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The Next Decade of Satellite Remote Sensing*

Landsats-C and -D, Seasat-A, the Space Shuttle, the European Spacelab, and a Synchronous Earth Observation Satellite may provide future remote sensing capabilities.

ABSTRACT: *In 1978, NASA will launch Landsat-C, Seasat-A, and the Heat Capacity Mapping Mission. For Landsat-D, to be launched about 1981, NASA plans to carry a Thematic Mapper with seven spectral bands and perhaps a Multispectral Scanner. The U.S. Geological Survey has proposed a three-band linear array sensor. Large format cartographic cameras will be carried as cargo bay payload on Shuttle sortie missions, as crew compartment payload on the European Spacelab, and as payload for unmanned spacecraft launched and serviced by the Shuttle. Geosynchronous real-time observing systems may be expected in the mid 1980s.*

INTRODUCTION

IN 1948 THE British astrophysicist Fred Hoyle wrote:

> "Once a photograph of the Earth, taken from the outside, is available—once the sheer isolation of the Earth becomes plain—a new idea as powerful as any in history will be let loose."

In late December of 1968, the crew of Apollo 8 on the historic first manned mission around the Moon obtained just such a photograph. Astronaut Jim Lovell radioed back:

> "From here the Earth looks like a fragile blue-green Christmas tree ornament."

and on Christmas eve, astronaut Frank Borman read from the book of Genesis:

> "And God called the dry land Earth; and the gathering together of the waters He called seas; and God saw all the things that He had made, and they were good."

In remarkable fulfillment of Fred Hoyle's prediction, that flight and those pictures changed forever the way mankind regarded his home on this planet. We have come to appreciate that, as Jim Lovell said:

> "The Earth is a grand oasis in the dark vastness of space."

We have a new and tender concern for the health and welfare of the Earth and the seas. We understand that environmental problems are not confined within national borders. Though in recent years the deep concern for the environment which characterized the late sixties and early seventies has been overtaken by the crises in energy and resources, we recognize that these too are global problems, and that effective remote sensing from spacecraft is probably the best hope of obtaining the information necessary to alleviate them without imposing undue stress on the environment. It is now more than 15 years since the first photographs of the Earth from space were taken with a hand-held camera on the Mercury 8 mission. And the first spacecraft designed specifically for Earth observations has been operating for more than five years. Remote sensing from space has come of age and we are about to

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begin the second generation of satellite systems.

LANDSAT-1 AND -2

Since July 1972, Landsat-1 has been orbiting the Earth at an altitude of 919 km and inclination of 99°. This sun-synchronous orbit provides coverage of adjacent swaths on consecutive days. An identical Landsat-2 was launched into the same orbit in January 1975. The characteristics of these satellites and the data and images produced by their sensors are by now well known and are summarized here merely as a point of departure for future systems.

Each spacecraft carries three Return Beam Vidicon (RBV) cameras which record a scene 185×185 km in three spectral bands, 475-575 nm, 580-680 nm, and 690-830 nm, with an effective ground picture element (pixel) size of about 80 m.

The Multi-Spectral Scanner (MSS) covers the same 185 km swath in four spectral bands, 500-600 nm, 600-700 nm, 700-800 nm, and 800-1100 nm, with a 79 m pixel, which is equivalent to about 200 m photographic ground resolution.

The detector signals are sampled, digitized, and transmitted to reception stations when the satellite is within range. By early 1978 receiving stations will be operating in:

Fairbanks, Alaska
Goldstone, California
Greenbelt, Maryland
Cuiaba, Brazil
Prince Albert, Saskatchewan
St. John's, Newfoundland
Fucino, Italy
Teheran, Iran

These stations have a data reception rate of 15 megabits/second. Additional stations are being negotiated with the eventual objective of worldwide coverage. For areas not within range of ground stations, the spacecraft are equipped with tape recorders to store image data until the next passage over a reception station.

The two spacecraft have recorded over 450,000 scenes providing nearly complete coverage of the world's land areas and repeated coverage for many areas. Most of this coverage is with the MSS and very little use has been made of the RBVs. At present (September 1977) both tape recorders on Landsat-1 and one of those on Landsat-2 have ceased functioning. Also, band-4 of the MSS on Landsat-1 has ceased operation.

Extensive experimentation has documented the utility of Landsat data for small-scale cartography, for land-use classification, for geologic exploration, and for other applications demonstrating the multispectral approach to interpretation of terrain features by both analog and digital techniques.

1978 SYSTEMS

The Landsat series will be continued with the launch in spring 1978 of Landsat-C. Its orbit will be identical with those of Landsats-1 and -2. However, the imaging sensors will be modified. The MSS will continue to provide four spectral bands with 79 m pixel in the visible and near infrared spectral bands. A fifth band will be added in the thermal infrared region (10.4 to 12.6 μm). The pixel size for this band will be 240 m. The RBV system for Landsat-C will provide panchromatic Earth images with nominally a factor of 2 improvement in ground resolution compared to Landsats-1 and -2. There will be two RBV cameras instead of three, and the lens focal length will be increased to 236 mm. This will provide an effective pixel dimension of about 40 m. The two cameras will be aligned to view adjacent 98×98 km ground scenes with a 13 km side-lap (Figure 1). Thus, a scene pair will cover nominally 183×98 km and two successive scene pairs will overlap each MSS frame. NASA plans to produce primarily digital tapes from Landsat-C. Processing into images and distribution to users will be performed by the

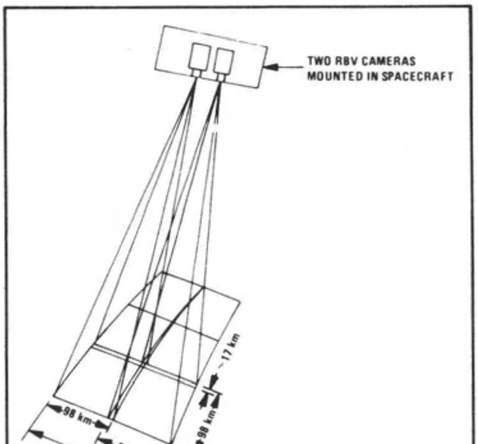

FIG. 1. Return Beam Vidicon Cameras on Landsat C. The two cameras will be arranged to cover overlapping 98×98-km areas, and two scene pairs will cover the same area as one Multispectral Scanner scene.

U.S. Geological Survey EROS Data Center at Sioux Falls, South Dakota. Image processing will be completely digital, using a computer-controlled laser beam recorder. A standardized contrast enhancement algorithm will be applied to all Landsat imagery. The EROS Data Center will also provide computer-compatible tapes for those users wishing to do their own processing.

Also planned for launch in spring 1978 is Seasat A, an all-weather day/night satellite designed primarily for observations of ocean dynamics. Operating at an altitude of about 800 km in a near-polar orbit, Seasat will carry five instruments: a radar altimeter, a five-channel microwave radiometer, a microwave scatterometer, a visible infrared passive radiometer, and an L-band synthetic aperture imaging radar (Figure 2). The radar will cover a 100 km swath with a resolution of about 25 m. It is designed primarily for sea state and sea ice observations but geologists are hoping to obtain useful coverage of land areas. Since there are no tape recorders on the spacecraft, radar data can be recorded only when the spacecraft is within range of the reception stations. U.S. stations will be located at Fairbanks, Alaska, Goldstone, California, and Merritt Island, Florida, providing complete coverage of the United States (except for Hawaii). Canada is installing a station at Shoe Cover, Newfoundland, and negotiations are under way with the European Space Agency (ESA) for a probable station at Oak Hanger, England, and a possible station in the Canary Islands. At this time NASA will be able to process only 10 minutes of radar data per day at the Jet Propulsion Laboratory. Foreign stations may install their own processors.

NASA has a number of small projects referred to as AEM (Application Explorer Missions). These are small, light-weight, relatively inexpensive payloads launched by the Scout Rocket; orbit insertion accuracy and attitude stabilization are marginal. One of these planned for early 1978 is the Heat Capacity Mapping Mission (HCMM). It will

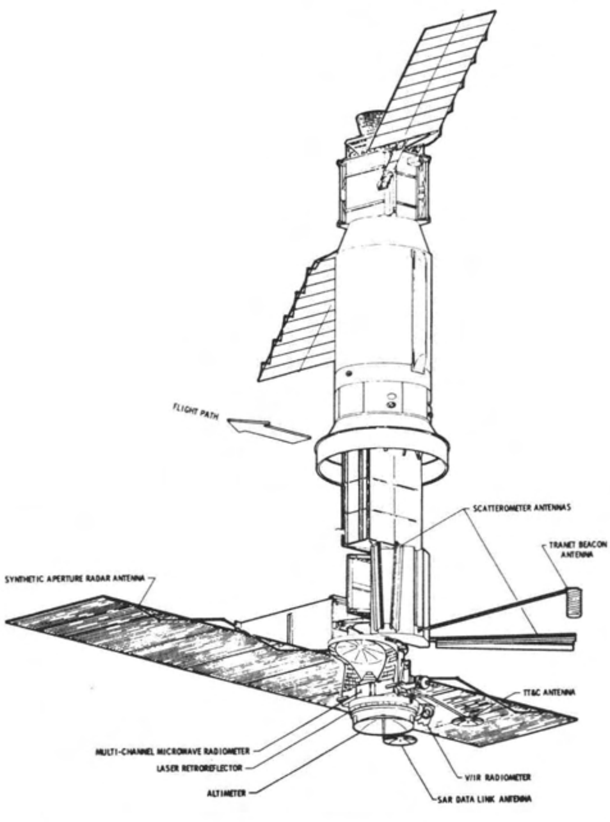

FIG. 2. Seasat Spacecraft. Solar arrays will provide power for five instruments, the largest of which is the L-band synthetic aperture radar.

carry a single-channel thermal sensor covering a 700-km swath with a 500 m pixel dimension. It will take both a daytime and nighttime pass over the same area at the peak of the heating and cooling cycle, in order to determine thermal inertia. This parameter may be diagnostic for some types of rock and soil.

New Developments

In the last few years NASA has had under development several new concepts which relate to remote sensing from space.

Far and away the largest of NASA's current programs is the Space Shuttle which will provide the Nation's principal space transportation system for at least the next two decades. The Shuttle will be launched by means of two strap-on solid fuel booster rockets. When these are expended they will be jettisoned and recovered for subsequent reuse. The Shuttle will then be carried into orbit using a large liquid fuel tank. When the proper orbit has been obtained the tank will be jettisoned and abandoned. The Orbiter vehicle will then perform its assigned missions in space and eventually return to land as an aircraft. The principal advantage of the Shuttle is that its major component, the Orbiter vehicle, is recovered and is reuseable. The first Orbiter vehicle, christened "Enterprise" by President Ford, is now undergoing initial flight tests. It is anticipated that eventually there will be a total of five vehicles and somewhere between 30 and 50 missions will be accomplished each year.

Initial launches of the Shuttle will take place from the Kennedy Space Center. Range safety conditions there restrict the maximum inclination to 57°, which will permit the Orbiter vehicle to cover the Earth from latitudes 57° N to 57° S. By 1983, launch operations should be available at the Vandenberg Air Force Base on the West Coast and at that time polar orbits can be attained. Circular orbits from 200 to 1200 km altitude can be achieved depending upon payload weight and orbit inclination. Mission duration will be from three to thirty days.

The Shuttle will operate in two different modes. In the sortie mode, experiments will be mounted in the Orbiter cargo bay and operated on orbit for periods of three to thirty days, and then returned to Earth. The cargo bay is 18.3 m long and 4.6 m in diameter and can carry a maximum 30,000 kg payload. The payload will consist of a combination of pressurized modules in which crew members can work in a shirt-sleeve atmosphere and a number of external pallet modules on which instruments can be mounted to operate in the open-space environment.

In the second mode of operation the Shuttle will be employed to carry individual spacecraft into space, to place them in appropriate orbit, and to service them on demand. A Remote Manipulator System (RMS) will extract the payload from the cargo bay and release it into its own orbit. Subsequently the Shuttle can rendezvous with a free-flying spacecraft, and the RMS can retrieve the satellite and return it to the cargo bay where it can be serviced, or else returned to Earth for major refurbishment. This mode will undoubtedly be most effective for remote sensing as experiments conducted in the manned sortie mode reach the status where they can become operational and cost effective with independent unmanned spacecraft. When the Shuttle is fully operational, it is expected to replace all expendable launch vehicles.

A second major development is the Tracking and Data Relay Satellite System (TDRSS). This will consist of two identical satellites** at geosynchronous altitude located at 41° and 171° west longitude. Both satellites will communicate with a single ground station at White Sands, New Mexico. They will transmit command data to other spacecraft operating at lower altitudes. They will also receive telemetry from as many as 20 spacecraft and relay these data to the ground station for further distribution. The TDRSS is expected to become operational in 1980. Because of the location of the two TDR spacecraft, there will be a zone of exclusion over the Indian Ocean where other spacecraft cannot communicate with the TDRSS. The size of this zone will depend upon the altitude of the spacecraft.

The third significant development is the Multimission Modular Spacecraft (MMS). This system will consist of a central structure to which can be attached standard modules for power supply, command and data handling, and attitude control (Figure 3). Two different propulsion modules will be available to permit altitude changes once the spacecraft is in orbit. These modules can be serviced individually in the Shuttle cargo bay. There will be a mission-unique adapter to fit the MMS to its particular payload. Other mission-unique equipment such as solar panels and communications antenna can be added as necessary. The MMS will have

** Actually there will be four satellites, but two of them will be used for commercial communications.

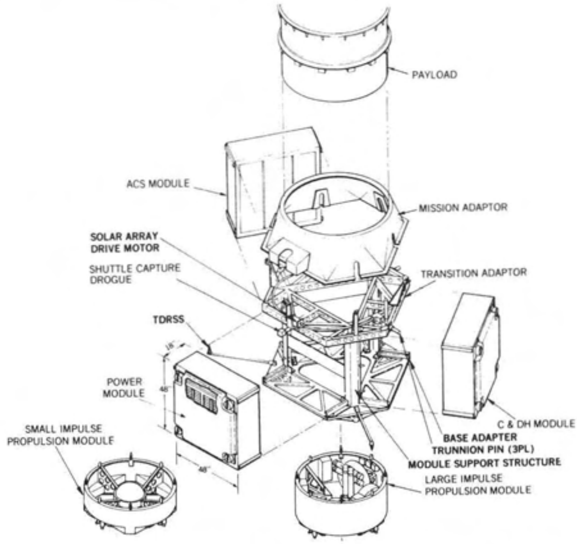

FIG. 3. Multi-Mission Modular Spacecraft. Interchangeable modules will provide power, attitude control, and command and data handling. Mission unique modules will provide propulsion and payload.

vehicle adapters for launch either by expendable launch vehicles or by the Space Shuttle.

The final development is a second generation multispectral scanner referred to as the Thematic Mapper (TM) (Figure 4). This instrument was conceived in response to continuing demands from experimenters for additional spectral bands and higher spatial resolution. The instrument is being designed to provide six or seven spectral bands with a 30-m pixel and one band in the thermal infrared with 120-m pixel. It should cover a swath of 185-km—the same as Landsats-1, -2, and -C. Initial design was based on an orbital altitude of 705 km, which is compatible with the payload capability of the Delta 3910 launch vehicle and subsequent retrieval and relaunch by the Space Shuttle. The data transmission rate will be around 84 to 150

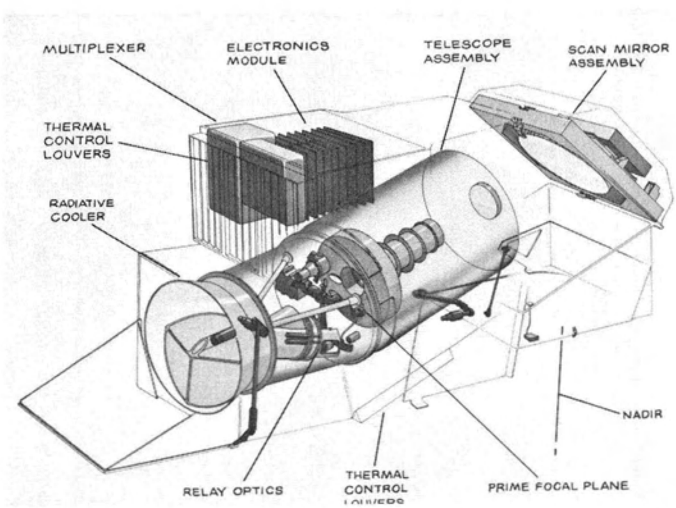

FIG. 4. Thematic Mapper. The instrument will provide six or seven spectral bands with a pixel dimension of approximately 30 m.

megabits per second, depending upon the number of bands and how often the detectors are sampled. The instrument consists of an oscillating scanning mirror, a primary imaging telescope, spectral band discrimination filters, detector arrays, radiative cooler, and operating and processing electronics.

LANDSAT-D

These several developments come together in NASA's plans for Landsat-D (Figure 5). As currently planned, in spring 1981 the Delta 3910 expendable launch vehicle will boost the MMS into a sun-synchronous circular orbit at about 705 km altitude. The principal sensor will be the TM. It was originally proposed to carry as a backup sensor the MSS as flown on Landsat-C, but funding for this has not been approved. Other spacecraft components will be a roll-up solar array to provide power, a wide-band transmission module for direct communication to data receiving stations, a steerable antenna for transmitting data to the TDRSS, and the Global Positioning System (GPS) being developed by the Department of Defense to provide an accurate record of position and altitude. From the TDRSS data will be sent to the receiving station in New Mexico, and thence via domestic communication satellite (DOMSAT) to the ground data processing and dissemination centers.

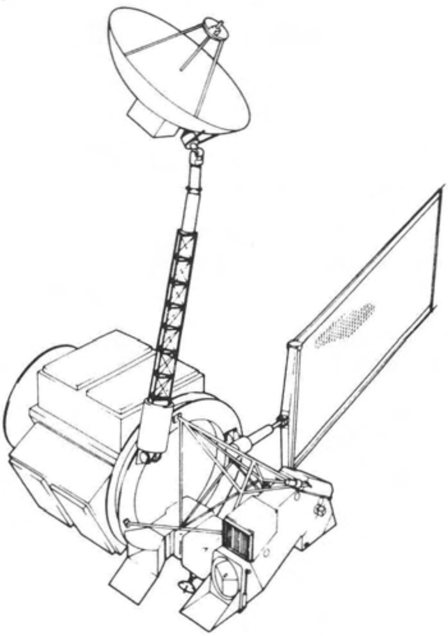

FIG. 5. Landsat-D. The Multi-Mission Modular Spacecraft will carry the Thematic Mapper and possibly the Multispectral Scanner from Landsat-C. A solar array will provide power and a gimballed antenna will transmit data to the Tracking and Data Relay Satellite.

NASA's plan, if Landsat-D proves successful, is to use the Shuttle to launch the backup spacecraft as Landsat-E about 1983, and to recover and refurbish Landsat-D. The two spacecraft would then be alternated on orbit to serve as an operational Earth observation system.

Not everyone is overjoyed with the plans for Landsat-D. This is evident first by the continuing requests to carry the MSS so that users will be able to get data that they are accustomed to handling. The enormous data rate from the TM will require that existing receiving stations be upgraded at a cost of several million dollars each. Even so, an average of only 50 scenes per day can be processed, and digital processing may be expected to cost on the order of $1000 per frame. The General Accounting Office has estimated that Landsat-D as currently planned will cost about $300 million, not including ground station modifications or data processing. The 705-km altitude will reduce the area of coverage of ground stations by about 25 percent and, more important, will destroy continuity of data. Instead of one day, the interval between adjacent swaths will be increased to either seven or nine days. However there are other orbits in the vicinity of 715-km altitude which will reduce the time delay between adjacent swaths to two days, and undoubtedly one of these will be finally selected.

As an alternative to Landsat-D, the U.S. Geological Survey suggested a three-spectral band sensor system based upon multispectral linear arrays (MLA). Two bands in the blue-green and near infrared would have resolutions comparable to that of the current Landsat MSS, while the third band in the green-red would have a resolution comparable to the TM. Orbit, coverage pattern, and data rate would be completely compatible with Landsats-1, -2, and -C.

A committee has been appointed by the Office of Science and Technology Policy to evaluate all the factors influencing the choice of spacecraft, sensors, orbit, and data handling for the system which follows Landsat-C.

STEREOSAT

Geologists and other Earth scientists have a continuing requirement for stereoscopic imagery that will permit interpretation and measurement of terrain relief, slope, strike, and dip. In response to this requirement, the

Jet Propulsion Laboratory has proposed a concept called Stereosat. The sensor system would consist of two 600-mm focal length telephoto lenses set at a stereo angle of 45° or 60°. The images would be focused on linear arrays having 1872 elements. A tradeoff on resolution and coverage resulted in the choice of a sun-synchronous circular orbit at 577-km, which would give a swath width of 31-km and a 19.3×16.6-m pixel. The system has been proposed for the Applications Explorer spacecraft. However, this spacecraft has limited attitude control and no spatial positioning capability. This would result in distorted images with insufficient information to remove the distortions by ground processing. The data rate for the two sensor arrays would exceed the capacity of available tape recorders so on-board data compression has been proposed. Because of the limitations of the AEM spacecraft, the MMS, launched and serviced by the Shuttle, is considered as an alternative. However, if this change is made the entire sensor package should be reconsidered to take advantage of the superior support capability of the MMS. At the moment (September 1977) Stereosat is not an approved or funded program.

Early Shuttle Flights

The first six Shuttle missions are referred to as Orbital Flight Tests (OFT). These are designed fundamentally to test the spacecraft systems, but they also provide an early opportunity for experimental payloads. OFT-2 and OFT-5 (later changed to OFT-6) were assigned to the NASA Office of Applications to develop the payload. OFT-2 is to carry an instrumented pallet, and OFT-6 is to test the independent spacecraft launch and retrieval mechanism. An Announcement of Opportunity (AO) was distributed to the science community and over 100 proposals were submitted for the two missions.

The final selection of payload for OFT-2 contains the following experiments:

- MAPS—Measurement of Air Pollution from Space.
  Gas filter correlation sensor operating in the thermal infrared to measure carbon monoxide levels in the troposphere.
- SMIRR—Shuttle Multispectral Infrared Radiometer.
  Ten-channel near-infrared non-imaging radiometer to measure reflectance in a 100-m strip along the ground track.
- OCE—Ocean Color Experiment.
  Ten-channel visible spectrum scanning radiometer producing low resolution digital images for identification of ocean bioproductivity.
- NOSL—Nighttime Optical Survey of Lightning.
  A 16-mm sound movie camera with photocell lightning detector for studying correlation between lightning and various types of severe storms.
- AWSO—All Weather Surface Observations.
  Modification of the Seasat L-band synthetic aperture radar to a 50° look-angle for recording terrain.

OFT-2 is scheduled for launch in July 1979, but there is strong indication that the allowable payload weight will be reduced so that some of the approved experiments may have to be dropped, and the mission may be delayed by six months or more.

At this time (September 1977) a final payload selection has not been made for OFT-6, presently scheduled for launch in March 1980. Principal candidates are the Multimission Modular Spacecraft and the Syncom 4 communications satellite. Choice will probably depend upon which system can be ready in time.

Large Format Camera

As long ago as 1967 the National Academy of Sciences recommended that a large format cartographic camera would be a useful space payload. Such a system was proposed on several occasions but for a variety of reasons the camera was never approved.

Now, however, NASA is funding the development of the Large Format Camera (LFC) as a Shuttle payload. The camera will have a 30-cm focal length, a 23×46-cm film format, and a magazine capacity of at least 1200 frames. From an orbital altitude of 300-km, each frame will cover 225×450 km with an image scale of 1:1,000,000 and a ground resolution of about 15 m. By operating the LFC with 80 percent forward overlap and the long format dimension in the direction of flight it will be possible to obtain a base height ratio of 0.3 to 1.2 by selecting various combinations of frames.

The LFC has not yet been assigned to specific Shuttle missions, but initial flights will certainly be as a pallet payload in the cargo bay (Figures 6 and 7). Photographs can be obtained whenever the spacecraft is in Earth-viewing mode and lighting conditions are suitable. These early sortie missions will be designed primarily to obtain coverage of the United States. From a 300-km orbit at 52° inclination, less than 900 frames would be required and in theory at least, 11 days of operation would be required. However, because of cloud cover several missions would undoubtedly be required.

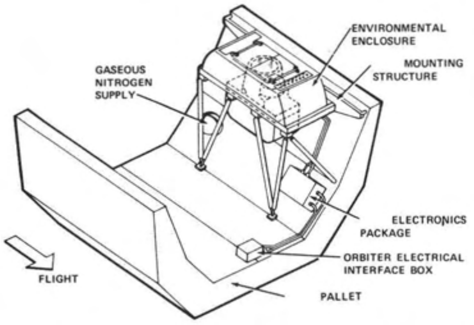

FIG. 6. Large Format Camera on pallet. The camera will be mounted in an envirionmental enclosure on the pallet which will provide interface to the Shuttle systems.

However, cartographers do not consider multi-role manned missions such as Shuttle sorties to be an efficient technique for acquiring photography. A clear example of this is the photographic coverage pattern obtained in 171 days of occupancy on the three Skylab missions. Only a few strips of cloud-free photography were obtained, and only a very few map sheets at scales compatible with the resolution of the photography were adequately covered by the missions. Based on this experience, cartographers consider the pallet camera payload as an interim measure and are looking at the spacecraft launch and service mode for the Shuttle as the best opportunity to obtain useful systematic photogrammetric data from space.

Two possibilities are under consideration. The first is "Buddysat" which is a spacecraft ejected from the Shuttle Orbiter by the RMS. It could contain the attitude control, command and data handling, and power supply modules from the MMS. It might remain tethered to the Orbiter, but probably would simply remain in its own nearby orbit. At the end of the mission, Buddysat would be brought back aboard the Orbiter and returned to Earth. The advantage of this approach is that Buddysat would be independent of Orbiter maneuvers during the mission. This mode would be most useful for long duration Orbiter flights. A study has been performed to incorporate the LFC on Buddysat. The spacecraft would also carry laser retroreflectors and the Global Positioning System.

The second possibility is integration of the LFC with the MMS, which can operate as a completely independent spacecraft. This mode will be most useful when near-polar orbits can be obtained with lifetimes of many months. Periodically the spacecraft can be recovered for exchange of film magazines or for return to Earth for complete refurbishment.

By raising the altitude to about 520-km and the orbit inclination to 96.5°, the entire Earth could be covered with about 6000 frames. Although, in principle, this requires only nine days of camera operation, this would certainly be spread out over several missions.

SPACELAB

The European Space Administration (ESA) is building the Spacelab as an approved Shuttle payload. The Spacelab will consist of a manned laboratory providing a shirt-sleeve atmosphere for scientists and a series of external pallets on which various experiments can be mounted. Initially the Spacelab will remain attached to the Shuttle orbiter, but

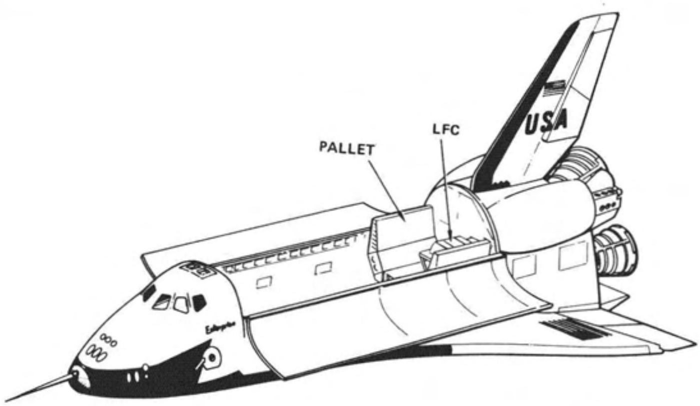

FIG. 7. Large Format Camera in Shuttle. The pallet carrying the camera can be installed on any Shuttle sortie mission which provides adequate Earth viewing time.

eventually it is planned for independent operation in space. The first Spacelab mission, originally scheduled for July 1980, will probably be postponed at least until December 1980. The altitude will be 250 to 300-km at an inclination of 57°, with a duration of seven days.

Among many other experiments on Spacelab will be a standard Zeiss 30/23 aerial mapping camera operating through a window in the manned laboratory. From a 250-km altitude this camera will produce an image scale of 1:820,000 with an expected ground resolution of about 20 m. Each frame will cover 190×190 km. The anticipated application is to determine the utility of the photographs for topographic mapping at scales of 1:50,000 and 1:100,000, particularly for developing countries.

NASA plans eventually to configure a Spacelab as an Earth Viewing Applications Laboratory (EVAL), but as yet there has been no selection of specific instrumentation.

There have been other proposals to ESA for Earth observation satellites, notably the SPOT spacecraft from France and the ARGUS spacecraft from German, but these have not been approved or funded. Also, the Japanese have tentative plans for five spacecraft called JEOS 1 through 5 (Japanese Earth Observation Satellites) carrying visible and near-infrared sensors capable of 50-m (JEOS-1) to 15-m (JEOS-5) resolution.

Large Space Telescope and Synchronous Earth Observation Satellite

One of the most sophisticated payloads for Shuttle launch and service is the Large Space Telescope (LST). This will consist of a 2.5-m diameter mirror collector in a Cassegrain-type telescope that will operate in circular orbit at 650-km altitude. Attitude stabilization will be adequate to make 10-hour exposures of faint astronomical objects. A variety of sensors may be introduced in the focal plane to record stellar radiation at numerous wavelengths. Some 85 proposals for experiments have been submitted to NASA. LST, though an approved project, has not yet been assigned to a specific Shuttle mission.

A study was made to evaluate the performance of the LST as an Earth-viewing system from geosynchronous orbit. At that altitude the theoretical resolution would be 10 m and the field of view would be 28×28 km with a 50-mm image tube, to 125×125 km with 23×23-cm film. However, in addition to the astronomers' violent objection, there are a number of technical reasons which make it impractical to put the LST at that altitude.

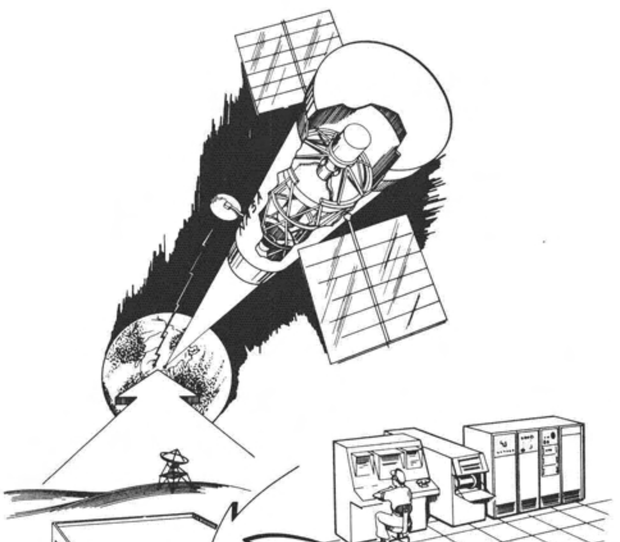

Fig. 8. Synchronous Earth Observation Satellite. The large Cassegrain telescope at synchronous altitude will provide real time monitoring of transient events.

The study performed on the LST did lead to consideration of a Synchronous Earth Observation Satellite (SEOS). In a contractor study the primary sensor would be a 1.8-m Cassegrain telescope with linear array detectors operating in four spectral bands including the infrared. The system would operate in a continuous coarse-scan mode providing 600-m resolution, but would be capable of switching to a fine-scan mode having a resolution of 16 to 60 m for areas of particular interest. Data would be transmitted to Earth for analysis (Figure 8). Placing Shuttle payloads at geosynchronous altitude will require the Spinning Solid Upper Stage vehicle, and this capability is not expected before the mid 1980s. SEOS is not yet an approved program.

Summary

The various systems that have been discussed are not in competition technologically, for each of them may be justified on its own merits. They may well, however, be in competition economically, for regardless of what one may think, the NASA budget is not inexhaustible. Nevertheless, what may reasonably be expected as operational satellite remote sensing systems in the next decade will include:

- Data transmission system. Continuously operating long-life sun-synchronous multispectral systems like Landsat with perhaps additional spectral bands and somewhat higher resolution.
- Cartographic free flyers. Recoverable satellites launched periodically into relatively low-altitude polar orbits, and carrying high-resolution cameras providing recovered film suitable for cartographic mapping.
- Geosynchronous real-time system. A long-life dual-resolution scanning telescope providing real-time monitoring of transient events.

The technology for these systems is clearly available, and a comprehensive program is slowly emerging from an overlong period of experimentation.

Conclusion

There can be no doubt that the Earth is being subjected to pressure as population and pollution place increasing strain on resources, energy, and food production. It is evident that remote sensing from satellites can provide information needed to alleviate these difficulties. However, finding technological solutions is only part of the task. There are major management questions that need to be resolved in the transition from experimental to operational programs, with the assurance that there is some reasonable overlap between those who bear the costs and those who reap the benefits. Furthermore, satellite remote sensing is essentially transnational in scope. Technology is now sufficiently advanced to make it imperative for nations to overcome the political impediments to some of the obvious applications. Quite clearly international cooperation will be more effective than international competition. Men of good will must eventually recognize that secrecy and security are not synonymous and that it is in the best interest of all nations to permit acquisition and dissemination of really useful information. This generation holds in trust for the future the good Earth and the seas which the Lord has made. We must recognize that the real purpose of our work is to asssit in the continuing act of creation by continually improving the condition of our fellow man wherever he may be. This is the real challenge and opportunity that satellite remote sensing presents.

Cover Photos Needed

Photographs suitable for the cover of *Photogrammetric Engineering and Remote Sensing* are needed. Either black-and-white or color may be used; however, because color reproduction is costly, we request that the donors of color material if at all possible cover the additional cost (approximately $750). Please submit cover material to the Editor, American Society of Photogrammetry, 105 N. Virginia Ave., Falls Church, VA 22046.