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MODIFICATIONS TO IMPROVE DATA ACQUISITION AND ANALYSIS FOR CAMOUFLAGE DESIGN

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) The report describes the results of modifications to a software program which clusters digitized, multi-spectral photographs of natural vegetative terrains into facsimiles of the original scenes in 3, 4, or 5 colors in CIELAB notation. Tasks that were addressed included optimization of the clustering to remove any bias introduced by the highly efficient histogram preprocessing scheme; evaluation of data separability parameters and a determination of the minimum numer of domains necessary to represent a scene; the ability to analyze a segment of the origi-scene; and the ability to plot each resulting domain individually.

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Summary

This report presents the results of a modification to a research program to acquire data on the spectral and spatial characteristics of natural vegetative terrains and to develop methodologies for the analysis of these data as an aid in the design of camouflage patterns for field clothing and large cloth shelters. The program has been concerned with camouflage for the visible spectrum and for human observers.

Technical aspects in the development of modifications of the existing software for data analysis are summarized and recommendations for further software development are presented.

The following tasks were addressed:

1. Optimization of the clustering in the CIE 1976 ($L^*a^*b^*$) color space to remove any bias introduced by the highly efficient histogram preprocessing scheme.

2. Evaluation of data separability parameters and a determination of the minimum number of color domains necessary to represent a scene.

3. Modification of the terrain analysis software so that the user can specify any rectangular segment of the original scene as the area of interest.

4. Modifications of the symbol plotting software to enable individual domain plotting.

All software has been implemented on the UNIVAC 1106 computer located at the Natick Research and Development Laboratories.

PREFACE

The reported work was performed for US Army Natick R&D Laboratories under Contract No. DAAK60-79-C-0072 (Modification No. P00005) with Mr. Alvin O. Ramsley, Project Officer. The Decilog effort was ably led by J. Richard Goldgraben. This work is part of Project 1L62723AH98, Clothing, Equipment, and Shelter Technology; Task AB, Passive Countersurveillance Measures for the Individual Soldier.

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1. OVERVIEW

a. Background

This report presents the results of a modification to a research program[1,2,3] to acquire data on the spectral and spatial characteristics of natural vegetative terrains and to develop methodologies for the analysis of these data as an aid in the design of camouflage patterns for field clothing and large cloth shelters. The program has been concerned with camouflage for the visible spectrum and for human observers.

Data from vegetative terrain bachgrounds are acquired by photographic and digitization procedures. Computer programs generate spectral reflectance curves for each resolution element in the scene and analyze the colorimetric characteristics of the terrain in terms of CIE 1976 (L*a*b*) color space. Among the outputs of the computer programs is a map showing the shape and distribution of regions in the scene possessing similar colorimetric characteristics. The spectral and spatial properties of these regions are to be used as the basis for the design of three, four, or five color domain camouflage patterns.

Terrain data were acquired for vegetative terrains typical of the temperate regions of Europe and North America in both the dormant and verdant state. Data

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[1] J. R. Goldgraben and B. Engelberg, Final Report on Data Acquisition and Analysis for Camouflage Design, Decilog, Inc., Melville, NY April 1981 (Decilog Report No. 236, Contract DAAK60-79-C-0072).

[2] J. R. Goldgraben and B. Engelberg, Procedures for the Acquisition and Analysis of Terrain Data for Camouflage Design, Volume 1, Software Manual, Decilog, Inc., Melville, NY, March 1981 (Decilog Report 234, Contract DAAK60-79-C-0072).

[3] J. R. Goldgraben and B. Engelberg, Procedures for the Acquisition and Analysis of Terrain Data for Camouflage Design, Volume 2, Manual for Photographic Data Acquisition and Film Digitization, Decilog, Inc., Melville, NY, March 1981. (Decilog Report No. 235, Contract DAAK60-79-C-0072).

for both front lighted direct solar illumination and solar illumination with moderately overcast sky conditions were obtained.

This report summarizes the technical aspects in the development of modifications of the existing software for data analysis and presents recommendations for further possible software development. Full documentation of the Data Processing and Analysis Software and of the Photographic Data Acquisition and Digitization Procedures are contained in references found on page 67.

The data processing and analysis software and the modifications under this phase of the contract have been implemented on the UNIVAC 1106 computer located at the Natick Research and Development Laboratories.

b. Task Requirements for This Phase

The following tasks were addressed under this Contract Modification:

(1) Optimization of Clustering

In the previously delivered data analysis program, a histogram algorithm (HIST) was used as a first step in the clustering of the CIELAB values of the scene pixels. This algorithm is highly efficient and greatly reduces the number of computations that must be performed by the Euclidean clustering algorithm (GEOM). This histogram process is not, however, an optimal process and the CIELAB coordinates of the final color domains can be influenced by the color coordinate increments used in the histogramming and by the number of intermediate clusters which exist when the clustering process switches from HIST to GEOM. The increment levels and number of intermediate domains are user-specified.

It was recommended, therefore, that an optimization routine be added to the existing color domain clustering process. The CIELAB values assigned to the three, four, or five color domains by the existing histogram and Euclidean algorithms are inputted into the optimization routine which re-adjusts the

CIELAB centroid values using a nearest means iterative optimization algorithm. The algorithm elminates most of the bias that may have been introduced in the histogram clustering and thereby makes the spectral and spatial characteristics of the final color domains independent of the user's choice of clustering parameters.

(2) Data Separability

Each of the scenes should be analyzed and the following tasks performed:

- Develop a metric which can be used to evaluate the "goodness" of the calculated domain centroids.
- Examine procedures for determining the "correct" number of domains for each scene.

(3) Scene Segmentation

The Terrain Analysis Software should be modified so that the user has the ability to specify any rectangular segment of the original scene as the area of interest. In this manner some unwanted areas could be removed (i.e, sky, grass) and the user could compare the intra-scene variability by processing selected segments of the scene.

(4) Domain Plotting

The symbol plotting routine should have the capability of plotting each domain individually as well as producing a combined plot. The usefulness of contour plotting should be examined.

2. OPTIMIZATION OF CLUSTERING

a. General Discussion

OPTIM is the clustering optimization routine. It is designed to remove some of the clustering imperfections either introduced by HIST or resulting from an improper selection of clustering parameters by the user. The actual algorithm for the optimization is contained in a subroutine of OPTIM called REDOM (See Figures 1 and 2).

The first time OPTIM calls REDOM, REDOM determines the domain centroid closest to each pixel. If the squared distance of a pixel to the closest domain is less than or equal to a user specified number of domain variances, REDOM assigns the pixel to that domain. If the pixel to domain centroid distance exceeds this value, the pixel is eliminated from the clustering on this and all subsequent iterations. REDOM then calculates new centroids and variances for the domains based on the assigned pixels, calls OUTPUT, and returns to OPTIM.

OPTIM now enters a loop governed by a user-parameter which specifies the maximum number of iterations through the loop. REDOM is called in each iteration and reassigns pixels to the closest domain centroids (which have been recomputed in the prior iteration) and keeps track of the number of changes in pixel domain assignments. REDOM then recalculates domain centroids and variances based on the new domain assignments, calls OUTPUT, and returns to OPTIM. If the number of domain assignment changes in an iteration, is 0, or if the maximum loop number is reached, OPTIM exits its loop.

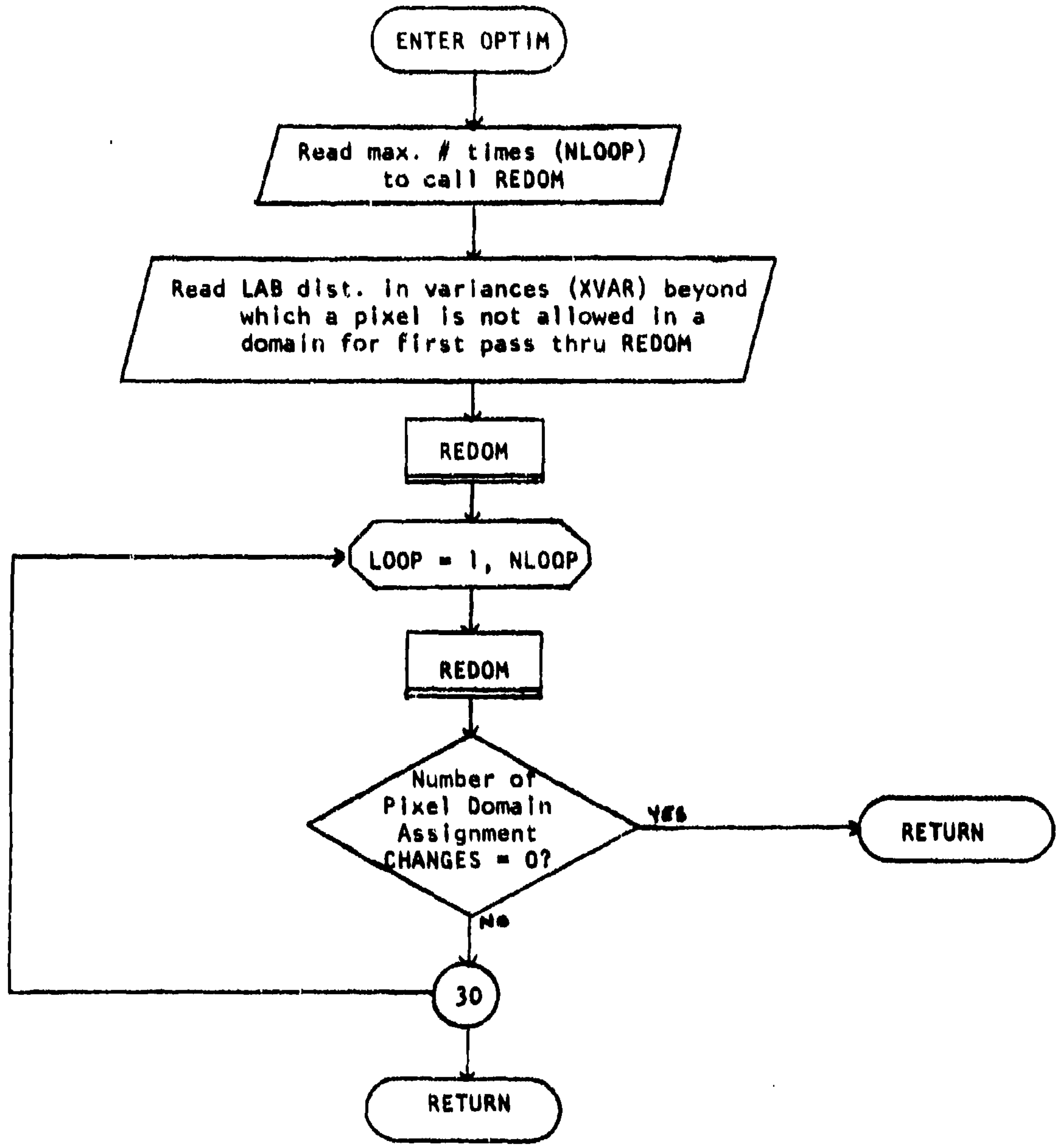


FIGURE 1 SUBROUTINE OPTIM

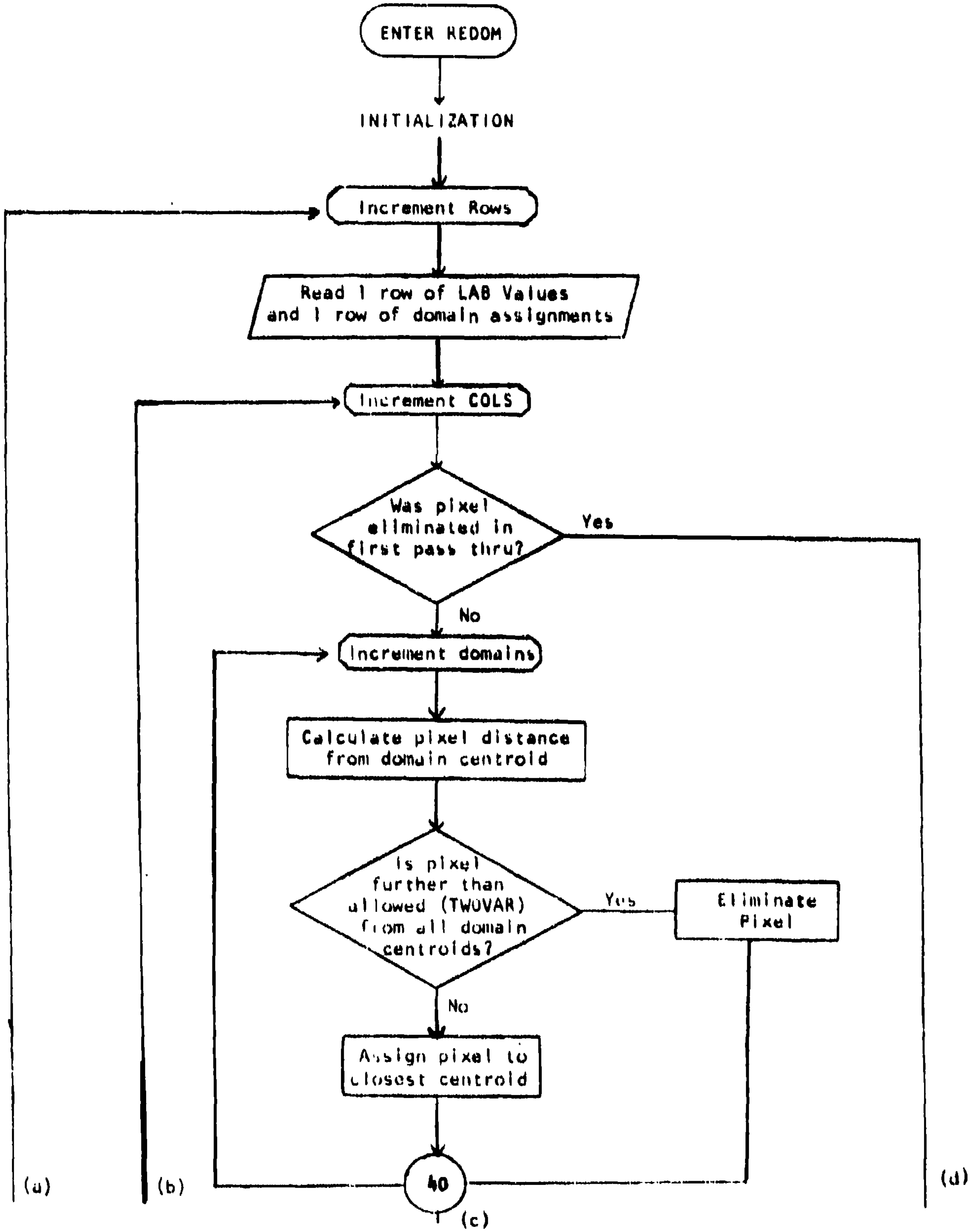


FIGURE 2 SUBROUTINE REDOM

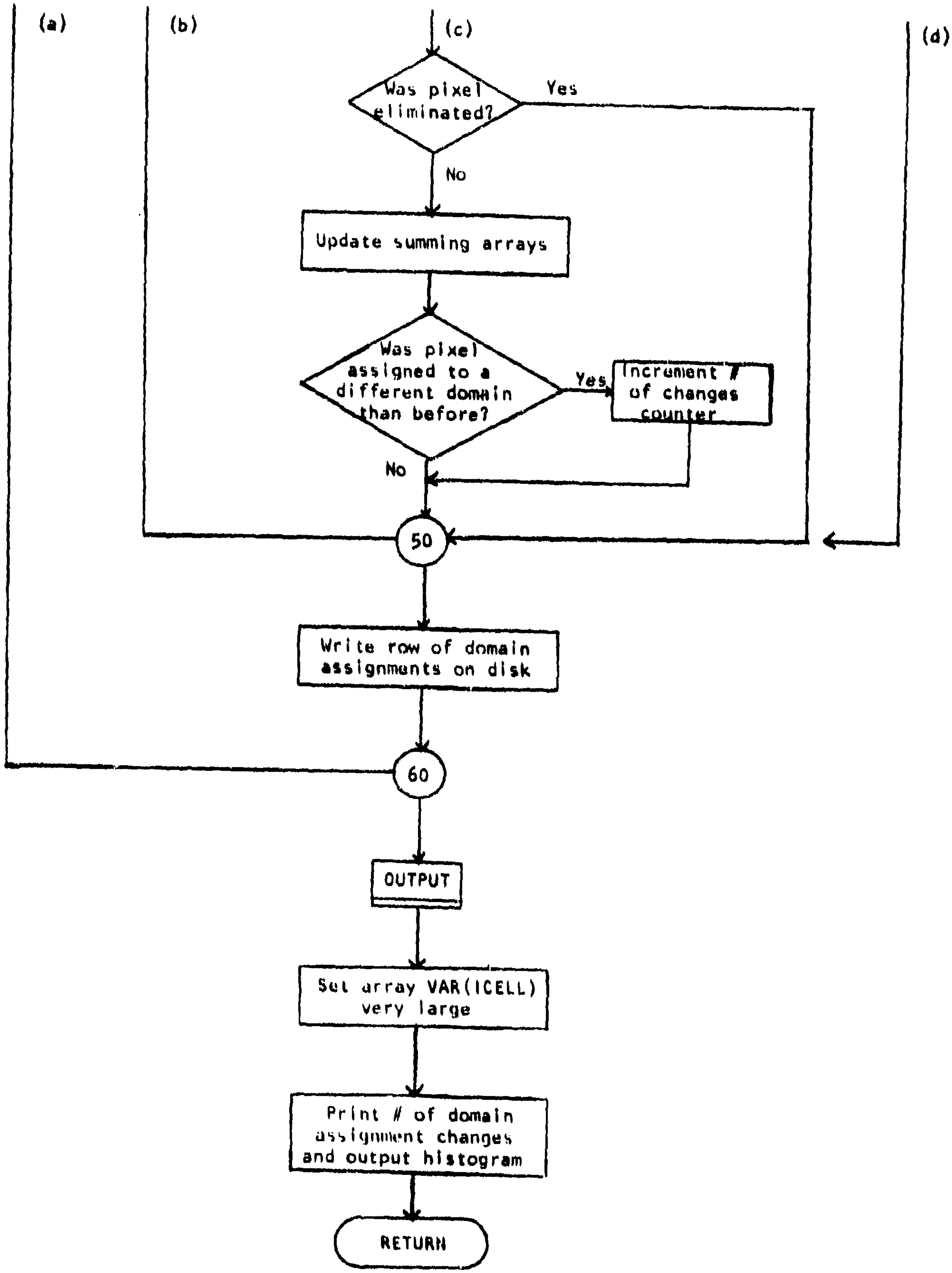


FIGURE 2 (CONTINUED)

b. Validation of Subroutine OPTIM

The method that was chosen to validate this routine was to intentionally select clustering parameters that produced incorrect results and to see how well OPTIM corrects for the improper selections. Scene 10 (4 Color Woodland Camouflage Cloth) was used as data since correct L*a*b* values are known for each of the four domains.

The improper clustering parameters were chosen by examining Table 4 of the Final Report on Data Acquisition and Analysis for Camouflage Design[4]. Case 7 was chosen and the results that were achieved, prior to running OPTIM, are repeated below.

TABLE 1 "IMPROPER" CLUSTERING PARAMETERS (No Optimization)

DOMAIN #	# OF PIXELS	L*	a*	b*
1	23	25.08	3.93	9.88
2	10	31.99	-10.06	12.00
3	10	26.11	2.97	10.90
4	23	24.98	2.95	9.57

The above run accounted for only 6% of the total number of pixels in the digitized scene (66 out of 1131) and only two distinct domains were produced.

OPTIM was then run (specifying a maximum of 15 loops) and the variance cut-off was sufficiently large so as not to discard any pixels on the basis of being too far from an obviously bad domain centroid. OPTIM needed only 10 loops to reach the situation where there were no changes in pixel domain assignments. The results of clustering after OPTIM are outlined below.

[4] See Reference 1.

TABLE 2 "IMPROPER" CLUSTERING PARAMETERS (After Optimization)

DOMAIN #	# OF PIXELS	L*	a*	b*
1	398	25.64	3.30	9.69
2	258	40.93	-3.26	16.16
3	312	30.97	-7.87	11.58
4	163	19.67	-.46	.89

These values can be compared to the run with "good" clustering parameters with no optimization (Table 3).

TABLE 3 "PROPER" CLUSTERING PARAMETERS (No Optimization)

DOMAIN #	# OF PIXELS	L*	a*	b*
1	356	24.79	3.10	9.20
2	160	41.17	-3.93	15.66
3	218	31.51	-8.05	12.10
4	82	18.10	0.33	-0.01

An examination of these three tables shows that even when starting from obviously incorrect domain centroids, OPTIM will iteratively adjust those centroids until they properly represent the scene. The minor difference between the two final results (Tables 2 and 3) can be attributed to the fact that the run with improper clustering parameters was forced (by the setting of a very high variance cut-off) to consider every pixel in the scene.

An interesting feeling for the workings of OPTIM can be obtained by examining Figure 3. This is a graph of a*b* space and shows the initial four improper domains and their associated L* values. The centroids of these domains are then shown to migrate to their final values during each iteration of OPTIM. The final L* values for the resulting centroids are also shown.

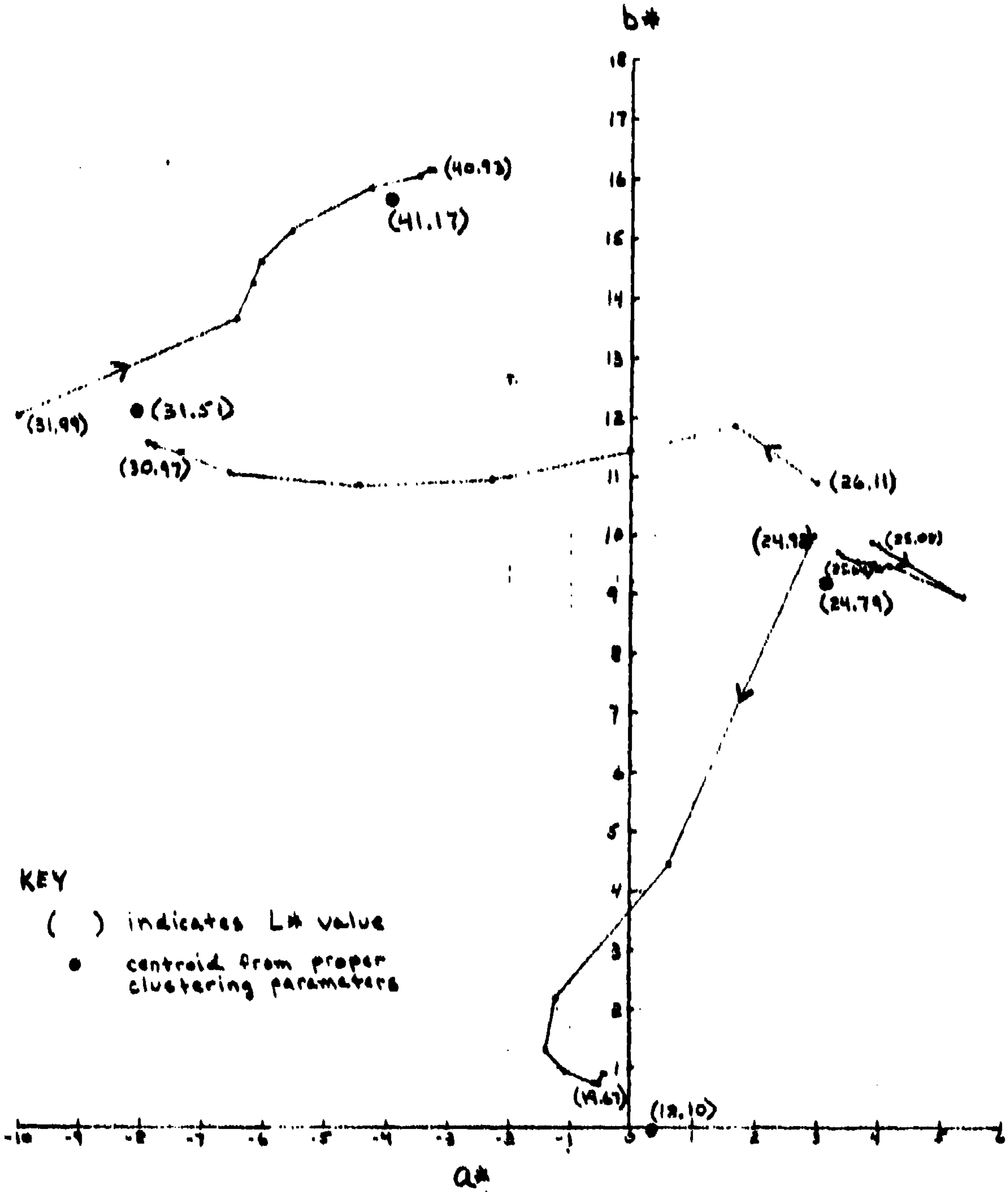


FIGURE 3 CENTROID MIGRATION DURING ITERATIONS OF OPTIM

3. DATA SEPARABILITY

This section describes some statistical tests which were performed on the CIE L*a*b* data. The purposes of these tests were to determine:

- For a given scene, what is the "correct" number of domains?
- After clustering, how "good" are the obtained domains?

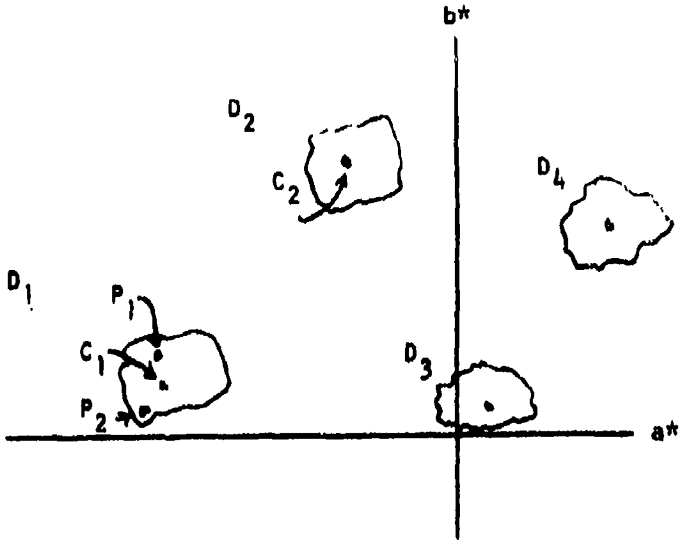
As will be discussed below, the first question can be answered only as to what is the minimum number of domains which adequately represent the scene. The answer to the second question is approached by testing whether the domains are statistically different from one another.

For all scenes analyzed, the minimum number of domains required was found to be three, four, or five. For the Woodland Camouflage Cloth, four domains were required. In all cases, at the minimum number of domains, they represented statistically "good" clustering.

a. Number of Domains Required

The Statement of Work requires that it be possible to reduce all real world scenes to five, four, or three domains. For any given scene, it seems appropriate to ask the question "How many domains should there be? " Phrased differently, this problem is finding the "optimum" number of domains.

Intuitively, it would seem that an analysis of the variances (squared vector distances in L*a*b* space) of domain and pixel L*a*b* values could be used to solve this problem. Figure 4 is a two dimensional plot of four idealized domains.



D_1 through D_4 represents Domains 1 through 4

C_1 and C_2 represents the Centroids of Domains 1 and 2

P_1 and P_2 are two Pixels within Domain 1

FIGURE 4 FOUR IDEALIZED DOMAINS

Note that all of the pixels used to cluster to the four imaginary domains are contained within the outline of the domain. Now, the separation of the domains should be related to the distance between the centroids (C_1 to C_2, C_1 to C_3, etc.) and the "compactness" of the domains should be related to the distance between pixels within a domain and the domain centroid (C_1 to P_1, C_1 to P_2, etc.)

The very use of the terms, between and within, suggests an Analysis of Variance where the statistical test of the "goodness" of the clustering is the ratio of the between cluster variance to the within cluster variance. This ratio, referred to as the F ratio, can be used to test a hypothesis that the obtained clustering arose from chance alone. If the obtained ratio is sufficiently large, this hypothesis is rejected and it is inferred that the clusters are, in fact, distinct.

Before proceeding in this manner, a literature survey was conducted in the Image Analysis area to determine what alternative procedures might have been developed. One paper[5] was found which discussed measures of the "goodness" of clustering. It discusses two useful criteria which are defined as B_4 and B_5. B_4 is equivalent to the F ratio discussed above. B_5 is the product of the between and within variances. B_5 is said to be useful since, when each pixel is a domain, within variance is zero, and when all pixels are assigned to one domain, between variance is zero. Hence, in both extremes B_5 is zero. The authors state that it follows that the "best" clustering occurs at the number of clusters which maximizes B_5.

Dacilog could find no logical basis for this assertion. Consider the processes which occur in clustering of a fixed number of pixels. If each and every pixel has a unique L*, a* and b*, clearly the "best" characterization of that scene is n domains, where n is the number of pixels. It is irrelevant, at this point, that this is of no value to camouflage design. As pixels are assigned to domains, and provided the number of pixels per domain is fairly large, the between domain variance will also increase as the number of domains decreases. If a "good" clustering algorithm, such as OPTIM, is used, the within domain variance will also increase as the number of domains is decreased. Therefore, B_5 will monotonically increase as the number of domains decreases and will be a maximum at two domains.

B_5 was calculated for each scene analyzed to date, and was found to be a maximum at two domains, and to decrease with increasing numbers of domains. It is concluded that B_5 is not a good criterion. For this reason B_4 (or, equivalently, the F ratio) is suggested for use to evaluate the number of domains required. B_4 is the ratio of the between domain variance to the within domain variance. This then can be a measure of the extent to which the domains account for the total scene variance.

One simply chooses the percentage of the total variance in all of the pixels being clustered which he wants to be accounted for by the domains. In the analysis done to date, 90% of the total variance has been the criterion.

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[5] G. B. Coleman and H. C. Andrews, Image Segmentation by Clustering, Proceedings of the IEEE, Vol. 67, No. 5, May 1979.

One then reads from a Table of Critical Values of F, the 90% values for 1-n degrees of freedom, where n is the number of domains.

Figure 5 is a plot of B_4 for the Woodland Camouflage Cloth for one through seven domains. The dashed line is the critical value at which the domains account for 90% of the total variance. If one goes to the next higher integral number of domains from the crossover, one sees the minimum number of domains which account for 90% of the total variance. Any higher number of domains will account for a greater proportion of the total variance. It may be noted in this example, the Woodland Camouflage Cloth, that four is the minimum number of domains required to account for 90% of the variance.

Figures 6 through 12 show similar plots for other scenes which have been analyzed. Note that the minimum number of domains is three (Scene 13) and the maximum is five (Scenes 3, 14, and 21; Table 4).

Figures 13 through 20 show the L*a*b* values for the domain centroids for each scene analyzed to date, together with a verbal description of the scene. Figures 13, 14, and 16 are dormant scenes. Note that all centroids are in the "red" quadrant. In Figure 14, it is believed that the two centroids below the horizontal axis may have been caused by digitizing the sky background between the limbs of the dormant trees.

Figure 15 depicts the domain centroids obtained from the analysis of the Woodland Camouflage Cloth. Despite the fact that there is no traceability between the reflectance targets used in the photographs and NLAB's colorimeter, one can observe the remarkable similarity between these values and those measured by NLAB's.

TABLE 4: MINIMUM NUMBER OF DOMAINS

SCENE #	TYPE	DESCRIPTION	MINIMUM # DOMAINS
3	Near	Deciduous, Brush (Dormant)	5
4	Far	Deciduous, Brush (Dormant)	4
10		Woodland Camouflage Cloth	4
11	Near	Fruit Orchard (Dormant)	4
12	Near	Deciduous, Brush (Verdant)	4
13	Far	Coniferous (Verdant)	3
14	Near	Deciduous, Brush (Verdant)	5
21	Far	Deciduous, Brush (Verdant)	5

SCENE 10

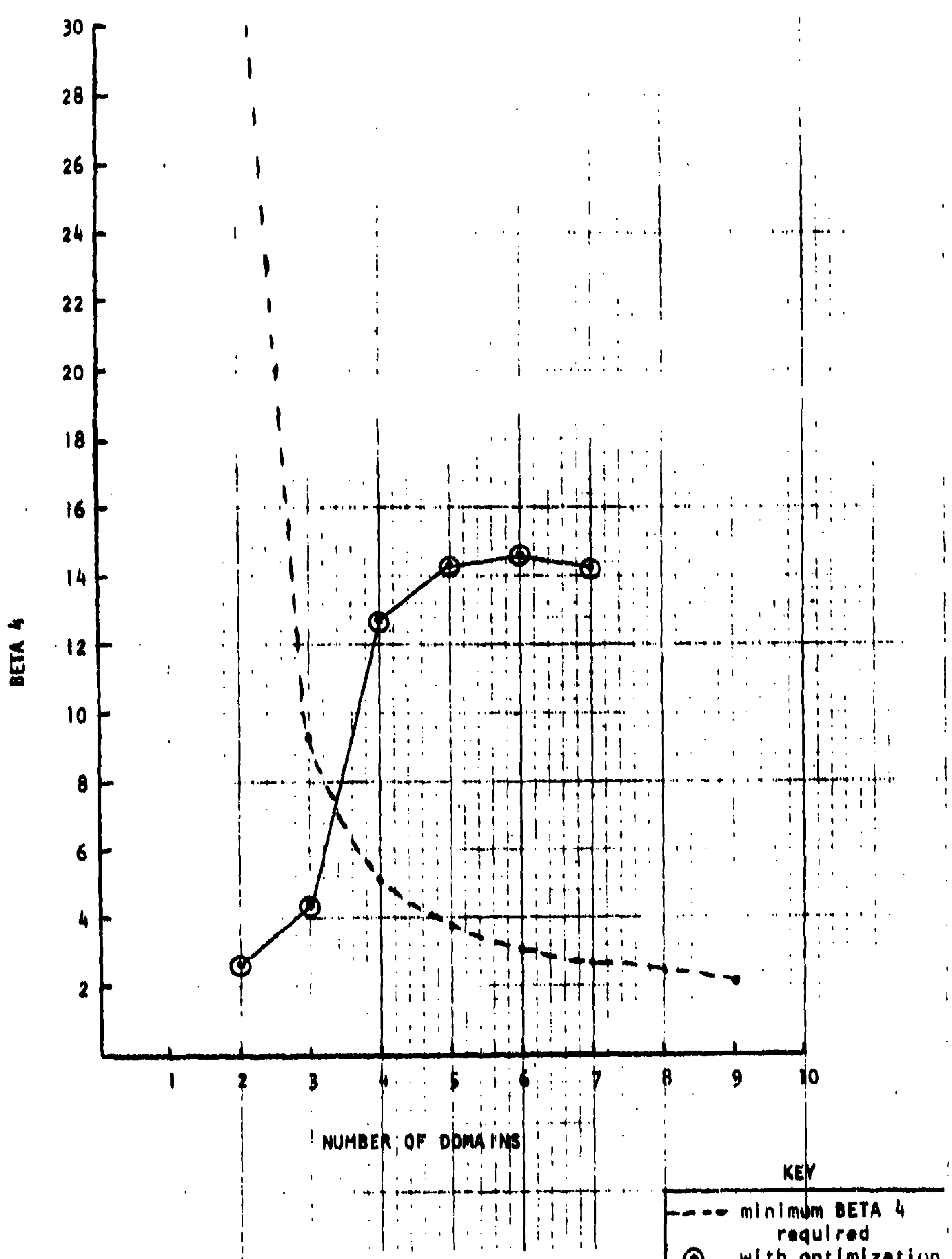

FIGURE 5 Scene 10 - Beta vs. Number of Domains

SCENE 3

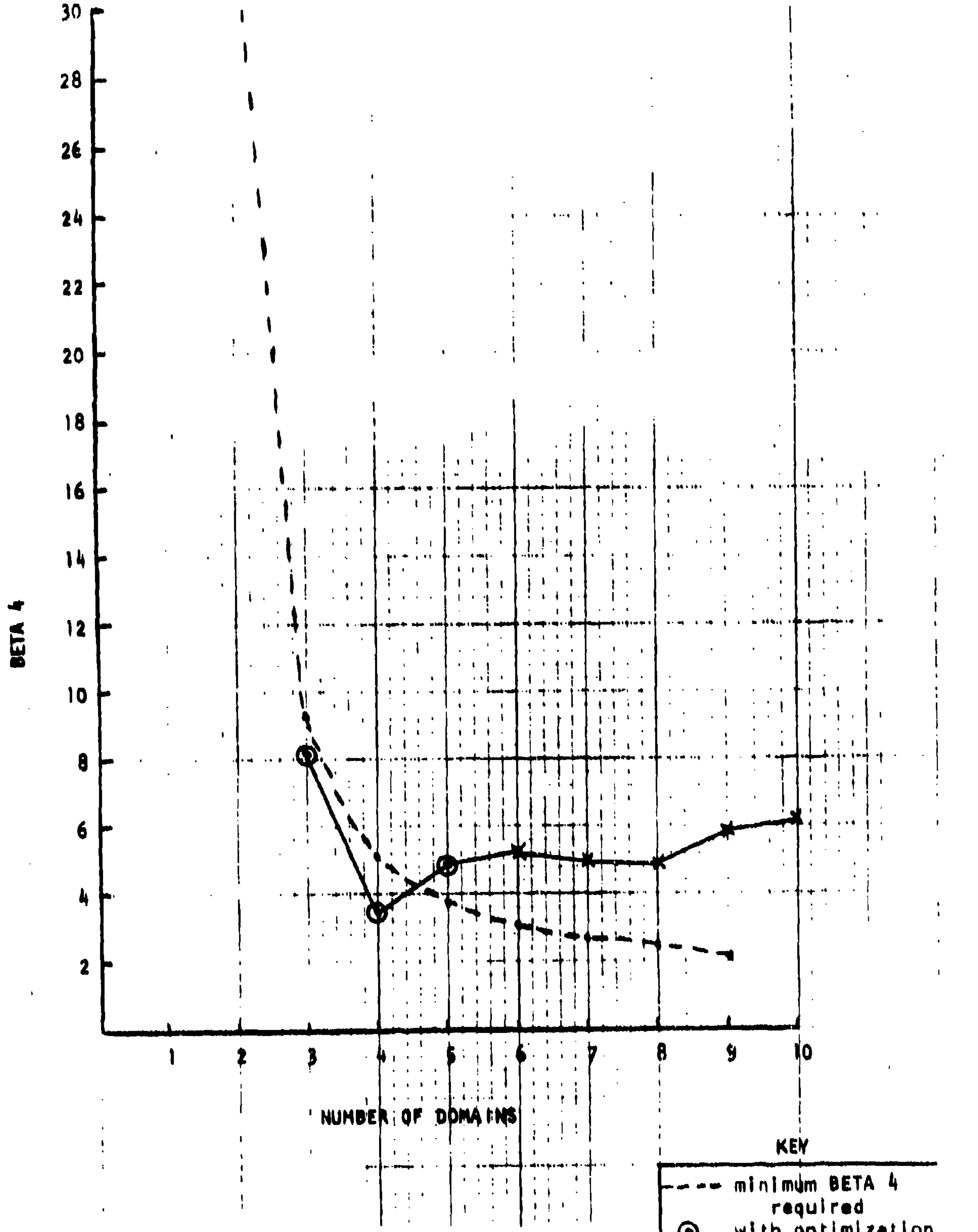

FIGURE 6 Scene 3 - Beta vs. Number of Domains

SCENE 4

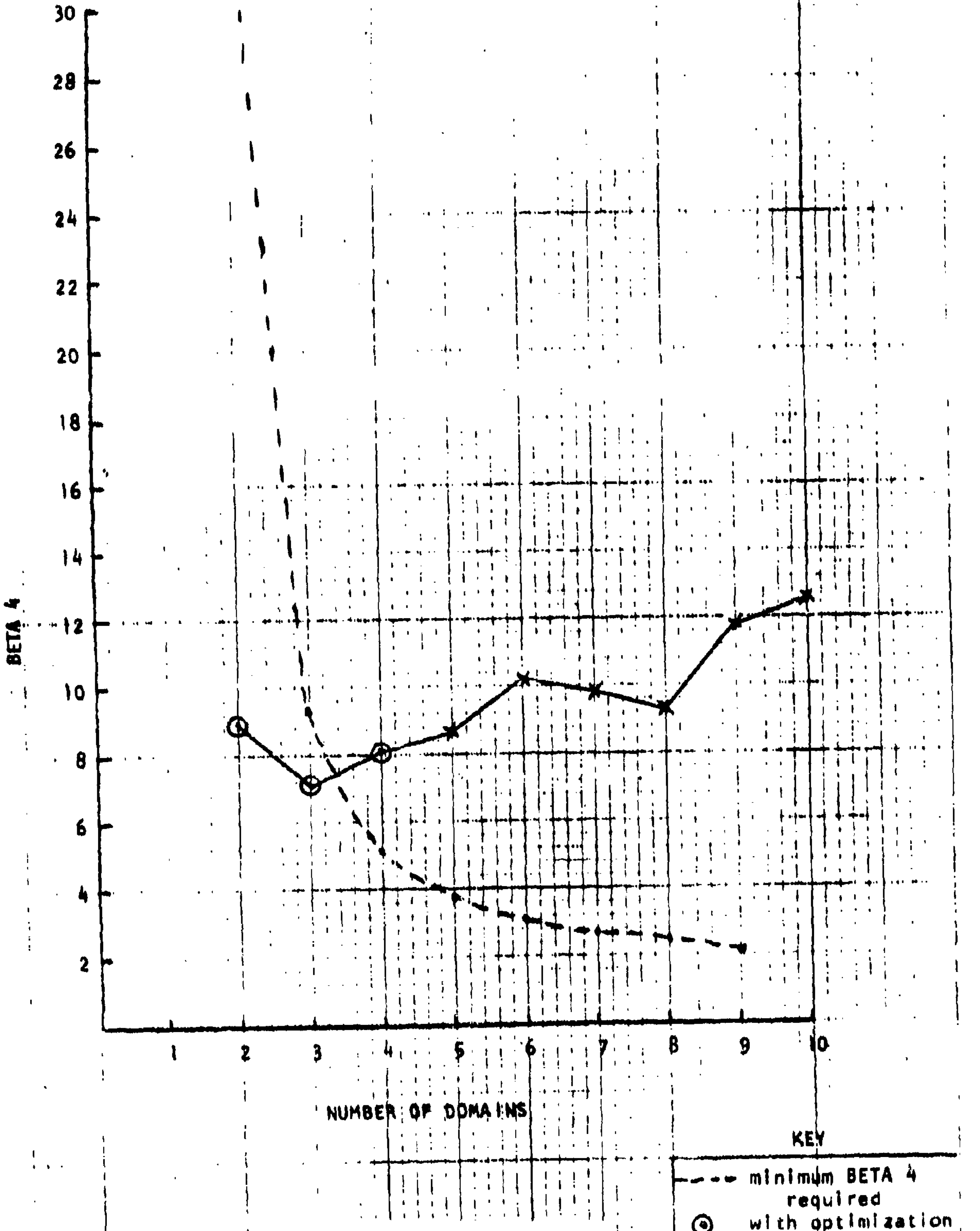

FIGURE 7 Scene 4 - Beta vs. Number of Domains

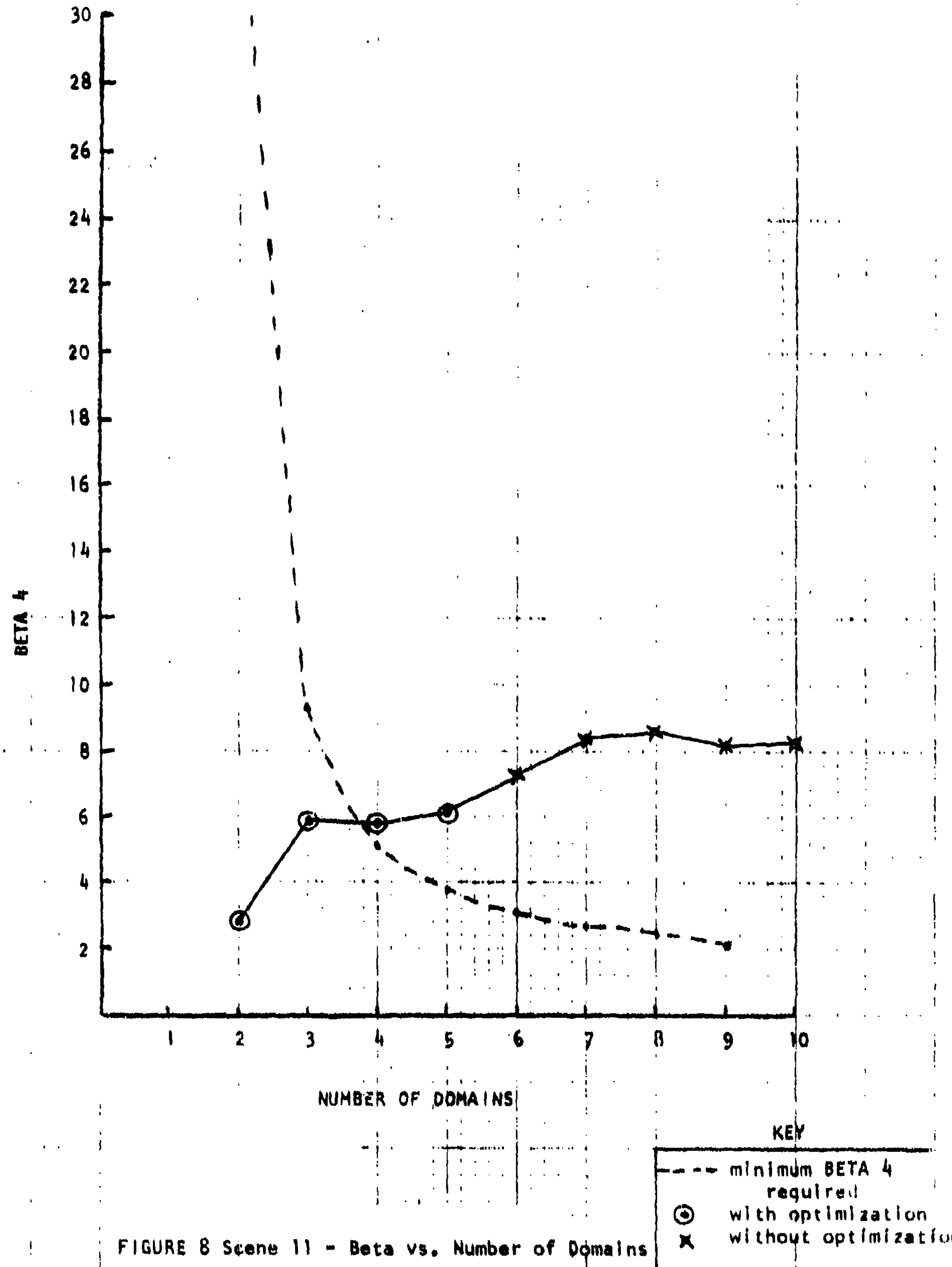

FIGURE 8 Scene 11 - Beta vs. Number of Domains

SCENE 12

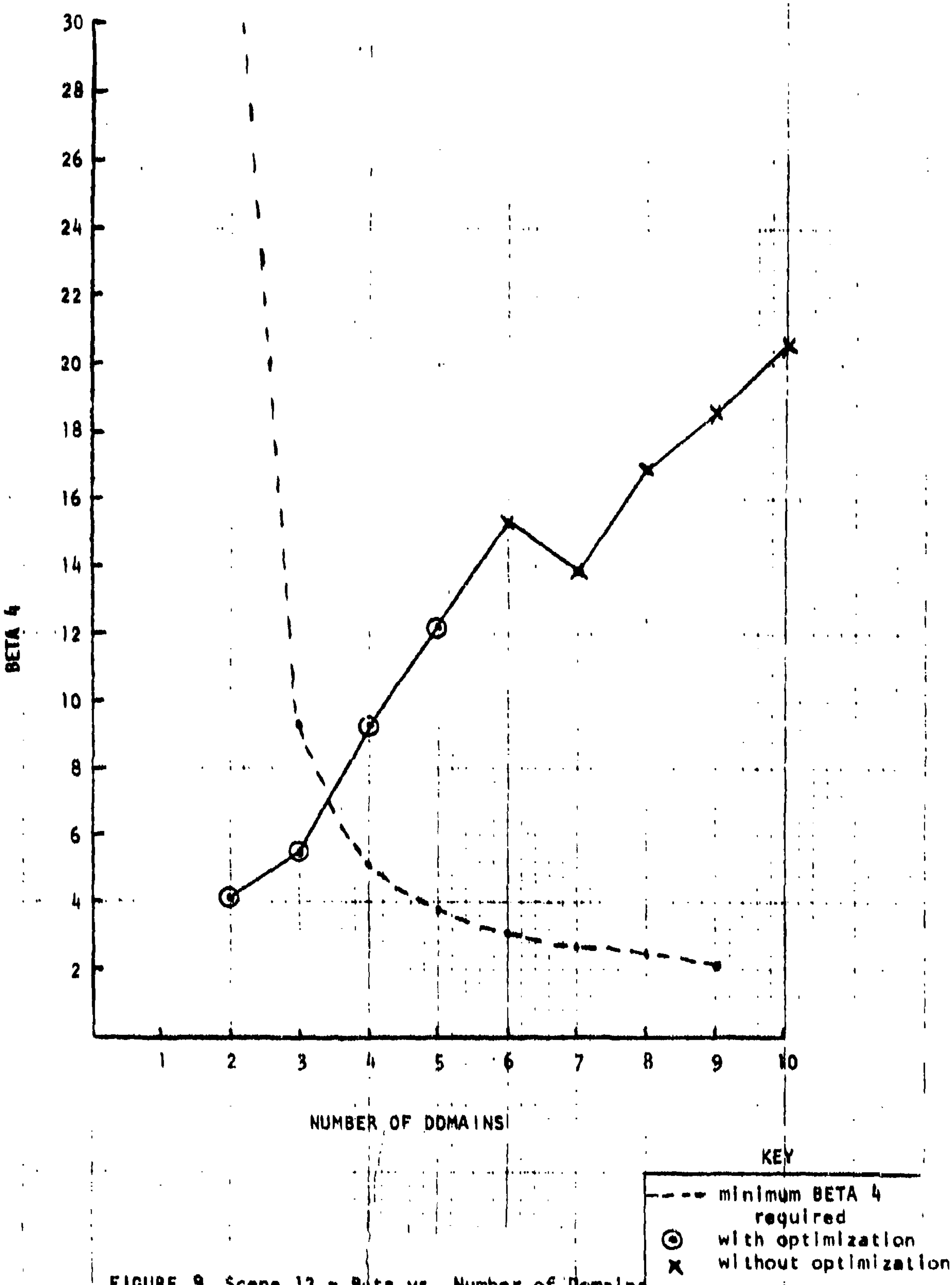

FIGURE 9 Scene 12 - Beta vs. Number of Domains

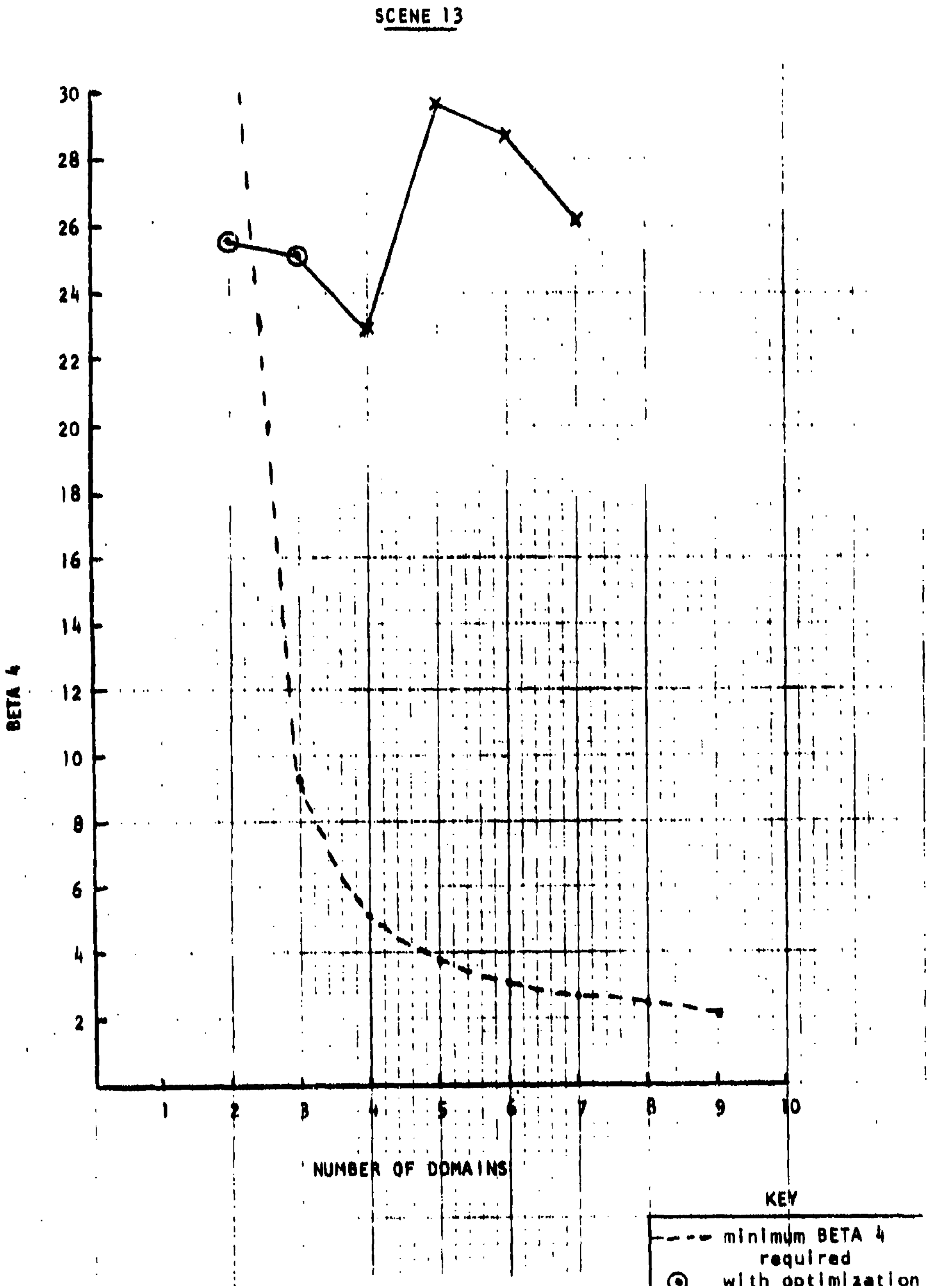

FIGURE 10 Scene 13 - Beta vs. Number of Domains

SCENE 14

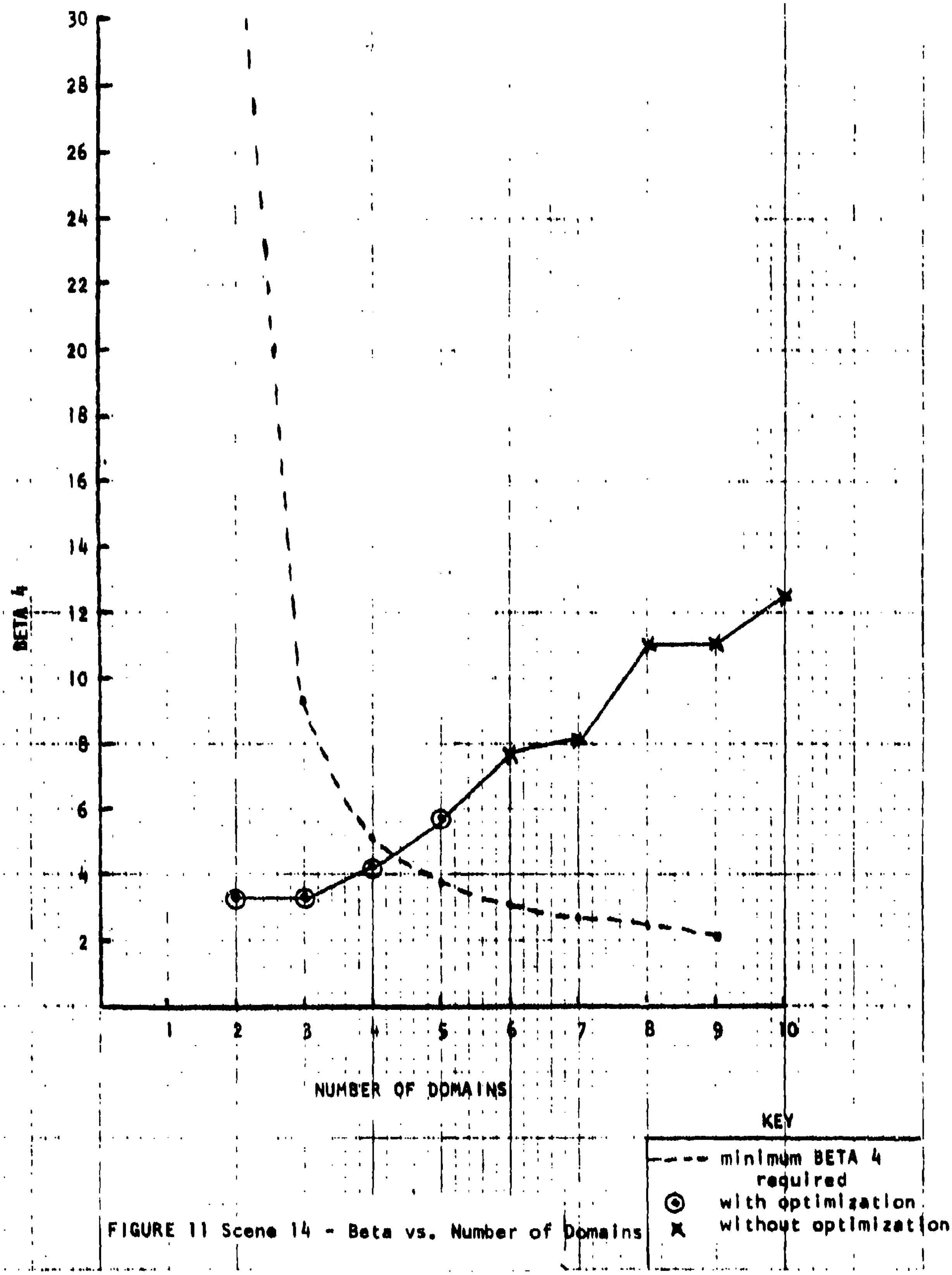

FIGURE 11 Scene 14 - Beta vs. Number of Domains

SCENE 21

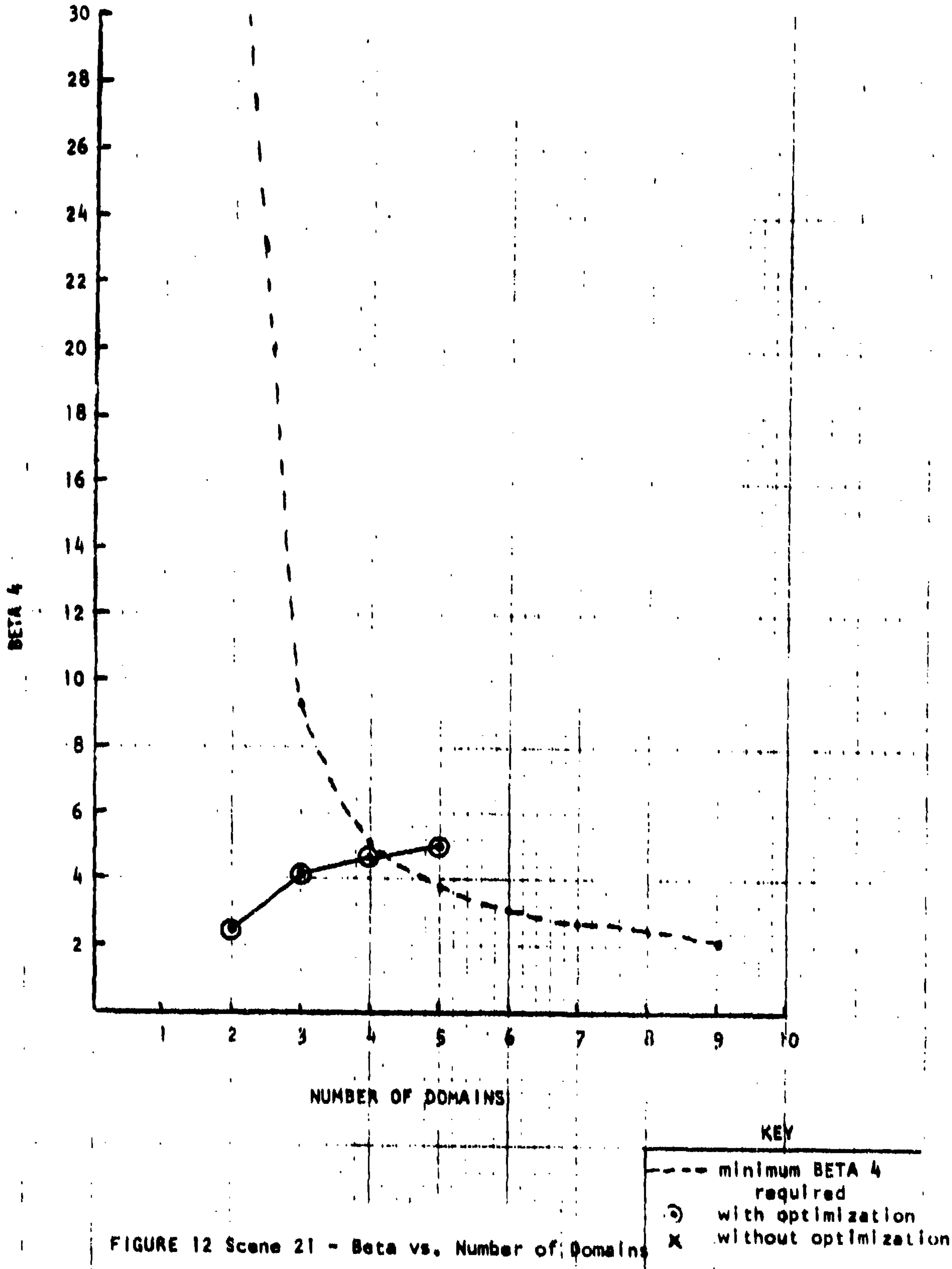

FIGURE 12 Scene 21 - Beta vs. Number of Domains

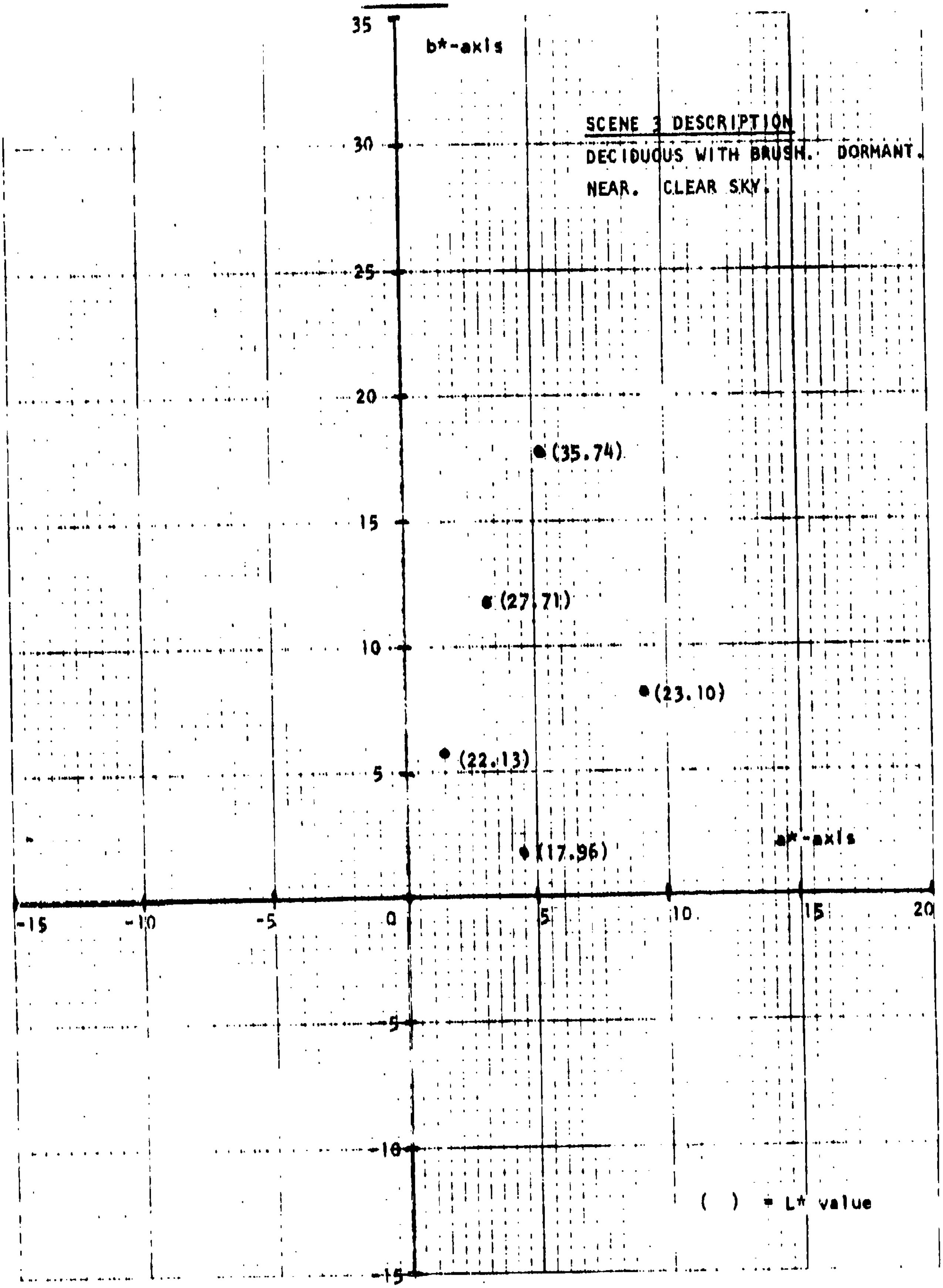

FIGURE 13 Scene 3 - Domains in a* vs. b* Plane

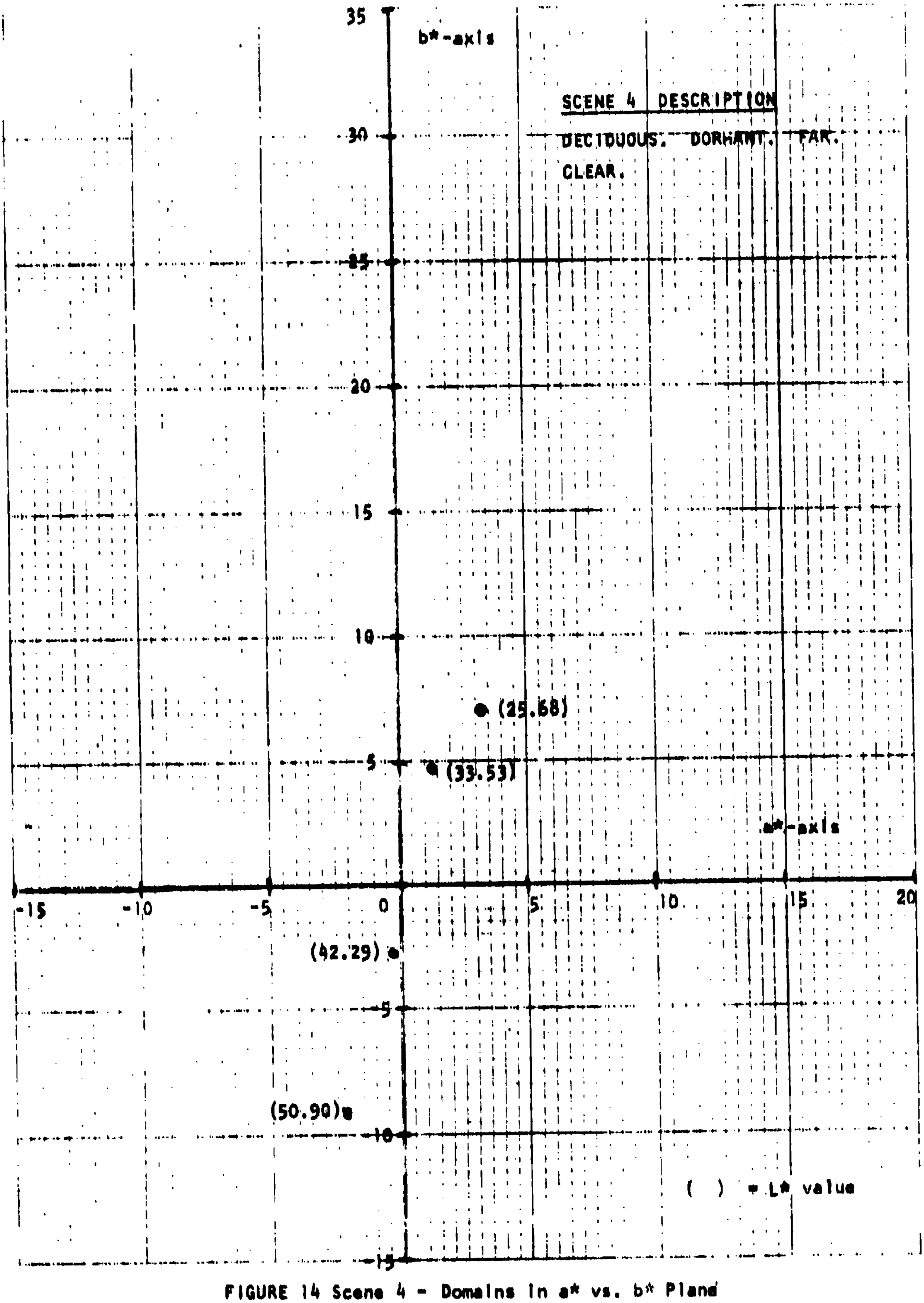

FIGURE 14 Scene 4 - Domains in a* vs. b* Plane

SCENE 10

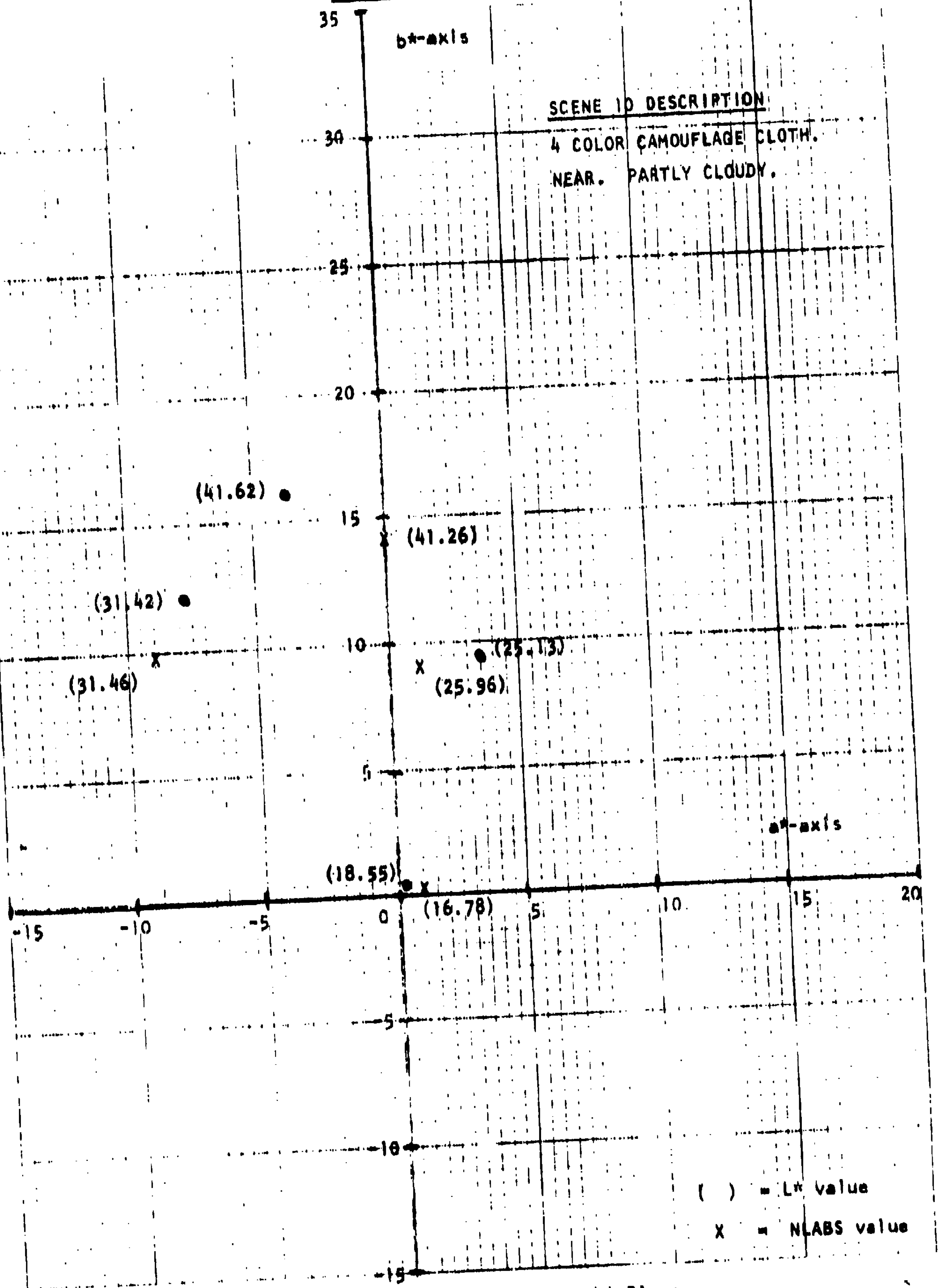

FIGURE 15 Scene 10-Domains in a* vs. b* Plane

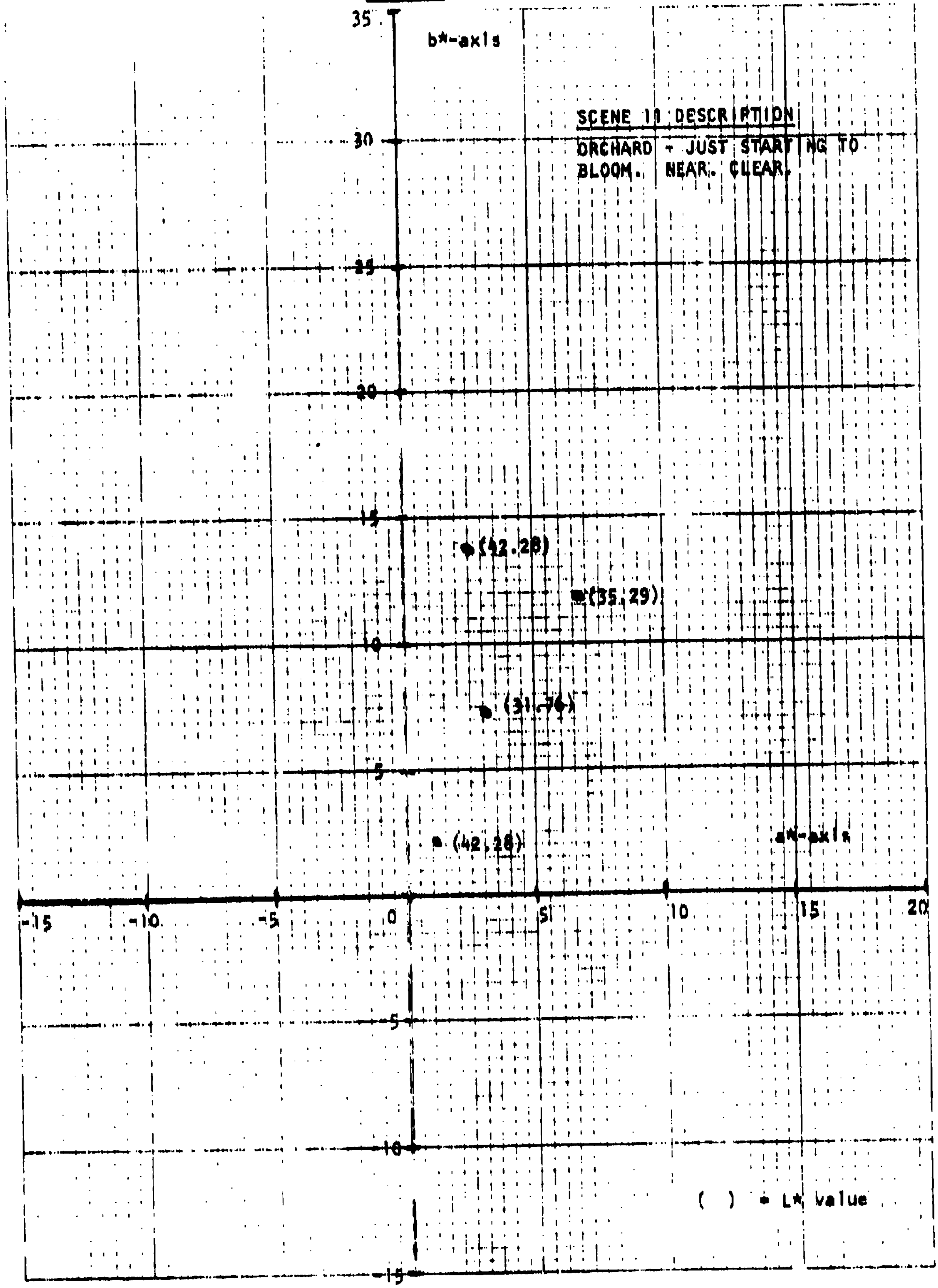

FIGURE 16 Scene 11 — Domains in a* vs. b* Plane

SCENE 12

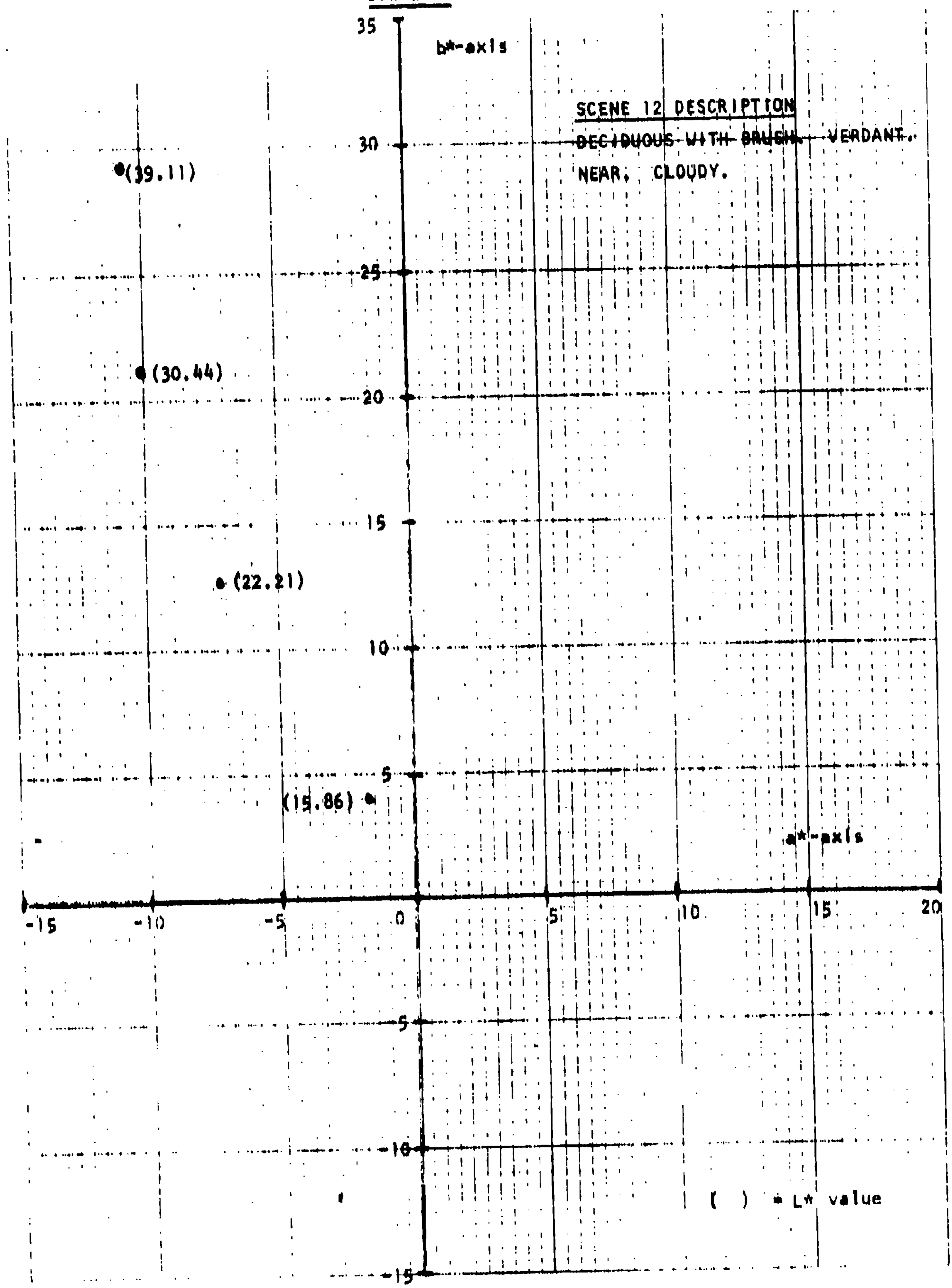

FIGURE 17 Scene 11 - Domains in a* vs. b* Plane

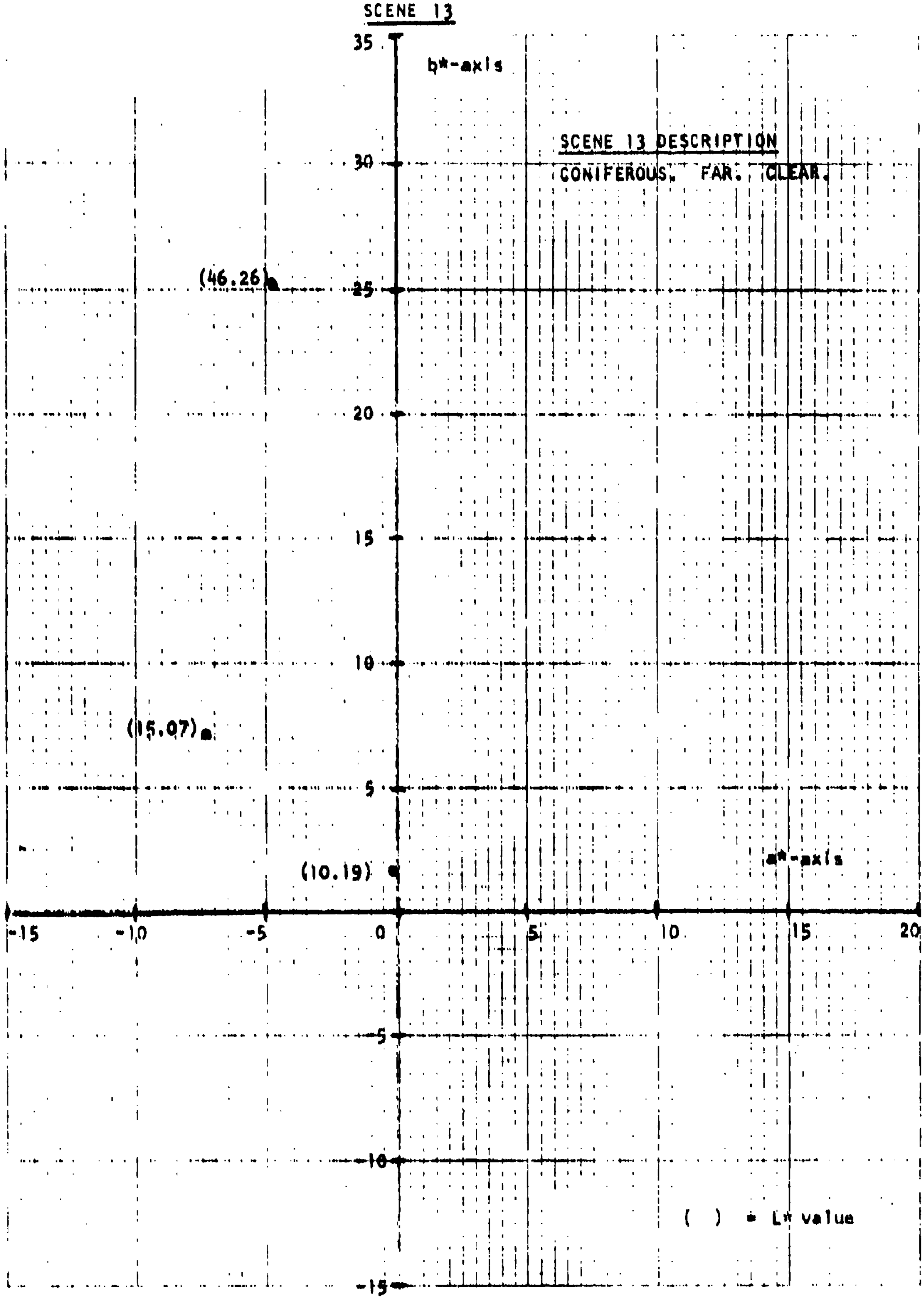

FIGURE 18 Scene 13 - Domains in a* vs. b* Plane

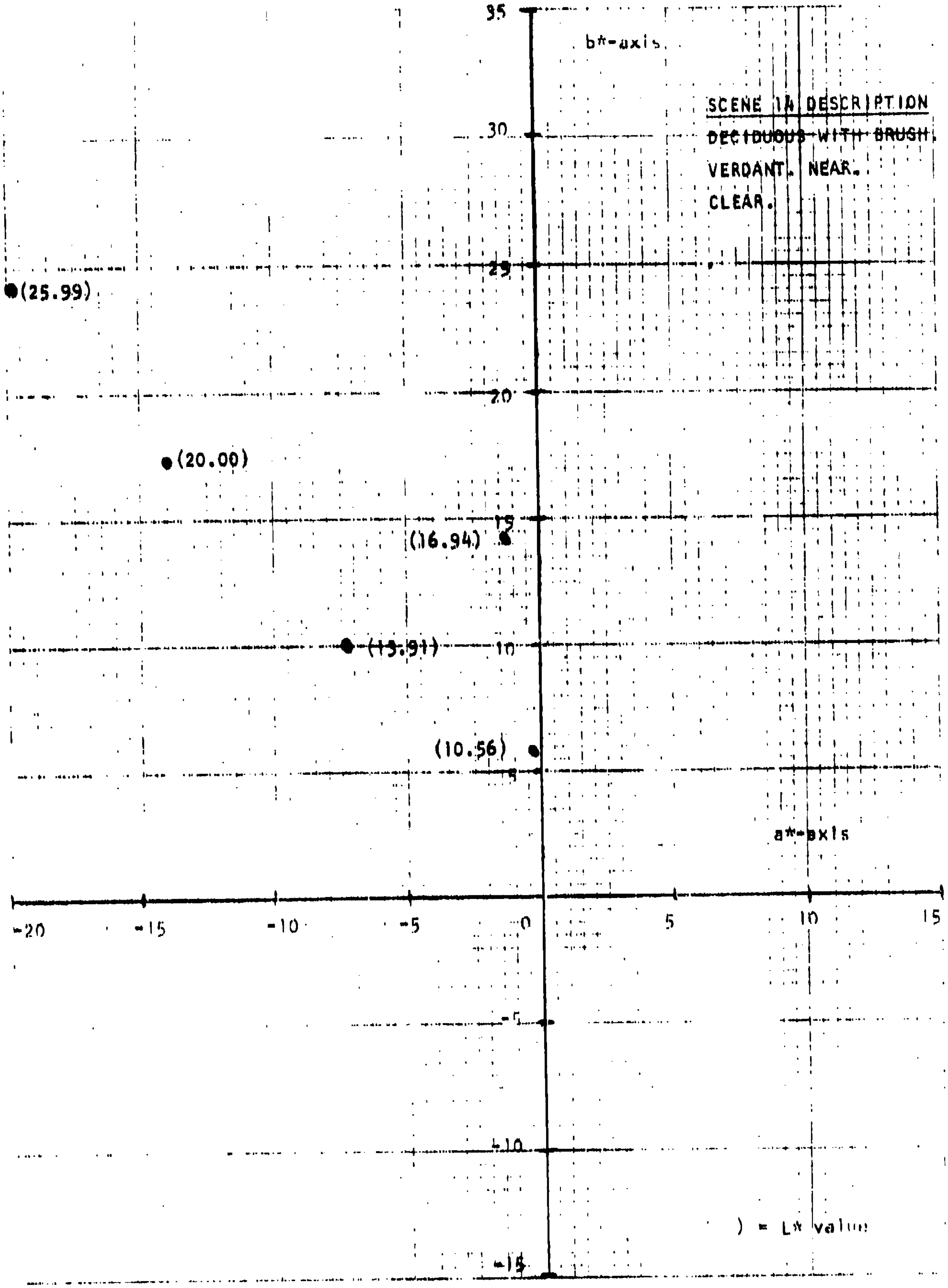

FIGURE 19 Scene 14 - Domains in a* vs. b* Plane

SCENE 21

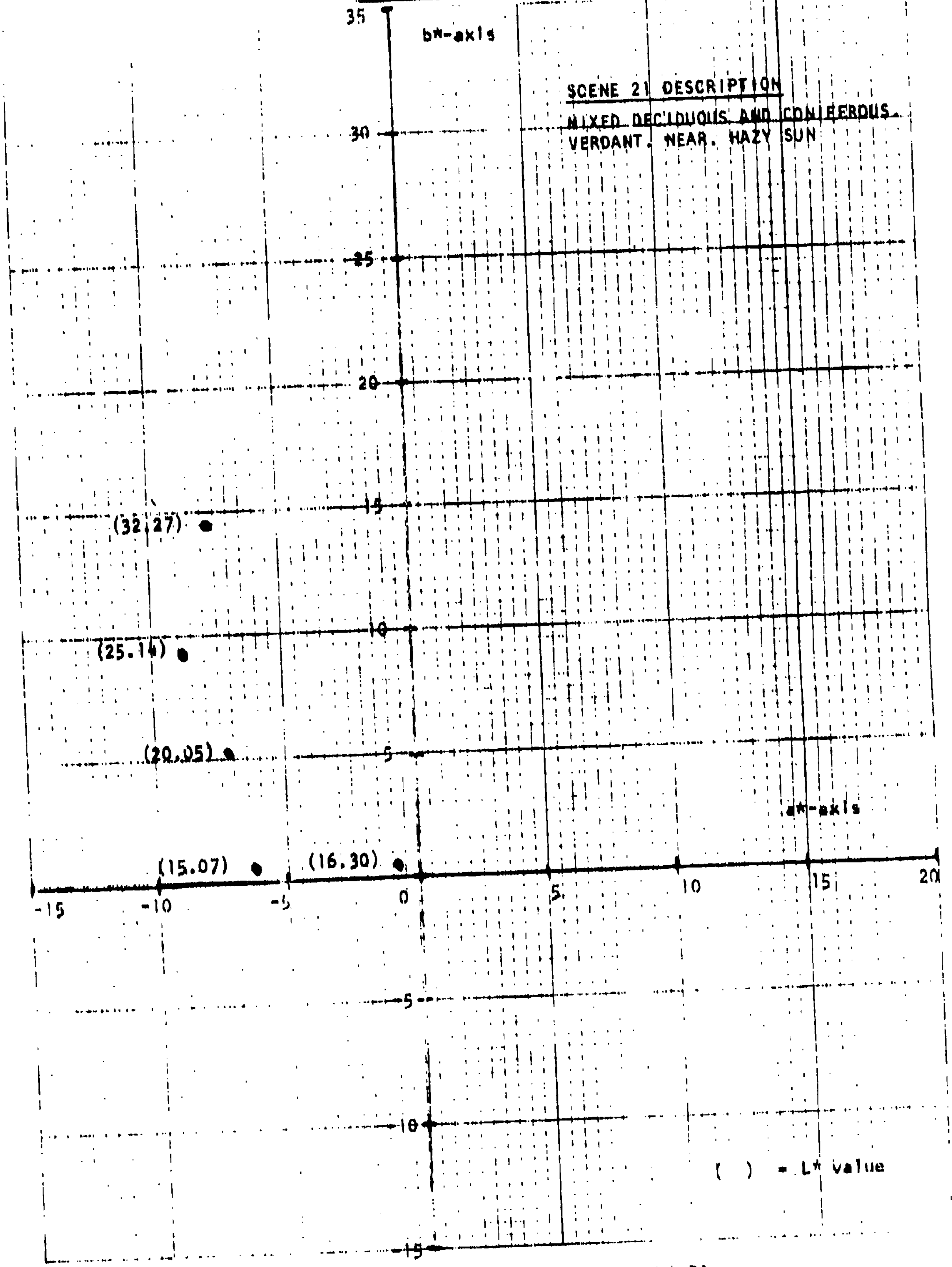

FIGURE 20 Scene 21 - Domains in a* vs. b* Plane

The remainder of the scenes are either coniferous or deciduous-verdant. All points are in the "green" quadrant. Each has a "black" domain. Figure 17, for example, displays a peculiarity of some deciduous-verdant scenes. Note the correlation among the values of the L*, a*, and b* values of the obtained centroids. The a* and b* components have been referred to by Ramsley[6] as an Iso Hue line. In this case, the value of L* is also correlated with both the a* and b* values. Whether or not this has any significance has not been investigated.

Finally, Figure 21 is a composite plot of the domain centroids for all scenes analyzed. Also shown is the space enclosed in a*, b* space by the centroids of the Woodland Camouflage Cloth. Since it seems intuitively logical that camouflage cloth should avoid extremes, visual inspection would indicate that the choice of L*a*b* values for the Woodland Camouflage cloth was good. An interesting exercise would be to start with these centroids, weighted by the number of pixels, and cluster to four domains. A comparison could then be made between the camouflage cloth values and the four domains. It is possible that, although only eight scenes have been analyzed, they are somehow representative of the world on which the Woodland Camouflage cloth was based.

b. "Goodness" of Domains

After clustering to the minimum number of domains, it is desirable to test the quality of the clustering. As will be discussed below, the statistical test compares the spacing between domain centroids with the "compactness" of the domains. The purpose of the test is to determine if the L*a*b* values of the domain centroids are statistically significantly different. If they are, clustering is "good" because the spacing between centroids is large, and the domains are "compact". The statistical tests will indicate the probability that the difference in L*a*b* values of any two centroids occurred by chance, as opposed to the difference having arisen from real characteristics of the scene. The results will be discussed below.

---

[6] A. O. Ramsley, Selection of Standard Colors for the Woodland Camouflage Pattern , US Army Natick Research and Development Laboratories, September 1981, (Technical Report NATICK-81/030).

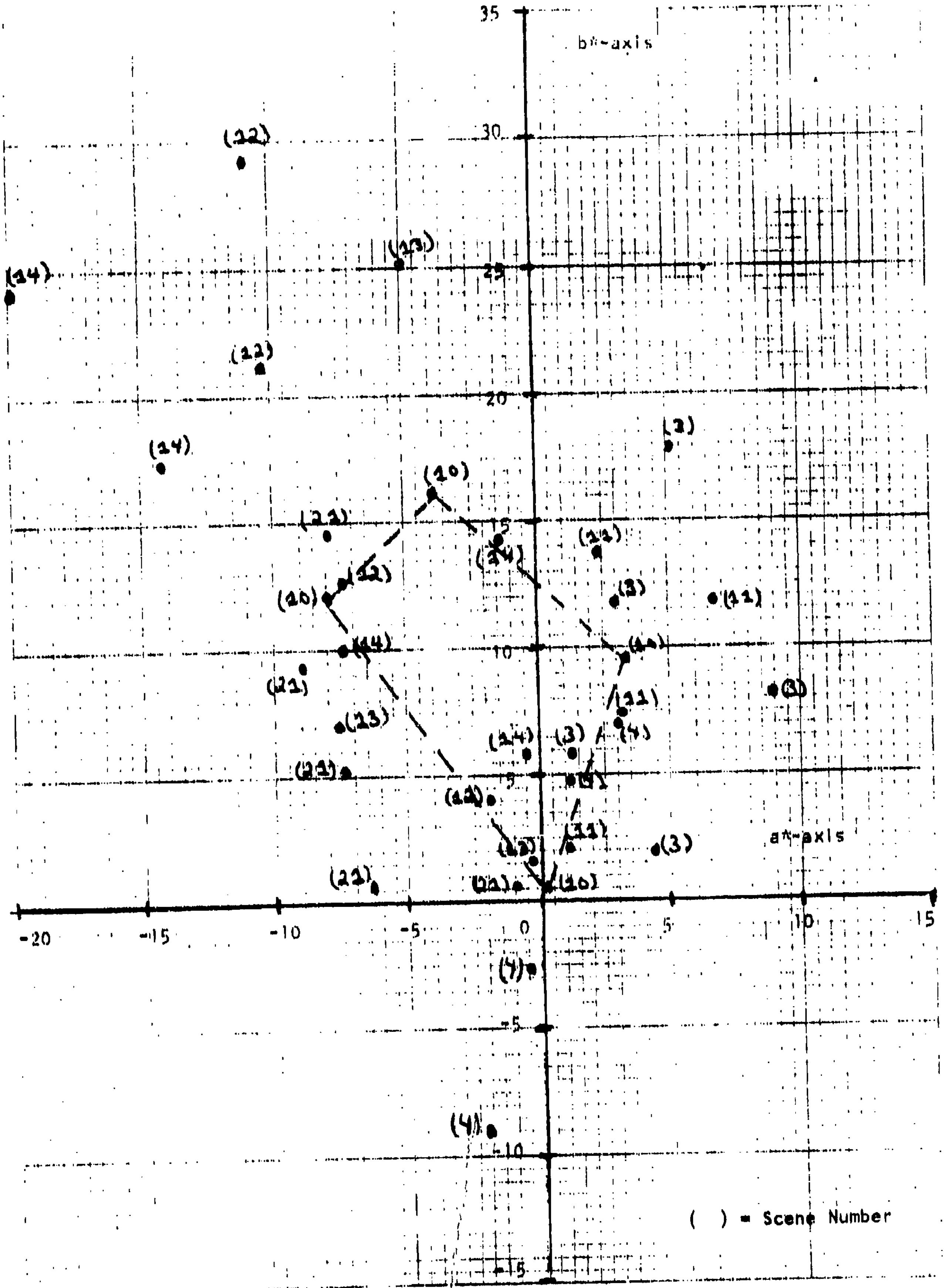

FIGURE 21 All Scenes - Domains in a* vs. b* Plane

Prior to this discussion, however, the practical significance of these tests should be evaluated. Due, at least in part, to the fact that very large numbers of pixels are assigned to each domain, the statistical tests become very sensitive. As a result, very small differences in the location of centroids will be found to be "statistically different". Thus, if a scene has been clustered down to ten domains, for example, the statistical tests could likely indicate that there are ten "significantly different" domains at the confidence level chosen.

The actual distance between some pairs of centroids in L*a*b* space may be small, even less than 1 unit, which is the <u>theoretical</u> visual difference threshold. Theoretical is underscored since it must be remembered that it is based on the 1931 standard observer, using the method of paired comparisons. The threshold which is applicable to camouflage cloth when viewed under field conditions is not known, but is probably larger than 1 unit.

Therefore, it should be kept in mind that the term "significantly different" or "different" refers to the precision and separability of domains from a statistical viewpoint and not to the visual difference between domains as applied to camouflage cloth in countersurveillance.

Student t and Fischer F tests were run to test the statistical significance of the distance between centroids in CIELAB space. The F test considers all domains simultaneously and compares their combined variance with the spectral variance in the overall scene. The t test compares distances between individual pairs of centroids with the pixel variance within the respective domains.

Both the t and F tests are calculated and printed out in subroutine OUTPUT for all clusterings of ten and fewer domains. Because the t test operates on pairs of centroids, multiple t tests had to be performed; and in order to keep the confidence level within each test high, an <u>a priori</u> confidence level of 0.99 was chosen. This means that if the obtained value of t exceeds the critical value or the probability is 0.01 or less, the difference is due to change. As it turned out, for the scenes analyzed to date, the values of all t's for ten and fewer domains are far greater than the critical value for 0.99 confidence. It is probable that, in the future, even higher confidence levels can be used.

On the basis of the t tests it is concluded that, with as many as ten domains, each and every domain is different from every other domain. Given this separability, it is inferred that the clustering is "good".

Because the F test compares each domain with the distance to all other centroids simultaneously, a lower confidence level, namely 0.90 was chosen *a priori*. The results of the F tests confirmed the results of the t tests. Again, with as many as ten and as few as two domains, each domain was compact as compared to the separation between all domains. Based on this conclusion, it is again inferred that the clustering is "good".

The obtained F and t statistics for each run analyzed are shown in the Appendix.

4. SCENE SEGMENTATION

a. General Discussion

One of the extensions to the software for the Analysis of Terrain Data for Camouflage Design was the ability to process only part of a total scene. In the original software package the user specified the number of columns and rows of the entire scene and the entire area was processed. The user is still required to specify the number of columns and rows of the entire scene but also to specify that part of the scene that is actually to be processed.

As can be seen from Figure 22 the user is required to specify the lower left hand and upper right hand corner of the rectangle of interest. This is accomplished by setting the variables ISEGR1 and ISEGR2 to the starting and ending row numbers, respectively. The variables ISEGC1 and ISEGC2 are set to the starting and ending column numbers, respectively. The Terrain Analysis Software then works on this scene segment in exactly the same manner as if it were the entire scene.

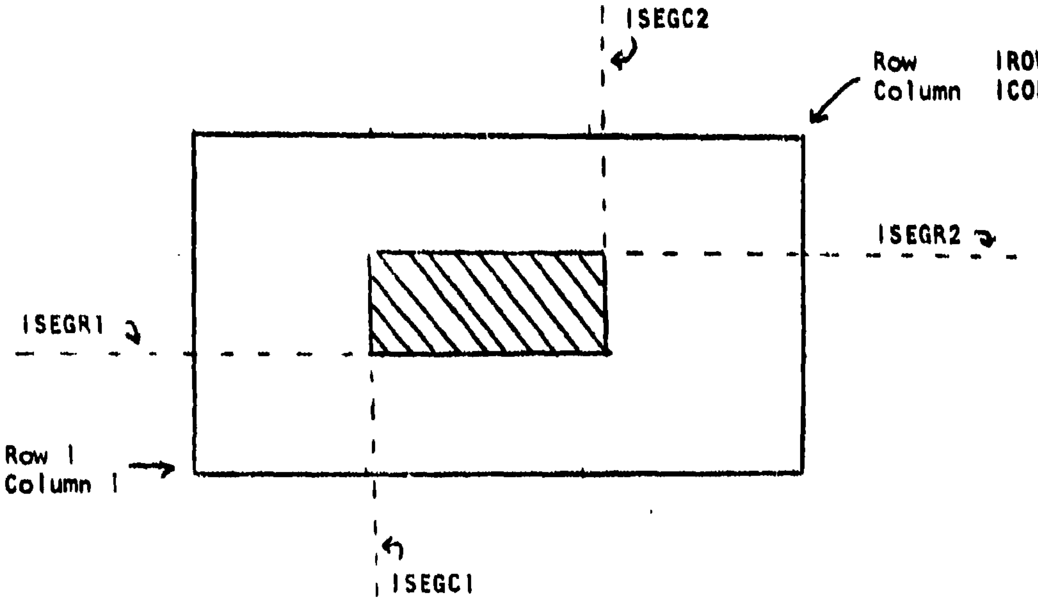

FIGURE 22 SPECIFYING A SCENE SEGMENT

b. Symbol Plots of Scene Segments

The modifications that were necessary to incorporate the ability to process scene segments extend to the plotting software. It seemed reasonable that the entire scene should be outlined and the scene segment plotted at the proper offsets. This allows easy comparisons of multiple runs of the same scene as well as a quick visual check of the area of interest. In order to accomplish this it was necessary to pass the coordinates of the segment, in addition to the size of the total scene to the plotting routine (SYMPLOT).

An example of this appears on the following pages. Figure 23 is a plot of the entirety of Scene 3 after being clustered to 3 domains. Arrows have been hand drawn to indicate the scene segment that was specified on a subsequent run of the analysis software. The scene segment coordinates that were specified were ISEGR1=30, ISEGR2=60, ISEGC1=50, and ISEGC2=80. The resulting plot can be seen in Figures 24 and 25.

The scene segment that appears in these figures was not generated by clustering. The option of specifying centroidal L*a*b* values and then assigning pixels to the closest domain centroid was used. This was done so that the segment plot and the segment area of the entire scene would be identical. It is important to realize that if we had clustered the scene segment the resulting centroids might have been very different.

FIGURE 23 SCENE 3

RANGE 50 M   SCALE FACTOR (OBJ CM/PLOT CM) 2.21

ILLUM W/CM²-MICRON: 50.00, 82.80, 93.50, 104.90, 117.90, 115.30,
109.40, 104.90, 104.40, 100.00, 95.70, 90.00,
87.60, 83.70, 80.20, 78.30, 71.60,

NFIN : 3	NSWTCH = 20	INCR = 1	
ITHRGH = 12	INTERV = 2	ISEOC1 =50	ISEOC2 =90
NFWCMX = 31	NFWRMX = 31	ISEOR1 =30	ISEOR2 =60

	DOMAIN NUMBER 1	2	3
SYMBOL		+	×
L*	35.93	25.40	20.49
A*	5.42	5.45	3.68
B*	17.33	10.62	4.64

FIGURE 24 SCENE 3

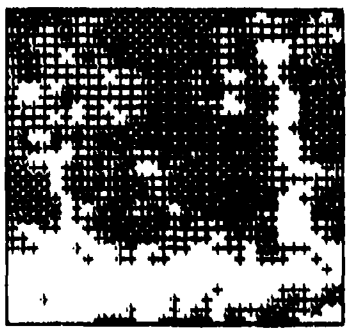

FIGURE 25 SCENE 3 SEGMENTED COMPOSITE, 3 DOMAINS

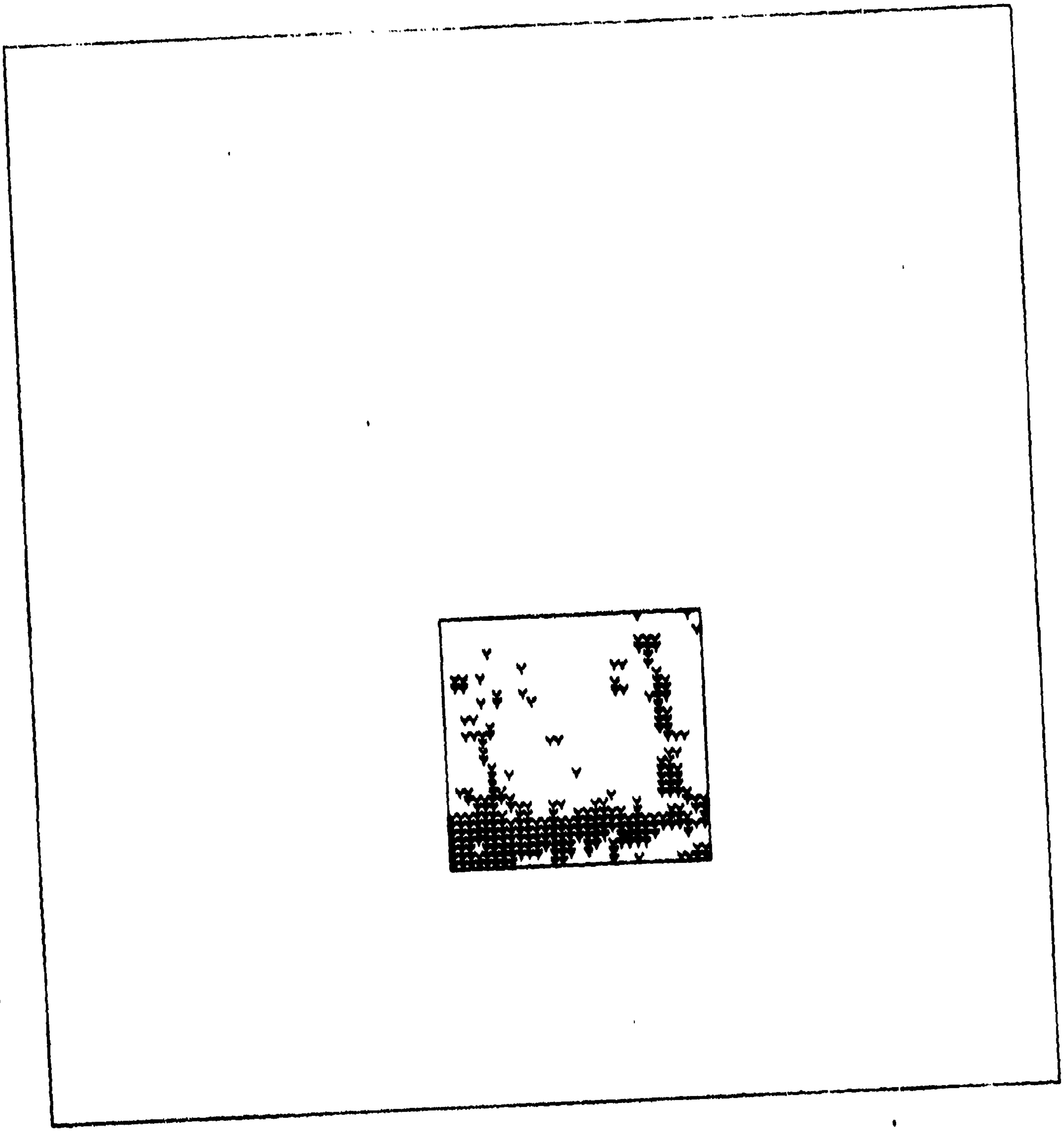

FIGURE 26 SCENE 3 SEGMENTED, DOMAIN 1

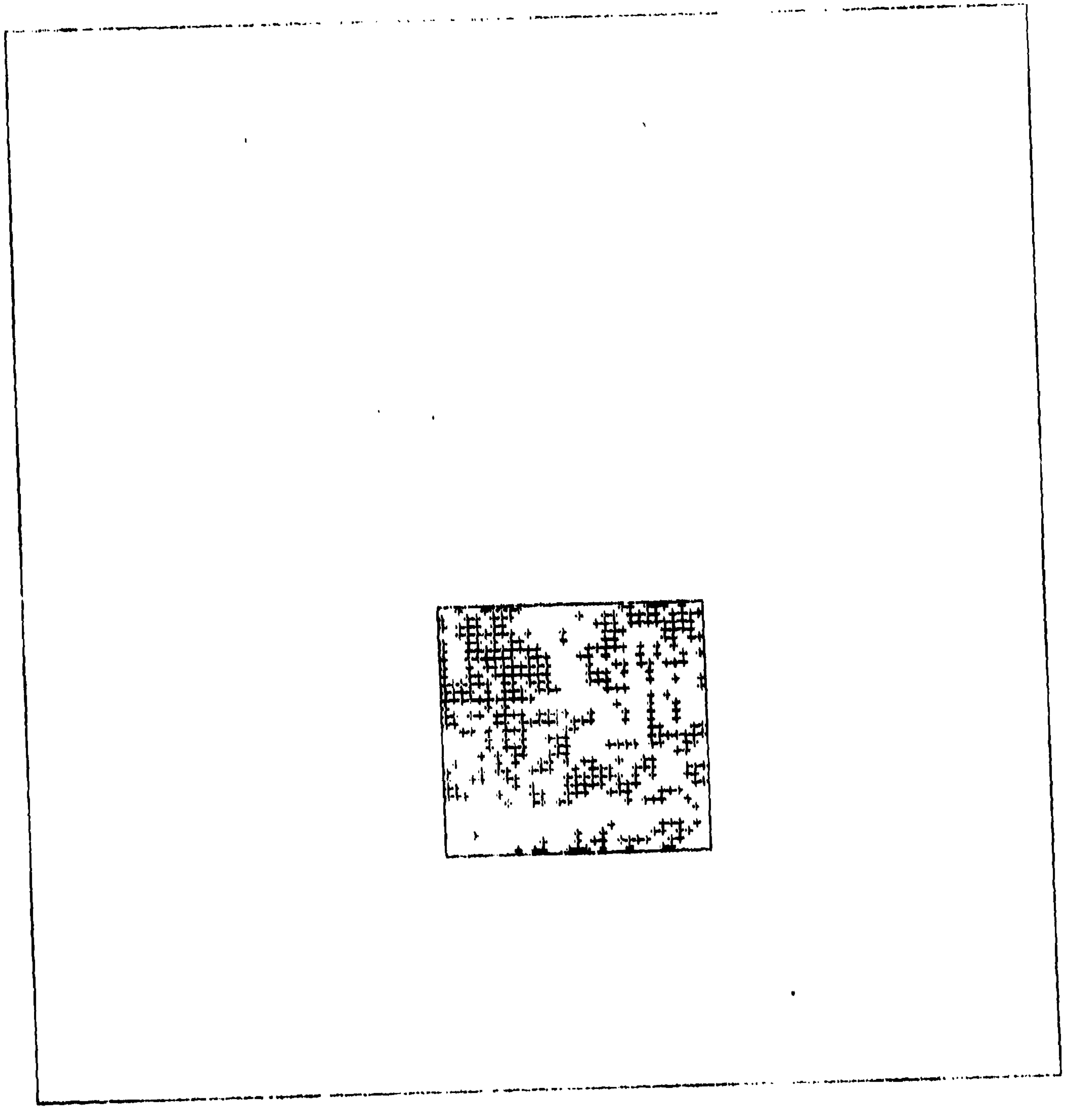

FIGURE 27 SCENE 3 SEGMENTED, DOMAIN 2

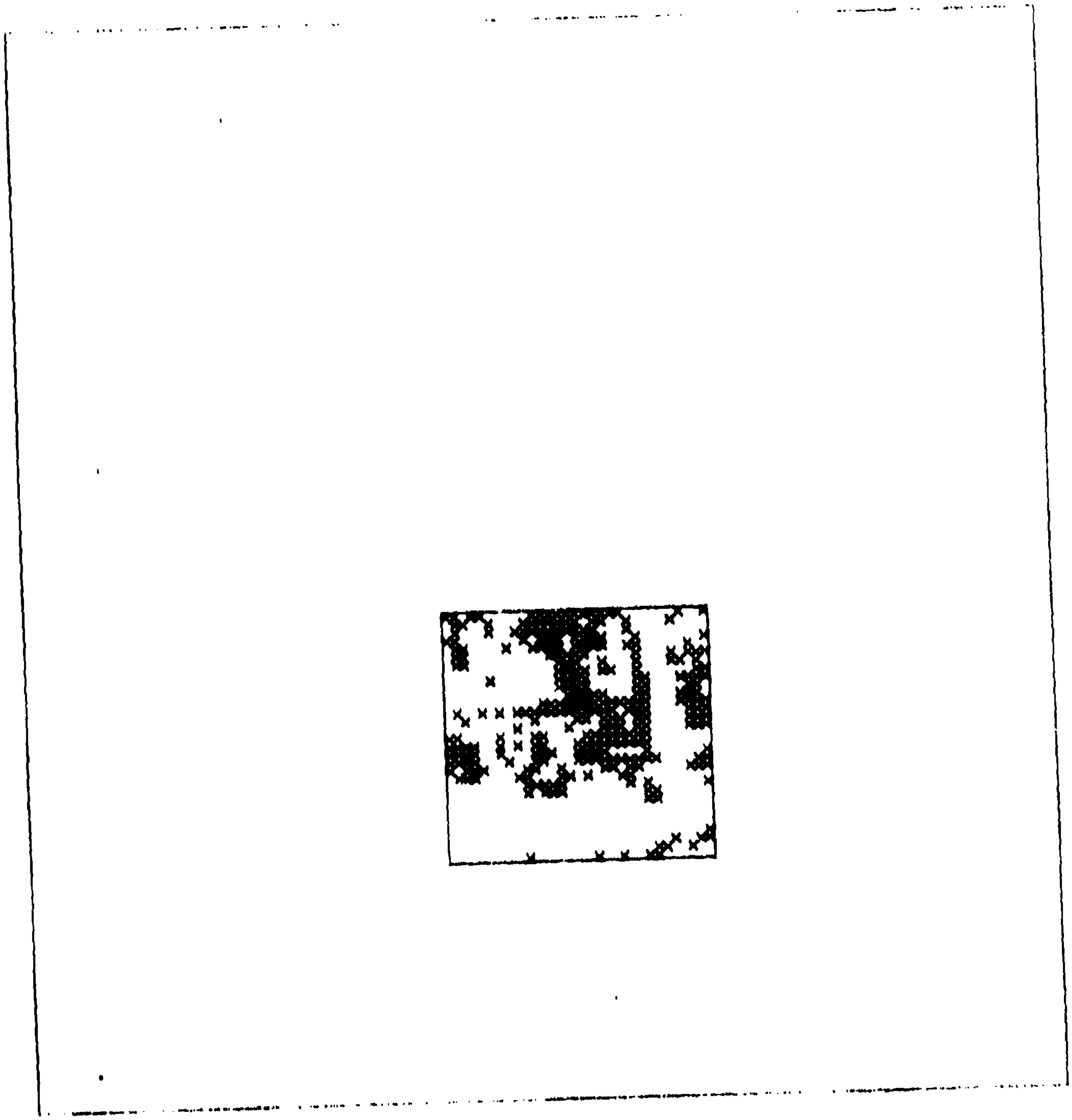

FIGURE 28 SCENE 3 SEGMENTED, DOMAIN 3

5. DOMAIN PLOTTING

a. Individual Domain Symbol Plots

The composite symbol plot that resulted from an analysis of Scene 3 (Dormant, Deciduous Brush-Near) is shown in Figures 31 and 32. In order to give the user a better appreciation of the shapes associated with each of the domains, the software was modified to allow for the plotting of each domain separately. The individual domain plots for Scene 3 can be found in Figures 33 through 37 and for Scene 13 in Figures 38 and 42.

The user has the option of plotting the composite alone, the individual domains alone, or both the composite and individual domains. The capability can be combined with scene segmentation and example results for Scene 3 are shown in Figures 24 through 28.

b. Contour Plotting

The usefulness of plotting contours as compared to the supplied symbol plots of domains was examined. It is felt that contour plotting of the composite domain data would not be of any help in the graphical representation of domain shapes. These contour plots would be arbitrarily misleading. It should be pointed out that contour plotting is not the same as shape outlining and this discrepancy is what creates most of the problems. A contour plot would graphically show the slope, or rate of change, between domains. This would arbitrarily assign a greater weight to a change from Domain 1 to Domain 5 then from Domain 1 to Domain 2.

Even if the contouring routines were used on the composite data to outline one domain at a time, similar to the individual symbol plots, the results would be misleading. Consider Figure 29 as a set of pixels with their associated domain numbers.

1	1	1	1	1	1	1	1	1	1	1
1	2	2	2	1	1	1	3	3	3	1
1	2	2	2	1	1	1	3	3	3	1
1	2	2	2	1	1	1	3	3	3	1
1	1	1	1	1	1	1	1	1	1	1

FIGURE 29: EXAMPLE DOMAIN DATA

If we were to draw contour lines at levels 1.5 and 2.5, in order to outline Domain 2, we would generate the plot shown in Figure 5-2.

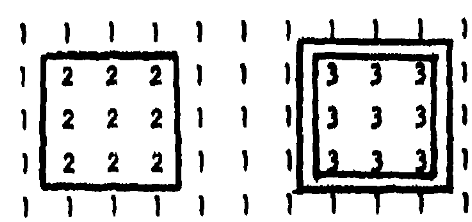

FIGURE 30: CONTOURING OF EXAMPLE DOMAIN DATA

The contour lines that were handdrawn were squared off for simplicity. The resulting plot, however, illustrates the problem with contouring. By definition contouring assumes that there must be a Level 2 between the Level 1 and 3 areas. This is indicating a faster rise on the right-hand side as compared to the left.

A method that might be of some use involves modifying the data file that is contoured. If the data file is edited so that only one particular domain is left intact, and all other values are changed to a background value, then contouring would outline this single domain. In this manner, by submitting five versions (each of which has only a single domain and a background), of the original data file to the contouring software, outlines of each of the five individual domains could be produced.

The Calcomp Contouring Package available on the UNIVAC 1106 has a size limitation that precludes using it on a complete scene. It would probably be more efficient to write shape outlining software than to attempt to expand the contouring package. Shape outlining software would not have the false area problems of contouring discussed above.

RANGE 60 M   SCALE FACTOR (OBJ CM/PLOT CM) 9.42
ILLUM W/CM²-MICRON: 50.00, 82.80, 93.50, 104.90, 117.80, 115.30,
109.40, 104.90, 104.40, 100.00, 95.70, 90.00,
87.60, 83.70, 80.20, 78.30, 71.60,

NFIN = 5   NSWTCH = 20   INCR = 1
ITHRSH = 324   INTERV = 6   IGEOC1 =1   IGEOC2 =120
NEWCMX = 120   NEWRMX = 132   IGEOR1 =1   IGEOR2 =132

	DOMAIN NUMBER				
	1	2	3	4	5
SYMBOL		+	×	☒	✳
L*	35.74	27.71	23.10	22.13	17.96
A*	5.28	3.20	3.33	1.53	4.53
B*	17.72	11.90	8.39	5.84	1.64

FIGURE 31 SCENE 3 COMPOSITE

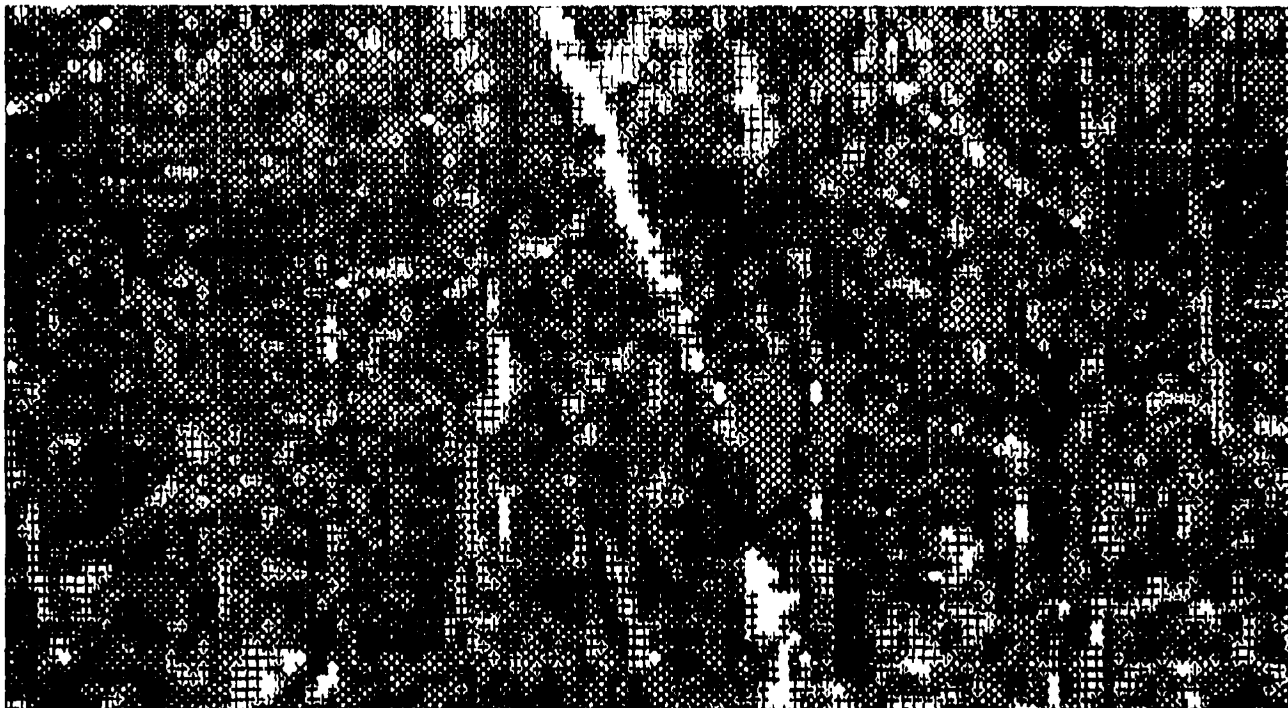

FIGURE 32 SCENE 3 COMPOSITE

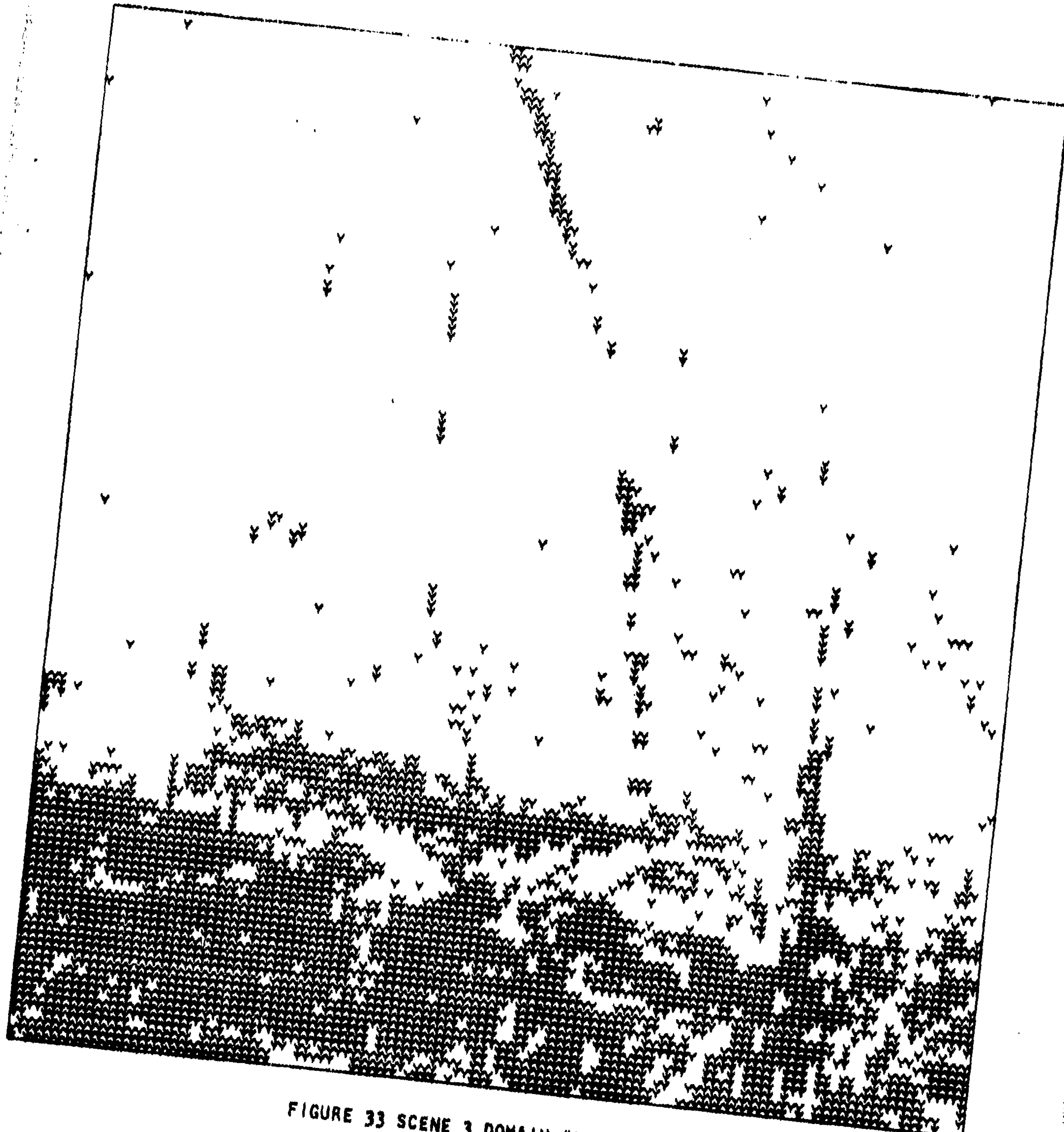

FIGURE 33 SCENE 3 DOMAIN #1

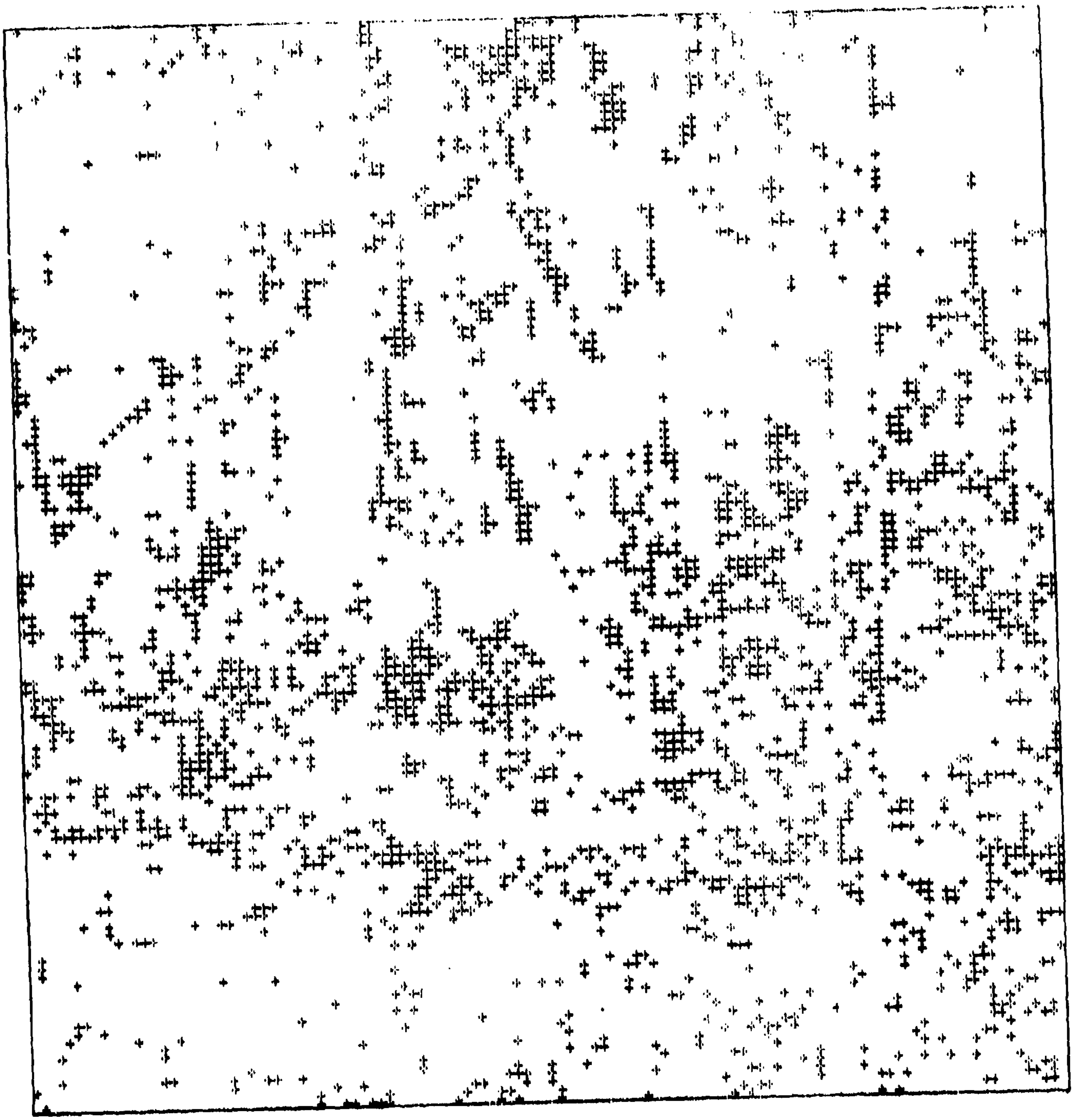

FIGURE 34 SCENE 3 DOMAIN #2

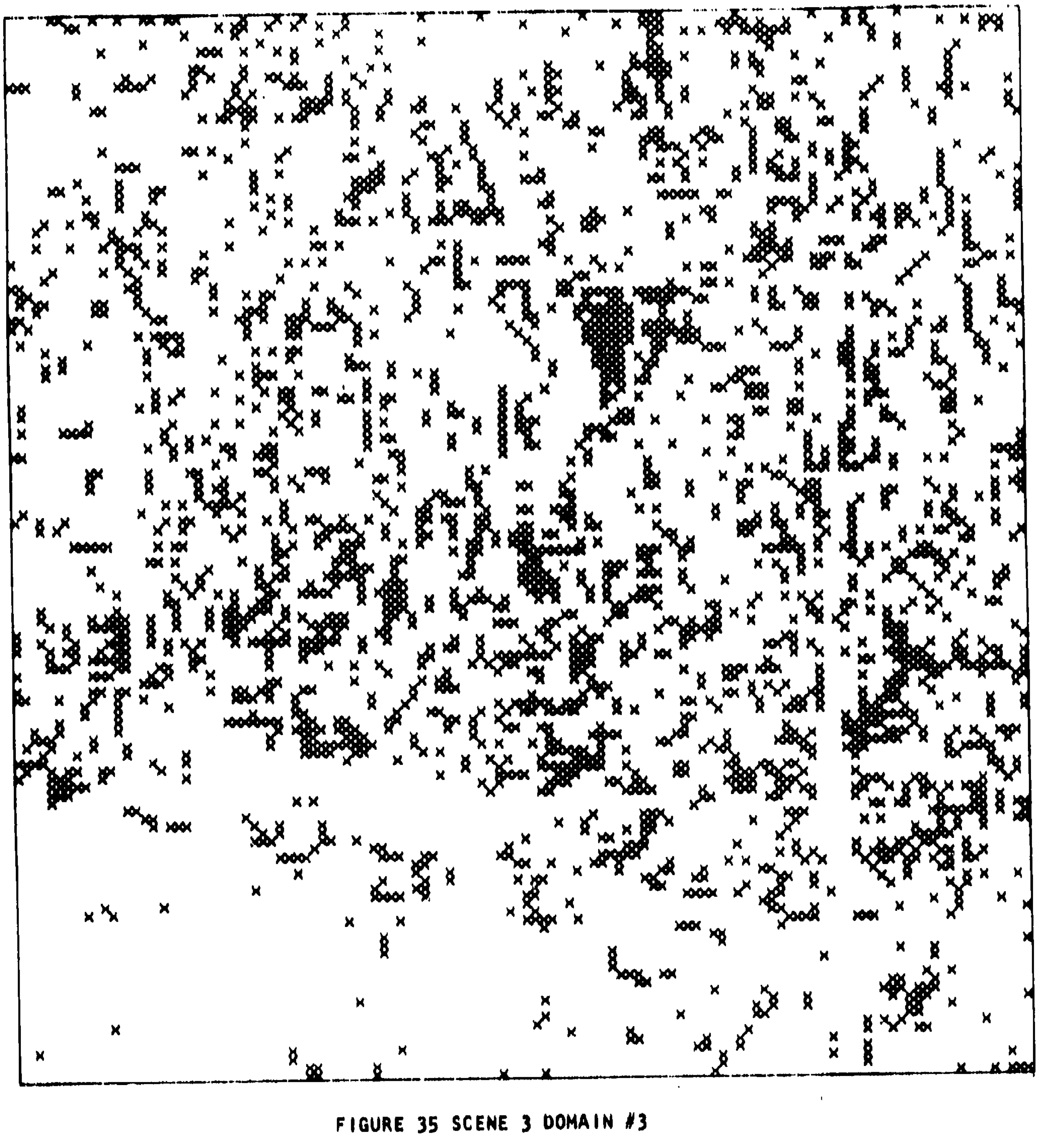

FIGURE 35 SCENE 3 DOMAIN #3

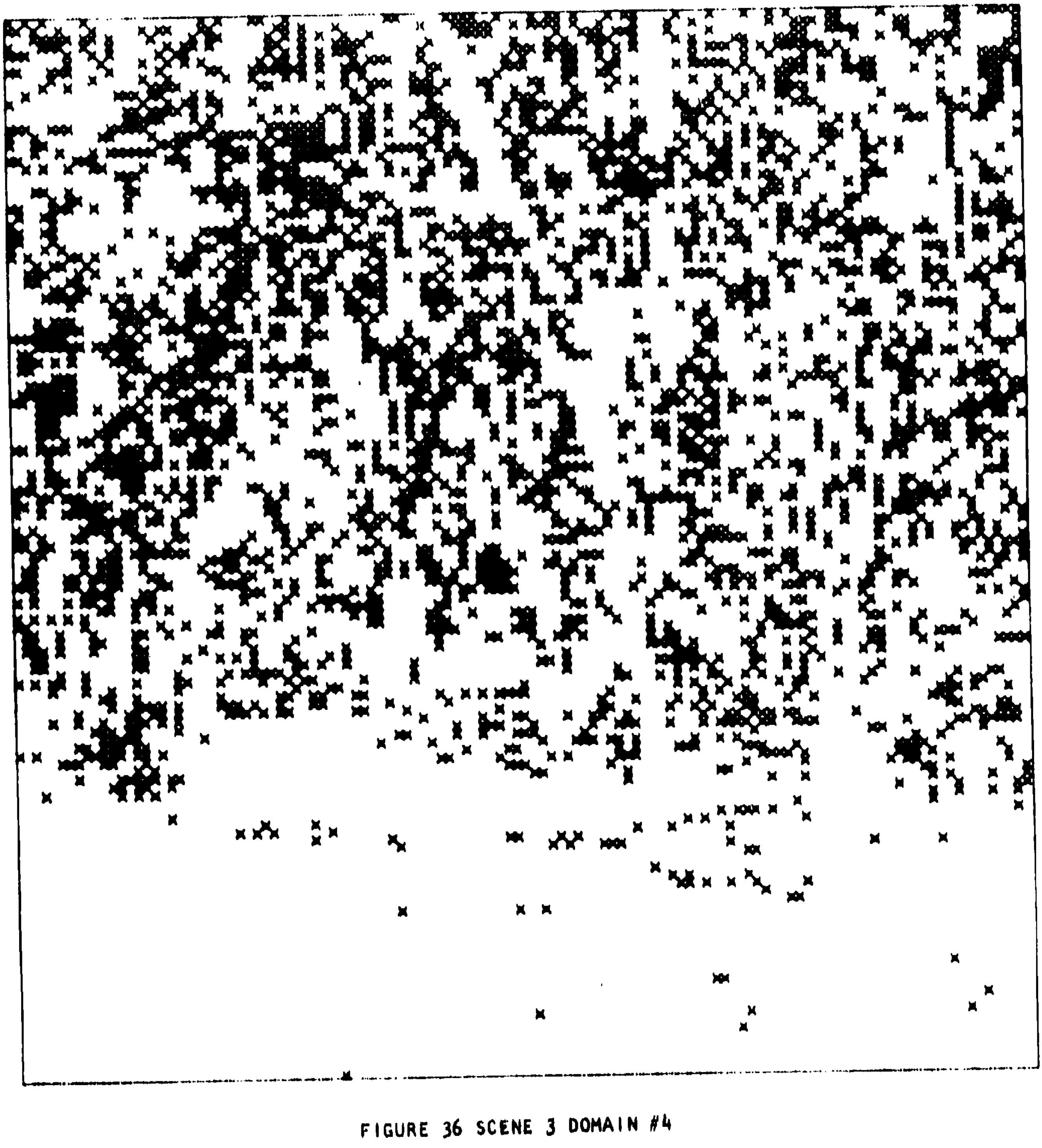

FIGURE 36 SCENE 3 DOMAIN #4

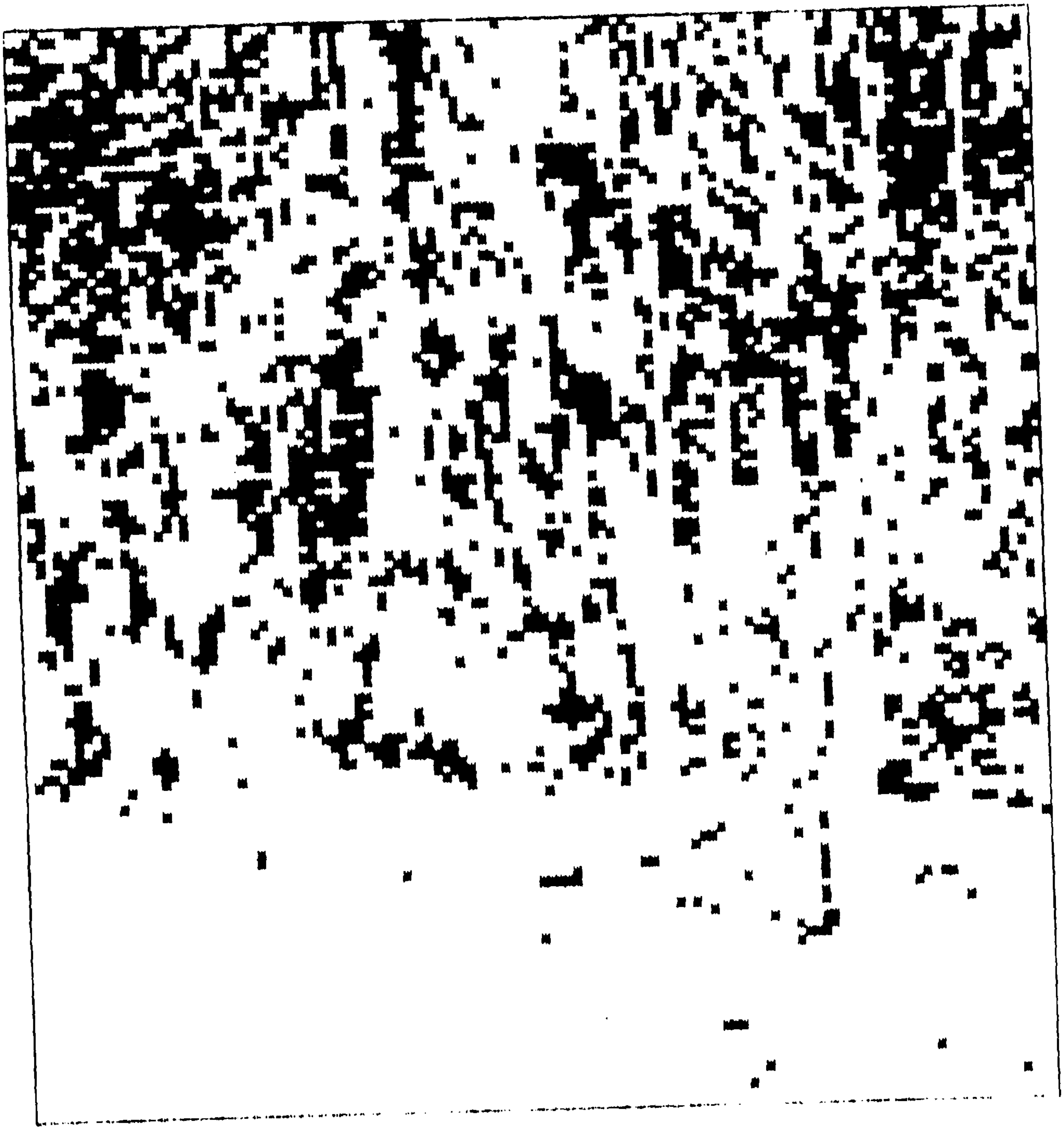

FIGURE 37 SCENE 3 DOMAIN #5

```
RANGE 500 M       SCALE FACTOR (OBJ CM/PLOT CM) 101.43
ILLUM W/CM²-MICRON:  50.00,  82.80,  93.50,  104.90,  117.80,  115.9?,
                     109.40,  104.90,  104.40,  100.00,  95.70,  99.00,
                     87.60,  83.70,  80.20,  78.30,  71.60,

NFIN = 3          NSWTCH = 20      INCR = 1
ITHRSH = 188      INTERV = 5       ISEGC1 =1       ISEGC2 =200
NEWCMX = 200      NEWRMX = 88      ISEGR1 =1       ISEGR2 =88
```

	DOMAIN NUMBER		
	1	2	3
SYMBOL		+	X
L*	46.26	15.07	10.19
A*	-4.72	-7.31	-0.02
B*	25.37	7.19	1.56

FIGURE 38 SCENE 13 COMPOSITE

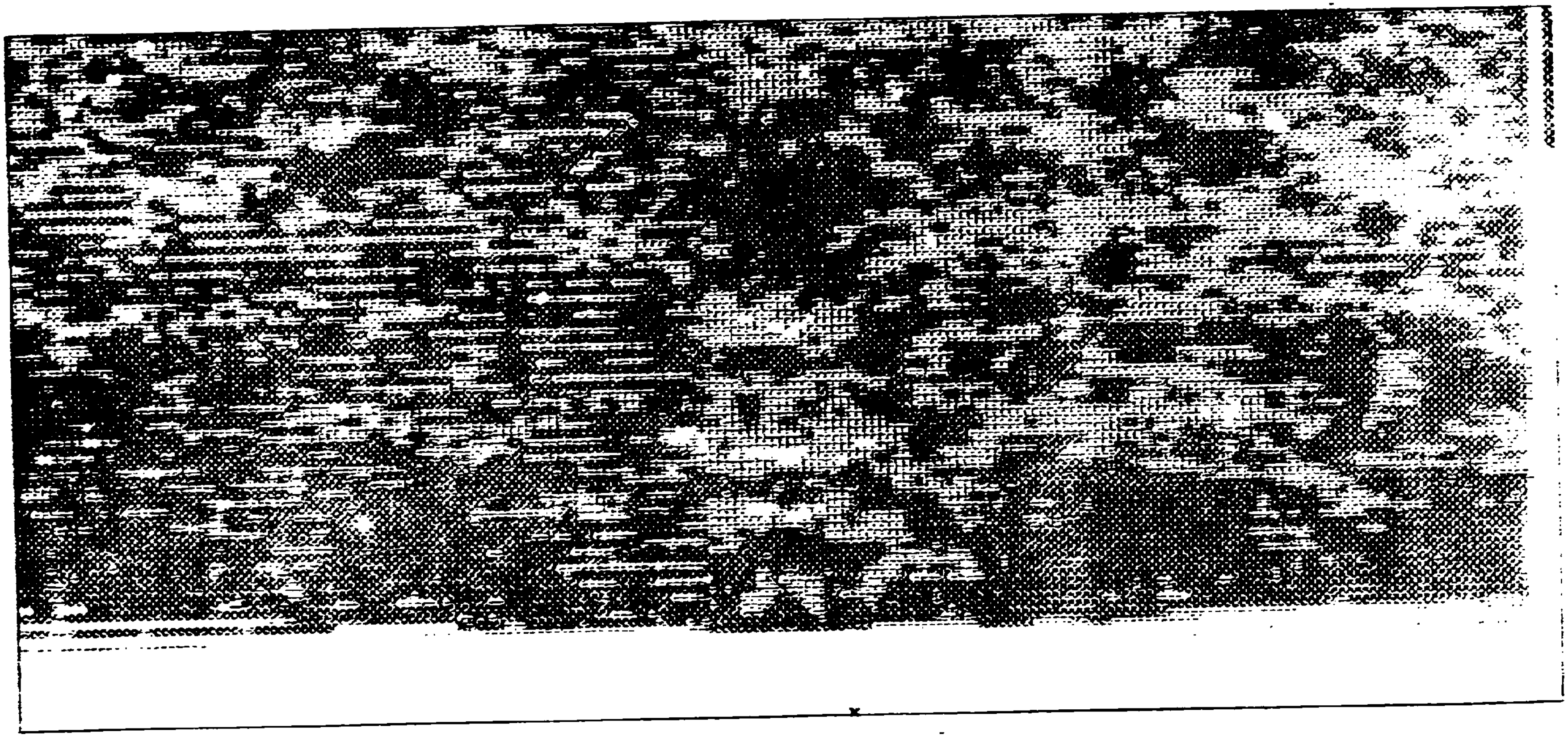

FIGURE 39 SCENE 13 COMPOSITE

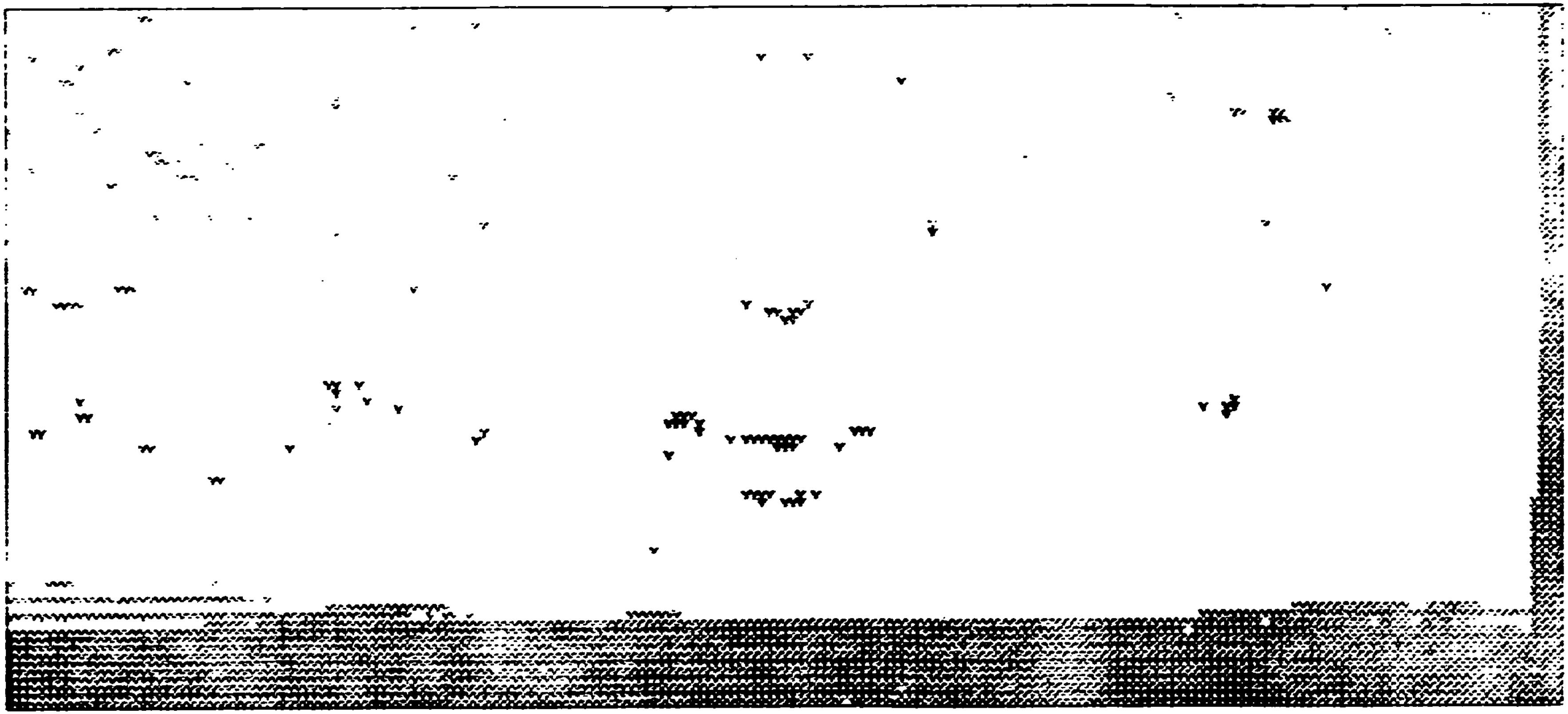

FIGURE 40 SCENE 13 DOMAIN #1

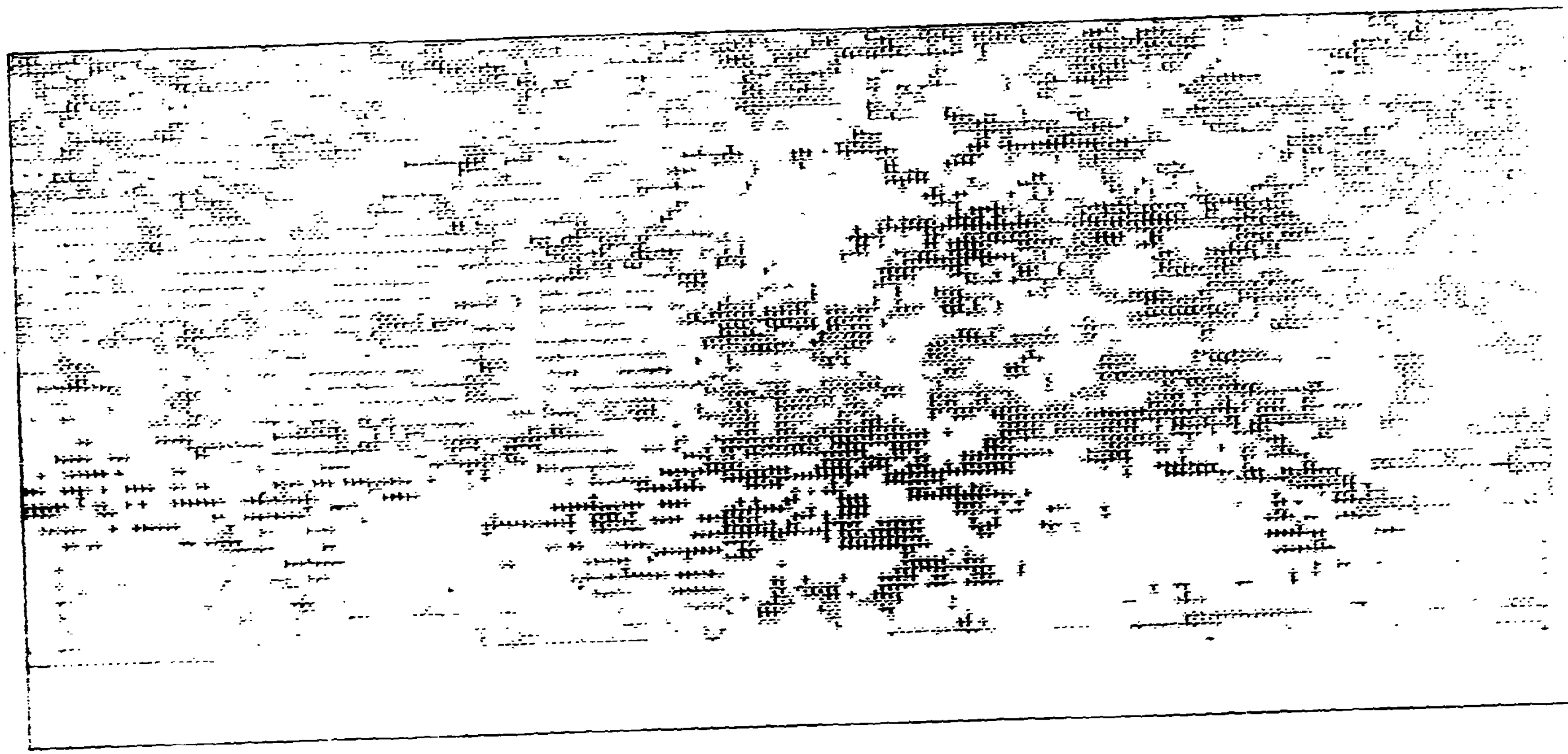

FIGURE 41 SCENE 13 DOMAIN #2

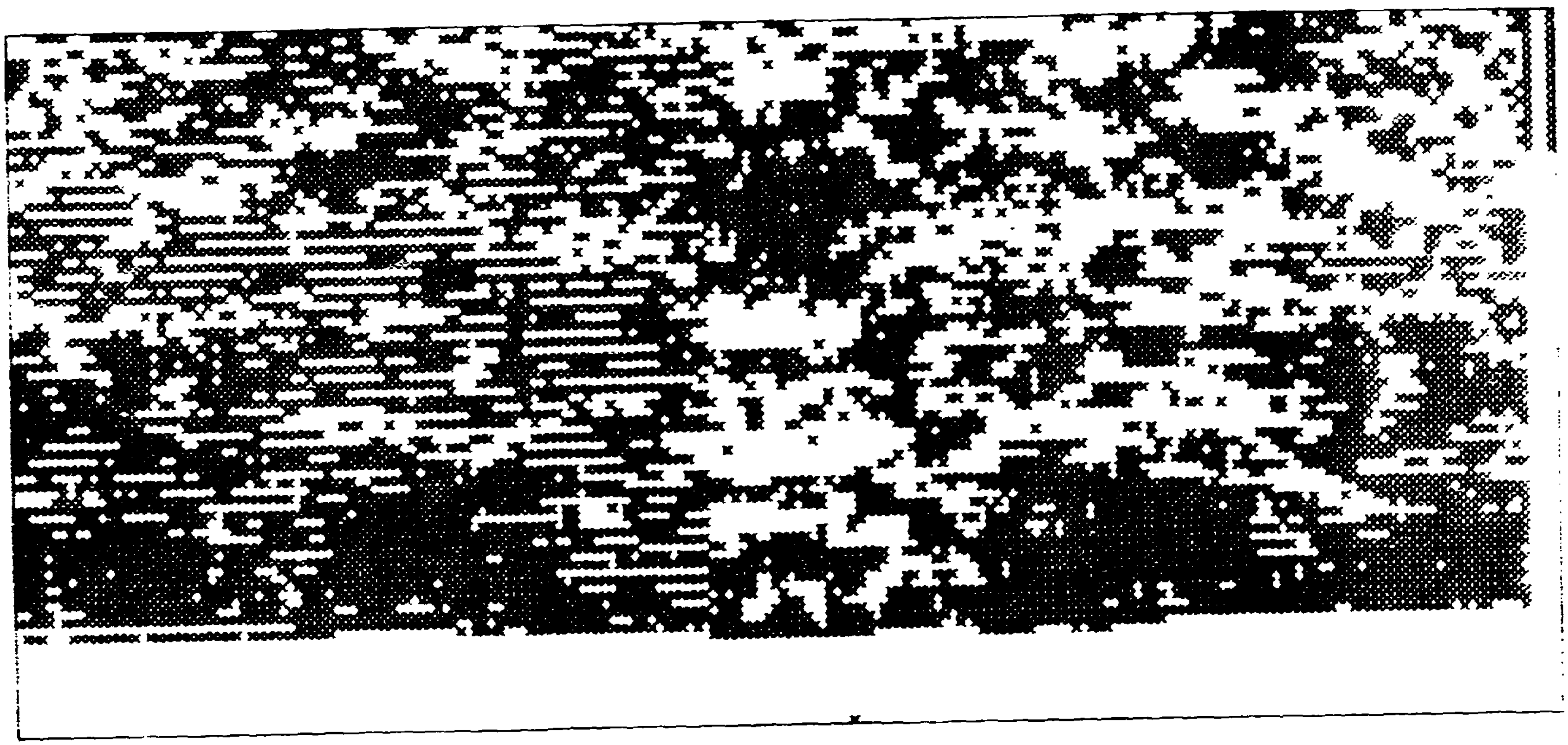

FIGURE 42 SCENE 13 DOMAIN #3

6. COMMENTS AND RECOMMENDATIONS

a. Scene Digitization

It is strongly recommended that additional scenes be processed and entered into the available scene data base. This would dramatically increase the utilization of the current analysis software.

b. Interactive Data Analysis with Graphic Output

The current data analysis software was written for the NLABS UNIVAC 1106 and operates in a batch processing mode. Although this was a reasonable and cost-effective approach for the initial development phase, the needs of the camouflage designer can best be served in an interactive environment with graphic output.

The current analysis software was structured in such a manner that it could be transferred to a mini/micro computing system (with a 16 bit word length) with only minor changes. The PDP 11/23 computer which is serving as a controller for the spectrophotometer would be an ideal host system for the interactive data analysis software. The difference in the word lengths between the UNIVAC (36 bits) and the PDP 11/23 (16 bits) has been analyzed and determined to be no problem.

An interactive menu-driven executive would need to be written. This executive would be responsible for guiding a user through a data analysis session as well as being an interface between the user and the graphic output devices.

Alternate output methods should be analyzed to increase the utility of the resulting domain assignment plots. These alternate methods should include video display systems (both Black and White and Color) with hard-copy capability as well as additional pen plotter presentations.

c. Alternate Data Collection Methods

The current photographic/digitization procedure is time consuming, and with respect to some details, less than optimum. An investigation of alternative techniques should be performed and a procurement specification should be developed.

As a minimum the approaches that should be examined include the acquisition of a black and white television camera, solid state array cameras, and solid state cameras with spectral outputs.

Systems should be analyzed for portability, reliability, camera sensitivity, resolution, signal to noise ratio through the interference filters, and other parameters still to be determined. The goal should be to provide a specification for a commercially available off-the-shelf system; however, special purpose designs should be examined for completeness.

This document reports research undertaken at the US Army Natick Research and Development Command and has been assigned No. NATICK/TR-83/011 in the series of reports approved for publication.

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Goldgraben, J. R. and B. Engelberg, Procedures for the Acquisition and Analysis of Terrain Data for Camouflage Design, Volume I, Software Manual, Decilog, Inc., Melville, NY, March 1981 (Decilog Report No. 234, Contract DAAK60-79-C-0072).

Goldgraben, J. R. and B. Engelberg, Procedures for the Acquisition and Analysis of Terrain Data for Camouflage Design, Volume II, Manual for Photographic Data Acquisition and Film Digitization, Decilog, Inc., Melville, NY, March 1981 (Decilog Report No. 235, Contract DAAK60-79-C-0072).

Ramsley, A. O., Selection of Standard Colors for the Woodland Camouflage Pattern, US Army Natick R&D Laboratories, IPL, September 1981 (Technical Report NATICK/TR-81/030).

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APPENDIX

Outputs of Terrain Analysis Software
Showing Statistical Data

NDOM 5

ICELL	NUMBER	CENTL	CENTA	CENTB	VAR
1	[illegible]	35.70	[illegible]	17.01	.9322585060+001
2	2195	18.24	[illegible]	1.92	.1282376313+002
3	1636	23.36	0.95	0.56	.1466559933+002
4	2574	21.94	[illegible]	5.10	.1155927601+002
5	[illegible]	27.12	[illegible]	11.79	.1669250137+002

TOTAL NUMBER OF PIXELS ASSIGNED TO DOMAINS = [illegible]

MEAN L = 25.21 MEAN A = [illegible] MEAN B = 9.25

TRACE OF SW = 17.31 TRACE OF SB = 95.35 BETA 4 = 6.67 BETA 5 = 1130.28

T TEST COMPARISON BETWEEN DOMAINS.

	1	2	3	4	5	6	7	8
2	.1625+003							
3	.1250+003	.9256+002						
4	[illegible]	.5993+002	.6186+002					
5	.6923+002	[illegible]	.5667+002	.5552+002				

RATIO OF BETWEEN/WITHIN DOMAIN VARIANCES:
.9317+001 .6773+001 .5923+001 .7514+001 .5203+001

NUMBER OF DOMAIN CHANGES = [illegible]

SCENE 3

NBOM 4

ICELL	NUMBER	CENTL	CENTA	CENTB	VAR
1	4559	50.90	-4.14	-9.39	.9355719566+001
2	3793	33.53	1.09	4.70	.2894445801+002
3	2506	42.29	-.09	-2.95	.3338665485+002
4	8592	25.66	3.38	7.02	.2272712517+002

TOTAL NUMBER OF PIXELS ASSIGNED TO DOMAINS = 19450.

MEAN L = 35.10   MEAN A = .56   MEAN B = -.08

TRACE OF SW = 27.60   TRACE OF SB = 178.48   BETA 4 = 7.56   BETA 5 = 4212.85

T TEST COMPARISON BETWEEN DOMAINS.

	1	2	3	4	5	6	7	8
2	.2278+003							
3	.6688+002	.8378+002						
4	.4441+003	.8390+002	.1558+003					

RATIO OF BETWEEN/WITHIN DOMAIN VARIANCES:
.1938+002   .6166+001   .5346+001   .7353+001

NUMBER OF DOMAIN CHANGES = 87

DISTANCE FROM CENTROID	DOMAIN 1	DOMAIN 2	DOMAIN 3	DOMAIN 4	DOMAIN 5
.00 - .49	25	5	0	21	0
.50 - .99	237	28	17	103	0
1.00 - 1.49	853	50	23	272	0
1.50 - 1.99	1012	92	43	460	0
2.00 - 2.49	603	184	77	652	0
2.50 - 2.99	426	219	99	782	0
3.00 - 3.49	271	274	146	850	0
3.50 - 3.99	231	358	185	856	0
4.00 - 4.49	215	411	211	928	0
4.50 - 4.99	193	329	220	764	0
5.00 - 5.49	214	340	264	577	0
5.50 - 5.99	148	320	240	521	0
6.00 - 6.49	116	248	202	408	0
6.50 - 6.99	59	239	197	368	0
7.00 - 7.49	0	225	169	301	0
7.50 - 7.99	0	204	135	226	0
8.00 - 8.49	0	148	137	192	0
8.50 - 8.99	0	80	105	154	0
9.00 - 9.49	0	38	35	74	0
9.50 - 9.99	0	1	1	23	0
10.00 - 10.49	0	0	0	0	0
10.50 - 10.99	0	0	0	0	0
11.00 - 11.49	0	0	0	0	0
11.50 - 11.99	0	0	0	0	0
12.00 - 12.49	0	0	0	0	0
12.50 - 12.99	0	0	0	0	0
13.00 - 13.49	0	0	0	0	0
13.50 - 13.99	0	0	0	0	0

NDOM 4

ICELL	NUMBER	CENTL	CENTA	CENTB	VAR
1	99	18.55	0.28	0.49	0.7717204571E+01
2	365	25.13	3.15	9.57	0.9722027[illegible]10E+01
3	256	31.42	-7.01	12.07	0.163074[illegible]591E+02
4	216	41.62	-3.04	16.12	0.161509[illegible]42E+02

TOTAL NUMBER OF PIXELS ASSIGNED TO DOMAINS = 936.

EAN L = 29.10 MEAN A = -2.06 MEAN B = 9.56

RACE OF SW = 12.49 TRACE OF SB = 163.17 BETA 4 = 13.06 BETA 5 = 2030.75

T TEST COMPARISON BETWEEN DOMAINS.

	1	2	3	4	5	6	7	8	9	10
2	0.3577E+02									
3	0.5071E+02	0.4290E+02								
4	0.7207E+02	0.5989E+02	0.3132E+02							

RATIO OF BETWEEN/WITHIN DOMAIN VARIANCES:

.2114E+02 0.1678E+02 0.9957E+01 0.1010E+02

NUMBER OF DOMAIN CHANGES = 0

DISTANCE FROM CENTROID	DOMAIN 1	DOMAIN 2	DOMAIN 3	DOMAIN 4	DOMAIN 5
0.00 - 0.49	1	12	0	2	0
0.50 - 0.99	6	40	13	11	0
1.00 - 1.49	10	64	24	19	0
1.50 - 1.99	20	48	27	20	0
2.00 - 2.49	21	53	33	28	0
2.50 - 2.99	10	32	24	24	0
3.00 - 3.49	8	14	18	14	0
3.50 - 3.99	10	24	18	21	0
4.00 - 4.49	8	9	13	14	0
4.50 - 4.99	3	16	11	12	0
5.00 - 5.49	1	16	21	9	0
5.50 - 5.99	1	20	15	9	0
6.00 - 6.49	0	11	19	8	0
6.50 - 6.99	0	6	11	14	0
7.00 - 7.49	0	0	8	7	0
7.50 - 7.99	0	0	1	4	0
8.00 - 8.49	0	0	0	0	0
8.50 - 8.99	0	0	0	0	0
9.00 - 9.49	0	0	0	0	0
9.50 - 9.99	0	0	0	0	0
10.00 - 10.49	0	0	0	0	0
10.50 - 10.99	0	0	0	0	0
11.00 - 11.49	0	0	0	0	0
11.50 - 11.99	0	0	0	0	0
12.00 - 12.49	0	0	0	0	0
12.50 - 12.99	0	0	0	0	0
13.00 - 13.49	0	0	0	0	0
13.50 - 13.99	0	0	0	0	0
14.00 - 14.49	0	0	0	0	0
14.50 - 14.99	0	0	0	0	0
15.00 - 15.49	0	0	0	0	0

SCENE 10

NDOM 4

ICELL	NUMBER	CENTL	CENTA	CENTB	VAR
[illegible]	[illegible]	15.22	6.95	11.24	.2572948456+002
[illegible]	[illegible]42	14.93	[illegible]	[illegible]	.44[illegible]12392+001
[illegible]	2743	42.25	[illegible]	15.68	.2768443198+002
[illegible]	3527	31.76	3.24	7.58	.3454614353+002

TOTAL NUMBER OF PIXELS ASSIGNED TO DOMAINS = 574[illegible].

MEAN L = [illegible] MEAN A = [illegible] MEAN B = 3.87

WEIGHTED TRACE OF SW = 22.55 TRACE OF SB = 1[illegible]7.97 BETA 4 = 5.[illegible]8 BETA 5 = 4799.92

T TEST COMPARISON BETWEEN DOMAINS.

	[illegible]	[illegible]	4	5	6	[illegible]	8
2	.[illegible]+[illegible]						
3	.[illegible]+[illegible]	.211[illegible]+003					
4	.[illegible]92+[illegible]	.1247+003	.2931+002				

RATIO OF BETWEEN/WITHIN DOMAIN VARIANCES:
.[illegible]+001 .3794+[illegible] .[illegible]27+[illegible] .4[illegible]+0[illegible]

NUMBER OF DOMAIN CHANGES = [illegible]4.

DISTANCE FROM CENTROID	DOMAIN 1	DOMAIN 2	DOMAIN 3	DOMAIN 4	DOMAIN 5
.[illegible] - .49	[illegible]	6	0	4	0
.[illegible] - .99	[illegible]	43	[illegible]	12	0
1.[illegible] - 1.49	[illegible]	1[illegible]1	82	42	0
1.[illegible] - 1.99	[illegible]	77	[illegible]	95	0
[illegible] - 2.49	[illegible]	[illegible]3	141	131	0
2.[illegible] - 2.99	[illegible]	48	173	170	0
[illegible] - 3.49	251	[illegible]4	218	224	0
3.[illegible] - 3.99	3[illegible]	[illegible]	[illegible]	268	0
4.[illegible] - 4.49	3[illegible]	7	[illegible]3	249	0
4.5[illegible] - 4.99	[illegible]	[illegible]	275	257	0
[illegible] - 5.49	[illegible]	[illegible]	249	2[illegible]5	0
[illegible] - 5.99	[illegible]	[illegible]	271	[illegible]6	0
[illegible] - 6.49	1[illegible]	[illegible]	[illegible]7	[illegible]5	0
[illegible] - 6.99	1[illegible]	[illegible]	218	[illegible]4	0
[illegible] - 7.49	[illegible]	[illegible]	173	271	0
[illegible] - 7.99	7[illegible]	[illegible]	138	273	0
[illegible] - 8.49	[illegible]	[illegible]	75	170	0
[illegible] - 8.99	[illegible]7	[illegible]	[illegible]4	1[illegible]2	0
[illegible] - 9.49	[illegible]	[illegible]	11	[illegible]5	0
9.[illegible] - 9.99	[illegible]	[illegible]	[illegible]	[illegible]6	0
[illegible] - 10.49	[illegible]	[illegible]	[illegible]	[illegible]7	0
[illegible] - 10.99	[illegible]	[illegible]	1	[illegible]	0
[illegible] - 11.49	[illegible]	[illegible]	0	0	0
11.[illegible] - 11.99	[illegible]	[illegible]	0	0	0
[illegible] - 12.49	[illegible]	[illegible]	0	0	0
12.[illegible] - 12.99	[illegible]	[illegible]	0	0	0
[illegible] - 13.49	[illegible]	[illegible]	0	0	0
13.[illegible] - 13.99	[illegible]	0	0	0	0

NDO= 4

ICELL	NUMBER	CENTL	CENTA	CENTB	VAR
1	777	30.?1	-13.56	29.27	.1903931791+002
2	3377	2?.?1	-7.29	12.57	.2350163269+002
3	3025	3?.44	-10.??	21.24	.3329?02872+002
4	4502	1?.56	-1.65	4.18	.2131661701+002

TOTAL NUMBER OF PIXELS ASSIGNED TO DOMAINS = 11241.

MEAN L = ?5.?? MEAN A = -7.4? MEAN B = ?6.?4

WEIGHTED TRACE OF SW = 25.17 TRACE OF S3 = 236.?2 BETA 4 = 9.38 BETA 5 = 5940.22

T TEST COMPARISON BETWEEN DOMAINS.

	1	2	3	4	5	6	7	8
2	.1?37+0?3							
3	.5?6?+0??	.2377+002						
4	.2?23+00?	.1?64+003	.1904+003					

RATIO OF BETWEEN/WITHIN DOMAIN VARIANCES:
.1???+??? .1???+??? .????+??1 .1???+?32

NUMBER OF DOMAIN CHANGES = ??7

DISTANCE FROM CENTROID	DOMAIN 1	DOMAIN 2	DOMAIN 3	DOMAIN 4	DOMAIN 5
.?? - .49	[illegible]	4	3	7	0
.5? - .99	7	26	13	65	0
1.0? - 1.4?	[illegible]	73	36	167	0
1.?? - 1.9?	[illegible]	11?	6?	26?	0
?.?? - ?.49	4?	1?7	112	3??	[illegible]
?.?? - ?.9?	[illegible]	???	157	3??	[illegible]
?.?? - ?.49	[illegible]	???	???	47?	[illegible]
?.?? - ?.9?	11?	26?	1?3	4??	[illegible]
4.?? - 4.49	1?6	?7?	?55	46?	[illegible]
4.50 - 4.99	?7	?31	?65	??2	[illegible]
?.?? - ?.4?	?7	2?7	???	???	[illegible]
?.?? - ?.9?	1?	???	?75	???	[illegible]
?.?? - ?.4?	?3	???	?67	?77	[illegible]
?.?? - ?.9?	17	1??	??2	17?	[illegible]
?.?? - 7.4?	[illegible]	1??	???	1?9	[illegible]
?.?? - 7.??	[illegible]	4?	1??	?8	[illegible]
?.?? - ?.49	1?	[illegible]	1?4	??	[illegible]
?.?? - ?.9?	1?	1?	[illegible]	??	[illegible]
?.?? - ?.4?	[illegible]	[illegible]	51	1?	[illegible]
?.?? - ?.9?	[illegible]	[illegible]	?4	15	[illegible]
1?.?? - 1?.4?	[illegible]	[illegible]	?2	[illegible]	[illegible]
1?.?? - 1?.9?	[illegible]	[illegible]	1	[illegible]	[illegible]
11.?? - 11.4?	[illegible]	[illegible]	[illegible]	1	[illegible]
11.?? - 11.9?	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
12.?? - 12.49	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
12.5? - 12.9?	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1?.?? - 1?.4?	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1?.?? - 1?.??	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

SCENE 12

NDOF 3

ICELL	NUMBER	CENTL	CENTA	CENTB	VAR
1	694	46.26	-4.72	25.37	.1031884003+002
2	2973	15.07	-7.31	7.19	.2925089645+002
3	7206	10.19	-.02	1.56	.1993794870+002

TOTAL NUMBER OF PIXELS ASSIGNED TO DOMAINS = 10873.

MEAN L = 23.84 MEAN A = -4.02 MEAN B = 11.37

TRACE OF SW = 19.84 TRACE OF SB = 551.36 BETA 4 = 27.80 BETA 5 = 10936.78

T TEST COMPARISON BETWEEN DOMAINS.

	1	2	3	4	5	6	7	8
2	.23[illegible]3+003							
3	.3273+003	.9279+002						

RATIO OF BETWEEN/WITHIN DOMAIN VARIANCES:
.5343+002 .1885+002 .2765+002

NUMBER OF DOMAIN CHANGES = 26

DISTANCE FROM CENTROID	DOMAIN 1	DOMAIN 2	DOMAIN 3	DOMAIN 4	DOMAIN 5
.00 - .49	2	3	12	0	0
.50 - .99	16	7	73	0	0
1.00 - 1.49	37	32	278	0	0
1.50 - 1.99	66	57	690	0	0
2.00 - 2.49	71	99	820	0	0
2.50 - 2.99	121	158	915	0	0
3.00 - 3.49	117	205	933	0	0
3.50 - 3.99	142	253	704	0	0
4.00 - 4.49	84	273	625	0	0
4.50 - 4.99	34	304	605	0	0
5.00 - 5.49	4	376	462	0	0
5.50 - 5.99	0	296	321	0	0
6.00 - 6.49	0	251	269	0	0
6.50 - 6.99	0	207	188	0	0
7.00 - 7.49	0	161	168	0	0
7.50 - 7.99	0	135	168	0	0
8.00 - 8.49	0	91	118	0	0
8.50 - 8.99	0	61	135	0	0
9.00 - 9.49	0	16	71	0	0
9.50 - 9.99	0	9	47	0	0
10.00 - 10.49	0	1	6	0	0
10.50 - 10.99	0	0	0	0	0
11.00 - 11.49	0	0	0	0	0
11.50 - 11.99	0	0	0	0	0
12.00 - 12.49	0	0	0	0	0
12.50 - 12.99	0	0	0	0	0
13.00 - 13.49	0	0	0	0	0
13.50 - 13.99	0	0	0	0	0
14.00 - 14.49	0	0	0	0	0
14.50 - 14.99	0	0	0	0	0

SCENE 13

NDOM 5

ICELL	NUMBER	CENTL	CENTA	CENTB	VAR
1	753	16.94	-1.23	14.25	.2489127350+002
2	1460	26.00	-14.18	16.41	.3509461975+002
3	2535	10.56	-.09	5.65	.1989096403+002
4	1731	13.91	-7.18	10.06	.1878633499+002
5	1305	25.99	-20.61	24.38	.4948855591+002

TOTAL NUMBER OF PIXELS ASSIGNED TO DOMAINS = 7784.

MEAN L = 17.48 MEAN A = -2.66 MEAN B = 14.15

WEIGHTED TRACE OF SW = 27.94 TRACE OF SB = 16[illegible].67 BETA 4 = 5.75 BETA 5 = 4489.46

T TEST COMPARISON BETWEEN DOMAINS.

	1	2	3	4	5	6	7	8
2	.5640+002							
3	.5327+002	.1125+003						
4	.3762+002	.6020+002	.6576+002					
5	.2884+002	.4768+002	.1486+003	.1044+003				

RATIO OF BETWEEN/WITHIN DOMAIN VARIANCES:
.6455+001 .4578+001 .3077+001 .8552+001 .3247+001

NUMBER OF DOMAIN CHANGES = 36

DISTANCE FROM CENTROID	DOMAIN 1	DOMAIN 2	DOMAIN 3	DOMAIN 4	DOMAIN 5
.00 - .49	2	0	1	0	0
.50 - .99	5	7	16	16	3
1.00 - 1.49	8	12	60	45	3
1.50 - 1.99	15	29	113	96	9
2.00 - 2.49	25	33	196	133	18
2.50 - 2.99	44	59	320	168	21
3.00 - 3.49	60	68	364	213	32
3.50 - 3.99	93	88	304	227	56
4.00 - 4.49	85	113	281	233	56
4.50 - 4.99	77	128	210	190	77
5.00 - 5.49	93	150	150	133	109
5.50 - 5.99	75	172	115	92	110
6.00 - 6.49	66	141	123	61	100
6.50 - 6.99	44	131	73	46	94
7.00 - 7.49	35	101	82	16	108
7.50 - 7.99	23	68	62	25	114
8.00 - 8.49	2	47	56	16	109
8.50 - 8.99	0	44	8	14	93
9.00 - 9.49	1	28	1	5	75
9.50 - 9.99	0	15	0	2	62
10.00 - 10.49	0	21	0	0	41
10.50 - 10.99	0	3	0	0	15
11.00 - 11.49	0	0	0	0	7
11.50 - 11.99	0	0	0	0	2
12.00 - 12.49	0	0	0	0	1
12.50 - 12.99	0	0	0	0	0

SCENE 14

NDOF 5

ICELL	NUMBER	CENTL	CENTA	CENTB	VAR
1	2051	32.27	-7.93	14.56	.2545269775+002
2	1483	16.30	-.87	.53	.1995340276+002
3	2588	20.05	-7.19	5.30	.1659502602+002
4	2552	25.14	-8.46	9.32	.2093219852+002
5	2004	15.07	-6.34	.55	.1259729564+002

TOTAL NUMBER OF PIXELS ASSIGNED TO DOMAINS = 10678.

MEAN L = 21.76 MEAN A = -6.16 MEAN B = 6.05

WEIGHTED TRACE OF SW = 19.05 TRACE OF SB = 95.35 BETA 4 = 5.01 BETA 5 = 1816.41

T-TEST COMPARISON BETWEEN DOMAINS.

	1	2	3	4	5	6	7	8
2	.1393+003							
3	.1119+003	.6222+002						
4	.6175+002	.9918+002	.5463+002					
5	.1627+003	.3993+002	.6160+002	.1124+003				

RATIO OF BETWEEN/WITHIN DOMAIN VARIANCES:
.3746+001 .4779+001 .5746+001 .4555+001 .7569+001

NUMBER OF DOMAIN CHANGES = 138

DISTANCE FROM CENTROID	DOMAIN 1	DOMAIN 2	DOMAIN 3	DOMAIN 4	DOMAIN 5
.00 - .49	2	1	5	6	8
.50 - .99	10	15	42	12	45
1.00 - 1.49	37	27	87	54	95
1.50 - 1.99	61	62	174	98	102
2.00 - 2.49	108	99	216	133	227
2.50 - 2.99	120	145	277	218	346
3.00 - 3.49	136	165	374	258	334
3.50 - 3.99	171	178	352	296	219
4.00 - 4.49	206	168	269	275	186
4.50 - 4.99	227	165	241	309	111
5.00 - 5.49	221	143	180	244	82
5.50 - 5.99	212	116	138	244	73
6.00 - 6.49	206	109	107	177	55
6.50 - 6.99	171	72	69	116	22
7.00 - 7.49	125	24	40	55	9
7.50 - 7.99	35	4	16	26	0
8.00 - 8.49	3	0	1	3	0
8.50 - 8.99	0	0	0	0	0
9.00 - 9.49	0	0	0	0	0
9.50 - 9.99	0	0	0	0	0
10.00 - 10.49	0	0	0	0	0
10.50 - 10.99	0	0	0	0	0
11.00 - 11.49	0	0	0	0	0
11.50 - 11.99	0	0	0	0	0
12.00 - 12.49	0	0	0	0	0
12.50 - 12.99	0	0	0	0	0

SCENE 21