

Reprinted from

**Symposium on
Machine Processing of
Remotely Sensed Data
and
Soil Information Systems
and
Remote Sensing and Soil Survey**

June 3-6, 1980

Proceedings

The Laboratory for Applications of Remote Sensing

Purdue University
West Lafayette
Indiana 47907 USA

IEEE Catalog No.
80CH1533-9 MPRSD

Copyright © 1980 IEEE
The Institute of Electrical and Electronics Engineers, Inc.

Copyright © 2004 IEEE. This material is provided with permission of the IEEE. Such permission of the IEEE does not in any way imply IEEE endorsement of any of the products or services of the Purdue Research Foundation/University. Internal or personal use of this material is permitted. However, permission to reprint/republish this material for advertising or promotional purposes or for creating new collective works for resale or redistribution must be obtained from the IEEE by writing to pubs-permissions@ieee.org.

By choosing to view this document, you agree to all provisions of the copyright laws protecting it.

AUTOMATIC PROCESSING OF COMPUTER COMPATIBLE TAPES WITH DATA FROM MULTISPECTRAL SCANNERS INSTALLED IN LANDSAT SATELLITES

NORBERTO SCQUIZZATO

Comision Nacional De Investigaciones Espaciales - Argentina

I. DESCRIPTION OF THE GROUND DATA ANALYSIS SYSTEM (SISTEMA TERRESTRE DE ANALISIS DE INFORMACION-STAI) OF THE NATIONAL COMMISSION ON SPACE RESEARCH (COMISION NACIONAL DE INVESTIGACIONES ESPACIALES - CNIE)

STAI is the Spanish acronym for the digital data analysis system for information processing from Multispectral sensors of LANDSAT satellites, or, from the Multispectral Multiband Scanner System (Sistema Multiespectral para Obtención de Información - SAMPOI) which the National Commission on Space Research (Argentine Republic) has installed at the Vicente López Teleobservation Center (Centro de Teleobservación Vicente López).

The STAI can be included among the digital processing systems called as interactive, having a great input and output diversification, but also having pre-processing capacity since it can convert HDDT, High Density Digital Tapes, from the SAMPOI Scanner into CCT, Computer Compatible Tapes.

In its original design, it had the following main units:

A. CENTRAL PROCESSOR UNIT (CPU)

It is a DEC PDP 11/15 computer having the following options:

1. KW11-P - Programmable real time clock.
2. KE11-A - Extended arithmetic element.
3. BM792-YA - Paper tape bootstrap loader.
4. KF11-A - Priority interrupt expansion unit.
5. KP11-A - Power fail/restart unit.

B. MAIN MEMORY SYSTEM

The main memory included in the original design has one slot 8K word of 16 bit read/write 900 Nano second core, DEC-ME11L, plus another two MM11 increments of similar characteristics, giving as a result a total capacity of 24K word addressable by program.

C. NINE TRACK MAGNETIC TAPE UNIT

The computer system has two magnetic tape units DEC-TU10 industry-standard compatible 9 track, each providing transfer rates of 36,000

characters per second. Data is recorded at 45 ips and 800 bpi in NRZI (Non Return to Zero change on one) mode on 0.5 inches tapes.

D. MAGNETIC TAPE CONTROLLER

This device distributes data from the Unibus for each one of the MTU, specifically it is a DEC-TM11 with a maximum capacity of up to 10 MTU.

E. TELETYPE WITH DL11 INTERFACE

It is employed as a communication means between the central processor unit and the operator.

This communication involves the punching and reading of paper tapes, likewise, the type out and the printing of information from the computer by the operator.

In our case, the Teletype is an ASR-33 model.

F. HIGH SPEED PAPER TAPE READER/PUNCH

Model DEC-PC11 is capable of reading eight-hole perforated paper tape at 300 characters per second, and punching tape at 50 characters per second.

G. INTERFACE EXTENSION UNIT

It contains additional interfaces needed to control the color Moving Window Display and SDIP.

It is composed of:

1. DC-DR11B - Direct memory access interface, quantity 2.
2. DEC-DR11C - General Purpose interface, quantity 3.
3. HP720 - Power supply.

H. SENSOR DATA INPUT PROCESSOR (SDIP)

This device is a self-contained unit of modular construction for the interface and control of a 14 track High Density Digital Tape recorder. It contains electronics for data decommutation and bit synchronization, work synchronization and sync detection.

CH1533-9/80/0000-0030 \$00.75 ©1980 IEEE

An interface generates the adequate film recorder signals for driving the black and white film recorder.

This unit also contains provisions for enabling computer controlled scan search at high speed (120 ips) and display the scan line number.

I. BLACK AND WHITE STRIP FILM RECORDER

The film recorder converts one channel of analog video information to 70 mm black and white film.

Basically, this unit is composed of a CRT (Cathodic Ray Tube) in front of which the 70 mm film is displaced, in a transversal direction with reference to the scanning.

The CRT employs its inner surface with phosphoric re-covering to allow the film, on the external surface, to be exposed line by line.

It is a Honeywell Visicorder Oscillograph Mod. 1856-LS-6 which has been modified.

J. PLAYBACK UNIT OF HIGH DENSITY DIGITAL TAPE

This tape playback unit system, Sangamo, Sabre IV, is capable of reproducing video data on standard one inch magnetic tape 14 track, which has been recorded with PCM Bi-phase-level data.

Seven discrete speeds are electrically selectable, but only three are used in the STAI, 1 7/8, 15 and 120 ips.

K. MOVING WINDOW DISPLAY MEMORY AND CONTROL

Since we need to display an image on a TV color monitor, it is necessary first to store it and afterwards to repeat or refresh it on the screen.

In other words, to display data it is necessary to store them in a dynamic refresh MOS memory, with sufficient capacity, which in our case is of 1.3 Megabits.

The performance of this device can be summed up as follows:

- Accepts three channels of digital data asynchronously.
- Provides eight levels of color intensity for each picture element in each channel.
- Displays 512 picture elements across each horizontal scan line.
- Displays 256 lines per frame.
- Refreshes display at 60 cycles per second.
- Allows to employ an overlapped rectangle on the image, called cursor, having variable dimensions and positions.
- Provides capability of shifting the raster one scan line, up or down.

Its control system accepts cursor use in

order to identify areas considered as samples, color selection and introduction of a value table to carry out certain color codification. Besides, it is used as interface for the color film printing unit.

It is formed by a RAMTEK unit GX 100/200 with 17 modular cards.

L. DISPLAY COLOR MONITOR

The monitor is a color TV screen of 19 inches, which receives analogic information from the display memory.

The introduction of an image in the screen is done line by line.

The scale of the displayed image portion on the screen is around 1:100,000 for LANDSAT satellites CCT.

M. SEVENTY mm COLOR FILM PRINTING SUB-SYSTEM

It consists of a second color TV set which receives the same data as the color monitor screen and a 70 mm photographic camera, which can operate in an automatic mode or by manual demand from the respective front panel.

N. OPERATOR'S INTERACTIVE PANEL

Through selecting switches the operator can introduce access hardware instructions to the CPU when the processing program is running.

In the STAI there are 16 switches, (Figure 1). They are the following:

1. Channel selected "R"
2. Channel selected "G"
3. Channel selected "B"
4. Category Assignment Switch
5. Call Cursor
6. Store
7. Upper Left-Lower right
8. M-1
9. T-1
10. Cursor direction
11. Move-Hold
12. Display Direction
13. Display Portion
14. Mode
15. Demand-Exposure
16. T-2

O. STAI OPERATING SYSTEM

The STAI Operating System is the "Tape Operating System", TOS, in consequence, operative programs are stored in magnetic tapes.

The present STAI tape operating system has the following main programs:

- L1: 2 - 20K Operating System
- L1: 3 - Argentina LANDSAT tape display

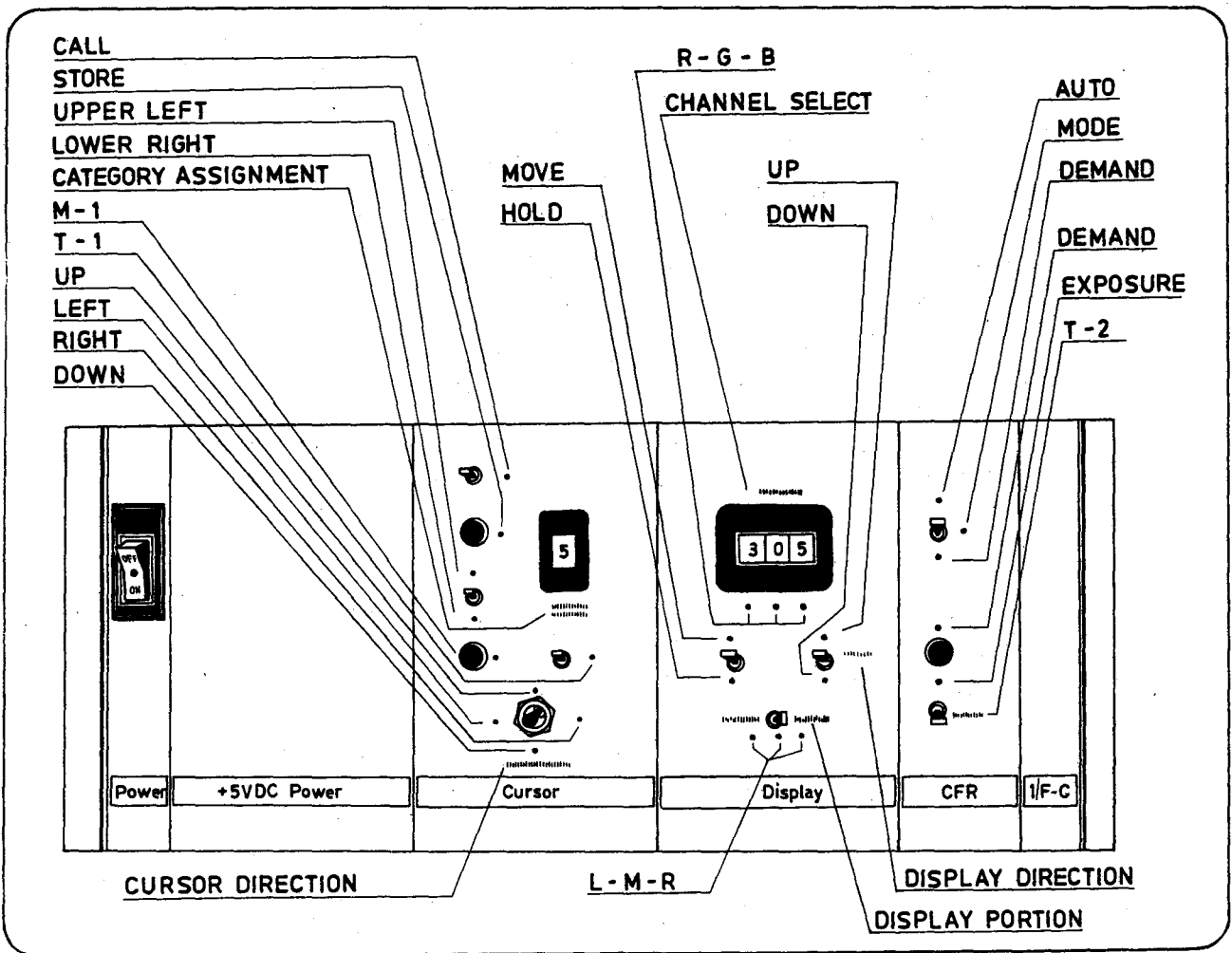


Figure 1. STAI - Operator's Interactive Panel

- L1: 4 - SAMPOI CCT tape display
- L1: 5 - MSDS CCT tape display
- L1: 6 - SAMPOI Aircraft video tape display
- L1: 7 - SAMPOI Aircraft video tape converter
- L1:10 - LANDSAT Categorical Analysis
- L1:11 - SAMPOI Categorical Analysis
- L1:12 - MSDS Categorical Analysis
- L1:13 - MSDS Format converter
- L1:14 - Categorization Accuracy Analysis
- L1:15 - LANDSAT Categorical Processor
- L1:16 - SAMPOI Categorical Processor
- L1:17 - MSDS Categorical Processor
- L1:20 - Processed Image Tape display
- L1:21 - Peripheral interchange program (PIP)

- Additional memory bank of 8K word, which then leads the capacity of installed memory to 28K word.
- RK11-05 disc unit of 2.4 Megabytes capacity and RK11-D controller.
- RK05J additional disc unit of 2.4 Megabytes capacity.
- RT11-03B Cartridge Disc Operating system.
- Alphanumeric Video terminal DEC-VT100 with its respective asynchronous DL11 interface.
- Automatic bootstrap loader DEC-M9301 YB.
- Line printer of 180 character per second and 132 columns, model LA 180.
- Card reader of 80 columns, DEC-CR11.
- FORTRAN IV-PDP compiler.

P. STAI-M

By STAI-M we mean the new configuration carried out in order to improve the former STAI design.

It adds to existing units, the following new devices:

The addition of these devices will allow, mainly, an increase in the processing speed, a greater input and output diversification, as well as, the input of FORTRAN IV programs.

Figure 2 is a STAI-M block diagram.

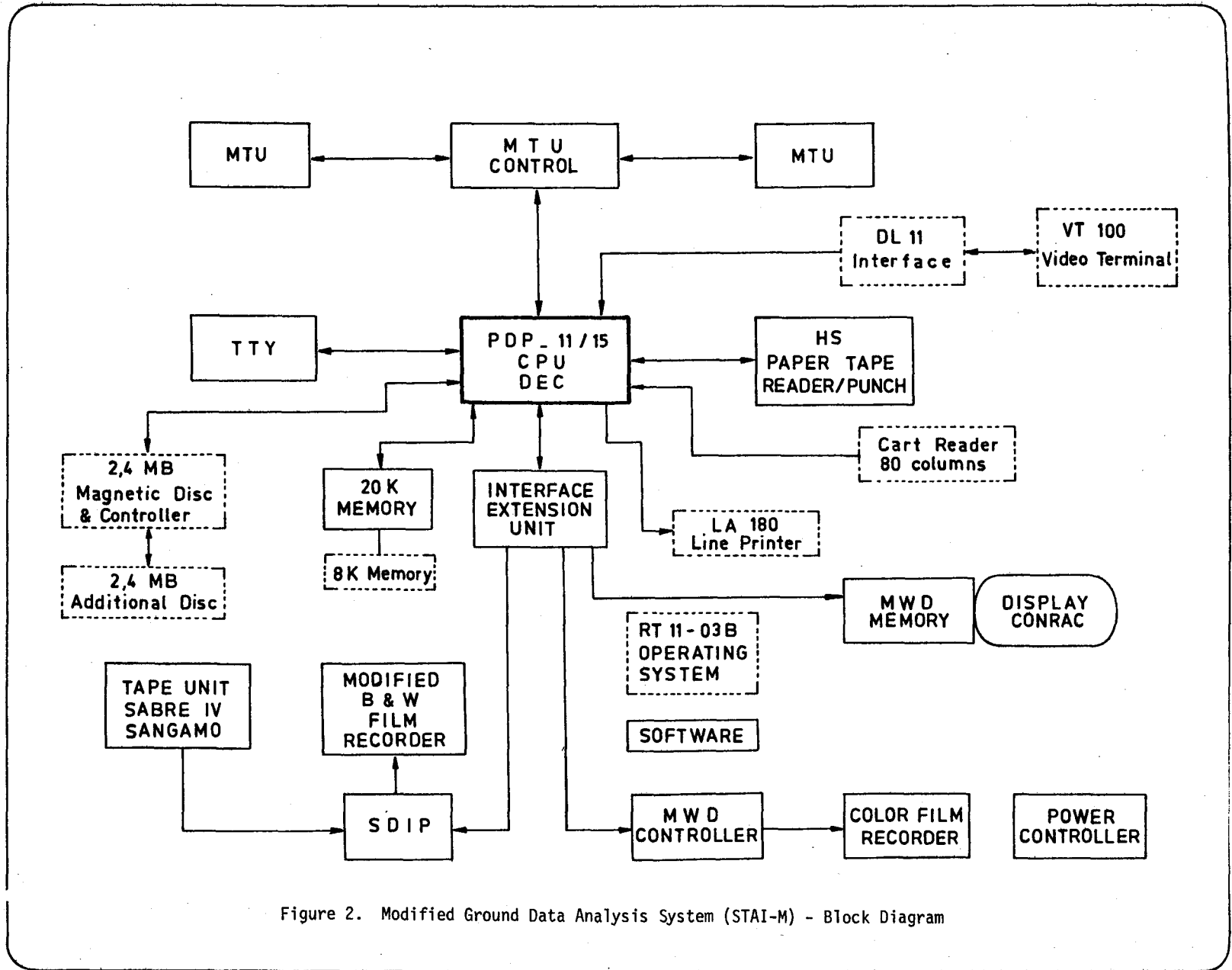


Figure 2. Modified Ground Data Analysis System (STAI-M) - Block Diagram

Q. FUTURE EXTENSIONS

Studies have been carried out in order to install with STAI-M the following devices:

1. Table Digitizer. It will allow to introduce in the process point coordinates located on conventional cartography, as well as, to carry out automatic processing of areas having different geometrical limits.
 2. OPTRONICS type Color Film Digitizer and Impresor. With this subsystem, 70 mm or 23 cm color high resolution films can be printed.
 3. Electrostatic Printer Plotter. It is foreseen to install this type of terminal to work on 22 inches wide paper.
- II. DISPLAY AND PROCESSING OF COMPUTER COMPATIBLE TAPES (CCT) PRODUCED BY NASA IN THE GODDARD SPACE FLIGHT CENTER FORMAT, BY MEANS OF THE L1:3 PROGRAM FOR THE MOVING WINDOW DISPLAY (MWD) OF THE STAI.

When this type of CCT is displayed in the STAI monitor, it can be visualized color portions of LANDSAT scenes in two kinds of color codification modes known as single channel color sliced and false color. In the first mode the operator can select a combination by means of the three selecting switches of 16 positions, 0 to 15, known as "channel select" which at the same time, are identified by "R", "G" and "B" letters in the operation panel of the system.

In this way with "B" switch, the operator selects the band to be displayed while with "R" and "G" switches he can change the transfer function of gray levels to a preassigned Table of color levels.

The transfer function is:

$$y = \frac{x - 16 R}{G + 1}$$

Where:

- y = resultant color, which can vary from level 0 to 255.
- x = gray level in "B" band, could vary from level 0 to 255, since for processing purposes the 128 levels are multiplied by 2 for bands 4, 5, and 6 and by 4 for the 64 levels of band 7.
- R = offset level over the axis x; R=0, 1, 2, 3, ...,14
- G = transfer gain or slope; G=0, 1, 2, 3, ...,15.

Figure 3 shows the representation of this function for R=0, R=7 and G=0, 1, 3, 7 and 15. Of the 256 possible color levels only 24 are assigned. This assignation is carried out through a predetermined color Table (Table 1) which can be modified by the operator if it is necessary.

In the second alternative, the false color displaying mode, the channel select switch of the operation panel changes its function in order that

Table 1

Color Level (y)	Intensity level established for each color			Resulting color on the monitor screen
	Red	Green	Blue	
1	0	0	0	Black
2	1	1	1	Dark gray 1
3	2	2	2	Dark gray 2
4	3	3	3	Dark gray 3
5	4	4	4	Bright gray 1
6	5	5	5	Bright gray 2
7	6	6	6	Bright gray 3
8	7	7	7	White
9	0	0	7	Blue
10	0	1	6	Turquoise blue 1
11	0	2	5	Turquoise blue 2
12	0	3	4	Turquoise blue 3
13	0	4	3	Green turquoise 1
14	0	5	2	Green turquoise 2
15	0	6	1	Green turquoise 3
16	0	7	0	Green
17	1	6	0	Yellow green 1
18	2	5	0	Yellow green 2
19	3	4	0	Yellow green 3
20	4	3	0	Yellow red 1
21	5	2	0	Yellow red 2
22	6	1	0	Yellow red 3
23	7	0	0	Red
24	7	0	7	Purple

it would be possible to assign to each one of the three colors one of the LANDSAT bands.

- "R": assigns band number indicated in it, to red.
- "G": assigns band number indicated in it, to green.
- "B": assigns band number indicated in it, to blue.

As an example, a false color codification which is usually very used is 7-6-5, that is, R=band 7, G=band 6; B=band 5, which corresponds to introduce gray scale of band 7 to red, that one of band 6 to green and of band 5 to blue.

The portion of image obtained over the color monitor depends upon the positions of the switches known as Display Portion and Category Assignment Switches of the operation panel.

The information contained in a CCT when it is displayed, comprehends a rectangle of around 46 km x 184 km having a correspondence with the 810

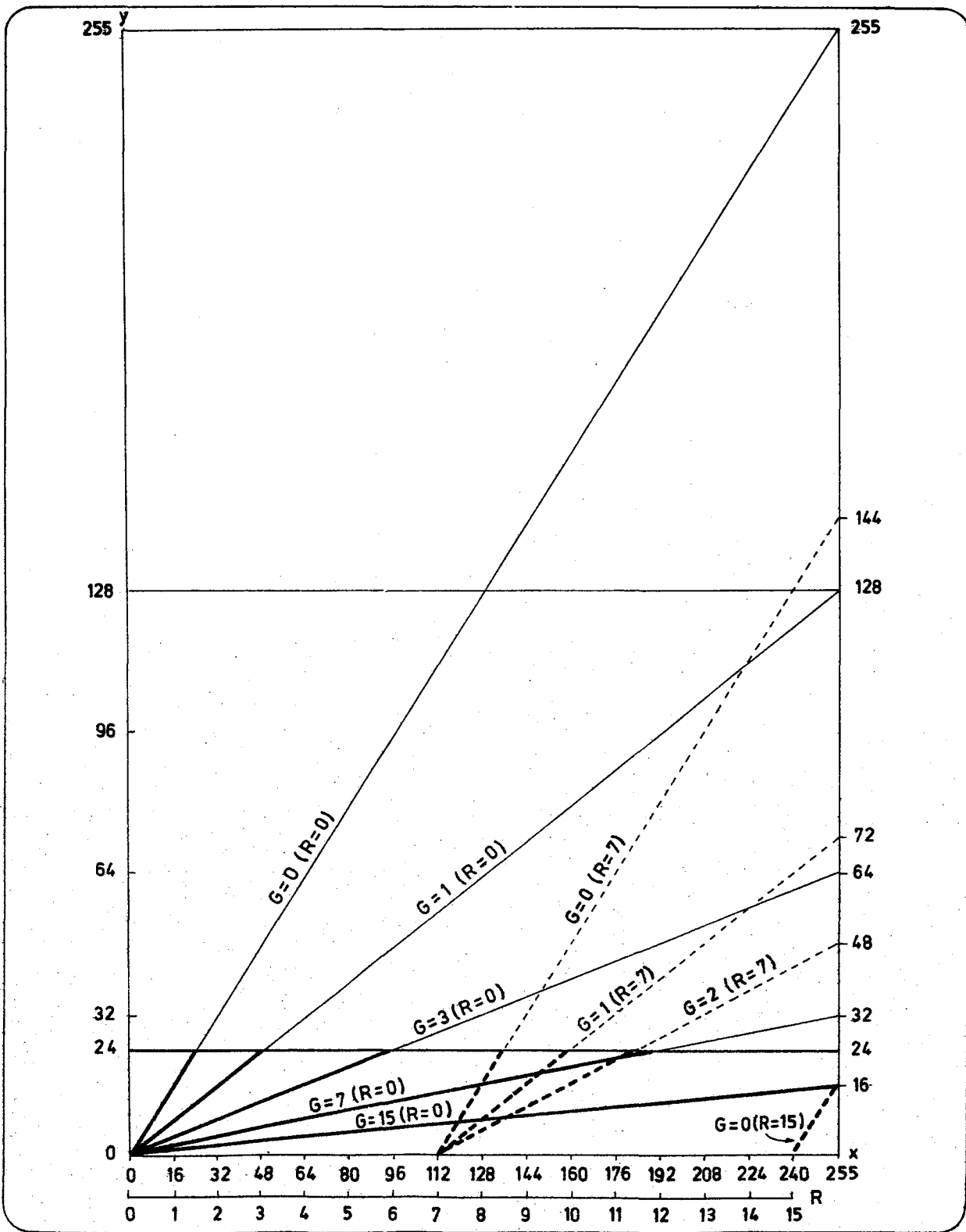


Figure 3. Transfer function

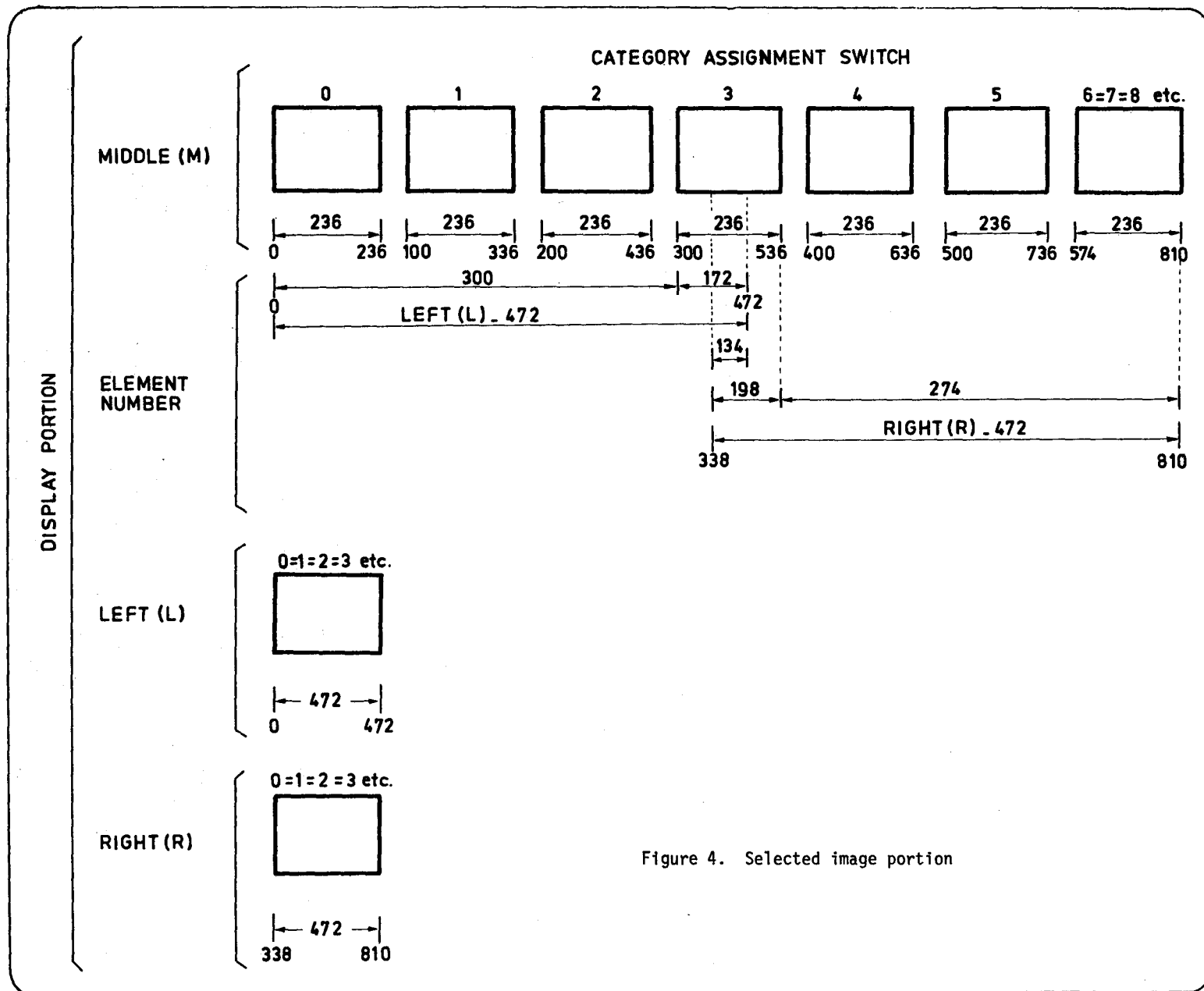


Figure 4. Selected image portion

elements per line and 2340 lines registered in it.

When the Display Portion switch is located in the left "L" position, the 472 pixels from each of the 256 lines are displayed while in "R" (right) position pixels are displayed from 338 to 810 of each one of the 256 lines. In these two positions the Category Assignment Switch does not affect the selected portion.

If we place the Display Portion switch in "M" (middle) position, 236 pixels are displayed, to which correspond 472 image elements, that is to say, that each pixel information is repeated in two consecutive image elements, with which we achieve a horizontal image enlargement, and now the displayed portion depends upon the Category Assignment Switch. If this switch is in "0" position the first 236 elements are displayed; if in "1" from 100 to 336; if in "2" from 200 to 436; if in "3" from 300 to 536; if in "4" from 400 to 636; if in "5" from 500 to 736 and if in "6", "7", "8" until "15", elements from 574 to 810 will be displayed.

Figure 4 illustrates upon the selected image portion for each one of the positions of these switches.

It is important to notice that image does not appear in the monitor in an instantaneous way, but it appears line by line, at a speed of six lines and a half per second.

The program which allows the displaying in some of these modes is individualized by L1:3 symbol. If the image is stopped by means of the Move-Hold switch of the operation panel, through the Call switch a rectangle can be called having variable dimensions and positions, rectangle known as cursor.

The operator, by means of this cursor can place known samples of the image and assign them to some of the groups under study, giving to the selected samples the groups number through the Category Assignment Switch. Finally, pressing the "Store" pushbutton the computer will print a listing by means of the teletype and will punch a paper tape through the high speed reader-punch giving the coordinates of the selected sample.

Listing N° 1 corresponds to this program, In it 3 groups have been selected with 2, 2 and 3 samples each one, respectively. On the listing some Spanish notes have been written down. The coordinates of each sample are established by the element number and pixel line number in the upper left corner and lower right corner of the cursor (Figure 5).

The punched paper tape is afterwards employed for the L1:10 program in order to obtain the total observation group number, the eigenvalues of the covariance matrix, the mean value of the group reflectivity in each one of the bands, the standard deviation of each group and two of the coefficients to be employed in the L1:15 classifi-

cation program.

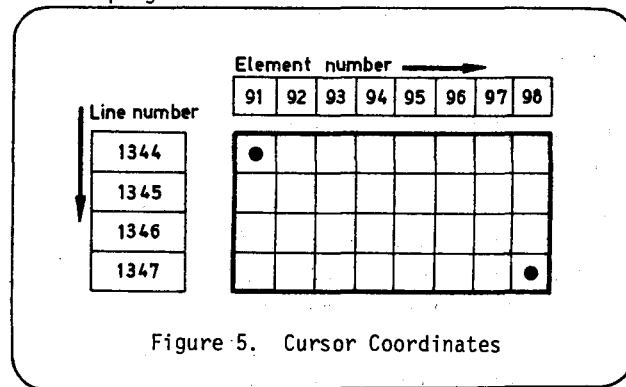


Figure 5. Cursor Coordinates

Through the L1:14 program conclusion can be obtained with reference to the accuracy with which the samples were selected.

Finally, through the L1:15 program, surfaces can be obtained, classified and quantified in square miles and square kilometers for each one of the groups of a scene selectable portion and this classification can be displayed, and printed on 70 mm color film, through a second color TV and conventional camera system, placed on the module next and at the right of the monitor.

Listing N°1

```
L1:3
.G
ARGENTINA LANDSAT TAPE DISPLAY
INITIAL RECORD NUMBER?
100
OPTION?
FC
OPTION?
CS
OPTION?
CT
OPTION? COORDENADAS EXTREMO SUPERIOR IZQUIERDO CURSOR
FC COORDENADAS EXTREMO INFERIOR DERECHO CURSOR MUESTRA GRUPO
E L E L MUESTRA GRUPO
757 317 771 322 1 1
771 340 777 347 2 1
21 597 44 610 1 2
91 1344 102 1348 2 2
91 1361 105 1368 1 3
91 1308 105 1322 2 3
62 1308 81 1322 3 3
```

Listing N°2

L1:10
.6

LANDSAT CATEGORICAL ANALYSIS
TAPE?

757	317	771	322	1
771	340	777	347	1
21	597	44	610	2
91	1344	102	1348	2
91	1361	105	1368	3
91	1308	105	1322	3
62	1308	81	1322	3

TAPE?

IF ANOTHER DATA TAPE, TYPE Y AND CR , OTHERWISE CR

TOTAL DE OBSERVACIONES
DEL GRUPO 1 = 146

GROUP 1 NO. OF OBSERVATIONS=146 DET=0.7303E 04

EIGENVALUES

1	480.28894
2	6.32716
3	0.68805
4	0.48286

BAND	MEAN	STD.DV.	COEFFICIENTS	
4	51.260	3.368	-0.19242	-0.06639
5	40.740	3.519	0.12876	-0.25848
6	81.356	3.796	0.12701	0.06395
7	94.082	4.733	0.13844	-0.00861

GROUP 2 NO. OF OBSERVATIONS=396 DET=0.3819E 03

EIGENVALUES

1	806.31085
2	21.20133
3	1.98440
4	1.08303

BAND	MEAN	STD.DV.	COEFFICIENTS	
4	42.591	2.217	-0.15840	0.25604
5	19.455	3.105	-0.16043	0.20782
6	10.611	2.697	0.30022	-0.04463
7	2.919	2.800	0.25915	-0.03601

GROUPS 3 NO. OF OBSERVATIONS=645 DET=0.6446E 02

EIGENVALUES

1	1065.94250
2	116.77979
3	1.39873
4	1.21108

BAND	MEAN	STD.DV.	COEFFICIENTS	
4	55.088	1.867	-0.03086	0.16716
5	37.141	1.304	-0.14311	0.67916
6	19.510	1.632	0.37891	0.12942
7	7.051	2.319	0.26460	-0.11872

III. IMAGE SCALE DETERMINATION OF THOSE IMAGES DISPLAYED IN THE MWD OF THE STAI, FOR COMPUTER COMPATIBLE TAPES FROM NASA

It is important to determine the scale by which images are visualized in the Moving Window Display of the STAI.

To display an image on the TV screen it is necessary to repeat or refresh it 25 times or more per second, for which it is required to employ a great capacity dynamic memory.

In the STAI, the dynamic memory for the display has 256 lines per 512 elements which gives a total of: $256 \times 512 = 131,072$ image elements for each color, and since there are three colors, it will be needed to store $131,072 \times 3 = 393,216$ bytes, since each individual color has 8 possible levels. each byte will have then 3 bits.

But, for the cursor we still need 43,690 bytes with which the total capacity of the dynamic memory will be $393,216 + 42,690 = 436,906$ bytes of 3 bit each one.

Notwithstanding, from the 512 image elements of a line only 472 will be employed for a scene data, since the remaining 40 elements are left for the notation margin.

As it has been mentioned, each forth of LANDSAT scene contains information of a paralelogram of 46 km x 184 km which has a correspondence with a 2340 line per 810 element matrix in the CCT.

When displaying is carried out with the Portion switch in "L"(left) or "R"(right) position, we will obtain a 256 lines per 472 elements frame, and in the "M"(middle) position the displayed frame will have 256 lines per 236 elements (Figure 6).

As it has been explained, each forth of line has 810 elements and this corresponds to 46 km, each element will then have an approximate length of:

$$\frac{46,000 \text{ meters}}{810 \text{ elements}} = 56.79 \frac{\text{meters}}{\text{element}}$$

That is to say that, each pixel of the scene can be displayed assigning an image element. For each reflectivity level of the pixel we assign an equivalent color level in the monitor screen.

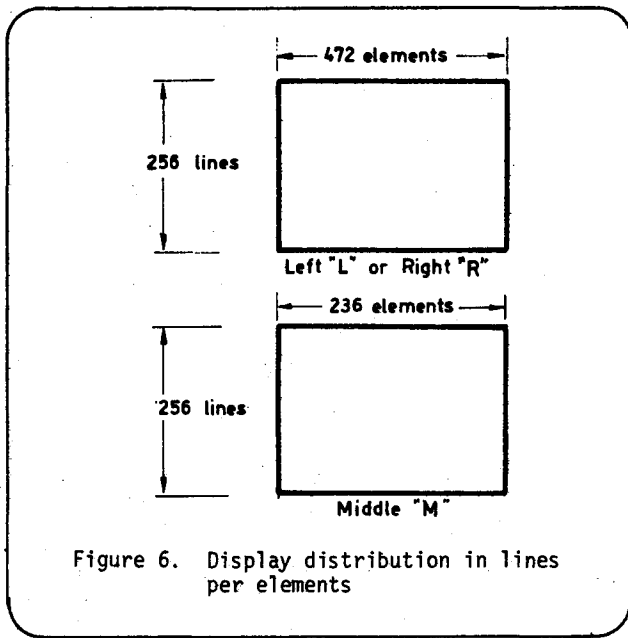


Figure 6. Display distribution in lines per elements

Thus, we would have an image element which will correspond to an area of 57 meters by 78 meters.

That is, foraa "L" or "R" frame will correspond, approximately, a rectangle of: 256 x 19,968 m per 472 x 56,79 = 26,804 meters, or, 236 x 56,79 = 13,402 meters for the "M" position (Figure 7).

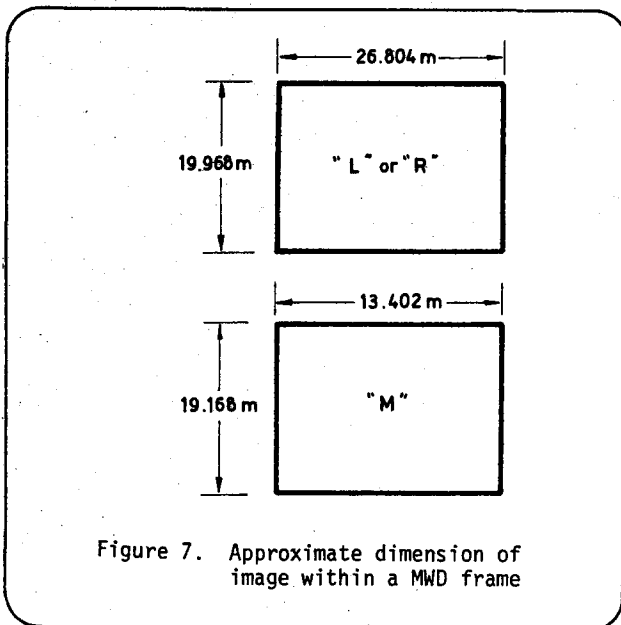


Figure 7. Approximate dimension of image within a MWD frame

Since the frame dimension of the MWD is 19.96 cm per 26.80 cm, it will give as a result a scale of:

For the "L" or "R" position:

$$\begin{array}{r} 0.268 \text{ m} \text{ ---} 26,804 \text{ m} \\ 1 \text{ m} \text{ ---} \frac{26.804}{0.268} = 100,000 \end{array}$$

Vertical scale: 1:100,000

$$\begin{array}{r} 0.1996 \text{ m} \text{ ---} 19,968 \text{ m} \\ 1 \text{ m} \text{ ---} \frac{19,968}{0.1996} = 100,000 \end{array}$$

Horizontal scale: 1:100,000, with which the "L" or "R" frame scale displayed will be 1:100,000.

On the contrary, for the "M" position, though vertical scale remains constant at 1:100,000, the horizontal scale is 1:50,000, since:

$$\begin{array}{r} 0.268 \text{ m} \text{ ---} 13,402 \text{ m} \\ 1 \text{ m} \text{ ---} \frac{13,402}{0.268} = 50,000 \end{array}$$

By which an object will appear enlarged to its double, in only one direction.

The author was born in Buenos Aires, Argentina. He received the degree in telecommunication engineering from the National University of La Plata in 1971. He worked for 5 years in the Remote Sensing Group of the State Secretariat of Agriculture and Livestock (Secretaría de Estado de Agricultura y Ganadería) of Argentina. In 1974, he attended several courses held in different Educational Centers of U.S.A.. At present, he is a staff member of the National Commission on Space Research (Comisión Nacional de Investigaciones Espaciales) and a member of the Faculty at the National Technological University of Buenos Aires.