Earth Orbiting Camera Systems

Invited Paper

14th Congress of the International Society of Photogrammetry
Commission IV
Working Group IV/4

by

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Abstract

The imaging facilities used for earth observation in the various space programs in existence are reviewed. Then the role of earth orbiting camera systems for mapping is discussed. They constitute a potential tool to solve the world's mapping problems at medium to small scales.

1. Introduction

Since the first satellite "Sputnik", put into an earth orbit by the Sovjet Union in 1957 a vast number of satellites have been launched: over 1400 by the Sovjet Union and over 1000 by the United States alone (about 350 of which by NASA). It is relatively recent that other nations have also entered space technology based on the experiences and successes of the space programs of the USA and the USSR.
One of these attempts is the formation of the European Space Agency ESA

in 1974. It was based on the conviction that pooling of the resources of the Western European nations would lead to a more effective development. Other nations now having space programs are Canada, China, France, India and Japan.

2. Past Satellite Imagery Missions

Satellites have been of various types:

1. Weather satellites
2. Telecommunication satellites
3. Navigation satellites
4. Reconnaissance satellites
5. Geophysical satellites
6. Earth observation satellites
7. Manned platforms

For a mapping of the earth's surface, only types 1,4,6 and 7 are of interest. The Tables 1a to d provide a survey of the previous missions using these satellite types.

name	country	time	resolution
Tiros 1-10	USA	1960-1965 h = 700 km	3,5 km Vidicon (visible)
ESSA 1-9	USA	1966-1969 h = 1500 km	3,5 km Vidicon (visible), APT
NOAA 1-	USA	1970 h = 1500 km	0,9 km (visible & thermal APT)
KOSMOS 1-92	UdSSR	1959-1965 h = 250 km	film cassette
KOSMOS -226	UdSSR	1965-1969 h = 600 km	Vidicon & IR
METEOR 1 ⟶	UdSSR	1970 ⟶	Vidicon, IR & APT
GEOS METEOSAT JAPAN	USA ESA GMS	GARP	

Table 1a: Weather satellites

name	country	time	resolution
NIMBUS 1-6	USA	1964 → h = 1000 km	Vidicon 1 km IR-Scanner 8 km
ATS 1-4	USA	1966-68 h = 36 000 km	color
LANDSAT 1-2	USA	1972 →	picture element on the ground 80 m 4 channels
LANDSAT 3	USA	1978 →	ground picture element 80 m 4 channels or ground picture elements 40 m 1 channel
SEASAT 1	USA	1978	ground picture element 25 m Radar-X-Band

Table 1 b: Earth observation satellites

name	country	time	resolution
SAMOS 1-∿80	USA	1962-1972	15 m cameras c = 90 cm film retrieval
MIDAS	USA	1967 → h = 3000 km geostationary	c = 90 cm IR,UV visible range
BIG BIRD	USA	1973 → h = 150 km	1-2 m c = 1,8 m cameras film retrieval

Table 1c: Reconnaissance satellites

mission	year	camera	H	c	format	resolution	ground resolut.
GEMINI 4-7	1965	Hasselblad C.Zeiss-Optics	200 km	80 mm	5,7 x 5,7 cm	20 Lp/mm	125 mm
GEMINI 10-12	1966	Maurer	200 km	80 mm	5,7 x 5,7 cm	20 Lp/mm	125 mm
APOLLO 7	1968	R220 Maurer	225-420 km	80 mm	5,7 x 5,7 cm	35 Lp/mm	70 m
APOLLO 9	1969	Hasselblad C.Zeiss-Optics	192-496 km	80 mm	5,7 x 5,7 cm	35 Lp/mm	70 m
SKYLAB (S190A)	1973	ITEK	435 km	152 mm	5,7 x 5,7 cm	29 Lp/mm	99 m
SKYLAB (S190B)	1973	ETC Acton	435 km	360 mm	11,5 x 11,5 cm	25 Lp/mm	38 m
SOJUZ 22-30	since 1976	MKF-6 Jena	250 km	125 km	5,5 x 8,1 cm	80 Lp/mm	25 m

Table 1d: Manned space platforms

3. Future Plans for Satellite Imagery Missions

The planned space missions are listed here separately for the space programs of the USA, of other countries and of ESA.

3.1. U.S. spaceborne remote sensing programs

A. Previous Developments as Prerequisites:

1. Space-Shuttle	Re-usable transporter
2. T.D.R.S.S.	Worldwide receiving system via geostationary satellites
3. Multimodular satellites	Standardized satellites

B. Systems under construction

1. LANDSAT - D
   1982

   Thematic mapper:

6 spectral bands	0.42-2.35 μm Picture element size on the ground 30 m
1 band	10-12.5 μm Picture element size on the ground 120 m
85 M bits/s via T.D.R.S.S.	data rate

2. Shuttle experiment (O.F.T.)

   a) large-format camera (ITEK)

   c = 30 cm
   23 x 23 cm size
   4000 exposures
   pallet

   b) SEASAT Radar (X & L band)

C. Planned systems or systems under discussion

1. MAPSAT (U.S.G.S.)

1 band	picture element on the ground 30-40 m
2 bands	picutre element on the ground 60-90 m
15 Mbits/s	data rate
h = 900 km	

2. STEREOSAT (J.P.L.) — diode lines (convergent)
picture element on the ground 15 m

3. MULTIMODULAR SATELLITES & LARGE-FORMAT CAMERAS

Life	6-9 months
Parking orbit	900 km
Mission orbit	250 km

3.2. Spaceborne remote sensing programs of other countries

USSR - INTERCOSMOS

Soyouz	MKF-6	in operation

FRANCE

SPOT on ARIANE	under construction
20 m picture element, 2 spectral bands	for launch in 1984
10 m picture element, 1 band	
250 images storable	

JAPAN

MOS (Marine Observation Satellite)	under construction and planned
50 m picture element, visible and thermal	1983
LOS (Land Observation Satellite)	1987
30 m picture element	

PEOPLE'S REPUBLIC OF CHINA

Program of the Jen Hsi-Min Space Technology Institute	planned

3.3. ESA spaceborne remote sensing program

A. Previous developments as prerequisites:

1) Manufacture of SPACELAB (E.R.N.O.)
   for multi-purpose use in the re-usable NASA space
   transporter SPACE SHUTTLE

2) Manufacture of the European launcher ARIANE

B. Systems under construction

1) SPACELAB-1 Experiment, h = 250 km, orbit inclination 57°,
   photogrammetric camera
   Zeiss RMK 30/23, 2 films = 1000 exposures
   Mission duration 1 week
   Launch: May 1983

2) SPACELAB-1 Experiment
   Microwave remote sensing

   in 3 modes:
   a) Microwave scatterometer
   b) Passive thermal sensor
   c) Photogrammetric radar in X-band (9,6 GHz)
      100 m picture element (25 m desired)
      Image width 9 km

C. Planned Systems or systems under discussion

1) COMSS Coastal Ocean Monitoring Satellite System (launch 1986)
   a. ocean color scanner (4 channels line diode, narrow-band)
   b. synthetic aperture radar, 30 m pixel desired but doubtful, suggested alternative: laser altimeter

2) LASS Land Application Satellite System (launch 1988 ?)
   a. multispectral scanner (line diode)
   b. synthetic aperture radar

3) Sensor Developments

suggested to be undertaken in the Federal Republic of Germany:

A) Camera Systems

a. development of a 23 x 23 cm format mapping camera for use on a Spaceshuttle pallet

b. adaptation of this camera on a SPAS-multimission free-flyer-platform

B) Scanners

a. completion of the diode array MOMS (modular optical multi-spectral scanner).

b. construction of a stereo-version of the MOMS ("Stereo-Moms") with one array looking forward, a second vertically down and a third aft

C) Radar

Two frequency synthetic aperture imaging radar

4. The Role of Earth Orbiting Camera Systems

Since the first manned earth orbiting space missions space photography has been utilized in the USA as well as in the U.S.S.R.
Cameras utilized in these missions mostly were non-photogrammetric resulting in image scales generally smaller than 1:1000 000. These images served generally interpretation purposes. NASA made their images of missions Gemini 4 to 7 (1965), Gemini 10-12 (1966), Apollo 7 and Apollo 9 (1968 and 1969) available for international use.

These images were able to demonstrate, what later automatic image acquisition systems with scanners, such as Landsat 1, 2 and 3 were able to achieve from 1972 on. The Landsat-Program has made the countries of the world aware of the potential of space imagery for the purposes of thematic mapping of geological features, of vegetation, of hydrological information and of land use. It was soon realized, however, that the spacial resolution of Landsat 1 and 2 of 79 m pixel size (and of Landsat 3 of 30 m pixel size) is much too coarse for reliable mapping with the standard of a topographic map.

Both the U.S.A. and the U.S.S.R. have demonstrated with improved camera systems in the missions Skylab (1973) and Sojuz (since 1976) that photographic resolutions between 25 to 40 m (corresponding to pixel sizes of about 10 to 15 m) could be reached. These cameras were photogrammetrically calibrated and they possessed image motion compensation. The drawback of these space-photography missions was that the missions were of relatively short duration, covering only isolated parts of the globe. On the other hand the formats of the images were not usable in standard photogrammetric plotting equipment. For that reason the capabilities of space photography could not be fully demonstrated to the mapping community throughout the world.

Various attempts are being made internationally to reach higher spatial resolution with future automatic earth resources satellites.

The success of the Landsat program was in its capability to proviede a worldwide coverage every 18 days if not inhibited by cloud cover or by transmission and reception conditions.

Several countries or country groups, among others Canada, Brazil, Zaire or the European Space Agency have entered agreements with NASA to receive Landsat data using their own receiving stations.

Most countries used these images in analogue form for photographic interpretation of geographical, geological, hydrological, biological or agricultural regional phenomena.

Much better interpretation results were used in multispectral classification of terrain features utilizing the 4 spectral channels of Landsat-data in digital form. While digital treatment of Landsat data was demonstrated to be superior in every respect to analog interpretation, it was realized at the same time that digital processing of Landsat data is very time-consuming and very costly. For that reason all received Landsat-images cannot be digitally processed at the moment to give optimal interpretation results.

At the same time the detectability of an object is limited to about 2,5 times the pixel size. Therefore Landsat 1 and 2 images are only able to resolve objects with sufficient contrast with certainty only, if they are at least 200 m in size.

Since many thematic and especially the topographic requirements call for detection of objects of a few meters in size only future earth resources

satellites are trying to achieve smaller pixel sizes: In the U.S.A. Landsat D is being designed for a pixel size of 30 m. Likewise France has decided on a pixel size of 30 for the SPOT-satellite.
The proposals in the U.S.A. for the Stereosat-satellite (15 m), of the European Space Agency (COMSS and LASS 30 m) and of Japan call for higher resolution than Landsat 1 and 2.
One of the limiting factors to achieve the desired resolution suitable for topographic mapping is the data transmission rate. While in a Landsat image 3200 image elements are digitized every 50 m along the scan (yielding an equivalent pixel size of 79 m) with 8 bit grey level information for each of the 4 spectral channels. With one scan every 79 m with a velocity of 7.7 km/sec 97 scans must be made per second. To transmit these a data rate of 10 M bit/sec is required.
For Landsat D a data rate of 85 M bit/sec will be necessary. The present technological limit is 200 M bit/sec disregarding cost considerations.
To reach the potential of current photography achievable with photogrammetric cameras, however, a data rate of 900 M bit/sec would be required. During the next decade it does not appear to be feasible to reach this rate economically.
Space photography therefore surpasses the capabilities of automatic sensors to provide data to solve cartographic problems at medium and small scales.

5. Planned and Suggested Space Photography Missions

Survey of mapping progress in the world published in "World Cartography" no. XIV indicate that current mapping methods utilizing aerial photography yield a too slow progress. The progress is not only a function of the area to be mapped but also in relation to the number of photographs to be utilized for mapping. Systematic photographic coverage from space leads to utilization of far fewer photographs, far fewer control requirements and should therefore lead to a faster progress in mapping.
The requirements for space photography are that

1. a sufficient resolution is achieved to detect all objects of interest
2. a specified positional accuracy can be achieved commensurate with mapping standards
3. a specified elevation accuracy can be achieved commensurate with mapping standards.

These requirements vary for the different mapping scales and for different types of terrain.
Based on these specific requirements a suitable space mapping system utilizing photographic cameras can be designed. The Institute of Photogrammetry at the University of Hanover in collaboration with the German Space Agency (DFVLR) has been engaged in a study of a suitable space photographic system in the socalled "Atlas"-Program.
The "Atlas"-program is composed of three phases:

Phase A: Utilization of a standard mapping camera in space to acquire photographic imagery from a low orbit out of a pressurized manned cabin.

Phase B: Use of an improved camera (optics image motion compensation) from a pressurized unmanned container.

Phase C: Use of the container in a free-flying retrievable unmanned satellite.

While phase B and C are at the proposal stage, phase A will be realized as an experiment during the first European Spacelab mission now scheduled to be carried into orbit in the NASA Space Shuttle Program in May 1983.

6. Spacelab One Metric Camera Experiment

The government of the Federal Republic of Germany has placed at the disposal of the European Space Agency (E.S.A.) a Carl Zeiss. Oberkochen, RMK 30/23 photogrammetric mapping camera, which has been modified to meet space requirements, as a European space facility. While the experiment is funded by the government of the Federal Republic of Germany, the DFVLR is responsible for procurement and engineering carried out by Zeiss, ERNO, MBB and Kaiser Trede to operate the camera electronically by ground commands and to accomodate it in the Spacelab module. E.S.A. cares for setting up experimentation in countries interested. It has issued a call for experiment proposal.
The response was overwhelming. Over 100 Institutions in all continents have expressed a worldwide interest to experiment with the imagery.
Based on these proposals a timeline for areas to be photographed has been drawn up subject to cloud cover conditions permitting photography.

Altogether 2 film magazines with a total of 1100 photographs can be exposed. In order to select the most suitable film types a joint cooperative test has been carried out utilizing high altitude photography involving aircraft of IGN of France and the DFVLR. Inthe evaluation the French Agencies CNES and IGN, the German Agencies DFVLR and IFAG as well as the University of Milano and Hannover were involved. They have already indicated that a photographic resolution of about 20 m (corresponding to a pixel size of 8 m) can be reached from Spacelab 1 utilizing black and white film. Infrared false color films yield slightly lower, but still acceptable resolution, while the color films available cannot be recommended.

The photographs will be taken with 80 % or with 60 % overlap. The 80 % overlap permits to utilize every 5th photo for a very large base-height ratio, yielding high elevation accuracy in plotting subsequent for image portions. The proposals have indicated that the images will be subject to a wide range of investigations and methods ranging from topographic to thematic mapping in various disciplines such as geography, geology, forestry, land use planning, agriculture, hydrology, coastal engineering and oceanography. Concerning the methods to be used all known mapping techniques are included: aerial triangulation, analog mapping, the use of analogue plotters, rectification, orthophoto-mapping, standard-photo-interpretation.

The experiments should give a clear indication over a wide area of the world, whether the further steps of the "Atlas" program should be pursued and with which energy.

7. Large Format Camera on Space Shuttle

In the United States similar experiences will be obtained with the Large Format Camera, LFC, built by Itek Corporation for NASA. It is to be utilized on Space Shuttle as an OFT-test facility. The first mission now planned for 1983 will be a low inclination mission, giving photographs of tropical and subtropical areas only.

Suggestions have been made to supplement the LFC on subsequent missions with two (forward and aft) panoramic cameras used on the later Apollo moon missions.

8. The MKF-6 Sojuz missions

Of special interest to the international community are the MKF-6 multispectral photographs made from all current Sojuz-missions. It would be a great service to photogrammetry if such test imagery could be made available to an international ISP working group.

9. Conclusion

The presently operating and planned earth orbiting camera systems will most likely confirm, that space photography is a potential tool to cope with the world's mapping problems at medium and small scales, and that its use will surpass the capability of automatic sensors in ground resolution, simplicity, accessibility, instrument-infrastructure and cost.

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