plesetsk	F-2?	97.7	631.0	662.0	82.5	1600.0
Kosmos 1768	Aug 2, 86	Plesetsk	A-2	89.8	255.0	269.0	82.6	6000.0
Kosmos 1771	Aug 20, 86	Tyuratam	F-1	104.2	910.0	1001.0	65.0	5000.0
Kosmos 1772	Aug 21, 86	Plesetsk	A-2	89.4	356.0	415.0	72.9	6300.0
Kosmos 1773	Aug 27, 86	Tyuratam	A-2	89.7	173.0	343.0	64.9	7000.0
Kosmos 1775	Sept 3, 86	Tyuratam	A-2	92.1	348.0	414.0	70.4	6300.0
Kosmos 1781	Sept 17, 86	Tyuratam	A-2	92.2	345.0	416.0	70.4	6000.0
Kosmos 1784	Oct 6, 86	Tyuratam	A-2	89.2	207.0	265.0	64.8	7000.0
Kosmos 1787	Oct 22, 86	Tyuratam	A-2	89.6	230.0	281.0	70.0	6300.0
Kosmos 1789	Oct 31, 86	Plesetsk	A-2	91.1	318.0	338.0	82.6	6300.0
Kosmos 1790	Nov 4, 86	Plesetsk	A-2	89.5	224.0	279.0	72.9	6300.0
Kosmos 1792	Nov 13, 86	Tyuratam	A-2	89.3	167.0	312.0	64.9	7000.0
Kosmos 1803	Dec 2, 86	Plesetsk	F-2?	115.9	1495.0	1499.0	82.6	700.0
Kosmos 1804	Dec 4, 86	Tyuratam	A-2	92.1	345.0	412.0	70.0	6300.0
Kosmos 1810	Dec 26, 86	Tyuratam	A-2	89.6	245.0	263.0	64.8	
Meteor 2-15	Jan 5, 87	Plesetsk	SL-14	104.1	942.0	961.0	82.5	
Kosmos 1811	Jan 9, 87	Tyuratum	SL-4	89.5	202.0	293.0	64.9	
Kosmos 1813	Jan 15, 87	Plesetsk	Sl-4	92.3	356.0	416.0	72.8	
Kosmos 1818	Feb 1, 87	Tyuratum	SL-11	100.7	786.0	800.0	65.0	
Kosmos 1819	Feb 7, 87	Plesetsk	SL-4	89.2	209.0	256.0	72.8	

	Launch Information			Orbital Parameters				
Name/Identification	Date	Site	Vehicle	Period (min)	Perigee (km)	Apogee (km)	Inclin (degrees)	Weight (kg)
Kosmos 1822	Feb 19, 87	Plesetsk	SL-4	89.7	228.0	287.0	72.8	
Kosmos 1823	Feb 20, 87	Plesetsk	SL-14	116.0	1479.0	1526.0	73.6	
Kosmos 1824	Feb 26, 87	Plesetsk	SL-4	89.6	167.0	345.0	67.2	
Kosmos 1826	Mar 11, 87	Plesetsk	SL-4	92.3	355.0	415.0	72.9	
Kosmos 1834	Apr 8, 87	Tyuratum	SL-11	92.8	404.0	418.0	65.0	
Kosmos 1835	Apr 9, 87	Tyuratum	SL-4	89.7	172.0	344.0	64.8	
Kosmos 1836	Apr 16, 87	Tyuratum	SL-4	89.9	241.0	293.0	64.8	
Kosmos 1837	Apr 22, 87	Plesetsk	SL-4	89.2	226.0	247.0	82.3	
Kosmos 1843	May 5, 87	Tyuratum	SL-4	92.2	347.0	415.0	70.4	
Kosmos 1845	May 13, 87	Tyuratum	SL-4	92.2	348.0	415.0	70.4	
Kosmos 1846	May 21, 87	Plesetsk	SL-4	91.2	323.0	342.0	82.4	
Kosmos 1847	May 26, 87	Plesetsk	SL-4	89.7	169.0	346.0	67.2	
Kosmos 1848	May 28, 87	Plesetsk	SL-4	92.3	357.0	414.0	72.9	
Kosmos 1860	Jun 18, 87	Tyuratum	SL-11	89.6	250.0	263.0	65.0	
Kosmos 1863	Jul 4, 87	Plesetsk	SL-4	92.3	357.0	416.0	72.9	
Kosmos 1865	Jul 8, 87	Tyuratum	SL-4	89.3	208.0	268.0	64.8	
Kosmos 1866	Jul 9, 87	Plesetsk	SL-4	89.8	167.0	361.0	67.2	
Kosmos 1867	Jul 10, 87	Tyuratum	SL-11	100.7	786.0	801.0	65.0	
Kosmos 1869	Jul 16, 87	Plesetsk	SL-14	97.7	634.0	667.0	82.5	
Kosmos 1870	Jul 25, 87	Tyuratum	SL-13	89.6	245.0	259.0	71.9	
Kosmos 1872	Aug 19, 87	Plesetsk	SL-4	90.8	247.0	385.0	72.9	
Kosmos 1874	Sep 3, 87	Plesetsk	SL-4	89.7	225.0	291.0	72.9	
Kosmos 1881	Sep 11, 87	Tyuratum	SL-4	89.6	231.0	276.0	64.8	
Kosmos 1882	Sep 15, 87	Plesetsk	SL-4	89.9	259.0	275.0	82.3	
Kosmos 1886	Sep 17, 87	Plesetsk	SL-4	89.8	168.0	359.0	67.1	
Kosmos 1889	Oct 9, 87	Tyuratum	SL-4	92.2	348.0	415.0	70.0	
Kosmos 1890	Oct 10, 87	Tyuratum	SL-11	92.8	403.0	417.0	65.0	

	Launch Information			Orbital Parameters				
Name/Identification	Date	Site	Vehicle	Period (min)	Perigee (km)	Apogee (km)	Inclin (degrees)	Weight (kg)
Kosmos 1893	Oct 22, 87	Plesetsk	SL-4	89.7	165.0	352.0	67.2	
Kosmos 1895	Nov 11, 87	Tyuratum	SL-4	89.7	227.0	288.0	70.4	
Kosmos 1896	Nov 14, 87	Tyuratum	SL-4	89.3	209.0	267.0	64.8	
Kosmos 1899	Dec 7, 87	Tyuratum	SL-4	89.6	229.0	282.0	70.4	
Kosmos 1900	Dec 12, 87	Tyuratum	SL-11	89.8	258.0	271.0	65.0	
Kosmos 1901	Dec 14, 87	Tyuratum	SL-4	89.8	174.0	355.0	64.9	
Kosmos 1905	Dec 25, 87	Tyuratum	SL-4	89.6	229.0	281.0	70.4	
Kosmos 1906	Dec 26, 87	Plesetsk	SL-4	89.9	257.0	277.0	82.6	
Kosmos 1907	Dec 29, 87	Plesetsk	SL-4	92.3	356.0	415.0	72.8	
Kosmos 1915	Jan 26, 88	Plesetsk	SL-4	90.2	195.0	375.0	72.9	
Meteor 2-17	Jan 30. 88	Plesetsk	SL-14	104.1	938.0	961.0	82.6	
Kosmos 1916	Feb 3, 88	Tyuratum	SL-4	89.8	171.0	361.0	64.9	
Kosmos 1920	Feb 18, 88	Plesetsk	SL-4	91.2	323.0	341.0	82.6	
Kosmos 1921	Feb 19, 88	Tyuratum	SL-4	92.2	347.0	415.0	70.0	
Kosmos 1923	Mar 10, 88	Plesetsk	SL-4	89.7	227.0	288.0	72.9	
Kosmos 1932	Mar 14, 88	Tyuratum	SL-11	89.7	247.0	267.0	65.0	
IRS-1A	Mar 17, 88	Tyuratum	SL-3	102.8	868.0	913.0	99.0	2000.0
Kosmos 1935	Mar 24, 88	Plesetsk	SL-4	89.5	168.0	332.0	67.2	
Kosmos 1936	Mar 30, 88	Tyuratum	SL-4	89.8	230.0	298.0	64.8	
Kosmos 1938	Apr 11, 88	Plesetsk	SL-4	89.7	224.0	290.0	72.9	
Kosmos 1939	Apr 20, 88	Tyuratum	SL-3	97.5	617.0	660.0	98.0	
Kosmos 1940	Apr 26, 88	Tyuratum	SL-12	1436.3	35782.0	35800.0	1.3	
Kosmos 1941	Apr 27, 88	Tyuratum	SL-4	89.3	224.0	257.0	70.3	
Kosmos 1942	May 12, 88	Plesetsk	SL-4	89.8	166.0	361.0	67.1	
Kosmos 1944	May 18, 88	Tyuratum	SL-4	89.2	212.0	261.0	64.8	
Kosmos 1945	May 19, 88	Tyuratum	SL-4	90.1	232.0	321.0	70.4	
Kosmos 1949	May 28, 88	Tyuratum	SL-11	92.8	404.0	418.0	65.0	

	Launch Information			Orbital Parameters				
Name/Identification	Date	Site	Vehicle	Period (min)	Perigee (km)	Apogee (km)	Inclin (degrees)	Weight (kg)
Kosmos 1951	May 31, 88	Plesetsk	SL-4	89.9	259.0	275.0	82.3	
Kosmos 1952	Jun 11, 88	Tyuratum	SL-4	89.7	230.0	287.0	70.0	
Kosmos 1955	Jun 22, 88	Tyuratum	SL-4	89.8	173.0	360.0	64.8	
Kosmos 1956	Jun 23, 88	Plesetsk	SL-4	91.5	332.0	368.0	82.4	
Okean 1	Jul 5, 88	Plesetsk	SL-14	97.7	635.0	666.0	82.5	
Kosmos 1957	Jul 7, 88	Plesetsk	SL-4	89.9	260.0	275.0	82.6	
Meteor 3-2	Jul 26, 88	Plesetsk	SL-14	109.4	1186.0	1208.0	82.5	
Kosmos 1962	Aug 8, 88	Tyuratum	SL-4	89.7	231.0	285.0	70.0	

ETR = Kennedy Space Center, Florida, USA.

WTR = Vandenberg Space Center, California, USA

Chronology current through December 1988.

Appendix A.2: Past and Present Satellites

Table 9: NOAA Advanced TIROS-N (ATN) Weather Satellites (E-J) 1983-91 Launches, U.S.A.

Objectives of Mission: Meteorological observations; measurements of sea surface temperature, sea ice, and snow cover; assessment of condition of vegetation

Orbit Characteristics: Polar, 833-870 km. altitude, 7 a.m. and 2 p.m. equator crossing times

Payload Characteristics:

Sensors	Applications	No.of Channels/ Frequencies	Spectral Range/ Frequency Range	Resolution	Swath Width
AVHRR/2 (Advanced Very High Resolution Radiometer)	Cloud Temp., Sea Surface Temp., Land Temp., Vegetation Index	5	0.58-12.5 μm	1.1 km at Nadir 4 km at Edge of Scan	2,700 km
HIRS/2 (High Resolution Infrared Sounder)	Temp. and Moisture Profiles	20	3.8-15.0 μm	17.4 km	2,240 km
SSU (Stratospheric Sounding Unit)	Atmospheric Sounding, Temp. Profiles	3	14.7 μm (Centered)	147 km	736 km
MSU (Microwave Sounding Unit)	Atmospheric Sounding	4	50.3-57.05 GHz	109 km	2,347 km
DCS (Argos) (Data Collection System)	Random Access from Buoys, Balloons, and Platforms	N/A	136.77 MHz 137.77 MHz	N/A	N/A
SAR (Search and Rescue)	Search and Rescue Operations	N/A	121.5 MHz 243.0 MHz 406.0 MHz	N/A	N/A
SBUV ψ (Solar Backscatter UV Experiment)	Solar Spectrum, Ozone Profiles, Earth Radiance Spectrum	12	252.0-339.8 nm	169.3 km	Nadir Viewing
ERBE (Earth Radiation Budget Experiment)	Determine Earth's Radiation Loss and Gain	8	0.2-50.0 μm	67.5 km	Horizon to Horizon
SEM (Space Environment Monitor)	Measurements of Solar Protons, Alpha Particles, "e" Flux Density	N/A	N/A	N/A	N/A

N/A: Not Applicable.
ψ Operates from Noon to Midnight.

Table 10: Geostationary Operational Environmental Satellite (GOES) 1985-87 Launches, U.S.A.

Objectives of Mission: Operational weather data, cloud cover, temperature profiles, real-time storm monitoring, severe storm warning, sea surface temperature

Orbit Characteristics: Geostationary at east and west longitudes

Payload Characteristics:

Sensor	Applications	No. of Channels/ Frequencies	Spectral Range/ Frequency Range	Resolution	Swath Width
VAS (Visible and Infrared Spin Scan Radiometer	Imaging-Day/Night Cloud Cover	5	0.55-0.7 μm 3.90-14.7 μm	1 km-Vis 8 km-IR	Limb to Limb
VISSR (Atmospheric Sounder)	Sounding-Temp. and Water Content	12	3.90-14.7 μm	7-14 km	Limb to Limb
DCS (Data Collection System)	Random Access from Buoys, Balloons, and Platforms	N/A	136.77 MHz 137.77 MHz	N/A	N/A
SEM (Space Environment Monitor)	Measurements of Solar Protons, Alpha Particles, "e" Flux Density	N/A	N/A	N/A	N/A
SAR (Search and Rescue)	Search and Rescue Operations	N/A	406.0 MHz	N/A	N/A

Table 11: Landsat Launches 1972-85, U.S.A.

Objectives of Mission: Operational and commercial data, land use inventory, geological/mineralogical exploration, crop and forestry assessment, cartography

Orbit Characteristics: Sun-synchronous, 705 km. altitude, 98.22 degree inclination, 9:30 a.m. equator crossing time, 16-day repeat cycle

Payload Characteristics:

Sensor	Applications	No. of Channels/ Frequencies	Spectral Range/ Frequency Range	Resolution	Swath Width
MSS (Multi-Spectral Scanner)	Land Use, Urban Planning, Mapping, Agriculture, Forestry, Water Resources, Geology, Mineral Resources	4	0.5-12.6 μm	80 m	185 km
RBV (Return Beam Vidicon)	Same as Above	1	0.5-0.75 μm	40 m	185 km
TM (Thematic Mapper)	Same as Above	7	0.45-12.5 μm	30 m-Vis/IR 120 m-Thermal-IR	185 km

Table 12: Nimbus-7
Launched 1978, U.S.A.

Objectives of Mission: Monitor atmospheric pollutants, ocean chlorophyll concentrations, weather, and climate

Orbit Characteristics: Sun-synchronous, 955 km. altitude, 99.29 degree inclination, equator crossing time at noon and midnight

Payload Characteristics:

Sensor	Applications	No. of Channels/ Frequencies	Spectral Range/ Frequency Range	Resolution	Swath Width
THIR* (Temperature Humidity Infrared Radiometer)	Map Global Cloudiness	2	6.5-.7.0 μm 10.5-12.5 μm	20.0 km 6.7 km	2,610 km
CZCS* (Coastal Zone Color Scanner)	Map Ocean Chlorophyll Concentrations	6	0.433-12.5 μm	0.8 km	1,600 km
SMMR (Scanning Multi-Channel Microwave Radiometer)	Sea Surface Temp., Near Surface Winds, Sea Ice, Snow, Rainfall, Soil Moisture, Water Vapor	5	6.6-37.0 GHz	25-150 km	780 km
ERB (Earth Radiation Budget)	Earth Radiation Budget on Synoptic and Planetary Scales, Solar Irradiance	22	0.2-50 + μm	1500 km-WFOVψ 150 km-NFOVϕ Solar-Disk	Horizon to Horizon
LIMS* (Limb Infrared Monitor of the Stratosphere)	Vertical Distribution of Temp., O_3, NO_2, HNO_3, and H_2O From Lower Stratosphere to Lower Mesosphere	6	6.1-17.2 μm	2 km Vertical	10-65 km Vertical
SAMS'* (Stratospheric and Mesospheric Sounder)	Vertical Distribution of Temp., N_2O, CH_4, CO, and NO in the Stratosphere and Mesosphere	12	4.1-100.0 μm	10 km Vertical	10-70 km Vertical
SAM II (Stratospheric Aerosol Measurement II)	Vertical Distribution of Stratospheric Aerosols in Polar Regions	1	0.98-1.02 μm	1 km Vertical	5-40 km Vertical
SBUV/TOMS (Solar Backscatter Ultraviolet and Total Ozone Mapping Spectrometer)	Ozone Profiles, Total Atmospheric Ozone, Incident Solar UV Irradiance, and Backscattered UV Radiance	12-SBUV Fixed 1-SBUV Continuous 6-TOMS Fixed	250-340 nm 160-400 nm 312-340 nm	11.3 deg. 11.3 deg. 3.0 deg.	200 km 200 km 2,700 km

*Not operational
ψWFOV is wide field of view
ϕNFOV is narrow field of view

Table 13: Earth Radiation Budget Satellite (ERBS) Launched 1984, U.S.A.

Objectives of Mission: Provide observation of the Earth's radiation budget

Orbit Characteristics: 610 km., non-Sun-synchronous, circular orbit, inclined 56 degrees to the equator

Payload Characteristics:

Sensor	Applications	No. of Channels/ Frequencies	Spectral Range/ Frequency Range	Resolution	Swath Width
ERBE Non-Scanner (Earth Radiation Budget Experiment)	Measurements Across the Shortwave Band, Total Radiation, Total Output of Radiant Heat	1-4	0.2-3.5 μm 0.2-50.0 μm	1,000 km along line of swath width	Limb to Limb-WFOV* 1,000 km-MFOVϕ
	and Light from the Sun	5	0.2-50.0 μm	Full Solar Disc	N/A
ERBE Scanner	Reflected Solar Radiation, Earth Emitted Radiation	3	0.2-50.0 μm	40 km	40 km Scans Limb to Limb
SAGE 11 (Stratospheric Aerosol and Gas Experiment)	Stratospheric Aerosols, O_3, NO_2, Water Vapor	7	0.385-1.02 μm	0.5 km	N/A

N/A: not applicable.
*WFOV is wide field of view
ϕMFOV is medium field of view

Table 14: Defense Meteorological Satellite Program (DMSP) Continuing Program, U.S.A.

Objectives of Mission: Operational weather data for Department of Defense

Orbit Characteristics: Circular Sun-synchronous, 833 km. altitude, 98.7 degree inclination, current equator crossing times 0620 and 1010 ascending, period of 101 minutes

Payload Characteristics:

Sensor	Applications	No. of Channels/ Frequencies	Spectral Range/ Frequency Range	Resolution	Swath Width
OLS (Operational Linescan System)	Global Cloud Cover Cloud Top Temperature, Sea Surface Temperature, Auroral Imagery	3	0.4-0.95 μm* 0.4-1.1 μm 10.2-12.8 μm	0.62 km	2,963 km
SSM/T (Sensor System Microwave/Temperature)	Temperature Profiles	7	50-60 GHz	172 km at Nadir 296 km at Edge of Scan	1,595 km
SESS (Space Environment Sensor Suite)	Precipitating Electrons & Protons, Ambient Electron/Ion	N/A	N/A	N/A	N/A
SESS Includes: SSIE/S-Ionospheric Plasma and Scintillation Monitor SSJ/4-Precipitating Electron/Proton Spectrometer SSJ*-Dosimeter SSM-Triaxial Magnetometer	Temperature and Density, Plasma Drift, Scintillation, Geomagnetic Field Fluctuations				
SSM/I (Sensor System Microwave/Imager)	Precipitation, Soil Moisture, Wind Speed Over Ocean, Sea Ice Morphology, Cloud, Water Liquid Water	7	19.3 GHz 22.2 GHz 38.0 GHz 85.5 GHz	50 km 25 km-Precip. Over Land, and Cloud Liquid Water Over Land	1,290 km
SSM/T-2ψ (Sensor System Microwave/Water Vapor)	Moisture Profiles	9	91.5-183 GHz	40 km	1,596 km
SSB/A (Gamma and X-Ray Spectrometer)	Gamma and X-Ray Detector	4	15-120 KeV	102 km Along Track 204 km Across Track	2,778 km
SSB/S (Gamma Ray Spectrometer)	Gamma and X-Ray Detector	4	45-165 KeV	102 km Along Track 204 km Across Track	2,778 km
SSB/X	Gamma and X-Ray Detector	3	60-375 KeV	102 km Across Track 204 km Across Track	2,778 km

N/A: Not Applicable.
*Low light visible down to one-quarter full moon illumination
ψ First flight on satellite S-13

Table 15: Geosat
Launched 1985, U.S.A.

Objectives of Mission: Gravitational measurements, oceanic data on windspeed, significant wave height, sea ice edge, fronts, detection of mesoscale features

Orbit Characteristics: 800 km. altitude, 108 degree inclination, 152-day repeat cycle first 18 months, 17-day repeat cycle second 18 months

Payload Characteristics:

Sensor	Applications	No. of Channels/ Frequencies	Spectral Range/ Frequency Range	Resolution	Swath Width
ALT (Altimeter)	Surface Windspeed, Significant Wave Height, Sea Ice Edge	1	13.5 GHz	3.5 cm (Vertical) 1.8-8.1 km (Horizontal) (Depending on Sea State)	1.8-8.1 km (Depending on Sea State)

Table 16: Meteosat 1-3
Launched 1977-87, European Space Agency (ESA)

Objectives of Mission: Operational weather data, cloud cover, water vapor imagery

Orbit Characteristics: Geostationary at 0 degrees longitude

Payload Characteristics:

Sensor	Applications	No. of Channels/ Frequencies	Spectral Range/ Frequency Range	Resolution	Swath Width
Visible and Infrared Radiometer	Day/Night Cloud Cover Earth/Cloud Radiance Temp. Measurements	3	0.4-1.1 μm-Vis 5.7-7.1 μm--IR 10.5-12.5 μm-IR	2.5 km or 5.0 km 5.0 km--IR	Limb to Limb
DCS (Data Collection System)	Random Access from Buoys, Balloons, and Platforms	N/A	N/A	N/A	N/A

N/A: Not Applicable.

Table 17: Geostationary Meteorological Satellite (GMS) Launched 1984, Japan

Objectives of Mission: Operational weather data, cloud cover temperature profiles, real-time storm monitoring, severe storm warning

Orbit Characteristics: Geostationary at 140 degrees east longitude

Payload Characteristics:

Sensor	Applications	No.of Channels/ Frequencies	Spectral Range/ Frequency Range	Resolution	Swath Width
Visible and Infrared Radiometer	Cloud Cover, Earth/ Cloud Radiance Temp. Measurements	2	0.55-.75 μm-Vis 10.50-12.50 μm-IR	1.25 km 5.0 km	Limb to Limb
SEM (Space Environment Monitor)	Measurements of Solar Protons, Alpha Particles, "e" Flux Density	N/A	N/A	N/A	N/A
DCS (Data Collection System)	Random Access from Buoys, Balloons, and Platforms	N/A	N/A	N/A	N/A

N/A: Not Applicable.

Table 18: Indian National Satellite System (INSAT-I and -II) Launched 1983 with follow-ons, India

Objectives of Mission Domestic telecommunications, meteorology, nationwide direct television broadcasting to rural communities, and radio and TV program distribution for rebroadcasting/networking

Orbit Characteristics Geostationary at 74 degrees east longitude, altitude 35,800 km

Payload Characteristics:

Sensor	Applications	No.of Channels/ Frequencies	Spectral Range/ Frequency Range	Resolution	Swath Width
VHRR (Very High Resolution Radiometer)	Day/Night Cloud Cover, Earth/Cloud Radiance Temp. Measurements	2	0.55-0.75 μm-Vis 10.50-12.50 μm-IR	2.75 km-Vis 11.0 km-IR	Limb to Limb
DCS (Data Collection System)	Random Access from Buoys, Balloons, and Platforms	N/A	402.75 MHz 4.0 GHz	N/A	N/A

N/A: Not Applicable.

Table 19: METEOR-2
Launched 1977, U.S.S.R.

Objectives of Mission: Meteorological observations; measurement of sea surface temperatures, sea ice, and snow cover; assessment of condition of vegetation

Orbit Characteristics: Near-polar 900 km. altitude, 81.2 degree inclination

Payload Characteristics:

Sensor	Applications	No.of Channels/ Frequencies	Spectral Range/ Frequency Range	Resolution	Swath Width
Scanning Telephotometer (for direct imaging)	?	?	0.5-0.7 μm	2 km	2,100 km
Scanning Telephotometer (for global coverage)	?	?	0.5-0.7 μm	1 km	2,400 km
Scanning IR-Radiometer (for global coverage)	?	?	8.0-12.0 μm	2 km	2,600 km
Scanning IR-Spectrometer	?	8	11.0-18.0 μm	30 km	1,000 km
Radiometric Complex	?	N/A	Protons, Electrons, 0.15-90 MeV	N/A	2-4 Space Angle

N/A: Not Applicable.

Table 20: Marine Observation Satellite (MOS) Launched 1987 with follow-ons, Japan*

Objectives of Mission: Observation of the state of sea surface and atmosphere

Orbit Characteristics: Sun-synchronous, 909 km. altitude, between 10 a.m. and 11 a.m. equator crossing times, 99.1 degree inclination, 17-day repeat cycle

Payload Characteristics:

Sensor	Applications	No. of Channels/ Frequencies	Spectral Range/ Frequency Range	Resolution	Swath Width
MESSR (Multispectral Electronic Self-Scanning Radiometer)	Sea Surface Color	4	0.5-1.1 μm	50 m	100 km
VTIR (Visible and Thermal Infrared Radiometer)	Sea Surface Temperature	4	0.5-0.7 μm 6.0-7.0 μm 10.5-12.5 μm	0.9 km-Vis 2.7 km-IR	1,500 km
MSR (Microwave Scanning Radiometer)	Water Content of Atmosphere	2	23.8 GHz 31.4 GHz	32 km 23 km	317 km

* MOS-1 Launched February 1987.

Table 21: Systeme Probatoire d'Observation de la Terre (SPOT) Launched 1986, France

Objectives of Mission: Operational land use and inventory monitoring system

Orbit Characteristics: Sun-synchronous, 832 km, 98.7 degree inclination, 10:30 a.m. equator crossing time, 26-day repeat cycle

Payload Characteristics:

Sensor	Applications	No.of Channels/ Frequencies	Spectral Range/ Frequency Range	Resolution	Swath Width
HRV (High Resolution Visible Range Instruments)	Land Use, Urban Planning, Mapping, Agriculture, Forestry, Water Resources, Geology	4	0.5-0.9 μm (Multispectral Mode) 0.5-0.73 μm (Panchromatic Mode)	20 m 10 m	60 km 60 km

Table 22: Indian Remote Sensing Satellite (IRS) 1987 Launch with follow-ons, India

Objectives of Mission: Provide agricultural, geological, and hydrological data for survey and management of natural resources

Orbit Characteristics: Sun-synchronous, 904 km. altitude, 22-day repeat cycle

Payload Characteristics:

Sensor	Applications	No. of Channels/ Frequencies	Spectral Range/ Frequency Range	Resolution	Swath Width
LISS-I (Linear Imaging Self-Scanner Sensor)	Land Use, Urban Planning, Mapping, Agriculture, Forestry, Water Resources, Geology, Mineral Resources	4	0.45-0.86 μm	73 m	148 km
LISS-II	Same as Above	4	0.45-0.86 μm	3.6 m	148 km

Appendix A.3: Planned Future Systems

Table 23: Earth Resources Satellite (JERS-1) 1991 Launch, Japan

Objectives of Mission: Global exploration of mineral and energy resources, management of agricultural and forestry resources, environmental monitoring and land use planning

Orbit Characteristics: Sun-synchronous, 560 km. altitude

Payload Characteristics:

Sensor	Applications	No. of Channels/ Frequencies	Spectral Range/ Frequency Range	Resolution	Swath Width
VNIR (Visible and Near Infrared Radiometer)	Land Use, Mapping, Agriculture, Forestry, Geology, Mineral Resources	TBD	TBD	25 m	150 km
SAR (Synthetic Aperture Radar)	Ice Topography	1	1.2 GHz	25 m	75 km

TBD:To Be Decided.

Table 24: NOAA Advanced TIROS-N (ATN) Weather Satellites (K-L-M) 1992-95 Launches, U.S.A.

Objectives of Mission: Meteorological observations; measurements of sea surface temperature, sea ice, and snow cover; assessment of condition of vegetation

Orbit Characteristics: Polar, 833-870 km. altitude, 7 a.m. and 2 p.m. equator crossing times

Payload Characteristics:

Sensors	Applications	No. of Channels/ Frequencies	Spectral Range/ Frequency Range	Resolution	Swath Width
AVHRR/3 * (Advanced Very High Resolution Radiometer)	Cloud Temp., Sea Surface Temp., Land Temp., Vegetation Index	6	0.58-12.5 μm	1.1 km at Nadir 4 km at Edge of Scan	Limb to Limb
HIRS/3 (High Resolution Infrared Sounder)	Temp. and Moisture Profiles, Radiation Budget	20	0.2-15.0 μm	17.4 km	2,240 km
DCS (Argos) (Data Collection System)	Random Access from Buoys, Balloons, and Platforms	N/A	136.77 MHz 137.77 MHz	N/A	N/A
SAR (Search and Rescue)	Search and Rescue Operations	N/A	121.5 MHz 243.0 MHz 406.0 MHz	N/A	N/A
SBUV ψ (Solar Backscatter UV Experiment)	Solar Spectrum, Ozone Profiles, Earth Radiance Spectrum	12	252.0-339.8 nm	169.3km	Nadir Viewing
SEM (Space Environment Monitor)	Measurements of Solar Protons, Alpha Particles, "e" Flux Density	N/A	N/A	N/A	N/A
AMSU-A (Advanced Microwave Sounding Unit-A)	All-weather Temp. Profiles	15	23.0-90.0 GHz	40 km	2,240 km
AMSU-B (Advanced Microwave Sounding Unit-B)	All-weather Atmospheric Profiles (Water Vapor, Precipitation, and Ice)	5	90.0-183.0 GHz	15 km	2,240 km

N/A: Not Applicable.
* Channels 3a and 3b are time-shared.
ψ Operates from Noon to Midnight.

Table 25: Geostationary Operational Environmental Satellite (GOES) 1989-2000 Launches, U.S.A.

Objectives of Mission: Operational weather data, cloud cover, temperature profiles, real-time storm monitoring, severe storm warning, sea surface temperature

Orbit Characteristics: Geostationary at east and west longitudes

Payload Characteristics:

Sensor	Applications	No. of Channels/ Frequencies	Spectral Range/ Frequency Range	Resolution	Swath Width
Imager	Imaging	5	0.55-12.5 μm	1 km-Vis 4 or 8 km-IR	Selectable Areas
Sounder	Atmospheric Sounding Temp. and Moisture Profiles	19	3.7-14.7 μm	4-8 km	Selectable Areas
DCS (Data Collection System)	Random Access from Buoys, Balloons, and Platforms	N/A	136.77 MHz 137.77 MHz	N/A	N/A
SEM (Space Environment Monitor)	Measurements of Solar Protons, Alpha Particles, "e" Flux Density	N/A	N/A	N/A	N/A
SAR (Search and Rescue)	Search and Rescue Operations	N/A	406.0 MHz	N/A	N/A

N/A: Not Applicable.

Table 26: Landsat 6 Earth Observation Satellite Company (EOSAT) 1989-92 Launches, U.S.A.

Objectives of Mission: Operational and commercial data, land use inventory, geological/mineralogical exploration, crop and forestry assessment, cartography

Orbit Characteristics: Sun-synchronous, 705 km. altitude, 98.21 degree inclination, 9:45 a.m. equator crossing time, 16-day repeat cycle

Payload Characteristics:

Sensor	Applications	No. of Channels/ Frequencies	Spectral Range/ Frequency Range	Resolution	Swath Width
ETM (Enhanced Thematic Mapper)	Land Use, Urban Planning, Mapping, Agriculture, Forestry, Water Resources, Geology	8	0.45-12.5 μm	15 m-Panchromatic 30 m-Vis/Near-IR 30 m-Shortwave-IR 120 m-Thermal-IR	185 km

Table 27: Upper Atmosphere Research Satellite (UARS) 1991 Launch, U.S.A.

Objectives of Mission: Coordinated measurement of major upper atmospheric parameters

Orbit Characteristics: 57 degree inclination, 600 km. altitude

Payload Characteristics:

Sensor	Applications	No. of Channels/ Frequencies	Spectral Range/ Frequency Range	Resolution	Coverage
CLAES (Cryogenic Limb Array Etalon Spectrometer)	Global Synoptic Measurement of Nitrogen and Chlorine Ozone Destructive Species, Minor Constituents Temperature	8 Spectrally Scanned Channels	3.5-12.7 μm	2.8 km (Limb) 0.25 cm^{-1} (Spectral)	50.7 km (Vertical Limb Coverage)
HALOE (Halogen Occultation Experiment)	Stratospheric Gas Species Concentrations	8 Fixed Channels	2.4-10.3 μm	2 km (Limb) (Gas filter-spectral)	6-150 km (Vertical Limb Coverage)
HRDI (High Resolution Doppler Imager)	Middle Atmospheric Winds	1 Spectrally Scanned Channel	400-800 nm	4 km (Limb) 0.001 nm (Spectral)	5-100 km (Vertical Coverage)
ISAMS (Improved Stratospheric and Mesospheric Sounder)	Atmospheric Temp. and Species Concentration	8 Spectrally Scanned Channels	4.6-16.6 μm	2.6 km (Limb) (Pressure Modulator-Spectral)	65 km (Vertical Limb Coverage)
MLS (Microwave Limb Sounder)	Vertical Profiles of Ozone and Oxygen, Wind Measurements, Inferred Pressure	3 Spectrally Scanned Channels	63-206 GHz	3 km (Limb) 50 mHz (Spectral)	15-85 km (Vertical Limb Coverage)
PEM (Particle Environment Monitor)	Precipitating Charged Particle Entry Measurements for Atmosphere	4 Measurements (Electrons, Protons, X-Rays, Magnetic Field)	1 eV-5 MeV (Electrons) 1 eV-150 MeV (Protons)	N/A	In Situ
SOLSTICE (Solar/Stellar Irradiance Comparison Experiment)	Solar Spectral Irradiance	3 Spectrally Scanned Channels	115-A30 nm	Solar-0.12 and 0.25 nm Stellar-0.5 and 0.10 nm	Solar/Stellar Pointing
SUSIM (Solar-UV Spectral Irradiance Monitor)	Solar Flux Changes	7 Fixed and Spectrally Scanned Channels	120-400 nm	0.1 nm 1.0 nm 5.0 nm	Solar Pointing
WINDII (Wind Imaging Interferometer)	Doppler Shift of Energy, Upper Atmospheric Winds	1 Spectrally Scanned Channel	550-780 nm	4 km (Limb) 1 nm (Spectral)	70-310 km (Vertical Limb Coverage)
ACRIMII (Active Cavity Radiometer Irradiance Monitor)	Total Solar Irradiance	3 Fixed Channels	0.001-1,000 μm	Broadband	Solar Pointing

N/A: Not Applicable.

Table 28: Ocean Topography Experiment (TOPEX)/Poseidon* 1991 Launch, U.S.A.

Objectives of Mission: Ocean topography, ocean current signatures

Orbit Characteristics: 1,334 km., 63.1 degree inclination, nominally circular orbit, 10-day repeat within 1 km.

Payload Characteristics:

Sensor	Applications	No. of Channels/ Frequencies	Spectral Range/ Frequency Range	Resolution	Swath Width
ALT (Dual Frequency Altimeter)	Sea Surface Topography Wave Height, Scalar Wind Speed, Content of Electron Ionosphere	2	13.6 GHz 5.3 GHz	1-3 cm (Vertical) 20 km x (2-10 km) (Horizontal) (Depending on Sea State)	2-10 km (Depending on Sea State)
Nonscanning Microwave Radiometer	Water Vapor Correction for Altimeter	3	18 GHz 21 GHz 37GHz	42 km 35km 22km	42 km 35 km 22 km
Laser Retroreflector Array	Tracking by Ground Based Lasers for Precision Orbit Determination	N/A (Passive)	N/A	N/A	N/A
TRANET Doppler Beacon	Tracking by Ground Based Receivers for Precision Orbit Determination	2	150 mHz 400 mHz	N/A	N/A
GPS Demonstration Receiver	Tracking to GPS Satellites	2 (Passive)	1,227 mHz 1,575 mHz	N/A	N/A
Solid State Altimeter	Sea Surface Topography, Wave Height, Scalar Wind Speed	1	13.65 GHz ±165 MHz	cm (Vertical) 7 km x (2-10 km) (Horizontal) (Depending on Sea State)	2-10 km (Depending on Sea State)
Dual Doppler Receiver (Doris)	Tracking by Ground Based Transmitters for Precise Orbit Determination	2	401.25 mHz 2,036.25 mHz	N/A	N/A

N/A: Not Applicable.
* Potential partnership with France

Table 29: Geopotential Research Mission (GRM)*ψ
1994 Launch, U.S.A.

Objectives of Mission: Measure gravity and magnetic fields for tectonophysics; mantle convection; internal structure and composition; crustal magnetic anomalies; and main magnetic field models

Orbit Characteristics: 160 km. circular, polar, 90 degree inclination

Payload Characteristics:

Sensor	Applications	No. of Channels/ Frequencies	Spectral Range/ Frequency Range	Resolution	Swath Width
Doppler Tracking system	Satellite-to-Satellite Tracking	2	420 GHz 91 GHz	100 km	N/A
DISCOS (Disturbance Compensation System)	Drag-Free Orbit	N/A	N/A	N/A	N/A
Magnetometers (Scalar and Vector)	Magnetic Field Measurements	TBD	TBD	100 km	TBD

* NASA is exploring the possibility of forming a joint mission with the European Space Agency
ψ Not included in the President's FY88 budget.
N/A: Not Applicable; TBD: To Be Decided.

Table 30: Magnetic Field Explorer (MFE)*ψ
Mid-1990s Launch, U.S.A.

Objectives of Mission: Measurement of Earth's main magnetic field

Orbit Characteristics: 600 km. circular, 97 degree inclination

Payload Characteristics:

Sensor	Applications	No. of Channels/ Frequencies	Spectral Range/ Frequency Range	Resolution	Swath Width
Scalar Magnetometer	Measurements of Earth's Surface and Interior Magnetic Fields	TBD	TBD	50 km	N/A
Vector Magnetometer	Measurements of Earth's Surface and Interior Magnetic Fields	TBD	TBD	50 km	N/A

* NASA is exploring the possibility of forming a joint mission with the European Space Agency
ψ Not included in the U.S. FY88 budget.
N/A: Not Applicable; TBD: To Be Decided.

Table 31: ESA Earth Remote Sensing Satellite (ERS-1) 1989 Launch with follow-ons, European Space Agency (ESA)

Objectives of Mission: Provide all-weather imagery of oceans, coastal water ice fields, and land areas

Orbit Characteristics: Sun-synchronous, 777 km. altitude, 10:30 a.m. equator crossing time, 3-day repeat cycle

Payload Characteristics:

Sensor	Applications	No. of Channels/ Frequencies	Spectral Range/ Frequency Range	Resolution	Swath Width
AMI-SAR Mode (Active Microwave Instrument-Synthetic Aperture Radar)	Ice Topography, Geologic Structures, Wind Fields, Wave Spectra	1	5.3 GHz	30 m	100 km
AMI-Wave Mode (Wave Spectrometer)	Wave Direction, Wave Length	1	5.3 GHz	25 m	5 km x 5 km (Every 100 km)
AMI-Wind Mode (Active Microwave Instrument-Wind Scatterometer)	Surface Winds	1	5.3 GHz	50 km	500 km
ATSR-M Radiometer (Along Track Scanning Radiometer)	Sea Surface Temperature, Atmospheric Water Vapor Content	3	3.7-12.0 μm	1 km	500 km
ATSR-M Sounder (Along Track Scanning Radiometer with Microwave Sounder)	Atmospheric Profiles	2	23.8 GHz 36.5 GHz	22 km	500 km
PRARE (Precise Range and Range Rate Equipment)	Precise Orbit Determination	3	2.25 GHz 7.2 GHz 8.4 GHz	N/A	N/A
ALT (Radar Altimeter)	Sea Surface Topography	1	13.5 GHz	0.5 m (Wave Height)	Nadir Viewing

N/A: Not Applicable.

Table 32: Radarsat 1992 Launch, Canada

Objectives of Mission: High-resolution studies of arctic area, agriculture, forestry, and water resource management; ocean studies

Orbit Characteristics: Sun-synchronous, 1,000 km. altitude, 99.48 degree inclination, 3-day repeat cycle

Payload Characteristics:

Sensor	Applications	No.of Channels/ Frequencies	Spectral Range/ Frequency Range	Resolution	Swath Width
SAR (Synthetic Aperture Radar)	Ice Topography	1	C or L Band	15-30 m	100 km
AVHRR* (Advanced Very High Resolution Radiometer)	Sea Surface Temp.	5	0.58-12.5 μm	1.1 km	2,940 km
RSCAT* (Radarsat Scatterometer)	Ocean Surface Wind Speed and Direction	1	14 GHz	25 km	600 km (Each Side)
Optical Sensor	TBD	TBD	TBD	TBD	TBD

TBD: To Be Decided.
* Proposed NOAA contributions

Table 33: Laser Geodynamics Satellite-2 (LAGEOS-2) 1993 Launch, Italy

Objectives of Mission: Measure changes in plate tectonic motions

Orbit Characteristics: Cicular orbit with 52 degrees inclination, 600 km. altitude

Payload Characteristics:

Sensor	Applications	No. of Channels/ Frequencies	Spectral Range/ Frequency Range	Resolution	Swath Width
Passive Laser Cornucube Reflectors	Measure Range to Satellite	N/A	N/A	N/A	N/A

N/A: Not Applicable.

Table 34: Space Station Polar Platform NASA Earth Observing System (EOS) Candidate Instruments 1994 Launch, U.S.A.

Objectives of Mission: Provide Earth observation capability in the atmospheric, oceanographic, and land sciences, and in solar terrestrial research

Orbit Characteristics: 824 km. altitude, 1 -1:30 p.m. and 9:30 a.m. equator crossing time, ascending node 2-day repeat cycle

Payload Characteristics:

Sensor	Applications	No. of Channels/ Frequencies	Spectral Range/ Frequency Range	Resolution	Swath Width
MODIS-N (Moderate Resolution Imaging Spectrometer-Nadir)	Surface (Land) and Cloud Imaging	36	0.4-14.2 μm	0.5-1.0 km	1,500 km at 824 km altitude
MODIS-T (Moderate Resolution Imaging Spectrometer-Tilt)	Surface (Ocean) and Cloud Imaging	64	0.4-1.1 μm	1 km	1,500 km at 824 km altitude
HIRIS (High Resolution Imaging Spectrometer)	Surface Imaging	196	0.4-2.2 μm	30 m	26 km
LASA (LIDAR Atmospheric Sounder and Altimeter-First Phase of the Laser Instrument Initiative)	Altimetry Cloud Top Height, Planetary Boundary Layer, Stratospheric and Tropospheric Aerosols, and Cloud Parameters	Multiple	UV Vis, and Near-IR	Vertical Profiles to better than 2 km	Nadir Only
LASA-MOD (LIDAR Atmospheric Sounder and Altimeter-Second Phase of the Laser Instrument Initiative)	Water Vapor Column Content, Ozone Column Content, Water Vapor Profiles, Ozone Profiles	Multiple	UV, Vis, and Near-IR	Vertical Profiles to better than 2 km	TBD
GLRS (Geodynamic Laser Ranging System)	Geological Drift	1	Vis	cm-level accuracy	Pointable
SAR (Synthetic Aperture Radar)	Land, Ice, and Ocean Images	3	5.3 GHz (C Band) 9.6 GHz (X Band) 1.25 GHz (L Band)	30 m	25-100 km
Radar Altimeter	Ocean and Ice Topography	1	5.3 GHz 13.5 GHz	3 cm RMS Precision Height	63 km 24 km
Scatterometer	Vector Wind Field	1	13.995 GHz	2 m/s Wind Speed 10% Angular Resolution	120-700 km from subsatellite point
LAWS (Laser Atmospheric Wind Sounder)	Tropospheric Winds	1	9-11 μm	1 m/s	300 km

Note: EOS information is subject to change based on ongoing studies.

Table 35: Space Station Polar Platform (cont.)
NASA Earth Observing System (EOS) Candidate Instruments 1994 Launch, U.S.A.

Objectives of Mission: Provide Earth observation capability in the atmospheric, oceanographic, and land sciences, and in solar terrestrial research

Orbit Characteristics: 824 km. altitude, 1 -1:30 p.m. and 9:30 a.m. equator crossing time, ascending node 2-day repeat cycle

Payload Characteristics:

Sensor	Applications	No. of Channels/ Frequencies	Spectral Range/ Frequency Range	Resolution	Swath Width
NCIS (Nadir Climate Interferometer Spectrometer)	Tropospheric Composition of CH4, H_2O, NO_3	Multiple	6-40 μm	Total Column Density to 1 km; 0.1° to 1 ° horizontal	Nadir TBD
CR (Correlation Radiometer)	Tropospheric Composition of CO	2	4.66 μm	Total Column Density to 1 km; 0.1° to 1° horizontal	4.4° field of view ±5 ° to Nadir
TIMS (Thermal Infrared Imaging Spectrometer)	Surface Imaging	2	3-14 μm	30 m	25 km
MLS (Microwave Limb Sounder)	Upper Atmospheric Composition of ClO, O_3, and many others	17	63-240 GHz	3 km vertical	Limb
F/P-INT (Fabry-Perot Interferometer)	Upper Atmospheric Winds	20	0.3-0.8 μm	3 km vertical	Limb
AMSR (Advanced Microwave Scanning Radiometer)	Precipitation, Snow and Ice, Sea Surface Temperature, Water Vapor	12	6-40 GHz	5 to 20 km Ground Resolution	1,500 km at 824 km Altitude
ESTAR (Electronically Steered Thinned Array Radiometer)	Soil Moisture	Multiple	1.4-6 GHz	10 km Ground Resolution at Nadir	1,000 km
IR Radiometer	Upper Atmosphere Composition of O_3, N_2O, Temp., and Wind	Multiple	8-25 μm	TBD	Limb 100 x 1.9° Field of View
PMR (Pressure Modulated Radiometer)	Upper Atmosphere Composition of CO, H_2O, CH_4, NO, NO_2, N_2O, C02, HNO_3, O_3, Temp., Aerosols	5	4.6 μm 16.7 μm	2.6 km Vertical at Limb	Limb
Submillimeter Spectrometer	Upper Atmosphere Composition of OH, HCl etc.	Multiple	0.05-0.1 cm	TBD	Limb 1.6 x 60° Field of View

Note: EOS information is subject to change based on ongoing studies.
TBD: to be decided.

Table 36: Space Station Polar Platform (cont.) NASA Earth Observing System (EOS) Candidate Instruments 1994 Launch, U.S.A.

Objectives of Mission: Provide Earth observation capability in the atmospheric, oceanographic, and land sciences, and in solar terrestrial research

Orbit Characteristics: 824 km. altitude, 1:30 p.m. and 9:30 a.m. equator crossing time, ascending node 2-day repeat cycle

Payload Characteristics:

Sensor	Applications	No. of Channels/ Frequencies	Spectral Range/ Frequency Range	Resolution	Swath Width
VIS/UV (UV Visible Spectrometer)	Upper Atmosphere Neutral and Ionized Atoms	Multiple	300-1,200A	TBD	Limb 30° Cone Angle
CLS (Cryogenic Interferometer/ Spectrometer)	Upper Atmosphere Winds and Oxygen Thermal Emissions	Multiple	2.5 μm–1 mm	Horizontal 80 km x 300 km Vertical 3.5 km	Limb 20-150 km
ERBI (Earth Radiation Budget Instrument)	Radiation Monitor	5	0.2-50 μm	N/A	Limb to Limb
PEM (Particle Environment Monitor)	Magnetospheric Energy Input to Atmosphere	Multiple	N/A Multiple Energy Ranges for Electrons, Protons, X-Rays, and Magnetic Field	N/A	N/A
SUSIM (Solar Ultraviolet Spectral Irradiance Monitor)	Solar Irradiance	8	Variable	N/A	N/A
ADCLS (Argos +) Advanced Data Collection and Location System	Random Access from Buoys, Balloons, and Platforms	N/A	N/A	Location to 1 km Velocity to .3 m/s	N/A

Note: EOS information is subject to change based on ongoing studies;
N/A: not applicable
TBD: to be decided.

Table 37: Space Station Polar Platform NOAA Operational Payload/Candidate Instruments 1994 Launch, U.S.A.

Objectives of Mission: Provide Earth observation capability in the operational atmospheric, and meteorological solar, terrestrial, and oceanic applications

Orbit Characteristics: 850 km. circular Sun-synchronous orbit, 9 a.m. or 1:30 p.m. equator crossing times

Payload Characteristics:

Sensor	Applications	No. of Channels/ Frequencies	Spectral Range/ Frequency Range	Resolution	Swath Width
MRIR (Medium Resolution Imaging Radiometer)	Precipitation, Cloud Patterns, Earth Radiation Balance, Sea Surface Temperature, Currents and Circulation, Sea Ice, Coastal/ Estuarine Sediments, Vegetation Classification and Condition, Land Use, Pollution	10	.45-12.5 μm	250 m	2,940 km
AMSU-A (Advanced Microwave Sounding Unit-A)	Atmospheric Temperature Sounding	15	23.8-89 GHz	40 km	2,230 km
AMSU-B (Advanced Microwave Sounding Unit-B)	Atmospheric Water Vapor Sounding	5	89-183 GHz	15 km	2,230 km
HIRS/3 (High Resolution Infrared Sounder)	Atmospheric Temp. and Water Vapor Profiles	13	3.76-14.49 cm^{-1}	10 km	2,230 km
ATSR (Infrared SST)	Sea-Surface Temperature	3	3.7, 11, 12 μm	1 km	500km
AMSR (Advanced Microwave Scanning Radiometer)	Cloud Moisture Content, Precipitation, All-Weather Sea Surface Temperature, Sea Surface Winds and Waves, Soil Moisture	12	6-90 GHz	20 km-at 6 GHz 2 km-at 90 GHz	120° Centered on Satellite Ground Track
Scatterometer	Sea Surface Winds and Waves, Currents and Circulation	1	13.995 GHz	25 km	600 km to Each Side Beginning 175 km from Nadir
Altimeter	Sea Surface Winds and Waves, Significant Wave Height, Currents and Circulation, Sea Ice	1	13.5 GHz	2.1° Beam Width	Nadir-Pointing
MEPED (Medium Energy Proton and Electron Detector)	Protons, Electrons, and Ions	N/A	30-80 KeV	N/A	N/A
Precipitating Electron, Proton, and Cumulative-Dose Spectrometer	Electron and Proton Dose	8	e--1-10 MeV p--20-75 MeV 30eV-30 KeV (cum. dose)	N/A	N/A
Ionospheric Plasma Monitor	Ambient Electron and Ion Density and Temperature	N/A	N/A	N/A	N/A

Table 38: Space Station Polar Platform (cont.)
NOAA Operational Payload/Candidate Instruments
1994 Launch, U.S.A.

Objectives of Mission: Provide Earth observation capability in the operational atmospheric, and meteorological solar, terrestrial, and oceanic applications

Orbit Characteristics: 850 km. circular Sun-synchronous orbit, 9 a.m. or 1:30 p.m. equator crossing times

Payload Characteristics:

Sensor	Applications	No. of Channels/ Frequencies	Spectral Range/ Frequency Range	Resolution	Swath Width
Scanning Gamma and X-ray Sensor	X-ray Intensity as a Function of Energy	N/A	2 KeV- < 100 KeV	N/A	N/A
X-ray Energy Detector	Energy	N/A	25-115 KeV	N/A	N/A
GOMR (Global Ozone Monitoring Radiometer)	Global Ozone	13	339.8-380 nm	169 km	169 km
ERBL (Earth Radiation Budget Instrument)	Earth Radiation Balance	8	0.2-50 μm	68 km	3,000 km
Argos DCPL (Data Collection and Platform Location)	Random Access from Buoys, Balloons, and Platforms	1	401.65 MHz	N/A	N/A
SARSAT (Search and Rescue Satellite-Aided Tracking)	Search and Rescue	3	121.5 MHz 243 MHz 406.025 MHz	N/A	N/A
TED (Total Energy Detector)	Total Energy of Precipitating Magnetospheric Electrons and Protons	N/A	0.3-20 KeV	N/A	N/A

N/A: Not Applicable.

Table 39. European Polar-Orbiting Platform 1995 Launch, E.S.A.

Objectives of Mission: Long-term comprehensive research, operational, and commercial Earth observations

Orbit Characteristics: Sun-synchronous, 850 km. (25 km.), 9:30-10:30 a.m. equator crossing time, descending node

Payload Characteristics:

Sensor	Applications	No. of Channels/ Frequencies	Spectral Range/ Frequency Range	Resolution	Swath Width
AMSU-A (Advanced Microwave Sounding Unit-A)	Atmospheric Temperature Profiles	15	23-89 GHz	50 km	2,250 km
AMSU-B (Advanced Microwave Sounding Unit-B)	Atmospheric Water Vapor Profiles	5	89-183 GHz	15 km	2,250 km
AOCM (Advanced Ocean Color Monitor)	Observe Optical Parameters of the Oceans	8	Visible and near infrared	250 m	1,140 km
ARA (Advanced Radar Altimeter)	Measure Wave Height, Wind Speed, Sea Surface Topography, and Shape of the Geoid	TBD	13.8 GHz	20 km (Nadir)	TBD
ARGOS	Data Collection and Location	N/A	401 MHz	N/A	N/A
ATLID (Atmospheric Lidar)	Atmospheric Parameters in the Middle and Lower Atmosphere	TBD	1.06 or 1.53 μm	10-50 km (Horizontal) 0.5 km (Vertical)	TBD
AVHRR (Advanced Very High Resolution Radiometer)	Cloud Temperature, Sea Surface Temperature, Land Temperature, Vegetation Index	6	0.63 and 12.0 μm	1.1 km	2,900 km (Crosstrack)
CCR (Corner Cube Reflector)	Orbit Determination	N/A	N/A	N/A	N/A
DF SAR (Dual Frequency SAR)	High Resolution Imaging of Land, Ice, and Coastal Zones	2	5.3 GHz and L or X band	TBD	200 km
HIRS-2 (High Resolution Infrared Radiation Sounder)	Vertical Temperature and Humidity Profiles of the Lower Atmosphere	20	3.8-14.5 μm	10 km	2,300 km (Crosstrack)
HRIS (High Resolution Imaging Spectrometer)	Surface Imaging	10	0.4-1.0 μm	20 m	60 km
HROI (High Resolution Optical Imager)	Land Applications	4	0.45-0.90 μm 1.6 and 2.1 μm	25 m	200 km
PPS (Precise Positioning Systems)	Orbit Determination	TBD	TBD	N/A	N/A
WINDSCAT (Wind Scatterometer)	Sea Surface Wind Speed and Direction	2	14 GHz 5.3 GHz	25 km	1,000 km

N/A: not applicable
TBD:to be decided.

This table represents the initial orbit configuration required for the European Polar-Orbiting Platform as given in the ESA report on Earth Observation Reauirements for the Polar Orbiting Platform Elements of the International Space Station, 1986, p. 36. European Polar Platform payload groupings are subject to change based on ongoing studies, changes in requirements, and priorities.

Appendix B: *Remote Sensing Organizations*

Appendix B.1: *Equipment Firms*

Adage, Inc.
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508/667-7070
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Contact: Mr. David L. Milgram

Aero Service
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Houston TX 77042
713/784-5800
Contact: Ms. Cynthia Sheehan

Alliant Computer Systems Corporation
One Monarch Road
Littleton MA 01460
508/486-4950
Contact: Mr. Peter Mascucci

Ameridian International, Inc.
P.O. Box 468
Amherst OH 44001
216/282-2011
Contact: Mr. Neil P. Yingling

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703/658-4000
Contact: Mr. William J. Cox

Baymont Engineering Inc.
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813/539-1661
Contact: Mr. Tony Blunt

Computer Sciences Corporation
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Contact: Mr. Ferron H. Risinger

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Environmental Research Institute
of Michigan (ERIM)
P.O. Box 8618
Ann Arbor MI 48107
313/994-1200
Contact: Mr. Larry Reed

Environmental Systems Research
Institute (ESRI)
380 New York Street
Redlands CA 92373
714/793-2853
Contact: Mr. S. J. Camarata

Geo Decisions, Inc.
211 W. Beaver Ave.
State College PA 16801
814/234-8625
Contact: Mr. Barry Evans

Geo Information Services, Inc.
P.O. Box 801
Starkville MS 39759
601/325-3279
Contact: Mr. W. Frank Miller

GeoGraphics
1318 Alms Drive
Champaign IL 61820
217/351-3154

GeoSpectra Corporation
P.O. Box 1387
Ann Arbor MI 48106
313/994-3450
Contact: Dr. Robert K. Vincent

GeoVision Systems, Inc.
5251 DTC Parkway, Suite 200
Englewood CO 80111
303/796-8200
Contact: Mr. Perry Evans

Geogroup Division of Manatron, Inc.
2560 Ninth St., suite 319
Berkeley CA 94710
415/549-7030
Contact: Mr. Joe Nicholson

GeoSpatial Solutions, Inc.
2450 Centro Avenue, suite E-1
Boulder CO 80301
303/442-2165
Contact: Dr. James Maslanik

Gould/ICD
(Imaging and Graphics Division)
46360 Fremont Blvd.
Fremont CA 94538
415/498-3200
Contact: Mr. Arif Janjua

Hunter GIS, Inc.
1121 Woodridge Center Drive, Suite 17
Charlotte NC 28217
704/357-3023
Contact: Ms. Pamela McCray

IBM Scientific Center
P.O. Box 10500
Palo Alto CA 94303
415/855-4155
Contact: Mr. H. J. Myers

INTERA Technologies Ltd.
101 6th Avenue Southwest, Suite 2500
Calgary, Alberta Canada T2P-3P4
403/266-0900
Contact: Mr. Marc Wride

Imaging Technology, Inc.
600 West Cummings Park
Woburn MA 01801
617/938-8444
Contact: Ms. Betsy Minich

Intergraph Corporation
One Madison Industrial Park
Huntsville AL 35807
205/772-2000
Contact: Mr. David Joffrion

International Imaging Systems (I^2S)
1500 Buckeye Drive
Milpitas CA 95035
408/432-3400
Contact: Mr. Eugene Gottesmann

Litton/Itek Optical Systems
10 Maguire Road
Lexington MA 02173-3199
617/276-2696
Contact: Mr. Dick Wollensak

Lockheed Engineering
& Sciences Company
1050 East Flamingo Road, suite 126
Las Vegas NV 89119
702/798-3155
Contact: Mr. Mark Olsen

Lockheed Engineering
& Sciences Company
Stennis Space Center, Building 1103
Stennis Space Center MS 39529
601/688-3095
Contact: Mr. Paul A. Caradec

Logica Technology Systems, Inc.
372 Washington St.
Wellesley Hills MA 02181
617/235-2424
Contact: Mr. Patrick Farley

MacDonald Dettwiler and Assoc., Ltd.
1876 Foxstone Drive
Vienna VA 22180
703/938-3995

MATRA Technology, Inc.
5300 Stevens Creek Blvd. Suite 420
San Jose, CA 95129
408/243-7170

Media Cybernetics
8484 Georgia Avenue, Suite 200
Silver Spring MD 20910
301/495-3305
Contact: Ms. Pam Kerwin

MTL Systems, Inc.
3481 Dayton-Xenia Road
Dayton OH 45431
513/426-3111
Contact: Mr. Ray Wabler

MK - Environmental Services
P.O. Box 7808
Boise ID 83729
208/386-5000
Contact: Mr. Kim Johnson

Noel Associates
P.O. Box 27730
Albuquerque NM 87125
505/243-8454 or 344
Contact: Mr. Jack Noel

Optronics/An Intergraph Division
7 Stuart Road
Chelmsford MA 01824
508/256-4511
Contact: Mr. Terry Wellman

PIXAR
3240 Kerner Blvd.
San Rafael CA 94901
415/499-3600
Contact: Ms. Barbara Koalkin

Perceptics Corporation
Pellissippi Parkway Center 725
Knoxville TN 37922
615/966-9200
Contact: Mr. Mike Howard

Petroconsultants
6600 Sandspoint Drive
P.O. Box 740619
Houston TX 77274-00619
713/658-0553
Contact: Mr. Ricardo J. Sotto

Ramtek Corporation
1525 Atteberry Lane
San Jose CA 95131
408/988-2211
Contact: Mr. Terry L. Babineaux

Recognition Concepts, Inc. (RCI)
P.O. Box 8510
Incline Village NV 89450
702/831-0473
Contact: Mr. Steve Meaders

Remote Sensing Consultants
860 Tolman Drive
Stanford CA 94305
415/723-3262
Contact: Dr. R. J. P. Lyon

SEP/SNECMA, Inc.
1825 South Grant Street, Suite 240
San Mateo, CA 94402
415/345-7997

Spectral Data Corporation
P.O. Box 615
Northport NY 11768
516/754-4850
Contact: Dr. Edward Yost

ST Systems Corporation (STX)
4400 Forbes Blvd.
Lanham MD 20706
301/794-5002
Contact: Mr. Mark Labovitz

SYNECTICS
10400 Eaton Place
Fairfax VA 22030
703/385-0190
Contact: Mr. James W. Altman

Terra-Mar Resource Info. Services
1937 Landings Drive
Mountain View CA 94043
415/964-6900
Contact: Mr. Donn C. Walklet

The Analytic Sciences Corporation (TASC)
55 Walkers Brook Drive
Reading MA 01867
617/942-2000
Contact: Dr. Tom Robertson

3M Corporation/Comtal
505 West Woodbury Road
Altadena 91001
818/798-1100
Contact: Mr. Ron Clothier

Unisys Defense Systems
5151 Camino Ruiz, M/D 01-C206
Camarillo CA 93011
805/987-6811
Contact: Mr. David J. Vandaveer

VEXCEL Corporation
2477 55th Street
Boulder CO 80301
303/444-0094
Contact: Dr. Franz W. Leberl

Vicom Systems, Inc.
2520 Junction Avenue
San Jose CA 95134
408/432-8660
Contact: Mr. David Mei

Appendix B.2: *Imaging and Equipment Firms*

Aero Service
3600 Briarpark Drive
Houston TX 77042
713/784-5800
Contact: Ms. Cynthia Sheehan

Ameridian International, Inc.
P.O. Box 468
Amherst OH 44001
216/282-2011
Contact: Mr. Neil P. Yingling

The Analytic Sciences Corp (TASC)
55 Walkers Brook Drive
Reading MA 01867
617/942-2000
Contact: Dr. Tom Robertson

Autometric, Inc.
5301 Shawnee Road
Alexandria VA 22312-2312
703/658-4000
Contact: Mr. William J. Cox

Computer Sciences Corporation
8728 Colesville Road
Silver Spring MD 20910
301/589-1545
Contact: Mr. Clinton A. Frum

DBA Systems
P.O. Drawer 550
Melbourne FL 32902
305/727-0660
Contact: Ms. Melody van Gorder

Decision Images
1000 Herrontown Road
Princeton NJ 08540
609/683-0234
Contact: Mr. Bob Mills

Delta Data Systems, Inc. (DDS)
321 North Curran Avenue
Picayune MS 39466
601/799-1813
Contact: Mr. Ferron H. Risinger

ESL, Inc.
495 Java Drive
Sunnyvale CA 94086
408/738-2888
Contact: Mr. Eugene Greer

ERDAS, Inc.
(Earth Resources Data Analysis)
2801 Buford Highway
Atlanta GA 30329
404/872-7327
Contact: Mr. Timothy Mullen

Environmental Research Institute
of Michigan (ERIM)
P.O. Box 8618
Ann Arbor MI 48107
313/994-1200
Contact: Mr. Larry Reed

Geo Decisions, Inc.
211 W. Beaver Ave.
State College PA 16801
814/234-8625
Contact: Mr. Barry Evans

GeoSpectra Corporation
P.O. Box 1387
Ann Arbor MI 48106
313/994-3450
Contact: Dr. Robert K. Vincent

GeoVision Systems, Inc.
5251 DTC Parkway, Suite 200
Englewood CO 80111
303/796-8200
Contact: Mr. Perry Evans

Geogroup Division of Manatron, Inc.
2560 Ninth St., Suite 319
Berkeley CA 94710
415/549-7030
Contact: Mr. Joe Nicholson

Geospatial Solutions, Inc.
882 East Laurel Avenue
Boulder CO 80303
303/442-2165
Contact: Mr. John Szagin

Gould/ICD
(Imaging and Graphics Division)
46360 Fremont Blvd.
Fremont CA 94538
415/498-3200
Contact: Mr. Arif Janjua

IBM Scientific Center
P.O. Box 10500
Palo Alto CA 94303
415/855-4155
Contact: Mr. H. J. Myers

INTERA Technologies Ltd.
101 Sixth Avenue Southwest, Suite 2500
Calgary, Alberta Canada T2P-3P4
403/266-0900
Contact: Mr. Marc Wride

International Imaging Systems (IIS)
1500 Buckeye Drive
Milpitas CA 95035
408/432-3400
Contact: Mr. Eugene Gottesmann

Litton/Itek Optical Systems
10 Maguire Road
Lexington MA 02173-3199
617/276-2696
Contact: Mr. Dick Wollensak

Lockheed Engineering and
Management Services
1050 East Flamingo Road, Suite 126
Las Vegas NV 89119
702/798-3155
Contact: Mr. Mark Olsen

Lockheed Engineering
& Sciences Company
Stennis Space Center, Building 1103
Stennis Space Center MS 39529
601/688-3095
Contact: Mr. Paul Caradec

MTL Systems, Inc.
3481 Dayton-Zenia Road
Dayton OH 45431
513/426-3111
Contact: Mr. John Sikora

MK - Environmental Services
P.O. Box 7808
Boise ID 83729
208/386-5000
Contact: Mr. Kim Johnson

Noel Associates
P.O. Box 2703-A
Albuquerque NM 87107
505/243-8454 or 344
Contact: Mr. Jack Noel

Remote Sensing Consultants
860 Tolman Drive
Stanford CA 94305
415/723-3262
Contact: Dr. R. J. P. Lyon

Spectral Data Corporation
P.O. Box 615
Northport NY 11768
516/754-4850
Contact: Dr. Edward Yost

Terra-Mar Resource Information
Services
1937 Landings Drive
Mountain View CA 94043
415/964-6900
Contact: Mr. Donn C. Walklet

VEXCEL Corporation
2477 55th Street
Boulder CO 80301
303/444-0094
Contact: Dr. Franz W. Leberl

Appendix B.3: *Image Processing and Equipment Firms*

Applied GeoEngineering, Inc.
P.O. Box 188
Applegate CA 95703
916/878-0540
Contact: Mr. Raymond A. Naylor

Barringer Geoservices, Inc.
15000 West 6th Avenue, Suite 300
Golden CO 80401
303/277-1687
Contact: Mr. Alan Klawitter, Sandy Perry

Dames & Moore
455 East Paces Ferry Road
Atlanta GA 30363
404/262-2915
Contact: Mr. Daniel D. Moreno

Denver Mineral Exploration (DEMEX)
1100 West Littleton Blvd., Suite 103
Littleton CO 80120
303/795-6122
Contact: Mr. Dave Procter-Gregg

Donald R. Wiesnet, Consultant
601 McKinley Street, N.E.
Vienna VA 22180
703/281-0216
Contact: Mr. Don Wiesnet

Earth Satellite Corporation
7222 47th St.
Chevy Chase MD 20815
301/951-0104
Contact: Mr. Max Miller

Earth Technology Corporation
100 West Broadway, suite 5000
Long Beach CA 90802
213/495-4449
Contact: Ms. Sally Rasmussen

ESL, Inc.
495 Java Drive
Sunnyvale CA 94086
408/738-2888
Contact: Mr. Eugene Greer

Geophysic International Corporation
9441 LBJ Freeway, suite 504
Dallas, Texas 75243
800/527-7004
Contact: Steve Dickson

Global Exploration Enterprises, Inc.
(GLOBEX)
2404 Paddock Lane
Reston VA 22091
703/620-9392
Contact: Mr. William Douglas Carter

Greenhorn and O'Mara, Inc.
9001 Edmonston Road
Greenbelt MD 20770
301/982-2800
Contact: Mr. Michael Pavlides

Hunting Surveys and Consultants, Inc.
122 E. 42nd St., Suite 1700
New York NY 10168
212/861-6916
Contact: Mr. Dick Brower

International Maritime, Inc. (IMI)
839 South Beacon St., Suite 217
San Pedro CA 90731
213/514-8304
Contact: Mr. Don Walsh

Io Geological Consultants
3041 White Birch Court
Fairfax VA 22031
703/591-9354
Contact: Ms. Michelle Stevens

Kreig, R. A. and Associates, Inc.
1503 W. 33rd Avenue
Anchorage AK 99503
907/276-2025
Contact: Mr. R. A. Kreig

KRS Remote Sensing
A Kodak Company
1200 Caraway Court
Landover, MD 20785
301/772-7800

Landmark Technologies, Inc.
7777 Bayberry Road
Jacksonville, FL 32216
904/730-0321

Lindsay Earth Exploration and Reserach
P.O. Box 17465
Salt Lake City UT 84117
801/277-3141
Contact: Mr. James B. Lindsay

MARS Associates, Inc.
1422 North 44th Street, Suite 109
Phoenix AZ 85008
602/267-8008
Contact: Mr. Ron H. Gelnett

Metrics, Inc.
1845 The Exchange, Suite 140
Atlanta GA 30339
404/955-1975
Contact: Mr. G. William Spann

Moran & Associates, Inc.
501 Hess Avenue, Suite 109
Golden CO 80401
303/526-1405
Contact: Dr. Bob Moran

NP&S Resource Information Specialists
Route 1, Box 339
Blacksburg VA 24060
703/951-0696
Contact: Dr. James L. Smith

NuTec Exploration, Inc.
P.O. Box 3004
Muskogee OK 74402
918/687-5458
Contact: Mr. Paul Yurko

Ocean Earth Construction
& Development Corp.
P.O. Box 1138 Canal Street Station
New York NY 10013
212/473-6778
Contact: Mr. Peter Fend

Orion, Ltd.
10 Desta Drive, Suite LL 120
Midland TX 79705
915/688-3355
Contact: Dr. James Lucas

ORYX Corporation
30 West Century Road
Paramus NJ 07652
201/261-0770
Contact: John Hiller

PetroImage Corporation
12875 West 15th Drive
Golden CO 80401-3501
303/234-0489
Contact: Mr. Lindsey Maness

Petroleum Information Corporation
4100 E. Dry Creek Road
Littleton CO 80122
303/740-7100
Contact: Mr. Tom Murdoch

Photo Science, Inc.
7840 Airpark Road
Montgomery Airpark
Gaithersburg, MD 20879
301/948-8550

Photographic Interpretation Corp
Rural Route #1, Box 187
Thetford Center VM 05075
802/333-9623
Contact: Mr. Vern H. Andersen

Precision Photo Labs, Inc.
P.O. box 14595
5758 N. Webster
Dayton, OH 45414
513/898-7450

Prime Computer, Inc.
500 Old Connecticut Path
Framingham MA 01701
508/879-2960
Contact: Richard Snyder

Satellite Exploration Consultants, Inc.
500 N. Loraine, Suite 1000
Midland TX 79701
915/687-0248
Contact: Mr. Randy Anderson

James W. Sewall Company
147 Center Street
Old Town ME 04468
207/827-4456
Contact: Dr. Mark A. Jadkowski

Solar Energy Research Institute (SERI)
1617 Cole Blvd.
Golden CO 80401
303/231-7238
Contact: Mr. Martin Rymes

Sterling Networks, Inc.
51 Rio Robles
San Jose CA 95134
408/435-5700
Contact: Dr. Paul O. Scheibe

Terra-Map East
13 Dartmouth College Highway
Lyme NH 03768
603/795-4855
Contact: Mr. Roger Arend

Visual Information Technology (VITEC)
3460 Lotus
Plano TX 75075
214/596-5600
Contact: Mr. Bill Morris

Appendix B.4: *U.S. Government Remote Sensing Agencies*

Defense Mapping Agency
6500 Brooks Lane
Washington DC 20315-0030
202/653-1375

Defense Mapping Agency
Inter American Geodetic Survey
Building 144, Fort Sam Houston
San Antonio TX 78234-5000
512/221-5606

Department of Interior
Bureau of Mines
Columbia Plaza, 2401 E. St., MS 6020
Washington DC 20242
202/634-1004

Department of the Interior
U. S. Geology Survey
Branch of Geophysics
Box 25046 MS 964
Denver CO 80225
303/236-1387

Dept. of Interior
Bureau of Land Management
Division of Engineering
730 Premier Bldg., Room 204
Washington DC 20240
202/343-5717

Earth Resources Observation Systems Data Center (EROS)
Mundt Federal Building
Sioux Falls SD 57198
605/594-6511

Goddard Spaceflight Center
National Environmental Satellite, Data and Information Service (NESDIS)
Landsat Operations Division
Code 050, Building 28
Greenbelt MD 20771
301/286-9407

Jet Propulsion Laboratory
4800 Oak Grove Dirve
Pasadena CA 91103

Landsat Group/NOAA
FB-4 Room 2051
Washington DC 20233
301/763-4522

NASA
Earth Resources Laboratory
Stennis Space Center MS 39529
601/688-2211

NASA Ames Research Center
Mail Stop 242-4: Tech Appl Branch
Moffett Field CA 94035
415/694-5897

NASA Ames Research Center/242-2
Technical Government Services
Moffett Field CA 94035
415/694-5000

NASA / Code EE
Office of Space Science & Applications
Earth Science and Application Division
Washington DC 20546
202/453-1706

NOAA
NESDIS
Office of Landsat Commercialization
Washington DC 20233
301/763-4522

NOAA
National Geophysical Data Center
325 Broadway
Boulder CO 80303
303/497-3000

NOAA
Environmental Research Laboratory
Great Lakes Environemtal Research
Laboratoy
2205 Commonwealth Blvd.
Ann Arbor MI 48105
313/668-2253

NOAA/NESDIS
Federal Building, Room 2096
Washington DC 20233
202/377-8090

NOAA/NESDIS, World Weather Group
U. S. Department of Commerce
Room 712
Washington DC 20233
202/443-8910

Nat. Cartographic Information Center
Stennis Space Center, Building 3101
Stennis Space Center MS 39529
601/688-3544

National Polar Oceanography Center
4301 Suitland Road
Washington DC 20390
301/763-7439

National Weather Service
6301 34th Avenue
Minneapolis MN 55450
612/725-6090

U. S. Army Corps of Engineers
P.O. Box 1027
Detroit MI 48231-1027
313/226-6413

U. S. Bureau of Mines
Building 20 Denver Federal Center
Denver CO 80225
303/236-0263

U. S. Bureau of Reclamation
P.O. Box 25007, Fed. Center, D-1524
Denver CO 80225
303/236-8092

U. S. Fish and Wildlife Service
Federal Building, Ft. Snelling
St. Paul MN 55111
612/290-3131

U. S. Forest Service
P.O. Box 906
Starkville MS 39759
601/324-1611

U. S. Geological Survey
2255 Gemini Drive
Flagstaff AZ 86001
602/527-7000

USDA Forest Fire Laboratory
4955 Canyon Crest Drive
Riverside CA 92507
714/351-6523

USDA Survey Research Service
Remote Sensing Br., Room 3839 South
Washington DC 20250
202/447-6201

USDA Soil Conversation Service
P.O. Box 6567
Ft. Worth TX 76115
817/334-4685

USDA
National Agricultural Statistical Service
1400 Independence Ave., SW
Washington DC 20250

U.S. Geological Survey
Director's Office
105 National Center
Reston VA 22092
703/648-4000

Appendix B.5: *Academic Remote Sensing Organizations*

Colorado School of Mines
Department of Geology
Golden CO 80401
303/273-3808

Colorado State University
Inst. for Research in the Atmosphere
Foothills Campus
Ft. Collins CO 80523
303/491-8448

Colorado State University
Range Science Department
Ft. Collins CO 80523
303/491-6677

Columbia University
Lamont-Doherty Geol. Observatory
Route 9W
Palisades NY 10964
914/359-2900

Dartmouth College
Department of Earth Sciences
Hanover NH 03755
603/464-2666

Georgia Tech
School of Geological Science, GA Team
Atlanta GA 30332
404/894-3893

Howard University
Geology/Geography Dept.
P.O. Box 1098
Washington DC 20059
202/636-6925

Kansas State University
Dept. of Agronomy
Evapotranspiration Laboratory
Waters Hall Annex
Manhattan KS 66506
913/532-5731

Kent State University
Department of Geology
Kent OH 44242
216/672-7987

Lab for Applications of Remote Sensing
Purdue Univ., 214 Entymalogy Hall
West Lafayette IN 47907
317/494-6305

Louisiana State University
Cadgis Research Laboratory, Room 216
Baton Rouge LA 70803
504/388-6134

Naval Postgraduate School
Department of Meteorology
Monterey CA 93943
408/646-2516

Northern Illinois University
Department of Geology
312 Davis Hall
Dekalb IL 60115
815/753-0523

Ohio State University
190 West 17th
Columbus OH 43210
614/292-2721

Oregon State University
Environmental Remote Sensing Lab
Corvallis OR 97331
503/754-3056

San Diego State University
Center for Earth Systems Analysis
Department of Geography
San Diego CA 92182
619/594-5466

South Dakota School of Mines
Inst. of Atmospheric Sciences
501 E. St. Joseph Street
Rapid City SD 57701
605/394-2291

South West Texas State University
Dept. of Geography and Planning
San Marcos TX 78666
512/245-2170

Stanford University
Applied Earth Science
310 Mitchell Building
Stanford CA 94305
415/723-0847

State University of New York
1400 Washington Avenue
Albany NY 12222
518/442-4770

Texas A & M Extension Service
Remote Sensing Research Unit
P.O. Box 267
Weslaco TX 78596
512/968-5533

Texas A&M University
Department of Oceanography
College Station TX 77843
409/845-7211

Texas Christian University
Remote Sensing & Energy Research
P.O. Box 30798
Ft. Worth TX 76102
817/921-7273

University of Alaska
Geophysical Institute
C. T. Elvey Building, Room 608
Fairbanks AK 99775-0800
907/474-7558

University of California
Scripps Satellite Oceanography Facility
A-014
La Jolla CA 92093
619/534-2292

University of California
Geography Department
Remote Sensing Research Unit
1629 Ellison Hall
Santa Barbara CA 93106

University of Colorado
Center for Study of Earth from Space
Division of CIRES for Remote Sensing
Boulder CO 80309
303/492-5086

University of Delaware
College of Marine Studies
Newark DE 19716
302/451-2336

University of Florida
Inst. Food & Agricultural Science
700 Experiment Road Station
Lake Alfred FL 33850
813/956-1151

University of Hawaii
Department of Geography
Hilo HI 96720
808/961-9547

University of Illinois at Chicago
Electrical Engineering and Computers
Communications Laboratory
Chicago IL 60680
312/996-5489

University of Kansas
Space Technology Center
Kansas Applied Remote Sensing Program

Lawrence KS 66045-2969
913/864-7720

University of Kansas
Center for Research, Inc.
2291 Irving Hill Road
Lawrence KS 66045-2969
913/864-4835

University of Massachusetts
Digital Image Analysis Lab.
Amherst MA 01003
413/545-2690

University of Michigan
Remote Sensing Laboratory
School of Natural Resources
Ann Arbor MI 48109-1115
313/763-5803

University of Missouri
Department of Atmospheric Science
Institute for Applied Meteorology
Columbia MO 65211
314/882-6591

University of Missouri
Geographic Resources Center
Extension Division
235 Electrical Engineering Building
Columbia MO 65211
314/882-6591

University of Nebraska
Remote Sensing Department
113 Nebraska Hall
Lincoln NE 68588
402/472-7536

University of Nevada-Reno
Mackay School of Mines
Reno NV 89557
702/684-6050

University of New Hampshire
Complex Systems Research Center
Durham NH 03824
603/862-1792

University of New Mexico
Technology Application Center
Albuquerque NM 87131
505/277-3622

University of New Mexico
Technology Application Center
Central Avenue, SE
Albuquerque NM 87131
505/277-3622

University of North Dakota
Department of Geography
Grand Forks ND 58202
701/777-4589

University of Oklahoma
Dept. of Geography
455 W. Lindsey, Rm 805
Norman OK 70319
405/325-5325

University of Rhode Island
Deppartment of Ocean Engineering
Remote Sensing Lab.
Narragansett RI 02882
401/792-6283

University of Rhode Island
Department of Geology
Kingston RI 02881-0807
401/792-2265

University of Southern California
Signal & Image Processing Institute
University Park / Mailcode: 0272
Los Angeles CA 90089-0272
213/743-5515

University of Tennessee
Department of Geography
Knoxville TN 37996
615/974-2418

University of Texas
The Center for Space Research
Bureau of Engineering Research
WRW-402
Austin Tx 78712
512/471-1356

University of Texas-Permian Basin
4901 E. University Blvd.
Odessa TX 79762

University of Wisconsin
CIMSS
Space Science and Engineering Center
1225 W. Dayton St.
Madison WI 53702-5799
608/263-4085

University of Wyoming
Dept. of Geology and Geophysics
Remote Sensing Laboratory
Laramie WY 82071
307/766-2330

Washington University
Earth & Planetary Science
Remote Sensing Lab.
Box 1169
St. Louis MO 63130
314/889-5679

Appendix C: *Remote Sensing Acronyms*

A

ADCLS	Advanced Data Collection and Location System
ADP	Atmospheric Dynamics Program
AFOS	Advanced Field Operations System
AGRISTARS	Agric. & Resources Inventory Surveys Through Remote Sensing
AID	Agency for International Development
AIS	Airborne Imaging Spectrometer
ALT	Altimeter
AMI	Active Microwave Instrument
AMR	Advanced Microwave Radiometer
AMSU	Advanced Microwave Sounding Unit
APT	Automatic Picture Transmission
ASF	Area Sampling Frames
ATN	Advanced TIROS-N
ATS	Applications Technology Satellite
ATSR	Along-Track Scanning Radiometer
AVHRR	Advanced Very High Resolution Radiometer
AVIRIS	Airborne Visible and Infrared Imaging Spectrometer
AWIPS-90	Advanced Weather Interactive Processing System

B

B/W	Black and White
BLM	Bureau of Land Management
BPI	Bits Per Inch; refers to digital data

C

C/C	Cloud Cover; percentage of a scene which is covered by clouds or shadows from clouds
CCD	Charge-Coupled Detector
CCRS	Canadian Center for Remote Sensing
CCT	Computer Compatible Tape; refers to digital image
CDA	Command and Data Acquisition (station)
CE	US Army Corps of Engineers
CEOS	Committee on Earth Observations Satellites
CGMS	Coordination on Geostationary Meteorological Satellites
CIR	Color-Infrared Film
CNES	French National Space Research Center
CNO	Chief of Naval Operations
COPARS	Committee on Practical Applications of Remote Sensing
COPUOS	Committee on the Peaceful Uses of Outer Space (UN)
COSPAR	Committee for Space Research
CRT	Cathode Ray Tube
CW Radar	Continuous Wave Radar
CZCS	Coastal Zone Color Scanner

D

DARPA	Defense Advanced Research Project Agency
DBS	Direct Broadcast System
DCP	Data Collection Platform
DCS	Data Collection System
DMSP	Defense Meteorological Satellite Program
DN	Digital Number
DOC	Department of Commerce
DOD	Department of Defense
DOE	Department of Energy
DOI	Department of the Interior
DOMSAT	Domestic Satellite
DORAN	Doppler Ranging
DOS	Department of State
DPSS	Metsat Data Processing and Services Subsystem
DSB	Direct Sound Broadcast (or Sounder)

E

EDC	EROS Data Center (Earth Resources Observation Systems) EDC is a USGS facility
EDIS	Environmental Data and Information Service
EDR	Environmental Data Records
EDT	Eastern Daylight Time
EMR	Electromagnetic Radiation
EMSS	Emulated Multispectral Scanner; similar to MSS
EOIS	Earth Observation Information System
EOS	Earth Observing System
EOSAT	Earth Observation Satellite Company
EPA	Environmental Protection Agency
ERB	Earth Radiation Budget
ERBE	Earth Radiation Budget Experiment
ERBI	Earth Radiation Budget Instrument
ERBS	Earth Radiation Budget Satellite
ERL	Environmental Research Laboratories
EROS	Earth Resource Observation System
ERS	ESA Remote-Sensing Satellite
ERTS	Earth Resource Technology Satellite (former name for Landsat)
ESA	European Space Agency
ESMR	Electrically Scanning Microwave Radiometer
ETC	Earth Terrain Camera (carried on Skylab)

F

FCC	Federal Communications Commission
FCC	False Color Composite
FLTSATCOM	Fleet Satellite Communications System
FOV	Field of View
FY	Fiscal Year

G

GAC	Global Area Coverage
GARP	Global Atmospheric Research Program
GCP	Ground Control Point
GEMS	Global Environmental Monitoring System
GEODSS	Ground-Based Electro-Optical Deep Space Surveillance
GEOS	Geodynamic Experimental Ocean Satellite

GIS	Geographic Information System
GLONASS	Global Navigation Satellites System
GMS	Geostationary Meteorological Satellite (Japan)
GMT	Greenwich Mean Time
GOES	Geostationary Operational Environmental Satellite (USA)
GOMR	Global Ozone Monitoring Radiometer
GOMS	Geostationary Operational Meteorological Satellite (USSR)
GPS	Global Positioning System
GRID	Global Resources Information Database
GRIS	Global Resource Information System
GSFC	Goddard Space Flight Center
GSTDN	Goddard Standard Tracking Data Network
GTS	Global Telecommunications Service

H

HCMM	Heat Capacity Mapping Mission
HDT	High Density Tape
HIRIS	High Resolution Imaging Spectrometer
HVR	High Resolution Visible Range

I

I/F	Interface
ICSU	International Council of Scientific Unions
IFOV	Instantaneous Field-of-View
IGBP	International Geosphere Biosphere Program
IGY	International Geophysical Year
INMARSAT	International Maritime Satellite Organization
INPE	Brazilian Space Research Institute
INR	Indian Remote Sensing Satellite
INSAT	Indian National Satellite
IOC	Intergovernmental Oceanographic Commission
IPOMS	International Polar-Orbiting Meteorological Satellite
IPS	Image Processing System
IR	Infrared
IRS	Indian Remote-Sensing Satellite
ISRO	Indian Space Research Organization
ITOS	Improved TIROS Operational Satellite

J

JERS	Japanese Earth Remote Sensing Satellite
JPL	Jet Propulsion Laboratory

L

LAC	Local Area Coverage
LACIE	Large Area Crop Inventory Experiment
LAGEOS	Laser Geodynamics Satellite
LANDSAT	Land Remote Sensing Satellite
LASA	LIDAR Atmospheric Sounder and Altimeter
LASE	LIDAR Atmosphere Sensing Experiment
LFC	Large Format Camera
LFMR	Low-Frequency Microwave Radiometer
LGSOWG	Landsat Ground Station Operators Working Group.
LIDAR	Light Detection and Ranging
LITE	Laser In-Space Technology Experiment
LTWG	Landsat Technical Working Group

M

MAGSAT	Magnetic Field Satellite (Earth's field)
METEOR	USSR polar meteorological satellite
METEOSAT	European Meteorological Satellite
MFE	Magnetic Field Explorer
MLA	Multispectral Linear Array
MMIPS	Man/Machine Interactive Processing System
MOMS	Modular Optoelectric Multispectral Scanner
MOS	Marine Observation Satellite
MRIR	Medium Resolution Imaging Radiometer
MSS	Multispectral Scanner

N

N-ROSS	Navy Remote Ocean Sensing System
NAFAX	National Facsimile Network
NAMFAX	National Meteorological Facsimile Network
NASA	National Aeronautics and Space Administration
NASDA	National Space Agency of Japan
NCAR	National Center for Atmospheric Research
NCC	Natural Color Composite
NCC	National Climatic Center
NCDC	National Climate Data Center
NEDRES	National Environmental Data Referral System
NEOC	National Earth Observations Center
NESDIS	National Environmental Satellite, Data and Information Service
NESS	National Environmental Satellite Service
NGDC	National Geophysical Data Center
NHAP	National High Altitude Photography Program of USGS
NMC	National Meteorological Center
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NOADN	National Oceanic and Atmospheric Data Network
NODC	National Oceanographic Data Center
NORAD	North American Aerospace Defense Command
NOSS	National Oceanic Satellite System
NPS	National Park Service
NSF	National Science Foundation
NSSDC	National Space Science Data Center
NSTL	National Space Technology Laboratories
NWS	National Weather Service

O

OCI	Ocean Color Imager
OFDA	Office of US Foreign Disaster Assistance
OMB	Office of Management and Budget
OMS	Orbital Maneuvering System (Shuttle)
ONR	Office of Naval Research

P

PAN	Panchromatic
PCC	Payload Control Processor
Pilot-OLUS	Pilot Online Users Service
PIXEL	Picture Element
PMCC	Payload Mission Control Center
PPI	Particles Per Inch

R

R/T	Real Time
RADARSAT	Radar Satellite (Canada)
RBV	Return Beam Vidicon
RFP	Request for Proposals

S

S/N, (SNR)	Signal-to-Noise Ratio
SAB	Space Applications Board
SAM	Sensing with Active Microwave
SAR	Synthetic Aperture Radar
SARSAT	Search and Rescue Satellite Aided Tracking
SASS	Seasat-A Satellite Scatterometer
SCAT	Scatterometer
SDSD	Satellite Data Services Division
SEASAR	Sea Synthetic Aperture Radar
SEASAT	Sea Satellite
SEB	Source Evaluation Board
SELPER	Society of Latin American Specialists in Remote Sensing
SEM	Space Environment Monitor
SIR	Shuttle Imaging Radar
SIR-A,B	Shuttle Imaging Radar-A,B
SISEX	Shuttle Imaging Spectrometer Experiment
SLAR	Side-Looking Airborne Radar
SMM	Scanning Multichannel Microwave Radiometer
SMS	Synchronous Meteorological Satellite
SPIs	System Performance Indicators
SPOT	Satellite Probatoire d'Observation de la Terre
SWIS	Satellite Weather Information Systems

T

TBM	Terabit Memory (trillions of bits)
TDRS	Tracking Data Relay Satellite
TDRSS	Tracking and Data Relay Satellite System
TIMS	Thermal Infrared Multispectral Scanner
TIROS	Television and Infrared Observation Satellite
TM	Thematic Mapper
TMS	Thematic Mapper Simulator
TOBS	TIROS Operational Vertical Sounder
TOPEX	The Ocean Topography Experiment
TOS	TIROS Operational Satellite
TOVS	TIROS Operational Vertical Sounder

U

UARS	Upper Atmosphere Research Satellite
UHF	Ultrahigh Frequency
UNEP	United Nations Environmental Program
UNESCAP	United Nations Economic and Social Commission for Asia
USDA	United States Department of Agriculture
USGS	United States Geological Survey
UV	Ultraviolet

V

VAS	VISSR Atmospheric Sounder
VHR	Very High Frequency
VHRR	Very High Resolution Radiometer
VIS	Visible
VISSR	Visible Infrared Spin Scan Radiometer
VLBI	Very Long Baseline Interferometry
VTR	Video Tape Recording

W

WCRP	World Climate Research Program
WEFAX	Weather Facsimile
WINDSAT	Wind Satellite
WMO	World Meteorological Organization
WOCE	World Ocean Circulation Experiment
WWB	World Weather Building

Appendix D: *Remote Sensing References*

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