Reprinted from

Eleventh International Symposium

Machine Processing of

Remotely Sensed Data

with special emphasis on

Quantifying Global Process: Models, Sensor Systems, and Analytical Methods

June 25 - 27, 1985

Proceedings

Purdue University
The Laboratory for Applications of Remote Sensing
West Lafayette, Indiana 47907 USA

PROCESSING OF MULTI-SENSOR REMOTELY SENSED DATA TO A STANDARD GEOCODED FORMAT

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ABSTRACT

To realize the full potential of remotely sensed data, it must be corrected and converted to a standard format. The Canada Centre for Remote Sensing (CCRS) has defined a standard geocoded format (Guertin et al.) which is compatible with the Canadian National Topographic System (NTS) series of maps. This paper gives the characteristics of the CCRS geocoded products, describes some of the benefits that will be dedrived from the application of geocoded products, and gives a brief overview of the Multi-Observational Satellite Image Correction System (MOSAICS) which is being developed to create these products. MOSAICS will correct and convert imagery from a number of different satellites and sensors into CCRS geocoded format, producing a large number of high accuracy CCT and film products.

I. INTRODUCTION

Since July 23, 1972 five LANDSAT satellites have been launched and have transmitted earth resources observation data to ground receiving stations around the world on a routine basis. LANDSATs 1-5 carried the Multi-Spectral Scanner (MSS) sensor which images the earth in 4 spectral bands at a resolution of 80 metres. LANDSATs 4 and 5 also carry the Thematic Mapper (TM) sensor which images the earth in 7 spectral bands at a resolution of 30 metres. The first two satellites in the SPOT series will carry 2 sensors, the Multi-Spectral Linear Array (MLA) which will image the earth in 3 spectral bands at a resolution of 20 metres and the Panchromatic Linear Array (PLA) which will image the earth in a single spectral band at a resolution of 10 metres. The SPOT 1 satellite is scheduled to be launched in October 1985. Table 1 gives some of the satellite system and sensor characteristics.

The image data from all these sensors contain significant geometric and radiometric distortions which must be corrected before the data can provide useful information. Furthermore, if these data are to be used in conjunction with each other and with digital data stored in geographic data bases, they must be transformed to a common format. CCRS has defined a standard geocoded data format for remotely sensed data and has contracted with MacDonald Dettwiler and Associates for the development of a system, the Multi-Observational Satellite Image Correction System (MOSAICS), to correct data from the MSS, TM, MLA and PLA sensors and convert these data to the CCRS geocoded format. MOSAICS will be phased into operation at the Prince Albert Satellite Station in 1986.

II. GEOCODED DATA

Geocoded data is defined to be imagery which has been transformed into a cartographic projection such as the Universal Transverse Mercator (UTM) in a format which is independent of sensor characteristics and satellite orbital parameters. This implies that absolute pixel locations in a geocoded product are defined uniquely in terms of the cartographic reference system; consequently, for a given product type a particular pixel number always refers to the same area on the ground. As a result, pixels from multitemporal products can be compared directly based only on pixel and line numbers. These products will be well suited to applications requiring multi-temporal and/or multi-sensor data and will be especially useful to applications requiring digital data for the update and maintenance of digital geographic data bases.

The important characteristics of CCRS geocoded products are described below:

A. ACCURACY

Images are corrected to subpixel accuracy, both in multitemporal registration and in absolute geodetic control. It should be noted that with the higher resolution sensors, and in particular, the SPOT PLA sensor which has an instantaneous field of view (IFOV) of 10 metres, it will be difficult to maintain this accuracy on a production basis due to limitations in the geometric correction model and to the accuracy of the available maps used for geodetic control.

B. PIXEL SIZE

The pixel sizes for products were chosen to meet the following criteria:

- pixels from sensors at different resolutions form a hierarchy of pixel sizes;
- product pixels should be oversampled with respect to the sensor IFOV;
- pixel sizes do not require impractical storage or processing requirements.

The CCRS geocoded product pixel sizes are given below:

MSS	50 metres
TM	25 metres
MLA	12.5 metres
PLA	6.25 metres

C. PROJECTION

CCRS geocoded products are transformed to the UTM projection. This projection was chosen because it is used for the NTS maps, it is used by many provincial mapping agencies and it is used as a standard for topographic mapping in over 50 countries.

D. PRODUCT FRAMING

A CCRS MSS or TM geocoded product is defined to be the smallest rectangular subscene encompassing an entire four-map NTS quadrange (2 by 2 map sheets) at 1:50 000 scale.

III. MOSAICS DESCRIPTION

A. DESIGN PHILOSOPHY

The MOSAICS design represents a new approach to the implementation of satellite processing facilities. Existing processing systems which have generally been designed to optimally process image data from a single satellite/sensor require costly redesign for expansion of processing for other types of sensors; MOSAICS is designed to provide image correction to a wide variety of sensor systems. MOSAICS will perform radiometric and geometric correction of imagery from LANDSAT-1, -2, -3, -4, and -5 MSS and TM sensors as well as processing of SPOT-1 and -2 MLA and PLA sensor imagery.

For future satellites in the LANDSAT and SPOT series with identical systems, MOSAICS will require only the addition of new parameters to its internal data bases. For other families of satellites, additional front-end hardware and software will be necessary, but, due to the design of MOSAICS, few changes will be required to the processing segment of the system. MOSAICS achieves this multiple sensor/satellite capability by using the following design criteria:

- a satellite-dependent front-end which acquires image and auxiliary data;
- a generally satellite/sensor independent processor which transforms the raw image into a standard corrected image format;
- a user dependent output end which produces output products in either a standard geocoded format, or in any special format or map projection which may be desired by the user.

B. SYSTEM OVERVIEW

The input to MOSAICS is raw imagery containing radiometric errors, and geometric errors resulting from satellite motion (orbit and attitude) and the sensor scanning mechanism. The main function of MOSAICS is to remove these geometric and radiometric errors from the imagery and to project the images into a standard format.

Tables 2, 3 and 4 give the MOSAICS product accuracy and throughput specifications. Overviews of the MOSAICS hardware and software configuration are given in Figures 1, 2 and 3.

C. SYSTEM FEATURES

Principal Processing Features The principal processing functions of MOSAICS include the following:

- imagery demultiplexing and conversion to a common format;
- radiometric and geometric correcting of imagery, including marking control points;
- converting imagery to a standard geocoded format;
- formatting and outputting of bulk and geocoded imagery to film and Computer Compatible Tape (CCT) products.

Product Output MOSAICS will generate the following types of products:

- precision-corrected geocoded subscene;
- systematic geocoded subscene;
- bulk-corrected full scene;
- bulk-corrected quadrant(TM only);
- raw full scene;
- raw quadrant (TM only).

Standard output products consist of 240 mm colour film generated on the MDA Colour FIRE 240 film recorder, and CCTs in the LANDSAT Ground Station Operator's Working Group (LGSOWG) format.

The main product, the geocoded subscene, consists of imagery that has been corrected for radiometric and geometric distortions and aligned with a specific map projection. Geocoded subscenes can be processed to one of two levels of geometric accuracy: systematic or precision. The level depends on the amount of ground truth employed during rectification. If no ground truth is used, the accuracy is completely determined by the spacecraft stability and the accuracy of the telemetry data which includes measurements of the satellite attitude and orbit. Therefore only systematic errors are removed, giving the name systematic geocoded subscene.

MOSAICS also produces bulk scenes. These are images of the same dimensions as raw input scenes with the systematic along-scan errors corrected. No change is made to pixel-size or scene orientation. Their accuracy is comparable to that of systematic geocoded sub-scenes.

Control Point Database A precision geocoded subscene requires the use of several points whose geodetic location is known. These points must be marked on the input imagery to allow spacecraft orbit/attitude determination. Initially, Ground Control Points (GCPs) must be taken from maps unless an existing control point database is available. MOSAICS maintains a control point database to which new control points are added as they are created for precision processing. A small section of imagery, or image chip, surrounding each control point is also stored in the database. This enables the control point to be located in future images without reference to the original map. Automatic location of control points in the input image is possible where a compatible image chip is available for the control point. MOSAICS will perform automatic correlation between two multitemporal images. Control points used in this manner are termed Registration Control Points (RCPs).

If a sufficient number of RCPs can be successfully located in the input image, a precision image can be created without operator intervention. Otherwise the operator will be requested to mark additional points until the desired accuracy is achieved. Supplemental Control Points (SCPs) can be created once the precision spacecraft orbit/attitude model for the scene has been generated. These are similar to RCPs except that the ground coordinates are predicted rather than directly measured from a map. These SCPs can be used to expand the control point database more rapidly than by digitizing from a map. This allows the future production of precision geocoded subscenes to proceed automatically.

Quality Assurance A moving window display system enables the operator to monitor imagery input from High Density Tape (HDT) as well as to review film products before exposure. This feature also allows visual assessment of a scene for cloud cover, swath drop-out, snow coverage, etc. before more extensive processing is applied. Quality asessment tools are provided for assuring the radiometric and geometric quality of the output products.

IV. CONCLUSIONS

MOSAICS will provide a large number of high accuracy CCT and film products in a standard and convenient format. The format and geodetic accuracy of MOSAICS geocoded products will greatly facilitate the processing of multi-temporal, multi-sensor data. As many agencies are now creating large digital geographic data bases, the need for high accuracy digital data to maintain and update these data bases will become acute. MOSAICS will provide imagery products that will be very useful in this application.

The MOSAICS architecture differs from previous image preprocessing systems in that it will process data from a variety of sensors and that it can be easily upgraded to process data from new sensors.

REFERENCES

1. F.E. Guertin and E. Shaw 1981, Definition and Potential of Geocoded Satellite Imagery Products, Proceedings of the Seventh Canadian Symposium on Remote Sensing, pp. 384-394.

2. F.E. Guertin, D. Friedmann, R. Simard, R.J. Brown, P.M. Teillet, Multiple Sensor Geocoded Data, Proc. of COSPAR 1984.

ACKNOWLEDGEMENTS

Florian E. Guertin, Jenny Murphy, Ron Kwok, Roger Nathan.

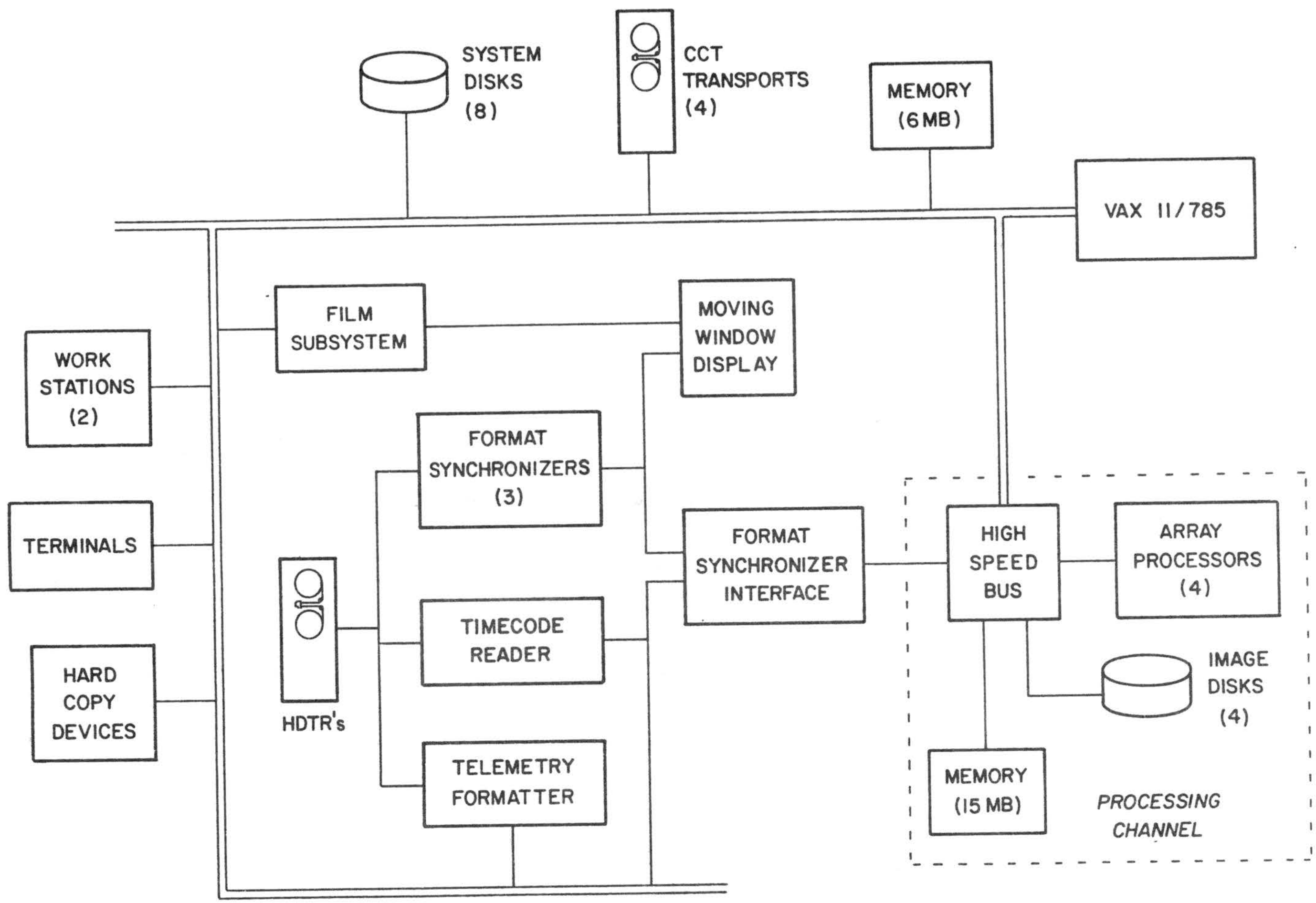

Figure 1

MOSAICS HARDWARE OVERVIEW

Table 1 - Satellite Sensor Characteristics

	LANDSAT(4,5)		SPOT	
	MSS	TM	MLA	PLA
Altitude	705 km		832 km	
Type	Polar Orbiting		Polar Orbiting	
Spectral Bands (Microns)	0.5-0.6 0.6-0.7 0.7-0.8 0.8-1.1	0.45-0.52 0.52-0.60 0.63-0.69 0.76-0.90 1.55-1.75 2.08-2.35 10.4-12.5	0.50-0.59 0.61-0.68 0.79-0.89	0.51-0.73
Ground Resolution (Metres)	80	30	20	10
Swath Width (km)	185	185	60	60
Data Repeat Cycle (Days)	16	16	26*	26*

*Because of pointing capability accessibility at 45 degrees is 1,4,1,4,1,4,1,4,1,4,1 days.

Table 2 Radiometric Accuracy Specification

ACCURACY(RMS % OF FULL SCALE)	MSS	TM	MLA	PLA
Intraband relative	1.5	0.8	1.2	1.2
Interband relative	1.9	2.0	3.0	N/A
Absolute	<10	<10	<10	<10

Table 3 - Geometric Accuracy Specification

ACCURACY (RMS)		MSS (IFOV)	TM (IFOV)	MLA (IFOV)	PLA (IFOV)
Bulk Product:	Relative	1.5	2.9	12.5	25
	Absolute	13.	35.	75.	150.
Systematic Geocoded:	Relative	1.5	2.9	12.5	25.
	Absolute	13.	35.	75.	150.
Precision Geocoded:	Absolute	0.5	0.6	1.2	2.3
	Multitemporal	0.35	0.5	0.6	1.0

Table 4 - Daily Production

PRODUCT TYPE	MSS	TM	MLA	PLA
Bulk Scenes	30	19	26	26
Systematic Geocoded Subscenes	29	22	26	26
Precision Geocoded Subscenes(RCP) (Digital Registration Control Points)	29	22	26	26
Precision Geocoded Subscenes (GCP) (Manual Ground Control Points)	4	4	4	4

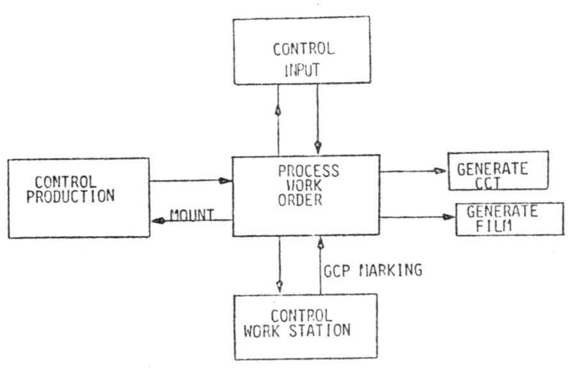

FIGURE 2 SOFTWARE BLOCK DIAGRAM

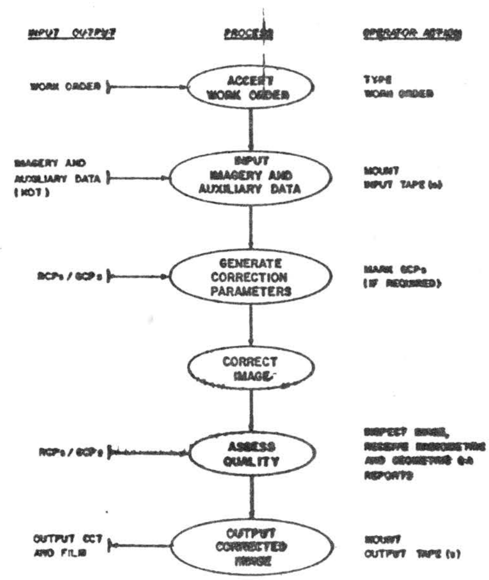

Figure 3

MOSAICS PROCESSING