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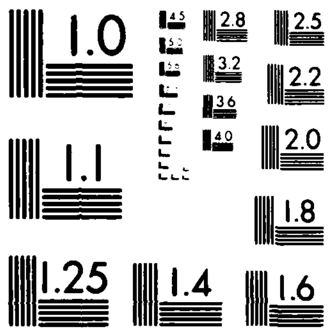
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PROCESSING OF GLOBAL AREA COVERAGE (GAC) DATA OF THE TIROS-N/NOAA SERIES POLAR ORBITERS

Global area coverage (GAC) data are the Advanced Very High Resolution Radiometer (AVHRR) imagery archived by NOAA/NESDIS. This documentation describes techniques for processing GAC data on a minicomputer-based display system, including techniques for transformation from satellite observed coordinates to polar stereographic and Mercator coordinates.

These techniques were developed and documented by Valentin Treis, meteorologist in the German Military Geophysics Office, Traben-Trarbach, Federal Republic of Germany, while he was on a year's tour as an exchange scientist with the Naval Environmental Prediction Research Facility.

Processing of Global Area Coverage (GAC) Data of the TIROS-N/NOAA Series Polar Orbiters

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Abstract

Global Area Coverage (GAC) data is stored data of the AVHRR instrument. The original HRPT resolution of 1.1 km is reduced to about 3.3 by 4.0 km. There are 120 scans per minute with 409 pixels each. The raw data are available from the National Climatic Data Center as tape copies that generally contain calibration information. In order to process the data on the SPADS, the data must be unpacked and written to a disk file in a specified format. Then, the image can be transformed in either Mercator or Polar Stereographic Projection, and the geographical background may be added.

1. Introduction

This documentation is meant as an aid for using the described software available for the SPADS Eclipse S250, for maintenance of the software and for understanding data formats as well as the techniques involved in processing the GAC imagery.

The NOAA Polar Orbiter Data User's Guide (1) as well as the NOAA Technical Memorandum NESS 107 (2) are most useful to understand the data formats and the retrieval techniques.

If any errors are found with these documents, the user should not hesitate to contact the responsible people; any constructive response will be appreciated.

2. The Raw Data

2.1 How to Order Data

Everybody working for the SPAD should contact the department head to get the account number to which the fees for the data copies should be billed prior to ordering data.

Then a letter should be written to the National Climatic Data Center, following the instructions described on page 1-1 of the NOAA Polar Orbiter Data User's Guide. Writing a letter will pay off, since a phone call is a potential source of misunderstandings. About $100 for a possibly faulty copy can be saved this way.

Up to now, it has been advisable to order 800 BPI copies directly compatible with the tape unit available to the S250. Since there will be a 1600 BPI tape unit available in connection with the MV4000, it is recommended to order 1600 BPI copies in the future. In doing so, more data can be written to one tape. Since the fees are charged per tape, money can be saved again.

2.2 Data Formats

2.2.1 The Tape Label (TBM Header)

The first record on the tape, described under 3.0.1 data set names and under 3.1.1 TBM header in the User's Guide (1), is 61 (16-Bit) words long and contains essential information about the copy in ASCII code. All other records on the tape should be 3220 words long.

2.2.2 Data Set Header

The second record is the data set header. Only the first 35 Bytes are of any meaning to the user. The rest are blanks to make the header record 3220 words long.

The tape direction coding in the DACS status word has probably been faultily described in the User's Guide (1).

The content of the first 35 Bytes has been described on pages 3-3 through 3-5 in the User's Guide (1).

2.2.3 Data Records

Records 3 through N (depending on the data volume) are data records. Each of these physical records contain two logical records, one per scan. One logical record is 1610 words or 3220 Bytes long.

The first 448 Bytes (224 words) of a logical record contain information about that particular scan, such as scan line number, start time of scan, calibration coefficients etc. Bytes 449 through 3176 (2728 Bytes or 1364 words) contain the GAC video data, the rest is left spare.

GAC raw data have 10 Bit per pixel, with the most significant Bit (MSB) at the left and the least significant Bit (LSB) at the right. Three pixels are stored in 4 Bytes (2 words), right justified. Thus, if all the Bits of three subsequent pixels were set to 1, the 4 Bytes would look as follows:

```
word N                         |word N+1                       |
0 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1|1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1|
----------------------------------------------------------------
  |pixel M        |////|pixel M+1     |////|pixel M+2     |////|
```

Since the hardware available is able to display 8-Bit data only, the left 8 Bits of each pixel must be extracted. This can be done using a masking as follows:

```
pixel M:    ISHFT (word N.and.37700K,-6
pixel M+1:  ISHFT (word N.and.17K,4).or.ISHFT(word N+1.and.174000K,-12)
pixel M+2:  ISHFT (word N+1.and.1774K,-2)
```

In the last two words, only the first two pixels are of any meaning, the third one is zero-filled.

Thus in the first 1362 words of each logical record, 2043 pixels are stored. Plus another 2 pixels in the last two words makes up to 2045 pixels per logical record or scan. Since there are 5 possible channels onboard the satellite, this results to 409 pixels per channel per scan. In case the satellite has only 4 channels, the data of the fourth channel are copied into the space reserved for the missing fifth channel. The data are written in the following sequence:

pixel 1 of channel 1, pixel 1 of channel 2, pixel 1 of channel 3, pixel 1 of channel 4, pixel 1 of channel 5, pixel 2 of channel 1, and so on. Caution: The pixel values of pixels 1, 2 and 409 of each scan have been found to be more or less regularly set to zero.

2.3 Processing the Tape

2.3.1 Quality Checks

The raw data are not always perfect. To test the tape for readability, program TAPETST may be run on the NOVA computer prior to running POLRGAC, the tape reading and processing program. This is advisable, since POLRGAC is able to continue reading upon you request, even if the data is faulty.

There is also a program available to test the raw data for proper time sequence of all the scans contained on the tape; this program is called GTMTST (GAC time test) and runs on the Eclipse S250. After the run of GTMTST is complete, the results can be listed on the line printer by typing: PRINT GTMTST.PR.

It is understood, that these testing procedures use a lot of paper. Ultimately, it seems to be worth it, since working with faulty data can never be satisfactory. Anyhow, GTMTST should only be run, if POLRGAC generates a strange looking image on the display. This visual quality control provided by POLRGAC is still not perfect, since missing scans in the original satellite data may have been omitted in the copy. So, the efficiency of testing the data depends largely upon the user's personal judgment.

2.3.2 Running POLRGAC

It seems not to be necessary to give too many details, because the program documentation of POLRGAC is already pretty detailed. Information that goes beyond the knowledge necessary to run POLRGAC is probably more useful to the user.

Prior to running the program, one should know which channels one wants to work with, and whether or not one needs a temperature/albedo look-up table. It is always advisable to write the header information of each image being processed to the printfile POLRGAC.PR; this enables the user to keep track of the imagery that has been processed. The same is valid for the look-up tables, that may be written to printfile GACCAL.PR. The information contained in POLRGAC.PR is essential for the generation of the proper ephemeris lateron. Thus, holes in the raw data, even missing lines, are not necessarily a reason to keep POLRGAC from performing its job.

2.3.3 The Albedo and Temperature Look-up Tables

The techniques involved in generating these tables (subroutine GACCAL) are in accord with the latest information available. Details can be found in the User's Guide (1) as well as in the NOAA Technical Memorandum NESS 107 (2).

2.3.4 Data Time Sequence

Since, on the one hand, there is a chance that the time sequence of the data on tape may be reversed, and, on the other hand, GACMOPS, the transformation program, expects the data as being time incrementing, POLRGAC would flip the whole image upside down prior to storing it to disk, if it encountered time decrementing data.

The ephemeris file used in connection with GACMOPS lateron is always time incrementing.

2.3.5 Satellite ID

POLRGAC is able to look for the satellite ID and to display it on the dialogue screen in the after launch code for TIROS-N through NOAA-8. For all future satellites of the same series, it would give the pre launch code, e.g. NOAA-E for NOAA-8. Thus, if the user wishes to get the after launch name for future satellites, the corresponding source code has to be changed in POLRGAC.

2.3.6 The Processed Image

The image displayed on the screen is scrolled up as a new image line is provided by the program. Since the image has a nearly uniform resolution of 3.3 km in flight direction and of 4.0 km in scan direction at the subpoint only, the image looks stretched in flight direction and the distortion at the left and right edges is clearly visible.

For ascending satellites, time incrementing recording assumed, the image is displayed "upside down", with the southernmost scan at the top of the screen. This is fully in order, and GACMOPS expects it this way.

2.4 Transforming the Processed Raw Image

2.4.1 Difference between GACMOPS and APTMOPS

All the techniques involved in the transformation process have been adopted from APTMOPS. But, as the name APTMOPS indicates, that program was designed to handle Automatic Picture Transmission (APT) data and was intended for regional operational use. Thus, GACMOPS had to be designed to handle data of a different format (GAC) from any location in the world.

In GACMOPS, only the names of the proper input image and the corresponding ephemeris file have to be typed in. Any output file naming is done automatically. The program also displays the geographical borders of the image on the dialogue screen.

An already transformed image may be displayed prior to starting the transformation of the input image; the result, if both images cover about the same area (which should be the case for subsequent orbits), would be a mosaic. GACMOPS is also able to generate a 1024 by 1024 image in 6 km resolution that covers areas from about 60 degrees polewards, with the pole at the center. The same area can be covered by a 512 by 512 km image in 12 km resolution. The orientation of these images is the standard FNOC orientation for either hemisphere.

The program uses 70 blocks of extended memory instead of 200 needed by APTMOPS; this is mainly possible because the data density of the GAC data is lower than that of the APT data.

As an additional option, GACMOPS swaps to the geography background generating program GACGEO, if desired.

2.4.2 Input Image

The input image must have 512 pixels per line; for GAC images processed by POLRGAC, the first 409 are video data, the rest is zero-filled. The number of lines is unlimited, but GACMOPS only processes up to 2760 lines that cover a recording time of 23 minutes.

For 12 km resolution Mercator projection at midlatitudes, about 1530 image lines are needed to cover the screen in vertical direction. For the same projection, but 3 km resolution, only about 306 raw image lines are needed to cover the screen.

This also shows, that a 3 km resolution Mercator projection does not make very much sense near 60 degrees latitude, since only about 306 raw image lines are available to cover 512 display lines. For Polar Stereographic Projection, this effect appears in ares near the equator. Thus, Mercator Projection is most useful in low and mid-latitudes, whereas Polar Stereographic Projection is best in mid- and high latitudes. Per definition, the Mercator projection used is true at 22.5 degrees N and S, and the Polar Stereographic projecting is true at 60 degrees latitude in either hemisphere.

2.4.3 Ephemeris File

To generate the ephemeris file, not only the start time of the image, but also some epoch information about the satellite is needed. The input data for POLRTRK, that generates the epoch and ephemeris file, can be found in the well known APT predict/TBUS messages (Part IV). These messages are collected at the SPADS computer room and should be available for the current year. Older messages may be available from the MetLab in building 15. As a last resort, the proper data may be ordered together with the raw data copies. The ephemeris must be generated for 60 sec intervals; the ephemeris start time must be less than or equal the image start time. In this case, the ephemeris timespan (counting from ephemeris start on) must be at least LMAX/120 minutes; LMAX is the number of lines contained in the input image. Thus, an ephemeris time span of two hours would cover one whole orbit of about 102 minutes of recording tome or 12240 image lines; generally, the user will work with smaller amounts of data that cover an area of special interest. Thus, GACMOPS will only need and accept up to 24 points out of the generally bigger ephemeris file.

POLRTRK is not able to predict the navigation for more than 7 days; for a longer period, the navigation would become totally unreliable, because no drag from the upper atmosphere is included in the technique. There will probably be another program available within the year, that will solve this problem. As a consequence, if POLRTRK is used, the epoch information should be of a date as shortly before image start time as possible.

2.4.4 Running GACMOPS

Program GACMOPS requires about 31 k of memory as well as 70 blocks of extended memory; 1 block of extended memory is reserved for referencing the memory and 69 blocks may be used to store data. Thus, up to 276 disk blocks can be transferred to extended memory, 128 at a time. In the whole, running GACMOPS requires at least 101 blocks of memory available to the terminal used to run the program.

The memory available can be checked by typing: GMEM. The answer could for example be: FG: 100 BG: 112 Contiguous: N (depending upon the total memory available to the system). In this case, GACMOPS could only be run in the background. To get more memory for the foreground, the standard SMFM command has to be used to redistribute the memory available.

The program itself also checks the memory available. If there is not enough memory to run the program, for example because the user forgot to check this prior to starting the routine, the following message will appear on the dialogue screen: NOT ENOUGH EXT. MEM. AVAILABLE. NUMBER OF BLOCKS AVAILABLE IS: N.

The central tasks performed by GACMOPS are the following:

- Check the memory available.
- Define the window map.
- Initialize the PGP.
- Ask for the name of the ephemeris file, open it and extract the desired information.
- Ask for the name of the image file, open it and extract the desired information.
- Check for compatibility of the two input files. If they are compatible, compute the block number of the ephemeris data required by the input image and extract the proper amount of ephemeris data. If the two files are not compatible, tell the user and exit. In both cases, close the file.
- Call ELOC to compute the earth location for 6 points to the left and 6 points to the right of the subsatellite point based on the earth location known from the ephemeris; do this for equal scan angle steps, to correct for distortion.
- Merge an already transformed image with the image to be transformed; this is done by displaying the stored image in the proper way.
- Transform the known (latitude, longitude)-pairs into (line, element)-pairs, so that the proper resolution factor as well as the display characteristics are taken into account.
- Solve a bilinear equation that describes the relationship between the known (line, element)-pairs and a predefined display benchmark-grid. From the solution, compute the raw image line and element corresponding to these benchmarks.
- Compute the raw image line and element corresponding to the remaining display points using interpolation. This is only done for points that are really covered by raw image data.
- Display the resulting image step by step.
- Store the image to disk.
- Swap to the geography background generating program GACGEO.
- Exit.

To shed more light on the techniques involved, the following paragraph gives a detailed description.

2.4.5 The Techniques Used

The number of subpoints needed to cover the image is computed by dividing the number of lines contained in the image (LMAX) by the time interval used in the ephemeris generation (60 sec) and adding 1 to the result; the maximum number of subpoints accepted by GACMOPS is 24. Thus, there are up to 24 points in flight direction, for which the earth location is known (Figure 1).

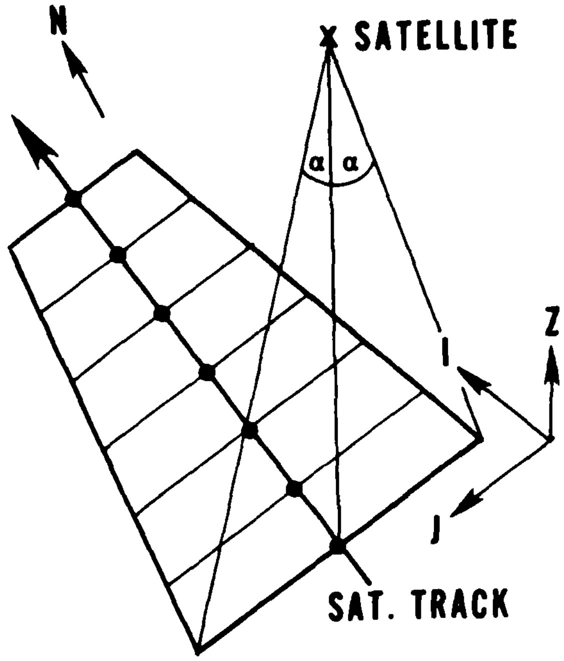

Figure 1. Satellite swath with seven marked subpoints (dots). α is ± 55.4 degrees from subpoints.

Subroutine ELOC is called to compute the earth location for 6 points to the right and 6 to the left of these subpoints (Figure 2). Thus, there are up to 24 times 13 points with known earth location available to GACMOPS. From known constants describing the image characteristics (120 lines per minute, 409 pixels per line, start time image and start time ephemeris), the raw image line and element pairs for all of these points can easily be computed.

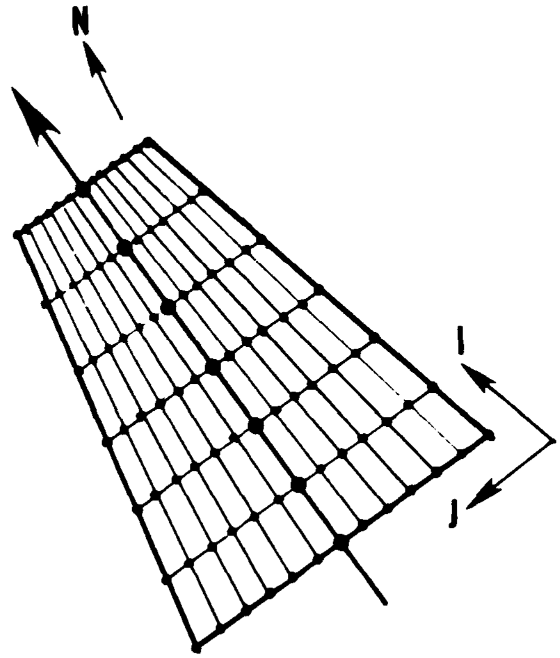

Figure 2. Satellite with 7 marked subpoints (dots) as well as 12 more points (thin dots) with known earth location per scan corresponding with the subpoints.

Using the proper transform and scale, the (latitude, longitude)-coordinates can be transformed into (Y, X)-coordinates; Y is the meridional, and X is the zonal axis. Figure 3 shows this for a Mercator transformation. I and J define the raw image ephemeris space. The (assumed) geographical borders of the image are: northernmost latitude is 25 N, southernmost latitude is 9 N, westernmost longitude is 0 E and easternmost longitude is about 26 E. Since the characteristics of the display (line and element resolution) have already been taken into account with the transformation, the display start and order in the (X, Y)-space have to be defined. This is taken care of by applying equations (1) and (2). The square enclosed by dashed lines in Figure 3 shows the area that would be covered by the display area.

(1) OFFSET = LN(TAN((ALATSTR+90.)*0.5))*C1*FAC+1.5

(2) ALINE = OFFSET - LN (TAN((ALAT+90.)*0.5))*C1*FAC

Equations (1) and (2) apply for Mercator projection only. From (1) and (2) it becomes clear, that for ALAT=ALATSTR, ALINE would be 1.5; for all points south of ALATSTR, ALINE would be greater than 1.5.

The technique to transform X into AELEM is very similar. Remember: the (AELEM, ALINE)-space is not the standard display space; for example, (AELEM=1, ALINE=1) would be displayed in the display position (0, 0).

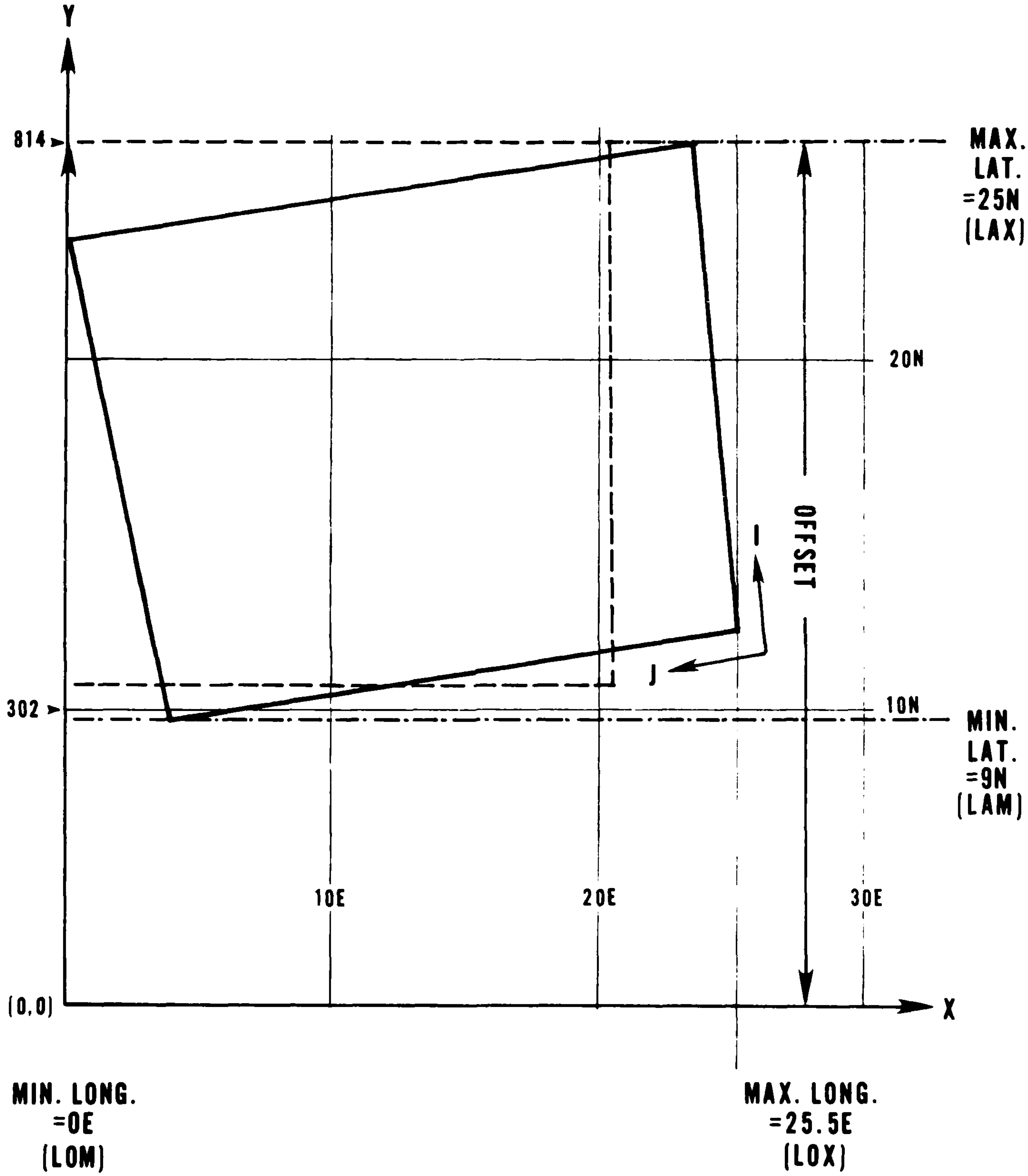

Figure 3. The transformed image in Mercator projection.

As Figure 4 shows, the ALINE and/or AELEM for some of the ephemeris benchmarks of the raw image could well be outside the display area. This problem can be taken care of by defining a display benchmark grid with the lower threshold in the count as 1, and the upper threshold as 33 in vertical and horizontal direction (65 for horizontal count in 1024 field). The counts are computed for each of the subareas defined by four neighboring benchmarks of the ephemeris grid as shown in Figure 5 following equation 3:

```
(3)  MS=AELEM(J+1,I+1)/16.
     ME=AELEM(J,I)/16.+0.5
     LS=ALINE(J,I+1)/16.
     LE=ALINE(J+1,I)/16.+0.5
```

If either MS and ME, and/or LS and LE are out of the predefined grid count range, the subarea is outside the display and will be ignored in further calculations. To make sure that as much as possible of the raw image will be used for the transformation, the lower and upper threshold values for the variables in equation (3) are set to 1 and 33. Seemingly, benchmark (1,1) in Figure 5 corresponds to (AELEM=16, ALINE=16) and benchmark (33,33) to (AELEM=528, ALINE=528). Relationship (4) makes clear, that JJ=1 really corresponds to AELEM=1 and so on:

```
(4)  LL=(II-1)*16+1      and      MM=(JJ-1)*16+1

     where:  II=LS,LE    and      JJ=MS,ME

     Example:  assume that II=1 and JJ=1
     From this follows, that:

     LL=(1-1)*16+1=1     and      MM=(1-1)*16+1=1
```

In a next step, the position of all the benchmarks covered by MS, ME, LS and LE relative to the ephemeris (J,I)-space is define by a bilinear equation of the following form:

```
(5)  RR*X + S*Y=P        and      RR*W + S*Z=E

     where X, Y, W and Z are defined as follows:

(6)  X=ALINE(J+1,I)-ALINE(J,I)
     Y=ALINE(J,I+1)-ALINE(J,I)
     W=AELEM(J+1,I)-AELEM(J,I)
     Z=AELEM(J,I+1)-AELEM(J,I)
```

For reference see Figure 6. P and E are calculated for each of the benchmarks in question as follows:

```
(7)  E= MM - AELEM(J,I)  and  P=LL - ALINE(J,I)
```

Using Cramer's rule (8), the bilinear can be solved for RR and S (9).

```
         |X    Y|          |P    Y|         |X    P|
(8)  D=|        |   DRR=|        |   DS=|        |
         |W    Z|          |E    Z|         |W    E|
```

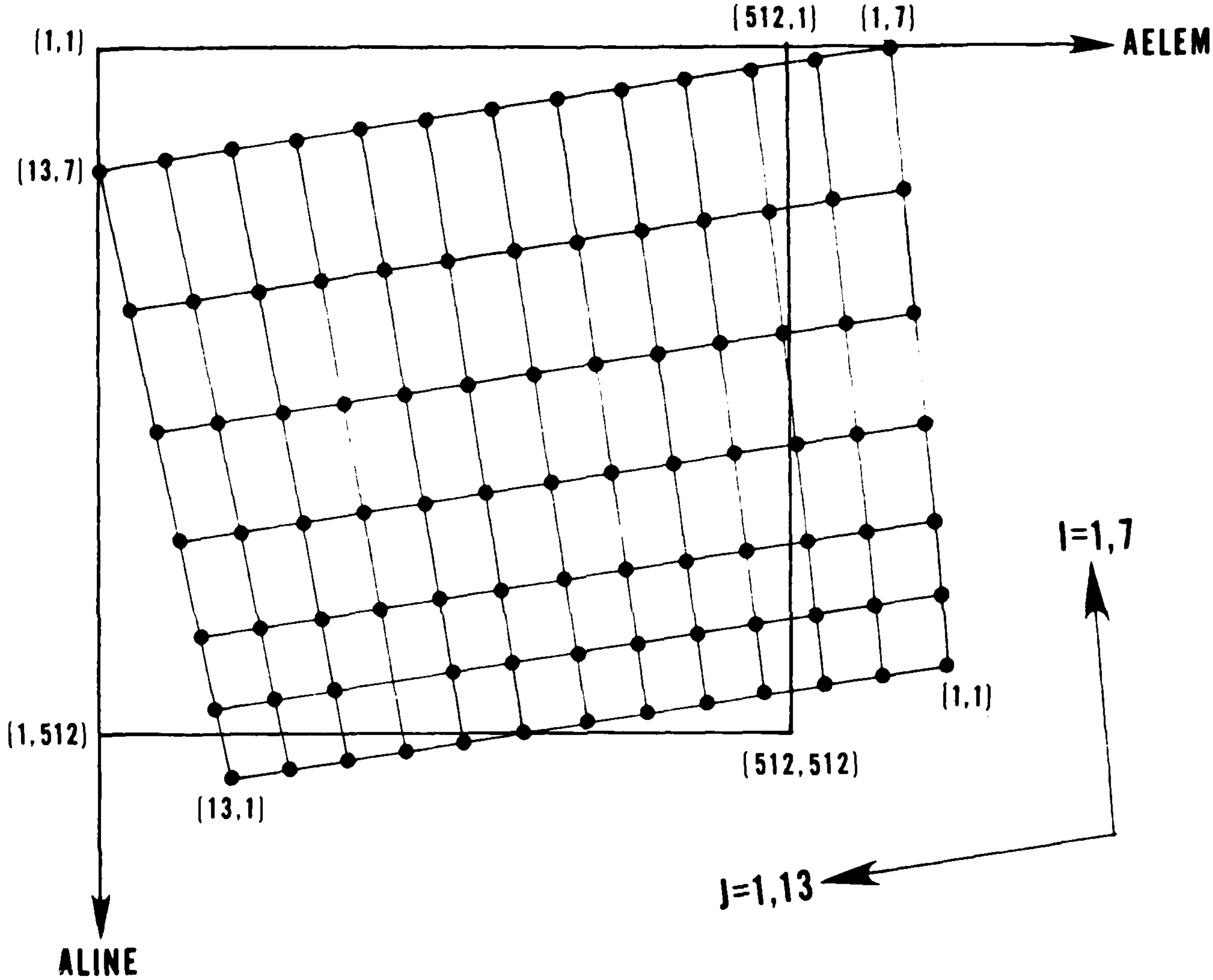

Figure 4. Relationship between transformed image and (AELEM,ALINE)-space.

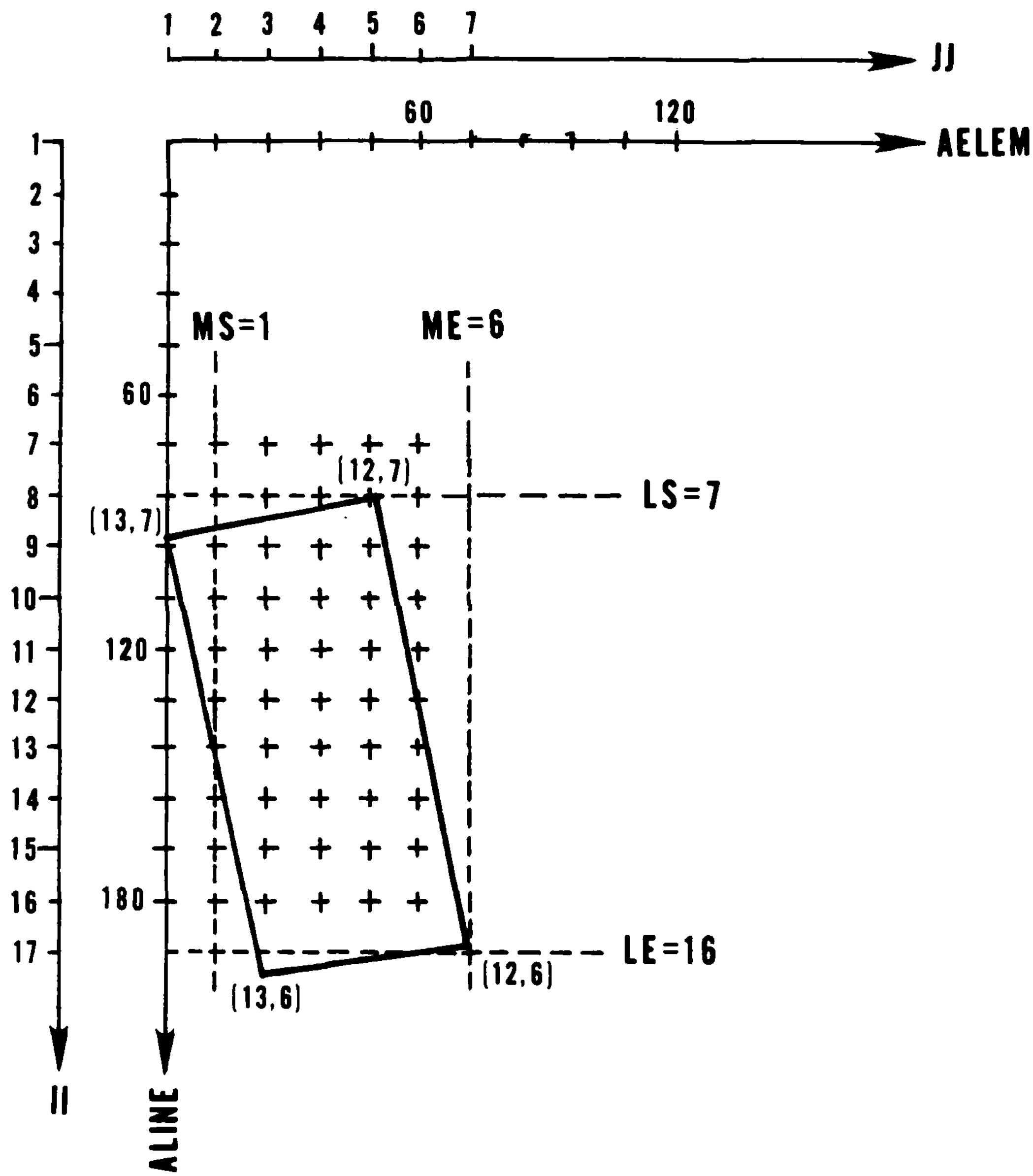

Figure 5. Relationship between image space and display grid (JJ,II)-space.

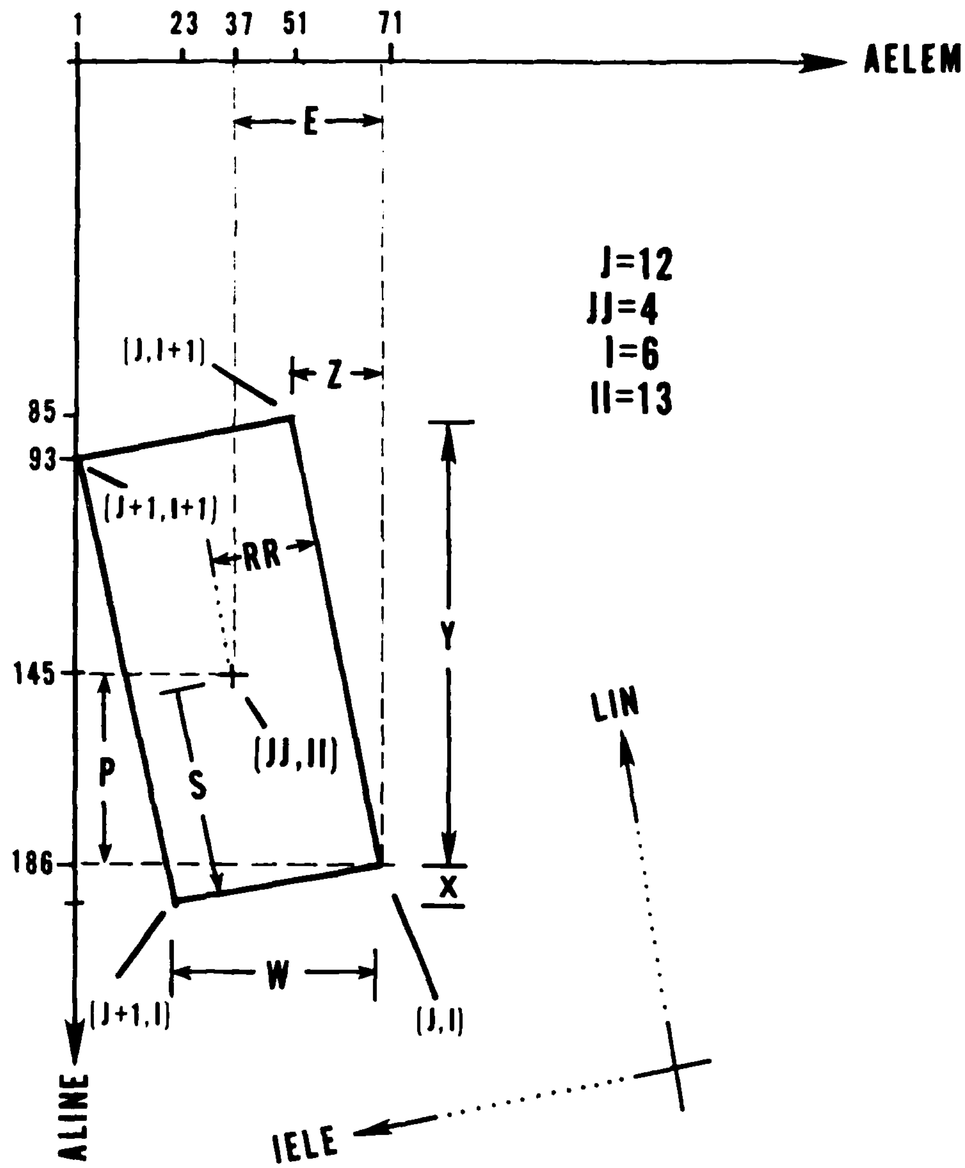

Figure 6. Bilinear relationship between the image (J,I)-space and the display grid (JJ,II)-space. Orientation of the raw image (LIN,IELE)-coordinate system also is shown.

(9) $RR = DRR/D$ and $S = DS/D$

Examples: 1. Assume, that the benchmark in question coincides with the ephemeris benchmark (13,7); from

$E=W+Z$ and $P=Y+X$ follows, that

$RR = (Z*(Y+X) - Y*W+Z))/D$,

$S = (X*(W+Z) - W*(Y+X))/D$ and

$D = (X*Z - W*Y)$

Thus, $RR=1$ and $S=1$ (see Figure 6).

2. Assume, that the benchmark in question coincides with the ephemeris benchmark (12,7); from

$E=Z$ and $P=Y$ follows, that

$RR = (Z*Y - Y*Z)/D = 0$ and

$S = (X*Z - W*Y)/D = 1$

3. Assume, that the benchmark in question coincides with the ephemeris benchmark (13,6); from

$E=Z$ and $P=X$ follows, that

$RR = (Z*X - Y*W)/D = 1$ and

$S = (X*W - W*X)/D = 0$

4. Assume, that benchmark in question coincides with the ephemeris benchmark (12,6); from

$E=0$ and $P=0$ follows, that

$RR = (Z*0 - Y*0)/D = 0$ and

$S = (X*0 - W*0)/D = 0$

This shows, that all benchmarks within the ephemeris grid subarea can be described by fractions of RR and S, with $0 \le RR \le 1$ and $0 \le S \le 1$; in the case described above, benchmark (12,6) is the origin of the coordinate system for which the bilinear equation has been solved.

Since the exact raw image line and element for (12,6) are known, the raw image line and element for all of the benchmarks in question can easily be calculated following equations (10) and (11).

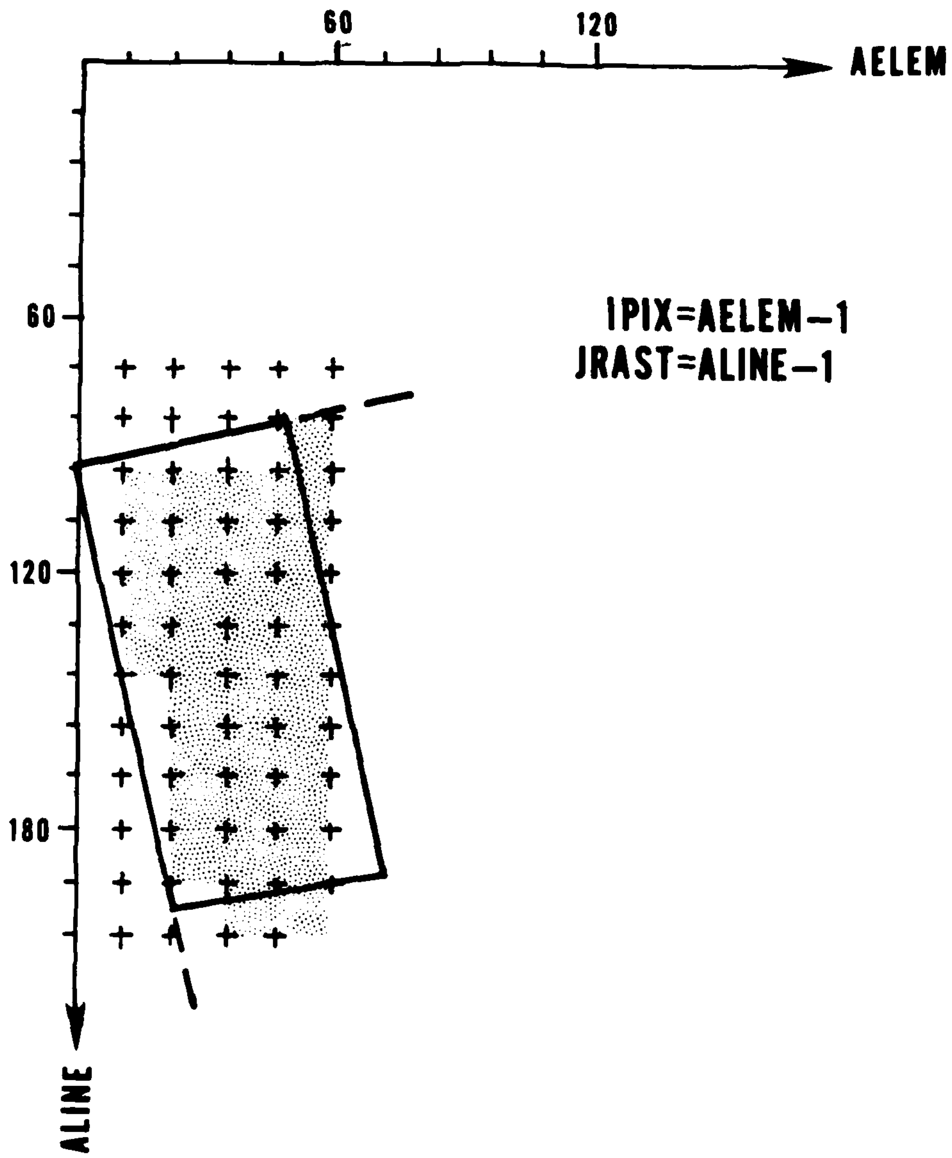

Figure 7. Relationship between image, benchmark grid, and displayed image. Shaded area is the displayed image.

(10) LQ= 2*TINT*(I+S-1.) - LINSTAR +1.5, where TINT= 60. (sec), and LINSTAR is a line offset, if the start time of the image does not exactly coincide with the time of the first ephemeris point.

(11) IEQ= ELDN*(J+RR-1.)+1. , where ELDN is the element density in scan direction (ELDN=409/12).

Example: Assume, that:

I = 3
J = 10
RR = 0.25
S = 0.70
LINSTAR = 20
ELDN = 409/12=34.0833

Following equations (10) and (11),

LQ = 2.*60.*(3+0.7-1) - LINSTAR +1.5 = 305 (integer)

IEG = 34.0833*(10+0.7-1) + 1. = 316 (integer)

See also Figure 8. Since JJ and II of the display benchmark grid are also know, LIN(JJ,II) is set to LQ and IELE(JJ,II) is set to IEQ. The following restrictions (12) apply to make sure, that only benchmarks covered with raw image data are taken into account for further processing.

```
     IF(LQ.LT.O.OR.LQ.GT.LMAX) set LIN(JJ,II) to zero
(12)
     IF(IEQ.LT.O.OR.IEQ.GT.IELMAX) set IELE(JJ,II) to zero
```

LMAX is the maximum raw image line, and IELMAX the raw image element (=409).

The filling of the display points between the benchmarks with raw image pixels is done by interpolation; as soon as the raw image pixel values for a 16 by 16 pixel display area are known, they are displayed on the screen.

To perform the interpolation, a certain number of raw image lines must be available to the computer (Figure 9). The required number of lines is transferred from disk to extended memory.

Since block zero of the input image is the header and LIN starts at 1, the number of blocks transferred to extended memory is (LX-LM)+1, starting at disk block LM.

For a 512 by 512 image, this procedure has to be performed 8 times in horizontal and 32 times in vertical direction. The interpolation is only done for 16 by 16 pixel subareas whose enclosing benchmarks have LIN and IELE values different from zero.

Upon completion of the interpolation, the content of the refresh memory planes used is stored to disk under the automatically determined output image filename.

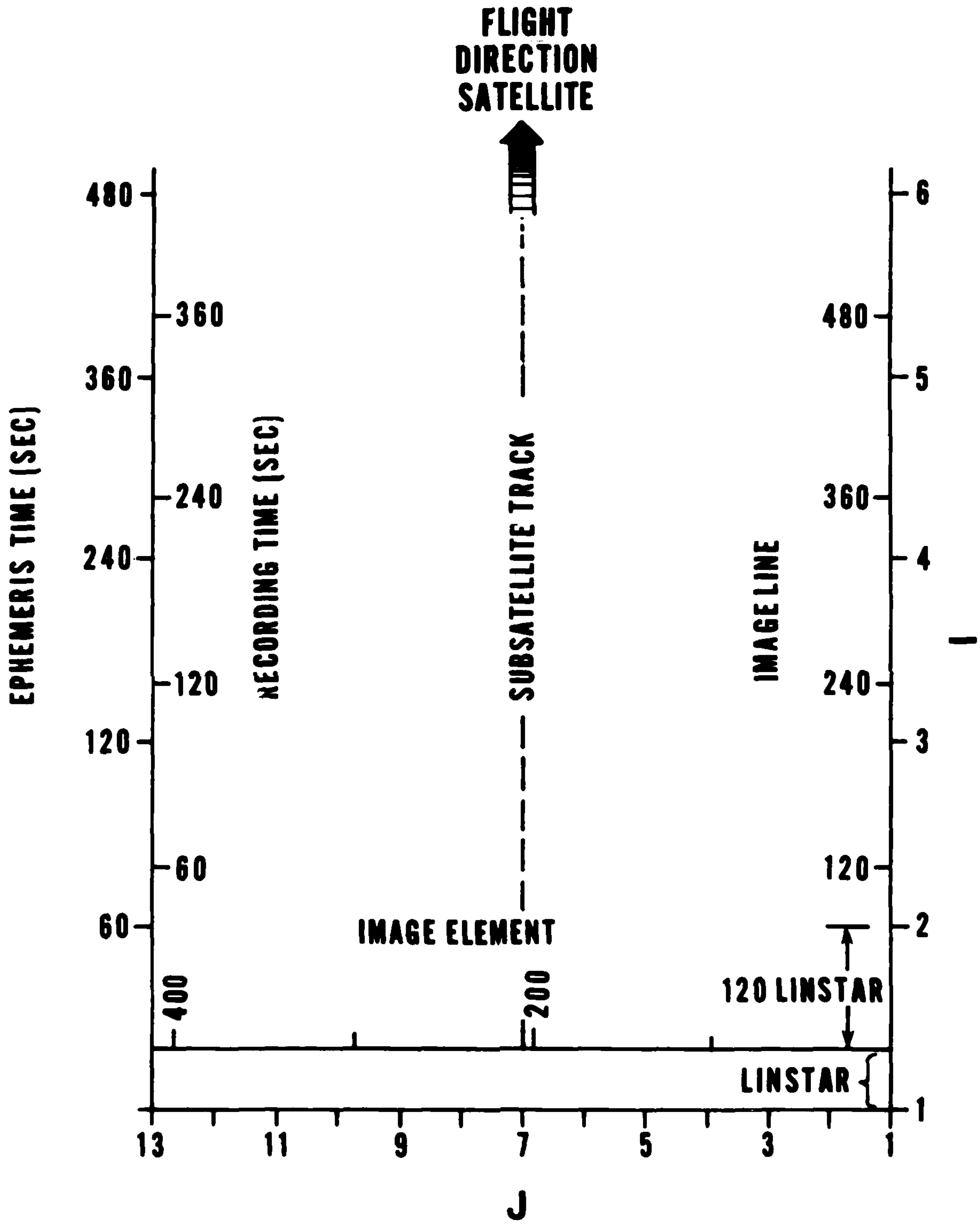

Figure 8. Relationship between raw image and ephemeris space.

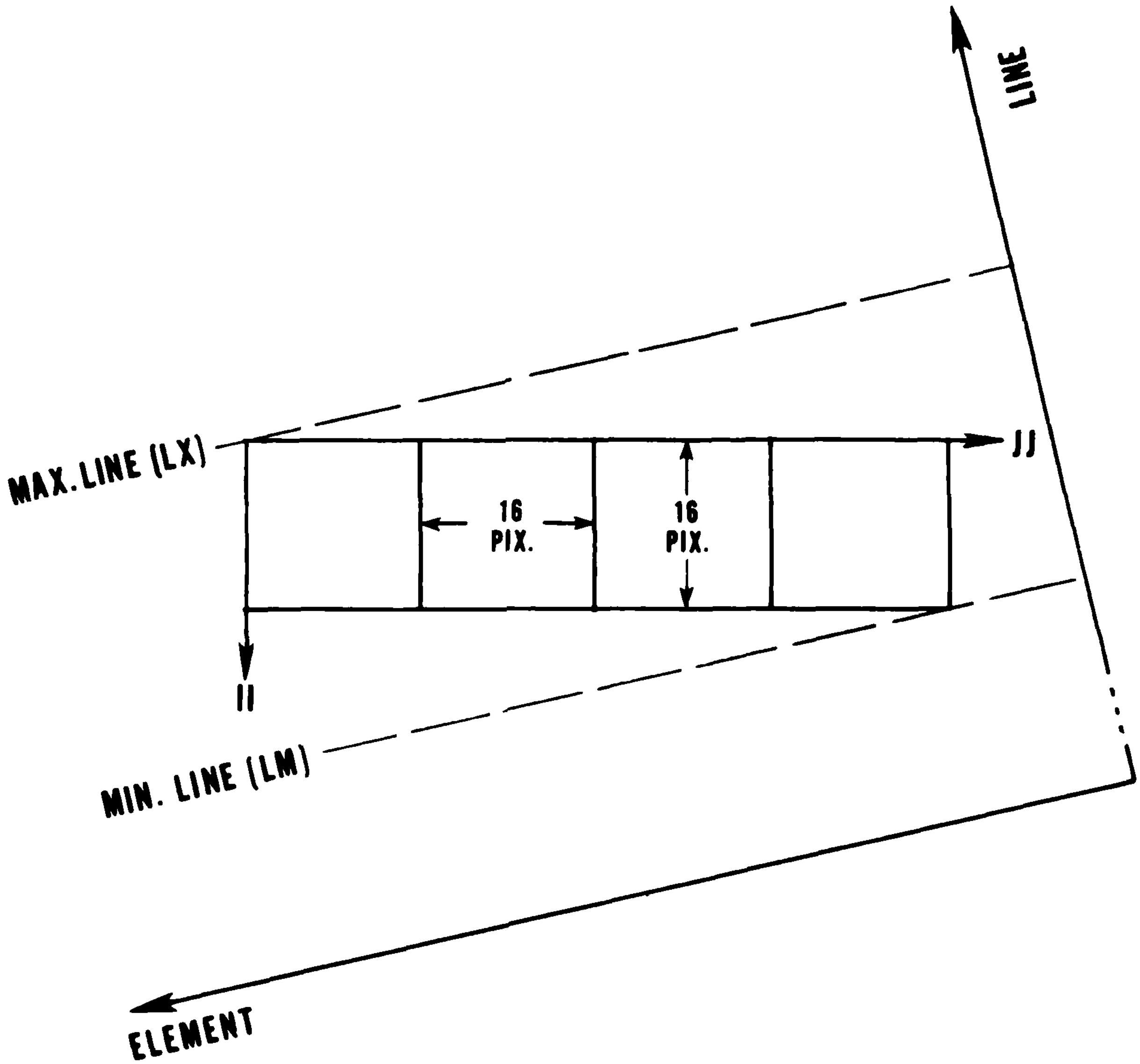

Figure 9. Relationship between raw image and one particular display subsection of the size ΔJJ by ΔII ($\Delta JJ = 4$ and $\Delta II = 1$) or 48 by 12 pixels.

Remark: The technique involving equations (5) through (9) is only valid for rectangular coordinate systems. Although the (J,I)-coordinate system is not strongly rectangular, rectangularity can be assumed, if the area in question is small enough. This condition is fulfilled for each of the ephemeris grid subareas.

For circumpolar presentation, the generation of a mosaic is standard, but may be omitted, if the mosaic stored on disk is too old compared with the input image. A time difference of one day is defined as upper limit, but the user is free to do a mosaic anyway. This would still make sense for the derivation of sea-surface temperatures, which are quasi-conservative for a time scale of one to two days at least. The software to do this for GAC data does not exist yet.

Circumpolar presentation may by performed in either 12 km resolution, generating a 512 by 512 image, or 6 km resolution, resulting in a 1024 by 1024 image. In the latter case, the image is processed in two halves, as Figure 10 shows.

Upon completion of one half image, the user may look at the image stored in the high order planes, too. Then, the content of all 16 refresh memory planes is stored on disk following th order described in Figure 11.

The program then clears all the refresh memory and starts processing the second half image.

The file organization described in Figure 11 has been chosen to facilitate the extraction of a 512 by 512 image from the 1024 by 1024 data base; for more information, see description of program GACGEO under paragraph 2.5 of this publication.

Since the pole is always at the center of the generated image, a slightly different technique is used to calculate the (AELEM, ALINE)-pairs from the known earth location (ALAT, ALONG) of one particular point. As in the standard Polar Stereographic projection, equation (13) is used to compute the radius of a specified latitude circle.

(13) RF = 1997.056P*FAC*COS(ALAT)/(SIN(ALAT)+1.), where FAC is 1.0 for 6 km resolution, and 0.5 for 12 km resolution.

For the southern hemisphere, ALAT has to be substituted by -ALAT.

The angle formed by a given longitude and the X-axis of the coordinate system described in Figure 12 is computed from that given longitude and the rotation (ROAN) of the system following equation (14).

(14) GF = (ROAN + ALONG)

Table (1) shows the sign of SIN(GF) and COS(GF) for both hemispheres; the quadrant count is as defined in Figure (12).

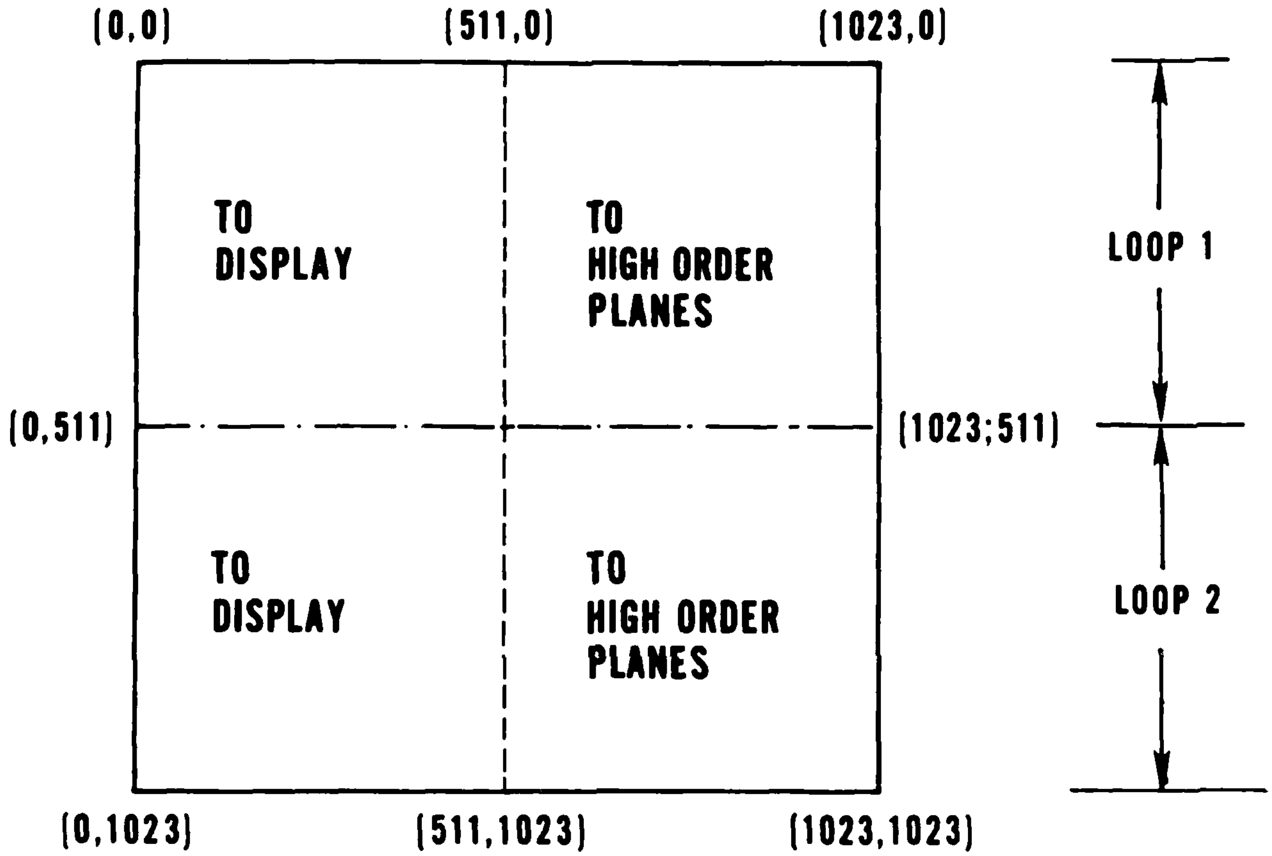

Figure 10. Working scheme for processing a 1024 by 1024 image.

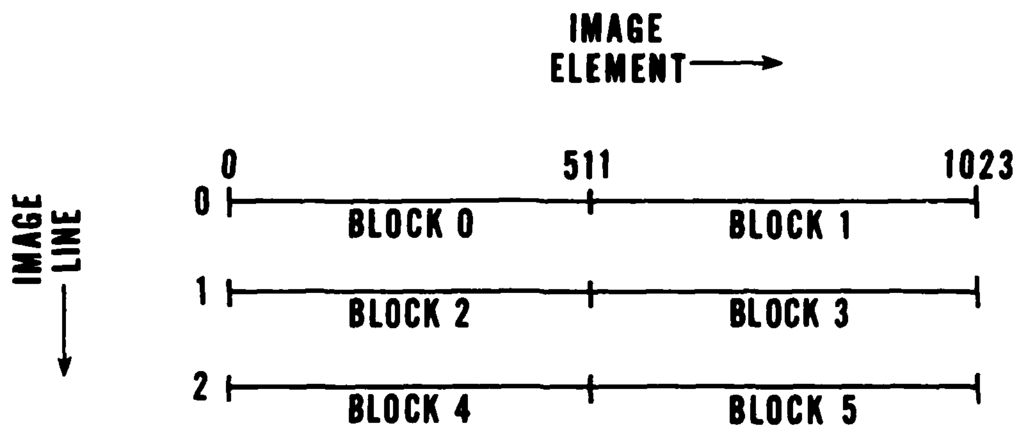

Figure 11. How the data is stored on disk.

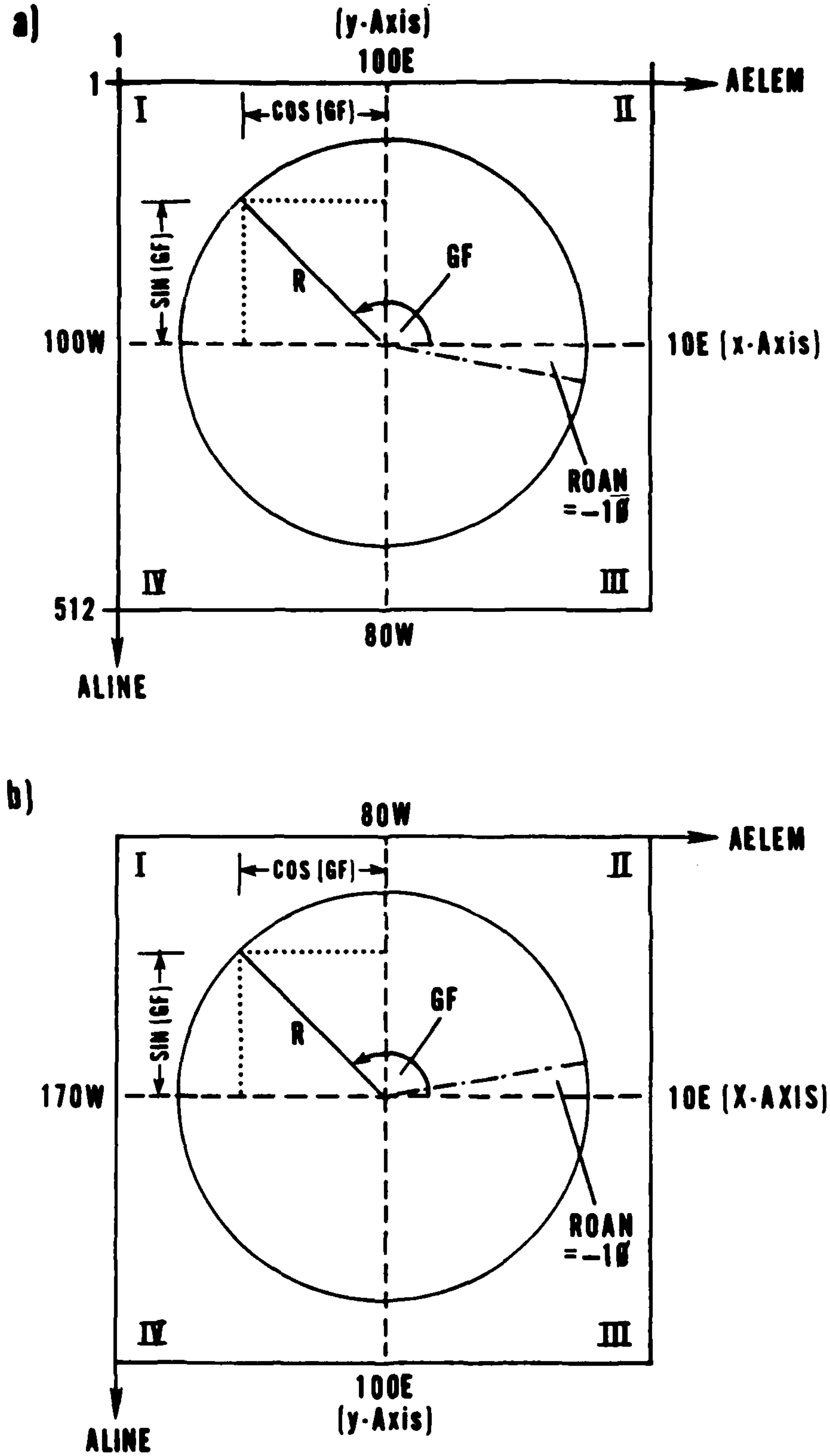

Figure 12. Circumpolar presentation: a) Northern Hemisphere; and b) Southern Hemisphere.

Quadrant

		I	II	III	IV
N.H.	SIN(GF)	+	+	-	-
	COS(GF)	-	+	+	-
S.H.	SIN(GF)	-	-	+	+
	COS(GF)	-	+	+	-

Table (1): Sign of COS(GF) and SIN(GF) in the four quadrants for both hemispheres.

Thus, equations (15) apply to compute (AELEM, ALINE) for a given earth location (ALAT, ALONG).

AELEM= FAC*512.5 + COS(GF)*RF

(15) ALINE= FAC*512.5 - SIN(GF)*RF for northern hemisphere

ALINE= FAC*512.5 + SIN(GF)*RF for southern hemisphere

For 6 km resolution, FAC*512.5 equals 512.5, for 12 km resolution, it equals 256.25; this describes the location of the pole in the (AELEM, ALINE)-space.

Example: Assume that RF= 100 and resolution 12 km.

1. Northern hemisphere and ALONG= 145 E = + 145:

   GF= -10. + 145. + 135. Thus: SIN(GF)= + 0.71 and COS(GF)= - 0.71

   AELEM= 256.25 + (-0.71)*100. = 185.25 ; left from center

   ALINE= 256.25 - (+0.71)*100. = 185.25 ; up from center

2. Southern hemisphere and ALONG= 125 W=-125:

   GF= -10. - 125. = - 135. Thus: SIN(GF)= -0.71 and COS(GF)= -0.71

   AELEM= 256.25 + (-0.71)*100. = 185.25 ; left from center

   ALINE= 256.25 + (-0.71)*100. + 185.25 ; up from center

2.5 Generating the Geographical Background

The user of satellite imagery certainly wants to know which area of the world is covered by the image he is viewing. To facilitate this, the standard SPADS procedure is to bring up a 6-Bit image on the screen, leaving two refresh memory planes to store geographical information. Generally, only one of the two planes is needed to bring up the geography. But, depending upon the plane the information is stored in, the color of the geography will either be green or red when being displayed. Program GACGEO brings up a 512 by 512 6-Bit image on the display and calls the proper geography generating subroutine, SMBKG for Mercator projection and SPSGEO for Polar Stereographic projection. In case the stored image is a 1024 by 1024 image, GACGEO extracts a specified 512 by 512 partition.

Generally, especially due to a faulty navigation, the geography will not fit the image exactly. This, of course, can only be seen, if any landmark is visible in the image. GACGEO is able to correct this for both projections.

2.5.1 Running GACGEO

Upon start of GACGEO, the program extracts the projection code as well as the resolution code from the name of the image to be provided with the geographical background. For Mercator projection as well as standard Polar Stereographic projection, the 512 by 512 image is displayed on the screen as 6-Bit data in one call to subroutine WIMAG. The two upper planes are cleared for writing of the geography overlay. For 12 km circumpolar images, which are also 512 by 512 pixels, the same procedure applies. If the projection code is ASCII "C" and the resolution code is ASCII "1", the program asks the user to enter the central latitude (CLAT) and longitude (CLON) of the area he wants to view. From these data, the line and element in the 1024 by 1024 image is computed, following equations (13) through (15). In case that either ALINE or AELEM is either less than 256.25 or greater than 768.75, the value in question is corrected such that it satisfies these threshold values. The reason for this is to make sure, that the resulting 512 by 512 image is always covered by data from the 1024 by 1024 data base. The result is the start line and element for the 512 by 512 image within the big file. (Figure 13).

One line of the 1024 by 1024 image, which is equivalent to two consecutive disk blocks, is read from disk at a time; a 512 word array is needed to hold these 1024 pixel values. Then, the data is unpacked and stored in a 1024 word array, one pixel per word. Next, the data is repacked into a 256 word array, starting at address AELEM of the 1024 array. This way, one image line of 512 pixels is provided to be displayed without losing a single pixel. The same procedure is performed 512 times.

Since for the four quarters of the big file, the starting block and element can be predefined, a slightly different and easier way exists to view them. As soon as the image is displayed, the program calls the proper subroutine to provide the geographical background.

2.5.2 Mercator Background

The subroutine XMBKG expects the ALATSTR and ALSTAR, describing the upper left corner coordinates of the Mercator image, as well as information about the resolution, the desired color, whether the geography or a solid land mask is desired and whether the lines displayed should be solid or not. The subroutine then displays the specified background. If adjustment of the overlay is desired, the vertical (I) and horizontal (J) offset in display pixels must be

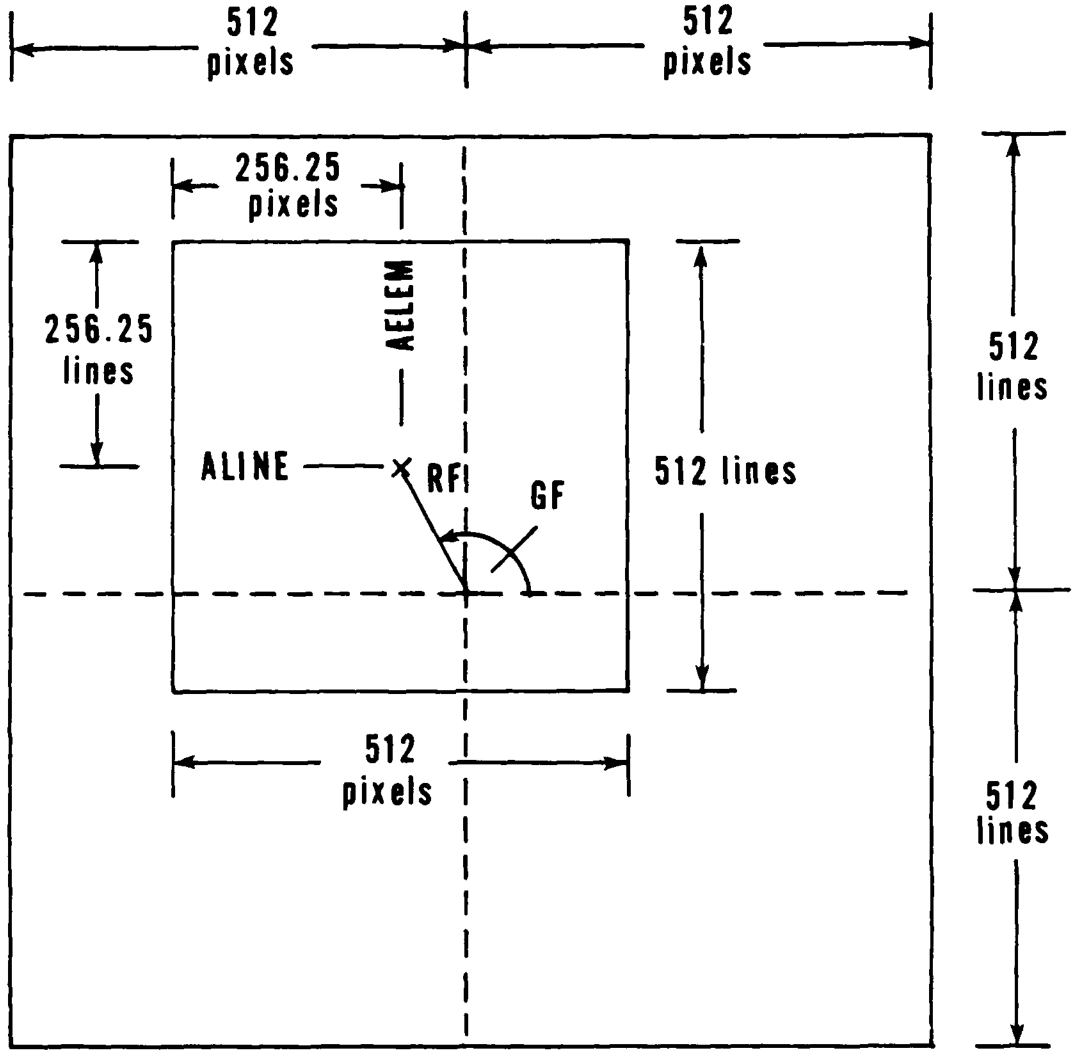

Figure 13. Relationship between extracted 512 by 512 image and 1024 by 1024 data base.

typed in, and the overlay is adjusted in another call to subroutine XMBKG.

2.5.3 Polar Stereographic Geography

In this case, subroutine PSGEO is called to generate the geography. SPSGEO is a subroutine version of program SPSGEO rewritten by the author to generate special geography overlays only. SPSGEO expects the central latitude and longitude of the area to be viewed, information about the resolution and about the rotation of the image relative to the standard FNOC data base; SPSGEO retrieves the geography from data file "COAST.1".

Since ALATSTR is the northernmost latitude for standard Polar Stereographic images, but ALSTAR is the central longitude, CLAT and CLON have to be computed using equations (16) and (17).

(16) RF= 1997.056*FAC*COS(ALATSTR)/(SIN(ALATSTR) + 1.)

RF is the offset of the image start from the pole; for images in the southern hemisphere, ALATSTR must be substituted by -ALATSTR.

If the image is in the northern hemisphere, 256.25 is added to RF. For images in the southern hemisphere, 256.25 is subtracted from RF. The result is the offset RF of the central image line from the pole. Equation (17) is then used to calculate the corresponding latitude.

(17) CLAT= 90. - 2*ATAN(RF / (FAC*1997.056))

The central longitude CLON equals ALSTAR. Given CLAT and CLON as well as the other information required, SPSGEO then generates the geography overlay. If the overlay has to be adjusted, subroutine ADPSGEO is called, given the CLAT, CLON and resolution as input.

ADPSGEO then asks the user for the display coordinates of a recognizable landmark and the corresponding geography point; these data are transferred using the graph pen and keyboard respectively.

ADPSGEO then corrects the central latitude and longitude, returns them to GACGEO and SPSGEO is called again to generate the correct geography (Figure 14). For Polar Stereographic projection, rotation is also involved in the adjustment. For circumpolar presentation, no adjustment of the geography overlay is available, because the data base is fixed.

2.6 Final Remarks and Outlook

The final products provided by the software described, satellite images containing the geographical background, are state of the art on the SPADS Eclipse S250 minicomputer. The execution time, starting at the execution of POLRGAC and ending with the completion of GACGEO, is about 20 to 40 minutes, depending upon the earth location of the imagery. The most timeconsuming process is the image transformation

The edges of the images look like a zigzag line. They could be smoothed out, but this would be enormously timeconsuming on the S250. On a faster computer, the technique using 16 by 16 pixel areas for the interpolation could be changed towards the edges such that 4 by 4 areas would be used instead. This would still produce a zigzag line, but it would already be much smoother.

Another technique could be used, defining the edges of the displayed image as functions of the display coordinates, such that only pixels satisfying these thresholds would be displayed. This would require to switch to a display

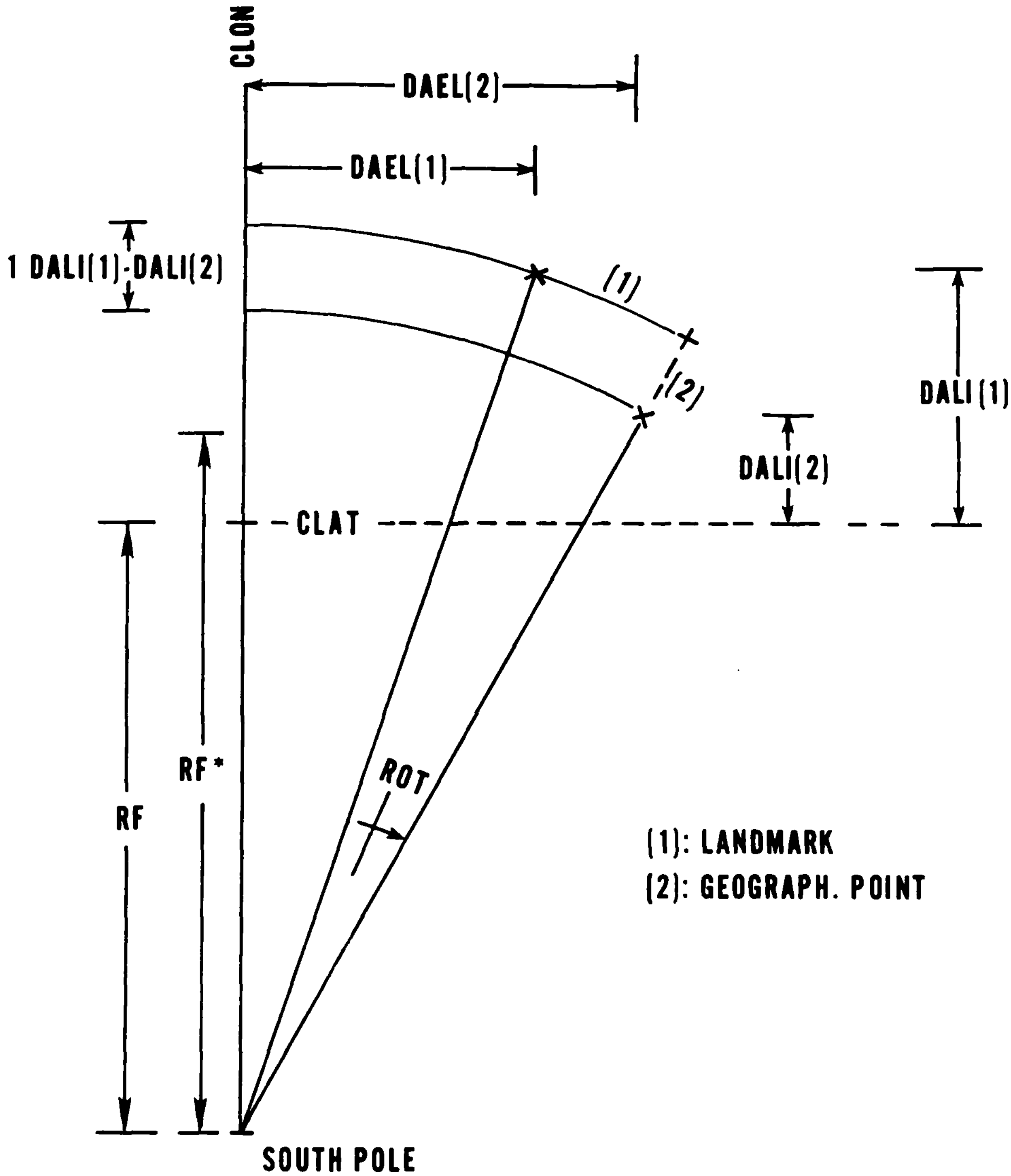

Figure 14. The polar stereographic geography overlay adjustment.

aster of only one pixel at a time right near the edge, which would slow down the display process considerably.

There is one thing the user cannot see in viewing the image: pixels 1, 2 and 409 are always omitted during the transformation, because their pixel values have been found to be almost always zero on the tapes. Their pixel values are substituted by the values of pixel 3 (for pixels 1 and 2) and 408 (for pixel 409). This is not recognizable in the resulting image, since for higher resolutions, the value of one particular pixel is used more than once at the edge of the image anyway. But this way, the resulting image does not show (black) holes at the corner points of the outermost 16 by 16 areas.

The choice of the resolution will generally be made with regard to the intended application. In the 12 km resolution image, for example, scattered cumuli will probably not show, whereas thunderstorms surely will. The same would apply for fog in narrow valleys. In the latter case, channel three can be most useful because in morning hours, fog and low stratus appear black in infrared imagery. This knowledge can be very usefully applied when a flight briefing for a low level helicopter flight is required. This is especially true during the cold season, because fog then is generally of the freezing type (hazard).

The fog and low stratus mentioned above is, in almost all cases, of the radiative type. Thus, no or very little medium and high cloud is present, and the low cloud, that goes with a more or less sharp inversion, can easily be detected.

It is things like this that could easily be done in a research environment, whereas in an operational environment there is almost no time to do so. The researcher can check special weather situations and order the proper GAC data afterwards for the area in question. And, for the near future, it would be very useful to add the capability to extract the multichannel sea surface temperature from the GAC imagery.

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