THE USE OF REMOTE SENSING PRODUCTS FROM SPACE FOR CARTOGRAPHIC APPLICATIONS IN DEVELOPING COUNTRIES OF RELATIVELY SMALL AREA

Makram A. MURAD-AL-SHAIKH
Institute of Technology
Zafaraniya, Baghdad
IRAQ
Commission Number IV

ABSTRACT

The operational mode of remote sensing introduced after the advance of this science has encouraged a profound change in cartographic applications. The products of remote sensing from space, in particular, have shown a relatively high accurate relationships; and since these products are also available on a relatively short periodic basis, they are, therefore, very useful for map compilation and updating.

This paper discusses the role of remote sensing from space in cartography, cartographic accuracy achieved by different sensors, and the ground resolution suitable for different map scales, with concentration being made on the application of such in developing countries of relatively small area.

INTRODUCTION

The primary reason for imaging from space has been discussed by a lot of researchers, among them Doyle (1984b); it is simply to compile maps such as thematic maps, image base maps, or conventional topographic line maps.

At least a decade ago it was envisioned that remote sensing products from space had become necessary and important to produce cartographic presentations of remote sensing data (Doyle, 1975).

The periodic acquisition of space imagery from different satellites at relatively short intervals (e.g. LANDSAT 5, every 16 days) has encouraged the use of these imagery in systematic map revision (Holden, 1984; Planques, 1984; Payne and Lawler, 1984).

Several researchers have studied the application of space imagery for cartographic representation. It seems that there were little problems involved in using such imagery for thematic mapping because such mapping is generally characterized by small scale with minimum attention given to map accuracy. Topographic mapping, on the other hand, needs higher degree of planimetric accuracy. It was, therefore, the task of a couple of researchers who have been trying to push up the accuracy limit of space imagery to accommodate larger scale mapping. Details of this problem will be discussed in detail within the paper with several citations.

A comparison between conventional mapping and mapping from space has been discussed by Doyle (1984a). Table 1 shows the economy of this new era of cartography. While the figures in this table are true for the United States, being a large country with established mapping and space facilities, it may not necessarily be that economical in a much smaller size country with

Table 1 Mapping the United States (Doyle, 1984a)

Conventional mapping		Mapping from space with LFC*	
National high altitude photography	$2/km^2	Coverage from Leasesat	$0.15/km^2
Mapping at scale 1:24 000 (adequate for compiling into 1:50 000)	$155/km^2	Mapping automated image map at scale 1:50 000	$ 26/km^2

*LFC : Large Format Camera on Space Shuttle Missions is the most economical system for mapping large areas such as the United States from an altitude of 225km which is good for 1:25 000 scale at 20m contour interval.

rather limited mapping and space facilities, like most developing countries. Nevertheless, mapping from space for such countries might become economical once they establish some kind of a preliminary space (remote sensing) center (Murad-al-Shaikh, 1985). A feasibility study may confirm such prediction; but it is out of the scope of this paper.

As the title of this paper indicates, only products from space missions will be treated, togetherwith how mapping in a small size developing country can benefit from such products.

MAP ACCURACY

Since topographic mapping requires accurate planimetric data, this section will be devoted to map accuracy standards.

Map accuracy standards have been established by almost all countries producing topographic maps. These standards differ among countries depending on their local needs and whether or not they have a developed mapping program (or they are in the process of developing one).

In almost all developing countries, map accuracy may not be clearly defined as an established standard. The accuracy of topographic maps published in such countries need to be checked for a general assessment and for producing map accuracy standards (Al-Masraf and Murad-al-Shaikh, 1985). It is consoling to learn that although the United States has an established National Map Accuracy Standards (NMAS) for quite some time, yet it was shown that it is not statistically vigorous, and was described by Gustafson and Loon (1982) as "redundant and hollow map evaluation method". One of the major disadvantages of the current U.S. official method of map accuracy evaluation (as stated by Gustafson and Loon), is that "it does not actually express map accuracy at all, but only answers the PASS/FAIL question".

Different steps in image mapping require different ground resolution. This ranges between 3.3 to 20 pixels/mm (Doyle, 1984b). Should a 10 pixels/mm compromise be chosen, Doyle demonstrated that there is a relationship between ground resolution of the sensor and the appropriate scale of reproduction as an image map represented by the following equation:

$S_m = 10\ 000\ R_p$ where S_m = map scale number

R_p = sensor ground resolution in m/pixel

also $S_m = 4\ 000\ R_{1p}$ where R_{1p} = sensor ground resolution in m/1p

i.e. 2.5 pixels are required to present the same information of 1 lp (Doyle, 1982).

In order to understand what could be extracted from images by the normal eye, in order to establish the range of usefulness of these images, Table 2 was constructed as a basis for such study.

Table 2 Image-eye interaction useful for cartography

P r o p e r t y	Value	Reference
Resolving power of observer's eye	5-10 lp/mm 7 lp/mm	Konecny et al, 1982 Doyle, 1982
Smallest dimension observable in the image	0.1-0.2 mm 0.14 mm	Konecny et al, 1982 Doyle, 1982
Extraction of reliable cultural planimetric detail requires a ground resolution of	2-3 m/lp or 1-2 m/pixel	Doyle, 1984b

It is worthwhile mentioning here that spatial resolution of image data has more to do with the scale of its cartographic presentation than does planimetric accuracy (Doyle, 1975).

Table 3 shows the requirements for image map series after the above criteria (adapted after Doyle, 1984b).

Table 3 Requirements for image map series

Scale number, S_m	Resolution		Contour interval*, m
	m/lp	m/pixel	
1 000 000	250	100	100
500 000	125	50	50
250 000	63	25	25
100 000	25	10	20
50 000	12.5	5**	10
25 000	6.3	2.5	5

*could have several intervals for a particular scale
**after Konecny, 1987

SOURCES OF SPACE IMAGERY

Several sources of imagery from space have become and are becoming soon available. This will provide several choices, making selection of a particular source better but more elaborate. It is, therefore, necessary that cartographers should have better education in what imagery are available and what are their different cartographic potentials in order to make a proper choice of imagery.

Table 4 gives different space imagery (provided by different space platforms) which are suitable for mapping.

Table 4 Space remote sensing systems available (or will be available) for mapping. Adapted from: Konecny et al, 1982; Radlinski, 1983; Doyle, 1984b; Jensen, 1984; McElroy and Schneider, 1984; Voûte, 1986; Konecny 1987; Lillesand and Kiefer, 1987; Verstappen, 1987.

Mission / Sensor	Flight altitude km	Pixel size or photographic resolution	Temporal resolution
SMS/GOES - VISSR	36 000	0.78-7km	0.5 hr
NOAA - AVHRR/2	1 450	1.1km	14.5/day
NIMBUS - CZCS	946	825m	2hr/day
HCMM	620	500m	day
		600m	day/night
SROSS II+ - MEOSS		80m/52m	
LANDSAT 1, 2, 3 - MSS	919	79m	18 days
RBV		40m	
LANDSAT 4, 5 - MSS	705	79m	16 days
TM		30m	
IRS 1A - LISS	904	73m/37m	
Space Shuttle - SIR-A	280	40m	8 hours
SIR-B		30m	
Cosmos 1689 - MSU-g		30m	
Skylab - 190A camera	435	38-79m ▵	
190B camera		17-30m	
EOS+ Polar Orbiter - SAR		25m	
ALS		7m	
MAPSAT+ - panchromatic	919	10m	
MS		30m	
LANDSAT 6+ - EMSS		30m	
ETM		15m	
Soyuz 22-30 - MKF-6	250	~25m*▴	
SEASAT× - RADAR	790	theor. 25m	
TERS+ - MSS		10m/20m	
SPOT - panchromatic	822	10m	
HRV (MSS)		20m	
JERS 1+ - SAR/MSS/SWIR		18m	
STEREOSAT+	713	15m	
LANDSAT 7+ - MLA (ALS)		10m	
Space Shuttle - LFC	296	9-5m*✧	
STEREO-MOMS+	300	8m	
SPACELAB+ - RMK30/23	250		
Atlas A		7.2m*	
Atlas B,C		3.6m*	
Std. Zeiss camera		20m	

+ future * equivalent × failed after 3 months of operation
▵ 20m (Konecny, 1987) ▴ 20m (Verstappen, 1987) ✧ 10m (Voûte, 1986)

TOPOGRAPHIC MAPPING FROM SPACE IMAGERY

Several researchers have worked on getting the most out of space imagery for topographic and image mapping at the largest scale possible through the ground resolution available by such imagery. Table 5 lists their findings.

It is worthwhile mentioning that the required pixel size for monoscopic observation is 3m for 1:50 000 scale mapping and 7m for the 1:100 000 scale. While the maximum pixel size suitable for 1:50 000 scale mapping is 6m for stereoscopic observation (Konecny et al, 1982).

Refering to Table 4 the above criteria is not met by a lot of space mission products for topographic mapping at scales 1:50 000 and 1:100 000. While Table 5 shows that at present only photogrammetric frame cameras (Metric Camera, MC,and Large Format Camera, LFC, on board the Space Shuttle) fulfills the requirements of topographic mapping at the 1:50 000 scale; and since the Space Shuttle missions have an intermittent program, they do not, therefore, deliver acceptable products for systematic world-wide production of maps at scales 1:50 000 and 1:100 000.

However, future missions are indicated in Table 5 which promise photogrammetric capabilities suitable for topographic mapping at 1:50 000 scale. Present missions could improve when Global Positioning Systems come on line which will reduce positional errors of the space platform.

THEMATIC AND IMAGE MAPPING FROM SPACE

Image mapping from space have been attempted by many to as large a map scale as 1:100 000. This is marked by the success of producing an image map of Dyersburg, Tennessee by the U.S. Geological Survey in 1982. Of-course, smaller scale image maps have been produced by many (see Table 5).

Almost all of the space imagery are suitable for thematic mapping. Among their use are the following selected thematic mapping projects:

1. Small scale rural land use maps in semi-arid developing countries were produced using orbital MSS imagery (van Genderen et al, 1978).
2. Water quality mapping were done using MSS imagery; Ocean Color Scanners (OCS) was useful for mapping water quality parameters in San Francisco Bay (Khorram, 1981).
3. TM data was better than MSS data in mapping land cover, discrimination of crop type and field definition (Nedelman et al, 1983).
4. NOAA-7/AVHRR performed as well or better than the LANDSAT/MSS in classifying large homogeneous areas. Therefore, AVHRR is promising for global land cover mapping (Gervin et al, 1983).
5. LANDSAT imagery can be processed to get an optically continuous tone which is useful in producing relief maps (Beer et al, 1978).
6. LANDSAT imagery was used with cartographic skills to produce new relief shading for the New Zealand's mapping sheets at production scale of 1:100 000 (Wright and Bradley, 1984).
7. HCMM image data was combined with LANDSAT/MSS band 7 to permit more reliable thermal mapping of water bodies from HCMM imagery (Schowengerdt, 1982).
8. Thermal infrared remote sensing may be used to measure the apparent temperature of materials and map the spatial distribution of their temperatures (Jensen et al, 1983a).

Table 5 Map scale upper limits for mapping from space imagery

Mission	Suitable for mapping at scale	Remarks	Reference
LANDSAT/MSS	small	resolution not sufficient for medium scale detail plotting	Wilson, 1984
	small-medium ≤1:200 000	for poorly mapped areas	MacRae et al, 1982
	≤1:500 000	not produced for topographic mapping	van Zuylen, 1978
	1:250 000	image maps of Antartica produced by different countries	Radlinski,1983 McGrath, 1983
	1:250 000	geological sheet of Sudan; useful for mapping in developing countries with incomplete base mapping at ≤ 1:100 000	McGrath, 1983
	1:250 000	image maps	Southard and Salisbury, 1983
		does not provide useful stereo; cannot compile topographic relief	Doyle, 1982
	<1: 50 000	does not meet requirements for 1:50 000; will be possible when GPS comes on line	Doyle, 1982
	1: 50 000	inadequate to map cultural features at this scale	Konecny, 1987
	1:250 000	requirements met for planimetric accuracy	Doyle, 1982
	≤1:250 000	adequate resolution for compilation of planimetric detail on topographic maps	Welch and Mathews, 1983
LANDSAT/TM	1:100 000	U.S. Geological map of Dyersburg, Tennessee	Radlinski, 1983
	1:100 000	image maps possible	Southard and Salisbury, 1983
SCANNERS	1:100 000-1:250 000	good for change detection	Konecny et al, 1982
SPOT*	<1: 50 000	does not meet requirements for 1:50 000	Doyle, 1982
	1: 25 000-1: 50 000	possible with stereoscopic capability	Southard and Salisbury, 1983
	1: 25 000-1: 50 000	can be used directly for detailed resource surveying	Verstappen, 1987
	1:150 000	topographic mapping possible but with ground control	Doyle, 1982
	1:150 000-1:300 000	topographic mapping possible	Konecny et al, 1982
FRAME CAMERAS	1: 50 000	possible	Konecny et al, 1982
MC and LFC	1: 50 000	from stereo models, 25m contour	Doyle, 1982
LFC	1:100 000	image map	Doyle, 1982

Table 5 continued

Mission	Suitable for mapping at scale	Remarks	Reference
LFC/NASA	1:100 000	topographic maps	Konecny et al, 1982
LFC panchromatic camera package	1: 25 000	from stereo models, 25m contour	Doyle, 1982
SPACELAB+			
Atlas A	1:100 000	topographic mapping	Konecny et al, 1982
Atlas B & C	1: 50 000	" "	
MC	1:150 000	image map	Doyle, 1982
Zeiss camera	1: 50 000	topographic mapping	Radlinski, 1983
MAPSAT+	1: 50 000	mapping with 25-40m contours	Doyle, 1982
	1:150 000	image mapping	Doyle, 1982
	1:150 000-1:450 000	topographic mapping	Konecny et al, 1982
RADAR	«1:250 000	can only serve as supplementary information	Konecny et al, 1982
STEREOSAT+	1:250 000	topographic mapping	Konecny et al, 1982
STEREO-MOMS+	1:100 000	topographic mapping	Konecny et al, 1982

+ future * considered a cartographic satellite by Konecny, 1987

Thematic mapping has practically no limit for scale, but are generally produced at small to medium scale (if topographic maps are not classified as thematic maps).

The need for thematic maps at different scales makes the use of space imagery inevitable, and for that purpose space imagery was generous in providing up-to-date information of our environment.

MAP REVISION

Due to the periodic repetition of space mission's orbit (a couple of satellites continue operational in orbit for few years) it was no surprise that space images were used for multi-temporal studies and map revision. Jensen (1983b) has outlined several activities for which updating is needed at specified periods; few examples are:

1. Boundaries need updated of all urbanized areas every 5-10 years for the Bureau of Census.
2. Land use change detection every 3-5 years.
3. Strip mining inventory every 2-5 years.
4. Highway condition and impact analysis every half year.
5. Cadastral maps updated every 1-2 years.

LANDSAT imagery was useful in delineating some urban features using multi-temporal LANDSAT data (Skitch, 1982). Payne and Lawler (1984) stated that LANDSAT images can be used directly for systematic revision of maps at scale of 1:250 000 and smaller; while revision of 1:1 000 000 scale topographic maps by LANDSAT imagery has been successfully developed and proven to be quick, accurate, and cost effective in relation to traditional techniques. The series can be revised independently of the 1:100 000 and

1:250 000 mapping programs.

LANDSAT/RBV imagery can be successfully used to update cultural and natural features portrayed on topographic maps (Bender, and Falcone, 1982). RBV imagery was also useful in identifying a major portion of the changes that occurred in the area investigated by Milazzo (1983): "RBV data can be a rough estimator of change in some environments".

LANDSAT/MSS data was used for the purpose of delineating land use change over time which was useful in monitoring a threatened area investigated by Baker and Drummond (1984) and revised the cartographic data as changes were detected. MSS data are considered useful for regional and national change detection (Jensen, 1981).

LANDSAT/TM was considered to be a better source of imagery as compared to the shortcomings of the RBV data in identifying the changes in the area investigated by Milazzo (1983). Jensen (1981) states that detailed change detection in land use at the urban fringe can be achieved by TM imagery. Holden (1984) confirms Jensen that TM imagery "have improved dramatically the interpretability of cultural features enabling detection even of construction details within urban areas". He also envisions that map revision will in future be most effectively carried out by remote sensing with new generation of high resolution satellite data.

SPOT imagery will prove adequate for metric revision of the 1:100 000 mapping as well as the monitoring function (Holden, 1984). Trial revision of the 1:100 000 and 1:250 000 small-scale maps using SPOT satellite simulation data have proved that "SPOT images make it possible to position the revised elements easily, objectively, and with great accuracy" (Planques, 1984).

Developing countries can benefit from such capabilities offered by space remote sensing products in their map revision programs.

CONCLUSIONS

Developing countries are definitely on the way of using space remote sensing products within their cartographic programs.

While topographic mapping from space imagery is not yet fully successful at scales 1:50 000 or larger, such countries can at present utilize these imagery for compilation and revision of smaller scales (probably 1:250 000 or smaller).

Thematic and image mapping programs from space imagery on the other hand, can go ahead with no hinderence and independent of the topographic mapping program. Thematic maps is a vital planning tool for the larger areas in developing countries. Space imagery could be used for studying land use change both in rural areas and at the urban fringe. Since thematic mapping from space imagery do not require high accuracy standards, it is generally possible to produce them at a scale of 1:100 000 or smaller.

While expanding the use of this high technology within the different governmental institutions in developing countries, one should not forget the importance of including such sophisticated technology within the education system, especially in the form of curriculum development to include remote sensing fundamentals, potential, and impact.

Map accuracy standards have to be established in developing countries for the sole benefit of making the map products in these countries a more reliable tool.

ABBREVIATIONS USED IN THIS PAPER

ALS	Advanced LANDSAT Sensor
AVHRR	Advanced Very High Resolution Radiometer
CZCS	Coastal Zone Color Scanner
EMSS	Emulated Multi Spectral Scanner
EOS	Earth Observation System (Polar Orbiter)
ETM	Enhanced Thematic Mapper
GOES	Geostationary Operational Environmental Satellite
GPS	Global Positioning System
HCMM	Heat Capacity Mapping Mission
IRS 1A	Indian Remote Sensing Satellite
JERS 1	Japanese Earth Resources Satellite
LANDSAT	Land Satellite
LFC	Large Format Camera
MC	Metric Camera
MEOSS	Monocular Electro-Optical Stereo Scanner
MOMS	Modular Opto-electronic Multispectral Scanner
MSS	Multi Spectral Scanner
NASA	National Aeronautics and Space Administration
NIMBUS	Clouds Satellite
NOAA	National Oceanic and Atmospheric Administration
OCS	Ocean Color Scanner
RBV	Return Beam Vidicon
SEASAT	Sea Satellite
SAR	Synthetic Aperture Radar
SIR	Shuttle Imaging Radar
SMS	Synchronous Meteorological Satellite
SPOT	Satellite Probatoire pour l'Observation de la Terre
SROSS II	Stretched ROhini Satellite Series
SWIR	Short-Wave InfraRed
TERS	Tropical Earth Resources Satellite
TM	Thematic Mapper
VISSR	Vissible and Infrared Spin Scan Radiometer

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