AN INTERNATIONAL OPPORTUNITY FOR AN ORBITAL IMAGING SYSTEM

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Abstract

The trend toward a new world order suggests new opportunities for better remote sensing of the Earth and its environment. These opportunities are enhanced by economies derived from technological progress. At considerable expense, satellites from a variety of nations are planned, or already have been launched, to sense various components of the Earth's atmosphere, oceans, and land surface. Recognizing that the cost to each nation proceeding individually is high, it is time to investigate the wide variety of sensors already planned or launched and then to discuss the opportunity to coordinate the international remote sensing efforts by flying one system. To focus the system requirements, it is useful to recognize that sensor data capable of producing information that meets standards for 1:50,000-scale products would satisfy most of the world's current imagery needs. A mission profile and sensor configuration that would repeat coverage of the Earth every 45 days with 5-meter pixels, in same-orbit stereo, is recommended to produce these data. The sensors should also contain sufficient spectral bands, with 10- to 30-meter pixels, to address the needs of the wide variety of international earth science data users. A proposed system concept, titled the Orbital Imaging System, would provide the needed global image base to aid earth systems scientists in monitoring, mapping, and managing the Earth's changing environment.

INTRODUCTION

The changing attitudes among nations offers the prospect of a new world order that is unprecedented in recent history. Nations are much friendlier with each other, and they have been much more open in expressing their national needs. There appears to be a spirit of cooperation not apparent over the last several decades. This change in international attitudes could be very timely. Mainly as a consequence of the rapid development of science and technology in the 20th century, the disturbances of Earth's natural systems by human interferences has increased dramatically. Since 1950, the world population has doubled. In the same time, the world energy consumption has increased by a factor of four (Lange, 1991). These developments all contribute to environmental changes that are unprecedented in scale and rate in the Earth's history. Recognizing this, it seems timely to capture the opportunity to promote projects that can be international in scope and provide economic benefits to each participating country. Remote sensing of the Earth from space is certainly a candidate for such consideration. It seems economically sensible to fly one appropriate sensor system and provide all contributing nations their needed data rather than to have separate nations each paying the full price for their own satellite system and its data.

There are a wide variety of applications on a global scale that require global observations, and remote sensing may be the key to obtaining the data needed for helping the world face its critical environmental problems. Global modeling for studying the Earth as a system is vital to man's study of our fragile planet.

In addition to global modeling and global change research, there are numerous conventional down-to-earth information needs that can be met by remote sensing technology. The basic categories that link man with his planet are as follows:

- Water
  - Surface distribution
  - Water quality
  - Subsurface landforms in shallow waters
  - Pollution patterns
- Snow
  - Surface distribution
  - Water content
  - Melting rates
  - Flood potential
- Cultural Features
  - City outlines
  - Major transport networks
  - Growth patterns and planning
- Vegetation
  - Natural vegetation distribution
  - Agricultural vegetation distribution
  - Relative vigor of vegetation
  - Seasonal changes and fire control
  - Deforestation
- Land
  - Landform analysis
  - Geologic structure
  - Land use
  - Soil moisture and type
  - Topography

From this basic list, it is readily foreseen that a team concept that involves the disciplines of hydrology, geology, geography, cartography, forestry, agriculture, and atmospheric science is essential. Representatives of these disciplines must work in concert with the world of nations to accomplish effective global environmental monitoring.

It is interesting that all of the above applications require information that can be provided by image data. Further, these applications need multispectral image data and contiguous global coverage on a periodic basis. In cloud-covered areas, synthetic aperture radar (SAR) images are vital where electro-optical sensors are ineffective. From 1972 to 1988, civilian remote sensing satellites consisted mainly of the U.S. Landsat series, and in 1986 the French SPOT satellite joined the ranks. Japan launched its Earth observation satellite, MOS-1, in 1987, and the Soviet Meteor satellite program has produced Earth observation data since 1977 (Lacoste, 1992). These satellites have fully demonstrated the value of multispectral image sensing. Since then, numerous other countries have followed by launching their own satellites. During the 1990's, as many as twenty national space agencies are planning space sensors for the international "Mission to Planet Earth" project. This project has been adopted as a primary focus for the International Space Year (ISY). In all, eleven member States from the European Space Agency (ESA), plus the United States, the former Soviet Union, Japan, China, Australia, Brazil, Argentina, and Pakistan are participating in this unprecedented effort to monitor the atmosphere, oceans, and land, and treat the Earth as a system (Lacoste, 1992). Although it is well recognized that many technological improvements are evident and more will be forthcoming in the new satellites, the result will be proliferation of data that is not necessarily compatible with a unified approach to solving global problems. These data are already composed of many different spatial and spectral resolutions, with different scales and scene sizes all taken from a variety of altitudes above the Earth. It could be very difficult to derive meaningful results from such a massive conglomerate of data in different formats.

CHARACTERISTICS OF EARTH OBSERVING SATELLITES

Table 1 provides a summary of representative satellite programs and their characteristics.

TABLE 1. EARTH OBSERVATION SATELLITES

Satellite Program	Country	Altitude (km)	Spectral Resolution	Highest Spatial Resolution (m)	Orbits Per Day	Repeat Cycle (days)	Swath Width (km)	Launch Dates
Landsat 1, 2, 3	USA	919	VNIR, TIR	80	14 - 1/18	18	185	7/72, 1/75, 3/78
Landsat 4, 5	USA	705	VNIR, SWIR, TIR	30	14 + 9/16	16	185	7/82 and 3/84
Landsat 6	USA	705	VNIR, SWIR, TIR	15	14 + 9/16	16	185	Planned 1993
SPOT 1, 2	France	832	VNIR	10 stereo	14 + 5/26	26	60	2/86 and 1/90
IRS 1A, 1B	India	904	VNIR	36	14 - 1/22	22	148	3/88 and 8/91
MOS-1a, 1b	Japan	909	VNIR, TIR	50	14 - 1/17	17	200	2/87 and 2/90
JERS-1 OPS	Japan	568	VNIR, SWIR	18 stereo	15 + 1/44	44	75	2/92
MOMS-01	Germany	291	VNIR	20 stereo	-	S	138	6/83 and 2/84
CBERS	China/Brazil	778	VNIR	19	15 - 17/26	26	113	TBA
ERS-1	Europe	745-825	C-band	30	-	3, 35, 176	100	2/92
Sojuzkarta KFA-1000	USSR	270	VNIR	5 stereo	-	-	80	-
S=Duration of space shuttle flights	VNIR=Visable and Near IR; SWIR=Short Wave IR; TIR=Thermal Infrared							

Table 2 (Alexander, 1991), shows the present and planned radar imaging satellites that could be useful for filling the gaps left by optical sensors due to cloud cover, etc.

TABLE 2. SYNTHETIC APERATURE RADAR SYSTEMS

Parameter	RADARSAT	JERS-1	ERS-2	ALMAZ-3
Country	Canada	Japan	Europe	Russia
Launch Date	1995	1992	1994	1994
Altitude (km)	794	568	787	300
Inclination (deg)	98.6	97.7	98.5	73
Period (min)	100.7	96.1	100.6	90
Sun-synchronous	Yes	Yes	Yes	No
Local Time of Ascending Node	18:00	22:30	22:30	-
SAR Band	C	L	C	S
Polarization	H	H	V	H
SAR Swath Accessibility Range (km)	510	75	100	2x350
Number of SAR Beams	16	1	1	2
SAR Resolution (m)	10-100	18	30	15-30
On-board SAR Data Storage (min)	2x14.5	20	0	2.5
Data Acquisition Stations Available	10	20	10	1
Source: Alexander, 1991				

Table 3 summarizes characteristics of electro-optical sensors that were recently published by authors from four space-oriented nations. These four nations surely represent the future trend in electro-optical sensors.

TABLE 3. SENSOR CHARACTERISTICS PROBABLE FOR THE FUTURE

Program	Country	Orbital Altitude (km)	Spatial Resolution (m)	Spectral Resolution	In Orbit Stereo	Swath Width (km)	Repeat Cycle (days)
SPOT	France[1]	832	5	VNIR, SWIR —	yes	60	26
JERS	Japan[2]	574	4	VNIR, SWIR —	yes	75	44
OMI	United Kingdom[3]	832	5	VNIR — —	yes	60	26
Landsat 6	United States[4]	705	15	VNIR, SWIR, TIR		185	16
Landsat 7	United States	Expected to be improvement over Landsat 6					

[1]Fratter, Baudoin, Munier, Baroud, 1991
[2]Nagura, 1992
[3]Bagot, 1991
[4]Williams, 1990

Certainly, this trend seems to be toward spatial resolution of 5 meters with in-orbit stereo plus refined multispectral bands in the visible and near infrared (VNIR) parts of the spectrum. Some of these features may be attained with Landsat 7. The MOMS-02/D-2 will have fundamentally different stereo imaging capabilities with 4.5 m pixels, but since it will be flown on the space shuttle (9/92) rather than being a near-polar orbiting satellite, regrettably it will fall short of the capability to provide global coverage.

DEFINING THE REQUIREMENT FOR AN INTERNATIONAL SYSTEM

Tables 1, 2, and 3 represent a significant amount of satellite experience by a variety of nations, but there has been no optimum design based on rigorous photogrammetric principles to create an ideal international sensor's characteristics. Perhaps the following assumptions are evident:

- Optical imaging sensors augmented by SAR sensors are needed to assure global coverage.
- Spatial resolution is going to 5-meters for the panchromatic band.
- Stereo coverage using the panchromatic band and obtaining stereo views from the same orbit is best.
- Orbital altitude ranges from 568 km to 919 km (15 or 14 orbits per day).

Topographic Data, Scale and Resolution Requirements

Topography is perhaps the single most important land surface characteristic that determines the climatic, hydrologic, and geomorphic regimes of the Earth (NASA, 1992). Consequently, without topographic data, one cannot model the Earth. The Earth is not fully mapped, but available topographic data generally take the form of topographic or image maps (or their digital equivalent), and digital elevation models (DEM). For many parts of the world coverage is limited, inaccurate, or nonexistent. Konecny (1990) summarized the results of a 1987 United Nations study that shows that less than 70 percent of the Earth's land surface has been mapped at scales of 1:100,000 and 1:50,000. Larger map scales are less available. Even where topographic data exist, the lack of standardization in scale, datum, and projection effectively limits the scope of a global study where precise topography is necessary. Studies of mountain belts, deserted areas, tropical rain forests, and polar areas—all critical environments for earth science research—suffer from inadequate topographic coverage. The increased use of geographic information systems (GIS) further increases the need for topographic data in standardized digital forms. GIS's require contour interval layers of data that accurately register to each other. It does little good to have elevations and contour describing the topography if they do not register with the vegetation and planimetric features that reside on the topography being described.

Even though all data are not scale related, most data are, and therefore, it is useful to establish a scale relationship to the data. Establishing a product scale sets up a basis for quantifying the accuracy and resolution requirements for measurements that are needed for mapping and modeling. Then, in turn, these product requirements establish the basis for defining satellite sensor system characteristics. In selecting the scale, it is important to recognize that most of the world's countries (except the United States) use 1:50,000-scale maps as a primary map series. A United Nations study (1976) shows that for 1:50,000- and 1:63,360-scale map products, contour intervals of 10 meters or greater occur with a frequency of 94 out of 100 times. Konecny (1990) has used this United Nations study to advocate the 1:50,000-scale topographic map as a product that would meet the needs of a majority of international users. The ISPRS Working Group IV/3 (1984) and Colvocoresses (1982) proposed electro-optical sensors for mapping at 1:50,000-scale. Also, Bagot (1991) of the British National Space Center recognized the use of 1:50,000-scale topographic products and proposed that they be made from electro-optical space systems.

The 1:50,000-scale topographic product, be it graphic or digital, for GIS's can be divided into three basic kinds of information: content, location, and elevation. Then, the U.S. National Map Accuracy Standards (NMAS) can be used as a basis for quantifying sensor system requirements for content (ground resolution), location (spatial position), and elevation (stereo measurement for digital elevation models) (Light, 1992).

Table 4 tabulates the NMAS for planimetric location accuracy and typical contour intervals for four map scales.

Table 4. NMAS requirements for location and typical contour interval

Map Scale	Location σ_L (m)	CI = 3.3 σ_h Typical contour interval (m) 5	10	20	30	40	50	100
250,000	75	-	10	20	-	40	-	100
100,000	30	-	10	20	-	-	50	-
50,000*	15	-	10	20	-	40	-	-
25,000	7.5	5	10	20	-	-	-	-

*1:50,000 scale requires $\sigma_h = \pm 3$ m for the smallest CI of 10 m.

The content is provided by the sensor's performance in terms of resolution (pixel size on the ground) and the associated radiometric value assigned to the pixel. Actually, there are three kinds of resolution: spatial, spectral, and temporal. Spatial resolution is meters per pixel, spectral resolution records the various wavelengths sensed by the detector, and temporal resolution is a measure of change from one point in time to the next.

Table 4 shows the 1:50,000-scale NMAS criteria for location and elevations. Because resolution requirements for ground pixel size can be related to elevation accuracy and contour interval, the sensor's ground pixel size is set by the required contour interval. Using this technique, the basic characteristics of the entire satellite mission are designed to produce the appropriate products.

Spectral Bands and Resolution

It appears that numerous scientists and photo interpreters endorse most of the spectral bands of the Landsat Thematic Mapper (TM), and SPOT Image Corporation has been very successful in marketing its stereo panchromatic band. Given these proven performers, an Orbital Imaging System (OIS) is herein proposed to meet 1:50,000-scale accuracy requirements for 10-meter contour intervals. The sensor design concept calls for the most frequently used spectral bands from the Landsat TM and the SPOT panchromatic band. Table 5 lists the most useful bands with the thermal IR band and one SWIR band shown as optional (Light, 1992).

Table 5. Sensor spectral bands with typical civil and military applications

Spectral region	Band width (µm)	Civil and military applications		Spatial resolution (m)
1. Panchromatic	0.51-0.73	• Topographic mapping • Charting • Digital elevation models	• Mapping and charting • Digital profiles • Area search, tanks, aircraft	5
2. Blue-green	0.47-0.57	• Water penetration • Distinguishes deciduous/coniferous trees	• Emphasizes lineaments • Provides detail in desert terrain	10
3. Red	0.63-0.69	• Plant type discrimination • Cultural feature discrimination	• Water pollution analysis • Depicts man's impact on vegetation	10
4. Near IR	0.76-0.90	• Land to water interface • Glacier mapping • Biomass content	• Supports land trafficability analysis • Camouflage detection	10
5. Short-wave infrared (SWIR)	1.55-1.75	• Vegetation type • Soil moisture content • Fires and geothermal activity	• Highlights bare soil and construction activity • Accents vegetation stress	30
6. SWIR optional	2.08-2.35	• Mineral exploration • Geology, rock types • Hydrothermal mapping	• Forest canopy discrimination • Accents geologic units	30
7. Thermal infrared (TIR) optional	10.4-12.5	• Thermal mapping • Volcanic/geothermal activity • Thermal plumes & current	• Monitor large buildings and power plants • Accents changes in cooling pond temperature	120

Determining Pixel Size for Spatial Resolution that Supports 1:50,000-Scale Data

Two different methods, one using a printing criterion and a second using a photogrammetric criterion, have been developed (Light, 1990) to determine the appropriate pixel size of the sensor footprint on the ground. The first method (printing criterion) assumes that the typical 150-line per inch lithographic printing screen (actually 300 lines per inch) can transfer all the information that can be used at normal viewing distance by the human eye when it observes quality image printing. The relationship between ground pixel dimension (m/pixel) and image scale (*Is*) is given by the following:

$$\text{Pixel size } (Ps) = \frac{1 \text{ inch}}{300 \text{ lines}} \times \frac{1 \text{ m}}{39.37 \text{ inch}} \times \text{Image Scale}$$

$$Ps = 8.47 \times 10^{-5} \times Is \qquad (1)$$

Example: for $Is = 50{,}000$

$$Ps = 4.2 \text{ m/pixel}$$

The second method (Light, 1990) uses the well-known parallax equation from photogrammetry as the criterion to determine the pixel size needed (see Table 4) to compute elevations accurate to meet $\sigma_h = 3$ m, which supports contour intervals (CI) at 10 m.

The equation to determine pixel size using the photogrammetric criterion is

$$PS = \frac{1}{K} \times \frac{B}{H} \times \sigma_h \qquad (2)$$

where

K is a nondimensional number expressing the degree to which correlation can be achieved with a stereoimage. For example: $K = 0.36$ means a correlation error of about ⅓ pixel.

B is the base distance between sensor positions when the stereo pixels are detected.

H is the orbital height of the sensor above the mean radius of the Earth.

$0.6 \leq B/H \leq 0.9$ is typical for space systems.

$\sigma_h = 0.3 \times CI$ as per NMAS.

Example: Assume $B/H = 0.6$ and $CI = 10$ m as given in Table 4.

$$Ps = \frac{1}{0.36} \times 0.6 \times 0.3 \times 10 \text{ m}$$

$$Ps = 5.0 \text{ m}$$

Recognizing that the 4.2 m and 5 m pixel sizes from the two methods are sufficiently equal, it can be concluded that pixels 5 m in size are sufficient for 1:50,000-scale topographic products, including DEM's and image map data for a wide variety of GIS applications.

Temporal Resolution

Temporal resolution is a function of revisit time for the satellite and its repeat cycle for covering the globe. Users of Landsat imagery are accustomed to repeat cycles of 18 and 16 days. SPOT's repeat cycle is 26 days, but because it employs a skip orbit and off-nadir pointing, SPOT claims a potential revisit capability of about 5 days. Image interpreters engaged in agricultural crop monitoring, change detection of moving targets, and other environmental catastrophes are accustomed to repeat cycles between 16 and 26 days, and may believe that the proposed 45-day repeat cycle for OIS is too long. The proposed solution is to build two OIS sensors and space them to provide an overall effective repeat cycle of 22.5 days. The cost for the second OIS is estimated at $80 million. This approach seems reasonable; both Landsat and SPOT also have more than one system in orbit.

ORBITAL PARAMETERS AND PHOTOGRAPHIC COVERAGE

Images can best be compared if sun lighting conditions at the time of acquisition are approximately the same. This requirement is met by selecting a near-polar sun-synchronous orbit where the angle between the Sun and the orbital plane remains constant throughout the year. Cartographers prefer the sun-synchronous orbit that provides Earth coverage in a sequential manner; that is, a swath is collected on day 1 and on day 2 the next adjacent swath is collected, which provides contiguous swathing coverage around the globe.

Period and Height of the Orbit

If orbits in the neighborhood of 600 km altitude ($\simeq$ 15 orbits/day) are chosen and the repeat cycle is to be 45 days, the period (T) (Light, 1990) is:

$$T = \frac{86{,}400}{15 - 1/45} \; \frac{\text{sec/day}}{\text{orbits/day}} \qquad (3)$$

$$= 5{,}768.546 \text{ (sec/orbit)}$$

$$= 96.142433 \text{ (min/orbit)}$$

Given the period (T), an equation to solve for the orbital height (H) above the mean radius (r) of the Earth is

$$r + H = \left[GM \cdot \left(\frac{T \text{ sec}}{2\pi} \right)^2 \right]^{\frac{1}{3}} \qquad (4)$$

where

$r = 6{,}371$ km

H is the orbital height above mean radius of the Earth

GM is the Earth's gravitational constant, 398,601 km^3/sec^2

Then,

$H = 581$ km

Also, using the denominator of equation 3, the number of orbits (R) in the repeat cycle are given by

$R = 45\ (15) - 1$

$R = 674$ orbits to cover the Earth in 45 days

At the Equator, the Earth's circumference is

$$2 \pi r_e = 2 \pi \text{ (6,378.160 km)} = 40{,}075.161 \text{ km}$$

Dividing the circumference of the Earth by 674 orbits yields the width of each orbital trace, which is also the Earth's westward shift (WS) per day as follows:

$$WS = \frac{40{,}075.161 \text{ km}}{674 \text{ orbits}} = 59.458 \text{ km} \qquad (5)$$

Sensor Swath Width

The actual sensor swath width must be some comfortable amount larger than the Earth's daily westward shift (WS) to provide image sidelap and to allow some orbit variations due to various perturbations of the trajectory. A standard 1:50,000-scale quadrangle covers 15 minutes of longitude. At the Equator, this is approximately 28 km. Expanding the 59.458 km by 7.6 percent yields a 64-km swath, which provides a comfortable sidelap to permit contiguous photo coverage. The 64-km swath can straddle two 15-minute quadrangle areas, which leads to a (64 x 64) km scene size. Figures 1 and 2 illustrate the ground coverage patterns described above.

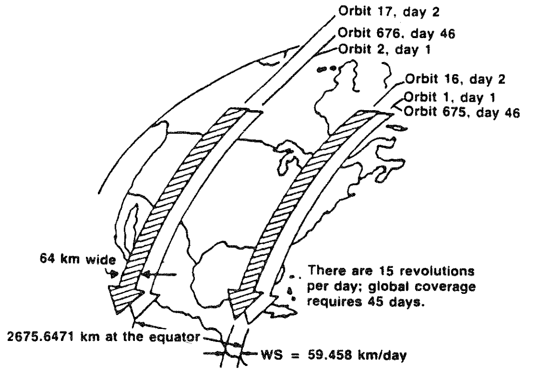
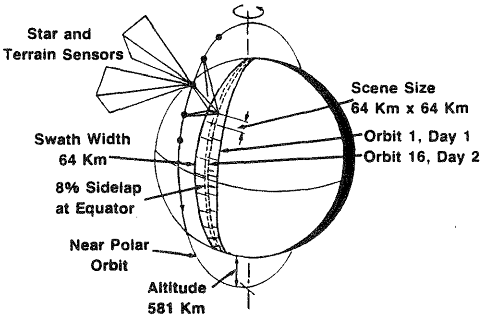


Fig. 1. Orbital imaging system ground coverage pattern



- **Period: 96.14 Min**
- **Orbits/Day: 15 - 1/45**
- **Repeat Coverage: 45 Days (674 Orbits)**

Fig. 2. Orbital Imaging System

SENSOR GEOMETRIC CONFIGURATION

Band 1, the OIS's panchromatic band (see fig. 2) is configured in convergent stereo mode. The Z-coordinates (elevations) are essentially the intersections of the converged sensor's rays in space. The vertical, down-looking sensor in the middle of figure 2 represents the other five multispectral images (not in stereo). Also, the two rectangular array sensors looking out to the celestial sphere are for sensing stars from which precise attitude can be determined and related to the convergent sensors.

Sensor Attitude

Assume that a rectangular array charge coupled device (CCD) sensor can respond to star light of magnitude five or lower and that there are approximately 5,400 useful stars distributed uniformly over the celestial sphere, the calculated star density (P) is

$$P = \frac{5{,}400 \text{ stars/sphere}}{41{,}253 \text{ square degrees/sphere}} \qquad (6)$$

$$\simeq 0.13 \text{ stars/square degree}$$

For a rectangular star sensor field of view, $7^0 \times 9^0 = 63$ square degrees, one can expect an average of 8.2 stars in the sensor's field of view (Junkins and Strikwerda, 1981). Light (1990) shows that typical sensor attitudes of ± 2 to 4 arc seconds are possible, and this star-derived attitude can be related to the Earth-looking panchromatic sensors via precalibration of the sensor configuration.

Sensor Position on Orbit

The Global Positioning System (GPS) will provide the sensor position as a function of precise time (typically 0.0001 sec) for each line of pixels. The integrated star and terrain sensor package synchronized with precise time should provide sensor location in space accurate to $\sigma = \pm 8$ meters. The sun-synchronous orbit for the OIS shown in figure 2 has an inclination of 97.7 degrees (Light, 1990).

ORBITAL IMAGING SYSTEM SUMMARY

In summary, the OIS proposes six essential characteristics that would meet global data requirements for 1:50,000-scale topographic products, including DEM's and image map data suitable for GIS's. These data would be an ideal set for global modeling and global change research useful for the entire international community. The six essential OIS characteristics are as follows:

1. 5-m ground pixel size in stereo.
2. stereoscopic coverage with the panchromatic band in the same orbit.
3. precise metric position, attitude, and calibration.
4. broad area coverage, 64 x 64 km scene.
5. contiguous global coverage every 45 days (or 22.5 days with two systems).
6. multispectral bands nearly equivalent to those most often used by the Landsat TM and SPOT.

Specifications for the OIS are as follows:

Mission: Imaging the Earth for topographic data, GIS, mapping and image applications at 1:50,000 scale and smaller.

Orbit:	Type	Sun synchronous, circular
	Inclination	Near polar, i $\simeq 97.7^0$
	Altitude	581 km preferred (range to 919 km is feasible)
	Period	96.143 minutes
	Orbits per day	15-1/45 $\simeq$ 15
	*Repeat cycle	Every 45 days (674 orbits)
	Nodal crossing	8:30 - 9:30 a.m. local time
	Velocity (V_s)	7.57 km/sec
	Ground velocity (V_g)	6.94 km/sec
	Number of orbits to cover globe	674
Terrain sensor:	Types	Linear array pushbroom each band
	Swath width	64 km (covers two 15-minute quadrangles)
	Pixel size	5 m for panchromatic band; 10 and 30 m for multispectral bands
	Array scan	Convergent stereosensor configuration
	Detectors in array	12,800 for panchromatic band
	Sensor positioning	GPS: $\sigma = \pm 8$ m
Attitude sensor:	Type	Rectangular arrays (2)
	Stars	Measures stars magnitude 5 or lower traversing array realtime
	Output	Attitude as a function of time
	ω, Φ, k	± 2 to 4 arc seconds

Sensitivity:

Band No.	Spectral Band	Color
1.	0.51-0.73	Panchromatic for stereomapping
2.	0.47-0.57	Blue green
3.	0.63-0.69	Red
4.	0.76-0.90	Near IR
5.	1.55-1.75	SWIR
6.	2.08-2.35	SWIR optional

Quantization:

Level:	8 bits per pixel	256 shades of gray
Scene size:	(64 x 64) km	Four 15-minute quadrangles
Data rate:	200 Mbps	Downlink compressed 8 to 4 bits
Sensor timing:	0.0001 sec	Relative timing

*If a shorter repeat cycle is desired, two OIS's spaced 22.5 days apart would satisfy the requirement.

Orbital Imaging System Options:

- Expanded Swath Width: OIS-112

Although the OIS with its swath width of 64 km is attractive for a variety of reasons, there are some users who would prefer a wider swath to cover a wider area of search. Expanding the OIS to a swath width of 60 nautical miles (112 km) is feasible. The orbital height would be 586 km (15-1/26 orbits per day) with a 26-day repeat cycle yielding 389 orbits to cover the globe. The main drawbacks to the OIS-112 are that data acquisition rates would increase and the cost to build the larger lens-detector array would also increase. However, the OIS-112 is a feasible option.

- Off-Nadir Pointing:

The advantage inherent in a satellite without moving parts for pointing to off-nadir targets is that the trajectory of the orbit is not perturbed by the rotating mass of the sensor. Then the sensor can be expected to remain in a more stable orbit longer. On the other hand, after the first four cycles (180 days) coverage of cloud-free areas will have been largely acquired. Then, the capability to point off-nadir, $\pm 30°$, renders the sensor much more capable of imaging international emergencies or phenomena on demand. If off-nadir pointing can be limited to emergencies, then pointing can be a valuable option.

The proposed OIS or the optional OIS-112 with or without off-nadir pointing as described above would satisfy users the world over. Topographic data including digital elevation models and image data meeting the standards for 1:50,000-scale will always be in demand. All of the OIS characteristics are within current technological capabilities and have been proven by performance in space programs such as Apollo, Landsat, and SPOT. The proposed Orbital Imaging System could be built and producing valuable data by the year 1997. The implementation of such a system incorporating a large number of contributing nations would probably be best accomplished under the auspices of an international organization for remote sensing such as the ISPRS which could play a key role in promoting this opportunity.

AN INTERNATIONAL ORGANIZATION FOR REMOTE SENSING

If one accepts that increased understanding of the Earth system is a basic human responsibility, then informed management of the planet's resources and the preservation of the global environment is a prerequisite (Wilson and Huntress, 1990). Recent progress in earth science research has sharpened the perception of human environmental impacts and global change, but not enough has been done in responding to the issues. There is an urgent need to provide monitoring tools to help manage these issues. One way to do this is to organize and focus on sensor requirements, data collection, data management, data modeling, and analysis on a global basis. The timing is excellent to establish an international organization devoted to Earth observation. Simply stated, some organization at the international level needs to be in charge. Numerous satellites are flying and planned, but no one Nation has a dominant market share of the international Earth observation industry. A study by Helm and Edelson (1991) has recognized the need to establish such an international organization; they suggest a commercial venture like INMARSAT or INTELSAT. For the next few years, until its data sales are self-supporting, an organization for remote sensing would need to depend on membership support to survive. Eventually, it should be economically self-sustaining.

Such an international organization should have as its objectives to:

- advise on the selection of sensor system characteristics;
- assist and coordinate with the scientific community;
- promote the use of remote sensing data;
- provide low cost data services;
- standardize media and simplify distribution;
- provide a single supply source for basic data packages.

Further, it should be an international organization with:

- membership open to all nations;
- initial membership investment based on percent of GNP;
- data provided to all members on a fair cost basis.

The new organization should closely coordinate its programs with international scientific programs such as the Mission to Planet Earth and should serve as the focal point for managing global modeling and global change research.

Such an organization should seek assistance through the United Nations. Together they should promote the benefits inherent in the economies of scale and the reduced overlap of a wide variety of remote sensing systems that will be flying by the end of the century.

Given the proper impetus, the proposed Orbital Imaging System could be producing valuable data under the auspices of an international organization dedicated to providing benefits to all member nations before the turn of the century.

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