17 July 1963

LEC:mb-454

COPY

Chief, Office of Naval Research
Department of the Navy
Washington 25, D. C.

Attention: Code 414, [redacted] STAT

STAT Subject: Contract [redacted]
Perception Concepts to Photo-Interpretation

Dear Sir:

This letter constitutes Letter Report No. 17 for the month ending 30 June 1963.

During June, effort under this contract was reinstated upon notification, receipt and execution of Amendment No. 6 to the Contract which authorized additional funding and performance time. Since this action took place after mid-month, technical activity was not sufficient to warrant issuance of a technical progress report for the period ending 30 June. The next progress report, No. 18 for 31 July 1963, will report technical activity commenced in late June through 31 July.

Very truly yours,

[redacted] STAT

Contract Administrator

STAT cc: [redacted]

PROJECT OBJECTIVES & ACCOMPLISHMENTS

PHASE I - APRIL 1960 to NOVEMBER 1960

OBJECTIVE

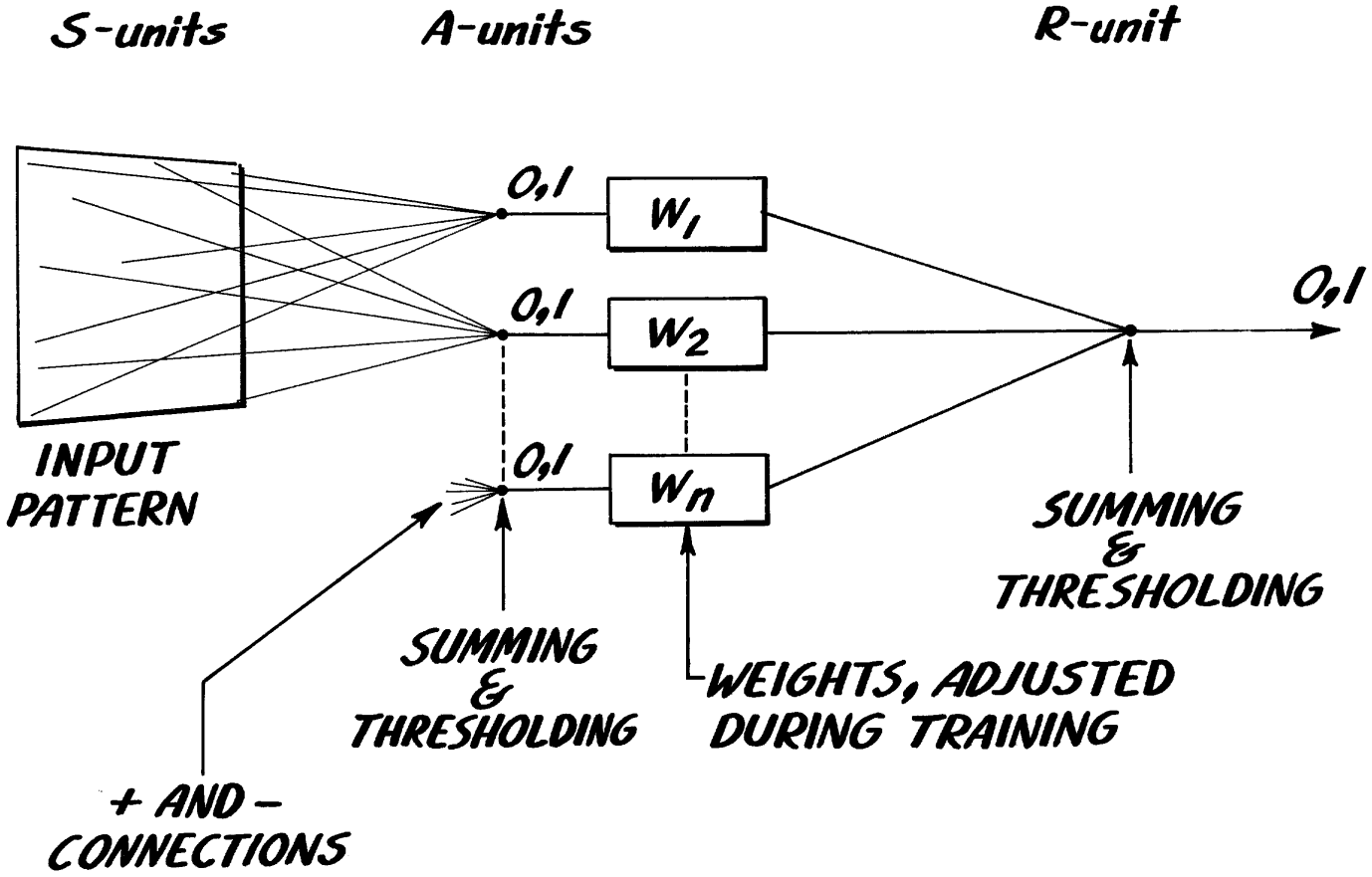
Determine feasibility of perceptron application to photo interpretation.

ACCOMPLISHMENTS

Used Mark I perceptron to demonstrate recognition of militarily interesting silhouetted targets.

Designed a Mark II perceptron.

SIMPLE PERCEPTRON



PHASE II - APRIL 1961 to APRIL 1962

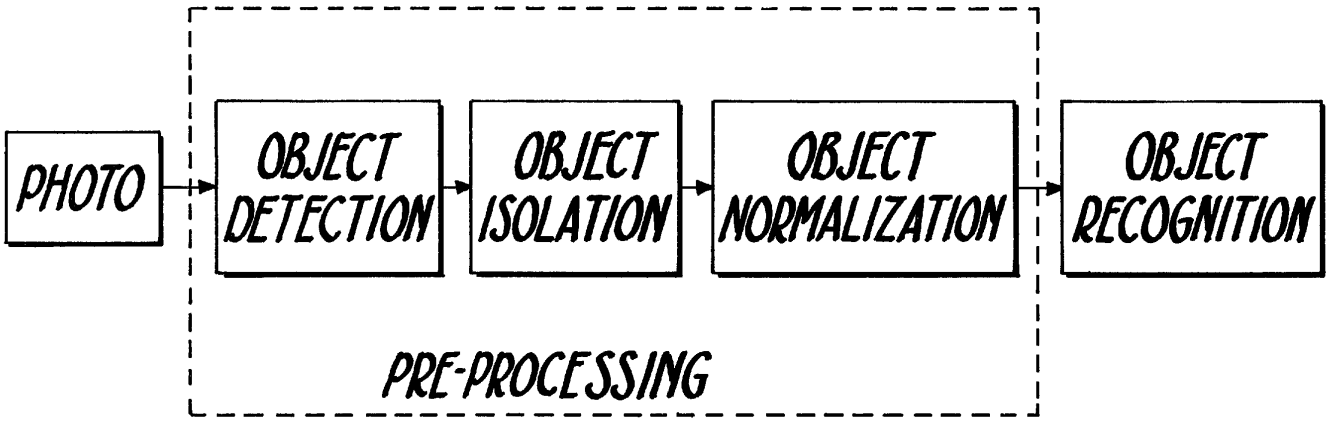
OBJECTIVES

Determine overall system to work with perceptron photo-interpretation device.

Isolate unusual requirements of system and prepare feasible solutions.

Provide for a photo-input capability for the IBM-704 digital computer.

OBJECT PRE-PROCESSING AND RECOGNITION



DETECTION

A. Detection should be independent of shape but should preserve shape.

B. Detection produces silhouettes.

C. Detection relies on

1. Differences in contrast
2. Outlining by edges
3. Textural differences.

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ISOLATION

A. Places each detected object or non-object in a separate frame.

B. Should handle objects within objects.

C. Should avoid breaking up images of objects.

STANDARDIZATION

A. Translates each object until its centroid is in the center of the frame.

B. Rotates each object until one of its principal axes is vertical.

C. Scales each object until it approximately fills a standard frame.

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OBJECT RECOGNITION

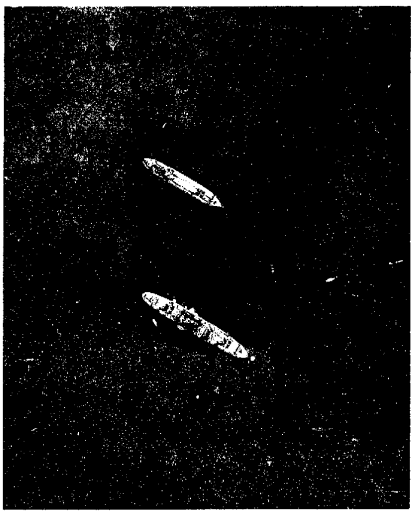
A. Uses a property list, linear discriminator, adaptive machine - a perceptron.

B. Bases its operation mainly on shape recognition, using perceptron principles.

C. Provides for the use of "objective" properties derived from both silhouette and from the full-grey-scale image.

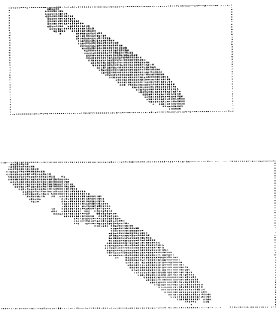
D. Provides for the use of object background information (water, terrain type, cultivation) in recognizing objects.

AN OBJECT SEGMENTATION AND STANDARDIZATION SEQUENCE IN AUTOMATIC PHOTO INTERPRETATION

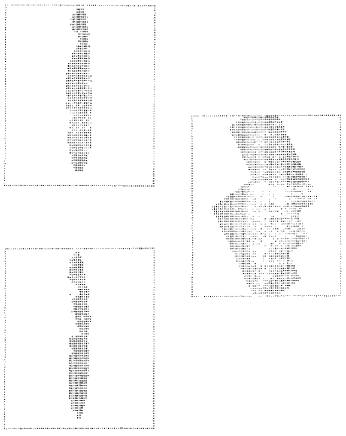


① ORIGINAL PHOTOGRAPH

② Processed Photograph after Object Detection and Low-Pass Filtering

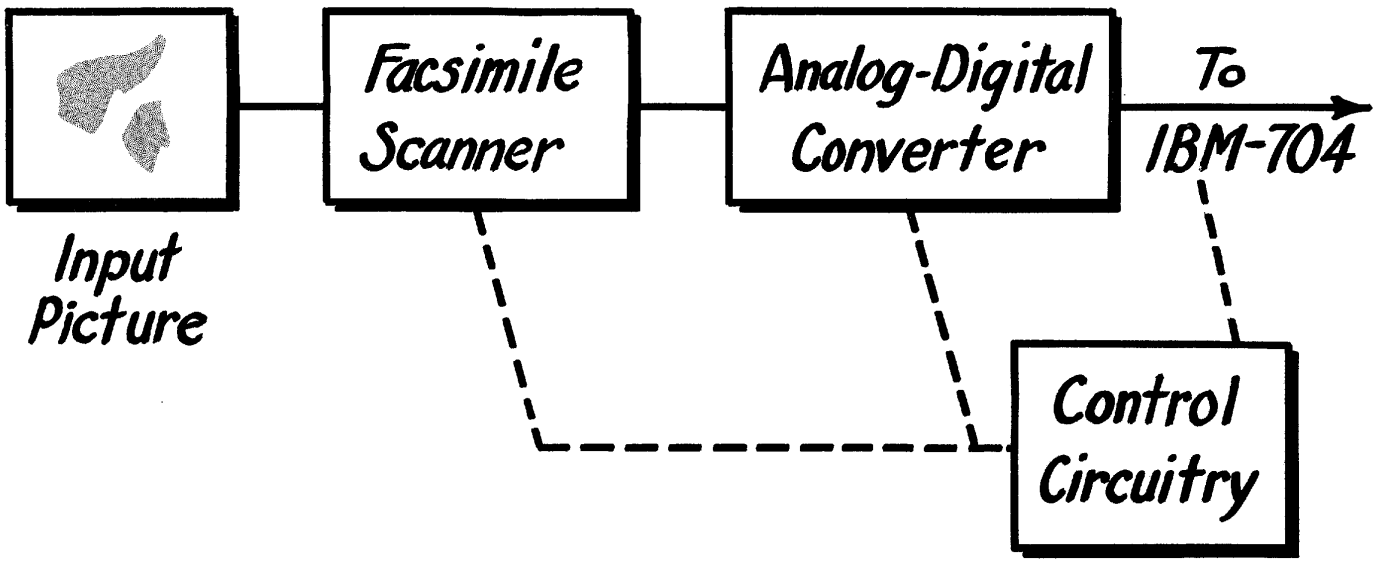


③ Isolated Silhouettes from Processed Photograph



④ Standardized from of Isolated Silhouettes

PHOTO INPUT FACILITY



PHASE II - ACCOMPLISHMENTS

1. Devised an overall system diagram which recognized the importance of pre-processing of photographs prior to a recognition function.
2. Established techniques for detecting, isolating, and standardizing objects of interest.
3. Developed digital computer programs which implemented detection, isolation, and standardization.

PHASE II - ACCOMPLISHMENTS (CONTINUED)

4. Provided a partial evaluation of pre-processing techniques.

5. Developed computer programs for implementing a large perceptron.

6. Developed 100 lines per inch, 16 level, photo input system.

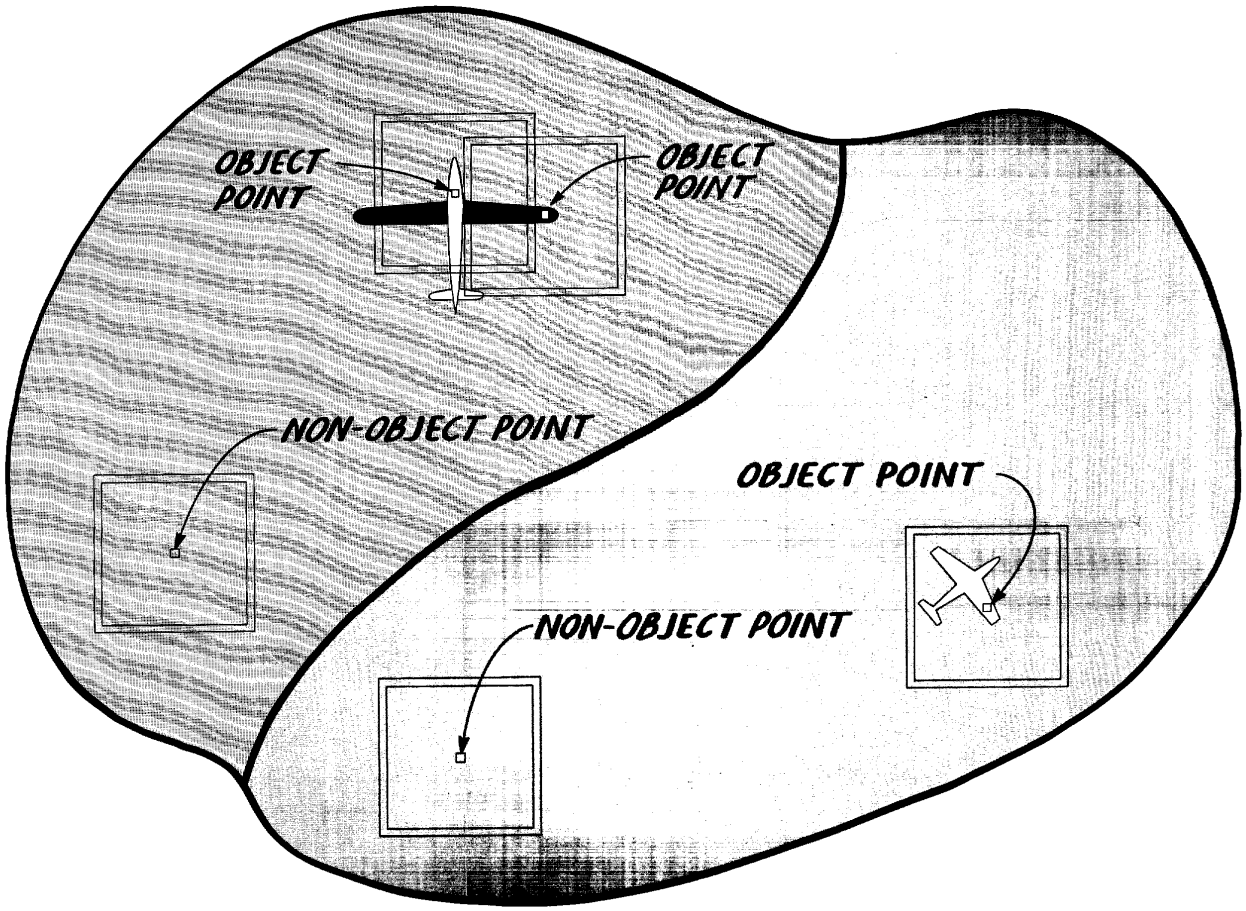
PHASE III - APRIL 1962 DECEMBER 1962

OBJECTIVES

1. Establish feasibility of pre-processing techniques that were proposed and partially evaluated in Phase II.
2. Develop techniques for detecting low contrast objects.
3. Establish requirements of perceptron-like device to recognize objects of military interest which are detected by pre-processing system.
4. Demonstrate, using the programs implemented on the IBM-704, a complete, but simple automatic photo interpretation device which can identify five or more simple object categories.

<table>
<tr><th>FUNCTION</th><th colspan="3">TECHNIQUE</th></tr>
<tr><td>OBJECT DETECTION</td><td>ANNULAR FILTER PLUS GAP FILLER</td><td rowspan="2">KOLMOGOROV-SMIRNOV TEST</td><td rowspan="2">SIMPLE UNIFORMITY TEST</td></tr>
<tr><td>OBJECT SEPARATION</td><td>ISOLATOR</td></tr>
<tr><td>VARIABILITY REMOVAL</td><td colspan="3">STANDARDIZER</td></tr>
<tr><td>OBJECT RECOGNITION</td><td colspan="3">PERCEPTRON</td></tr>
</table>

ANNULAR FILTER USED FOR OBJECT DETECTION



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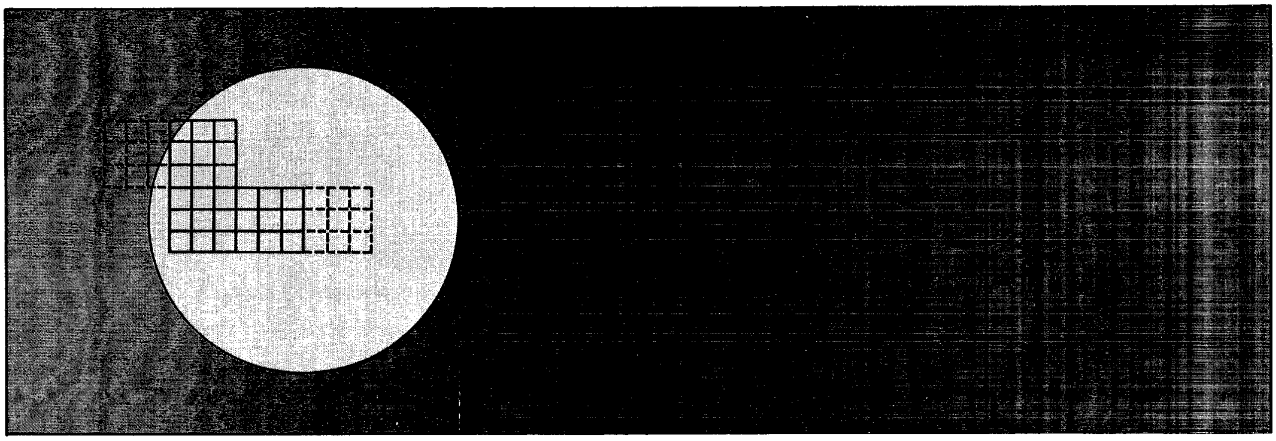
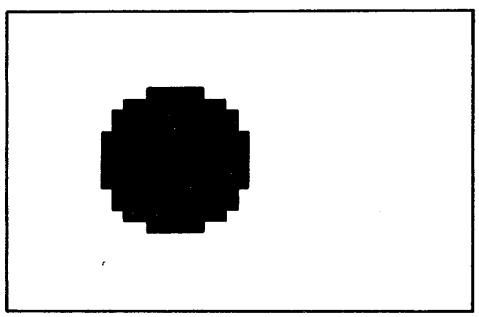
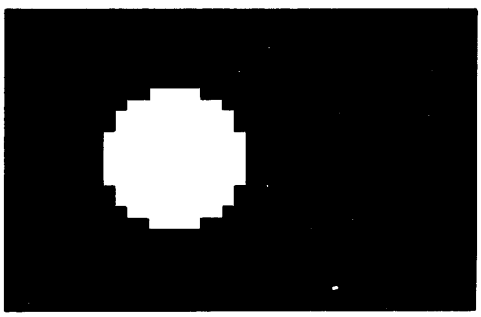
DETECTION AND ISOLATION USING K-S TWO SAMPLE TEST



RESULTS (HALF SIZE) OF K-S PROCEDURE OPERATING ON PICTURE ABOVE

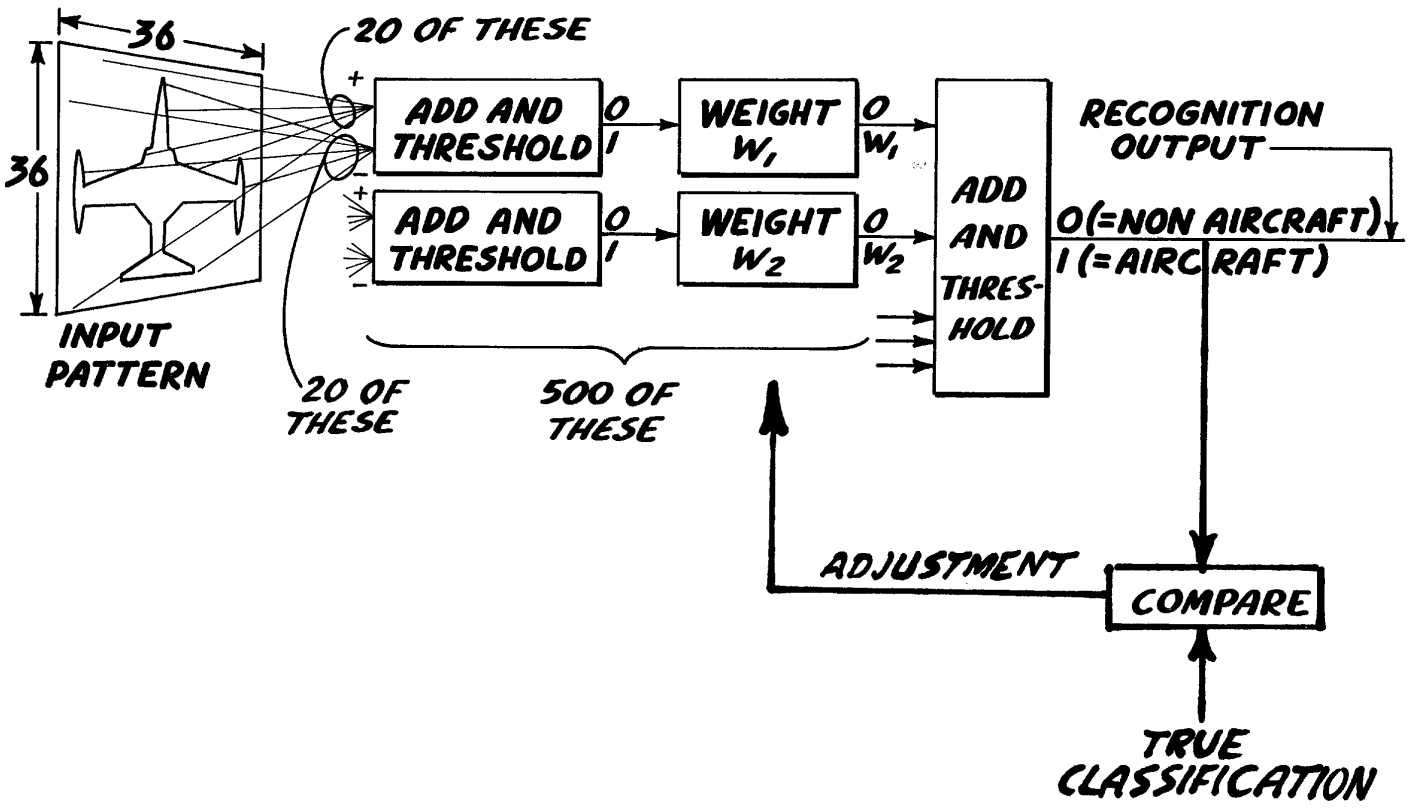


OBJECT 1



OBJECT 2

RECOGNITION EXPERIMENT



PHASE III - ACCOMPLISHMENTS

1. IMPROVED PHOTO INPUT FACILITY
2. UTILIZATION OF PHOTO OUTPUT FACILITY
3. DEVELOPMENT OF HYPOTHESIS TESTING TECHNIQUES FOR DETECTION/ISOLATION PROCESS
4. DEVELOPMENT OF NON-LINEAR FILTERING TECHNIQUES FOR GAP FILLING
5. PREPARATION AND DIGITAL PROCESSING OF A LARGE NUMBER OF PHOTOGRAPHS
6. ESTABLISHED CAPABILITY OF A 500 A-UNIT PERCEPTRON TO RECOGNIZE NOISY, MILITARILY INTERESTING OBJECTS

SUMMARY OF CURRENT CAPABILITY

1. DETECTION:

a) ANNULAR FILTERING WORKS WELL IN REGIONS OF LOW OBJECT DENSITY.

b) K-S DETECTION WORKS WELL IN REGIONS OF HIGH OBJECT DENSITY AND IN LOW CONTRAST SITUATIONS.

2. ISOLATION AND STANDARDIZATION

GENERAL PURPOSE COMPUTER IMPLEMENTATION IS STRAIGHTFORWARD.

3. RECOGNITION

EXPERIMENTS WITH NOISY SYNTHESIZED PATTERNS ARE VERY SUCCESSFUL.

4. DEVELOPED CAPABILITY FOR PHOTO PROCESSING RESEARCH

PICTORIAL INPUT AND OUTPUT FACILITIES FOR COMPUTER.

LIBRARY OF OPERATING COMPUTER PROGRAMS.

AREAS REQUIRING ADDITIONAL RESEARCH EFFORT

STUDIES UTILIZING IBM-704 COMPUTER

1. Further investigate techniques for object detection such as:
   a. Improvements in presently-devised techiques
   b. Use of spectrum consistency tests
   c. Using [redacted] flying spot scanner, investigate detection with expanded gray-scale
2. Conduct additional recognition experiments using actual material
3. Investigate techniques for improving recognition by inclusion of:
   a. Objective properties
   b. Full gray-scale images

AREAS REQUIRING ADDITIONAL RESEARCH EFFORT

INVESTIGATIONS OF SYSTEM IMPLEMENTATION TECHNIQUES

4. STUDY OF IMPLEMENTATION TECHNIQUES FOR:

a. Processes which use the same process at every picture element such as:
   1. Annular filter
   2. Low pass filter
   3. Gap filler

b. Processes which require exploration and dynamic decision such as:
   1. Kolmogorov-Smirnov technique
   2. Simple consistency test
   3. Isolator

c. Processes involved in standardization

d. Recognition Processes
   1. Interconnection problems
   2. Property derivation
   3. Weights
   4. Training

e. System Integration

PROGRAM A

CONTAINS ALL THE ITEMS DISCUSSED RELATING TO STUDIES UTILIZING THE IBM-704 COMPUTER.

CONTAINS INVESTIGATION OF IMPLEMENTATION TECHNIQUES FOR :

1. Processes which use the same process at every point in the picture
2. Processes which require exploration and dynamic decision

PLUS PRELIMINARY INVESTIGATION OF THE OTHER IMPLEMENTATION PROBLEMS.

PROGRAM B

CONTAINS THE FOLLOWING:

1. Investigation of techniques for object detection plus investigation, to a limited extent, of new techiques
2. Additional recognition experiments using actual material
3. Investigation of techniques for improving recognition by inclusion of objective properties
4. Investigation of techniques for implementing processes which use the same process at every picture element such as:
   a. Annular filter
   b. Low-pass filter
   c. Gap filler

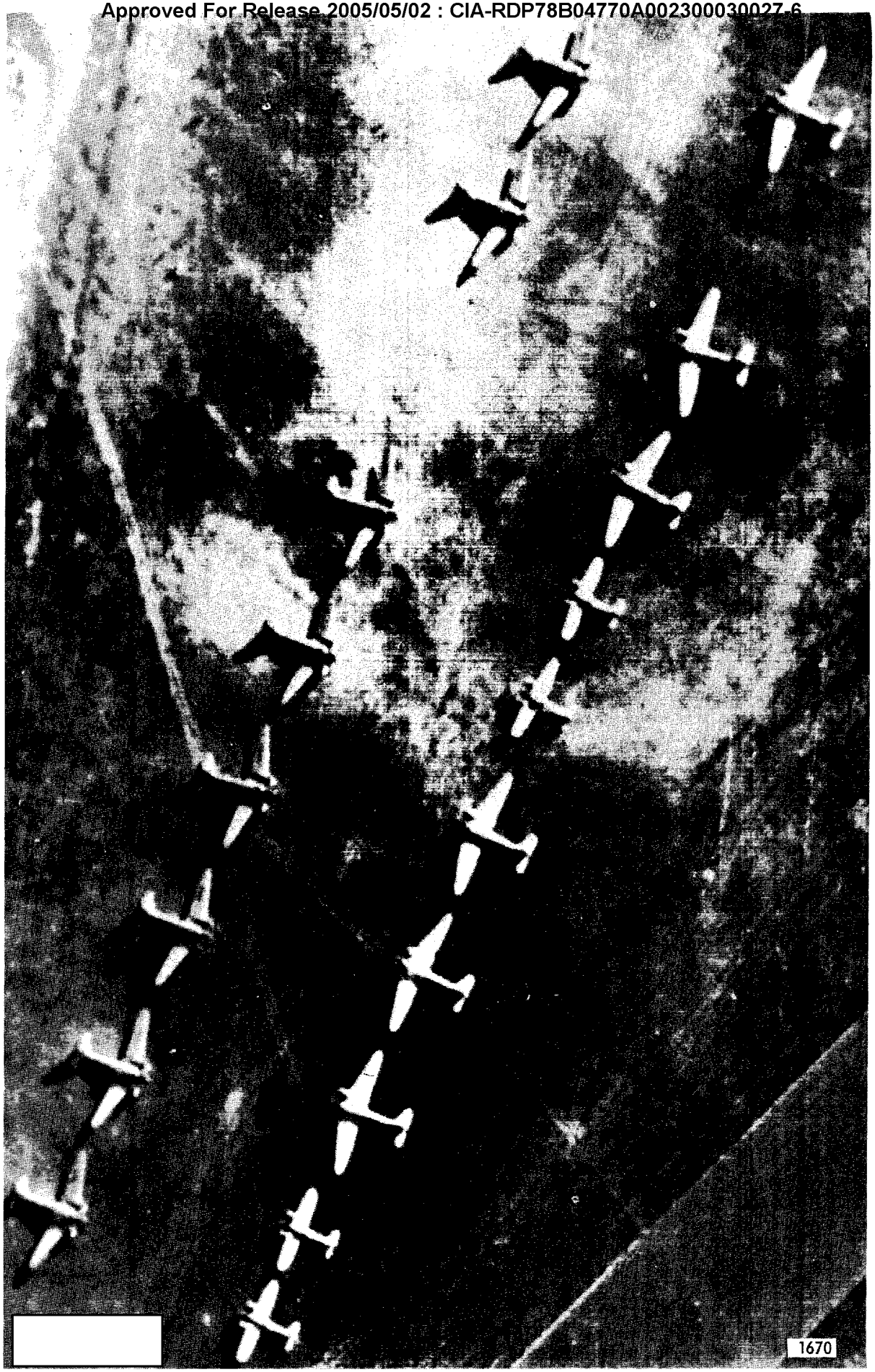


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Figure 1 ORIGINAL PHOTOGRAPH

Figure 2 EDITED VERSION OF FIGURE 1

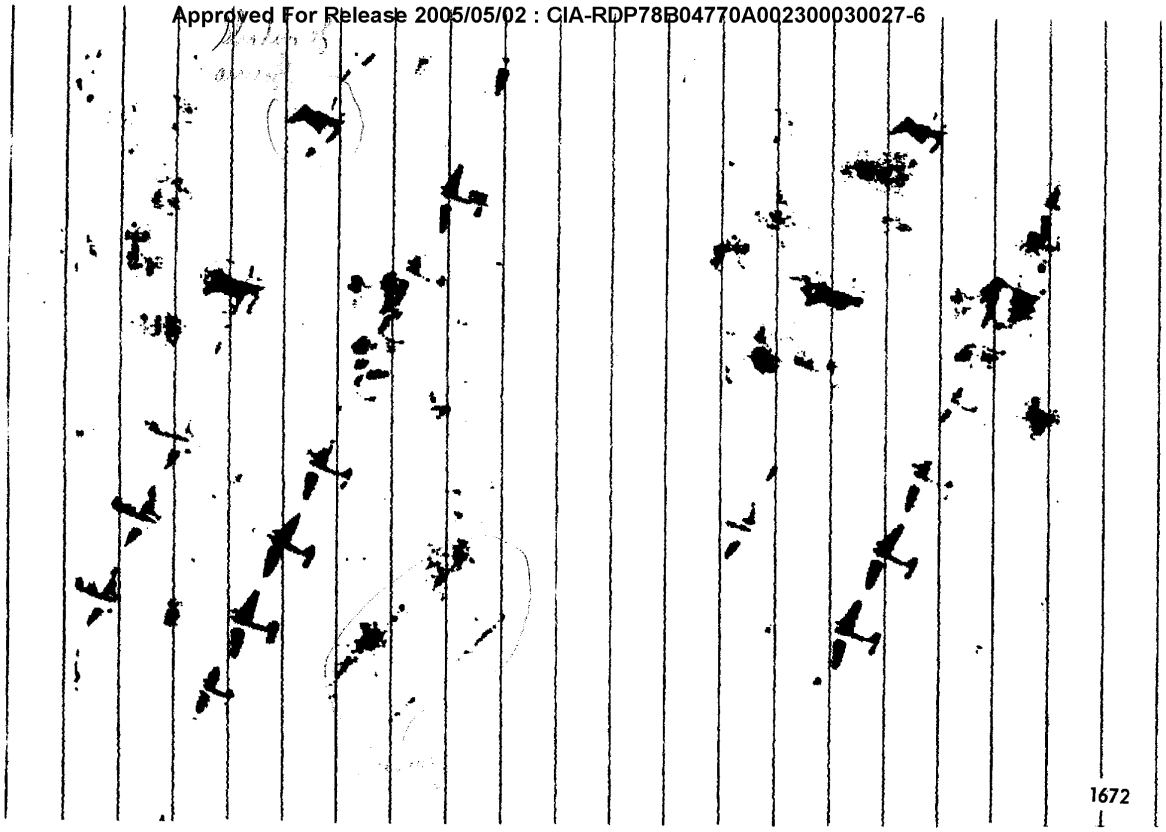


FIG. 3 ARRULAR PAPER OUTPUT FOR TWO APERTURE SIZES

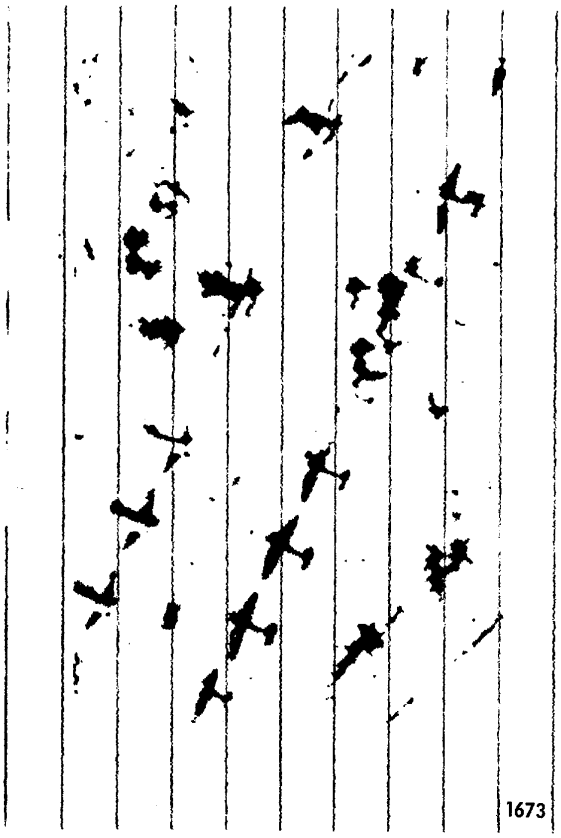


Figure 4 OUTPUT OF GAP FILLER APPLIED TO FIGURE 3(a)

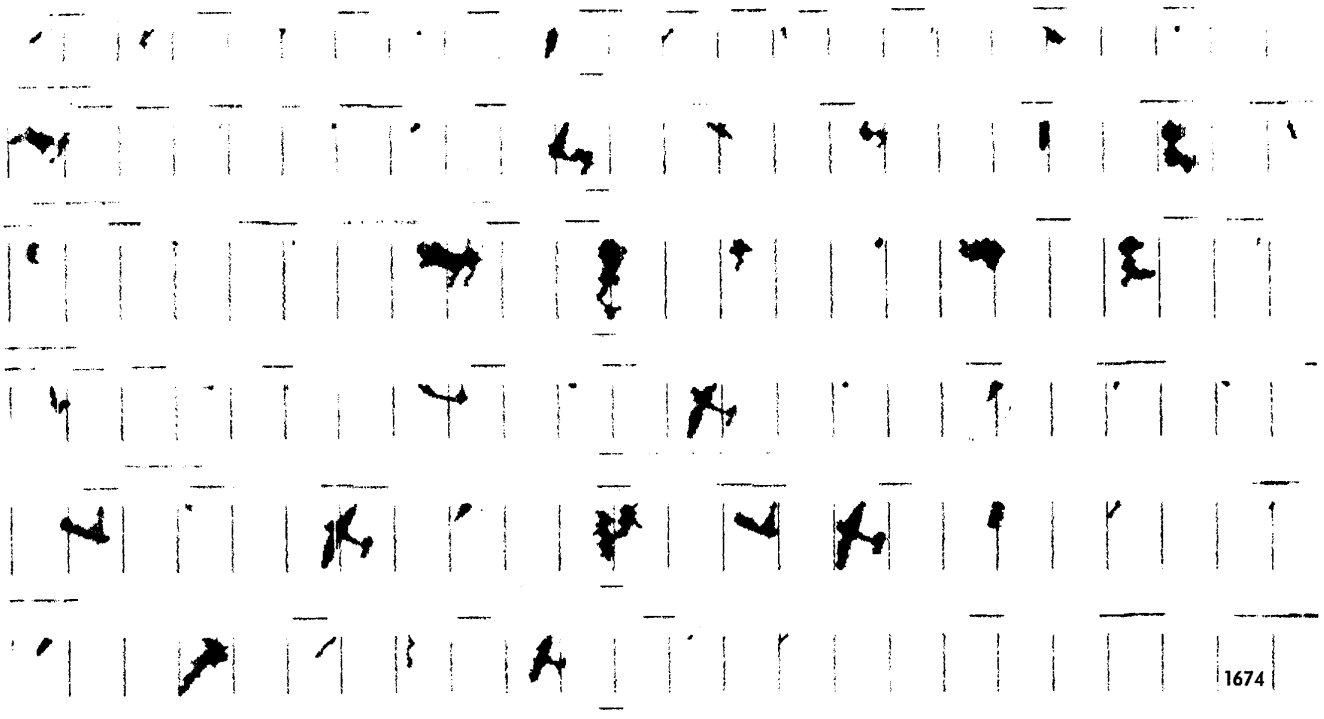


Figure 5 OUTPUT OF ISOLATOR APPLIED TO FIGURE 4

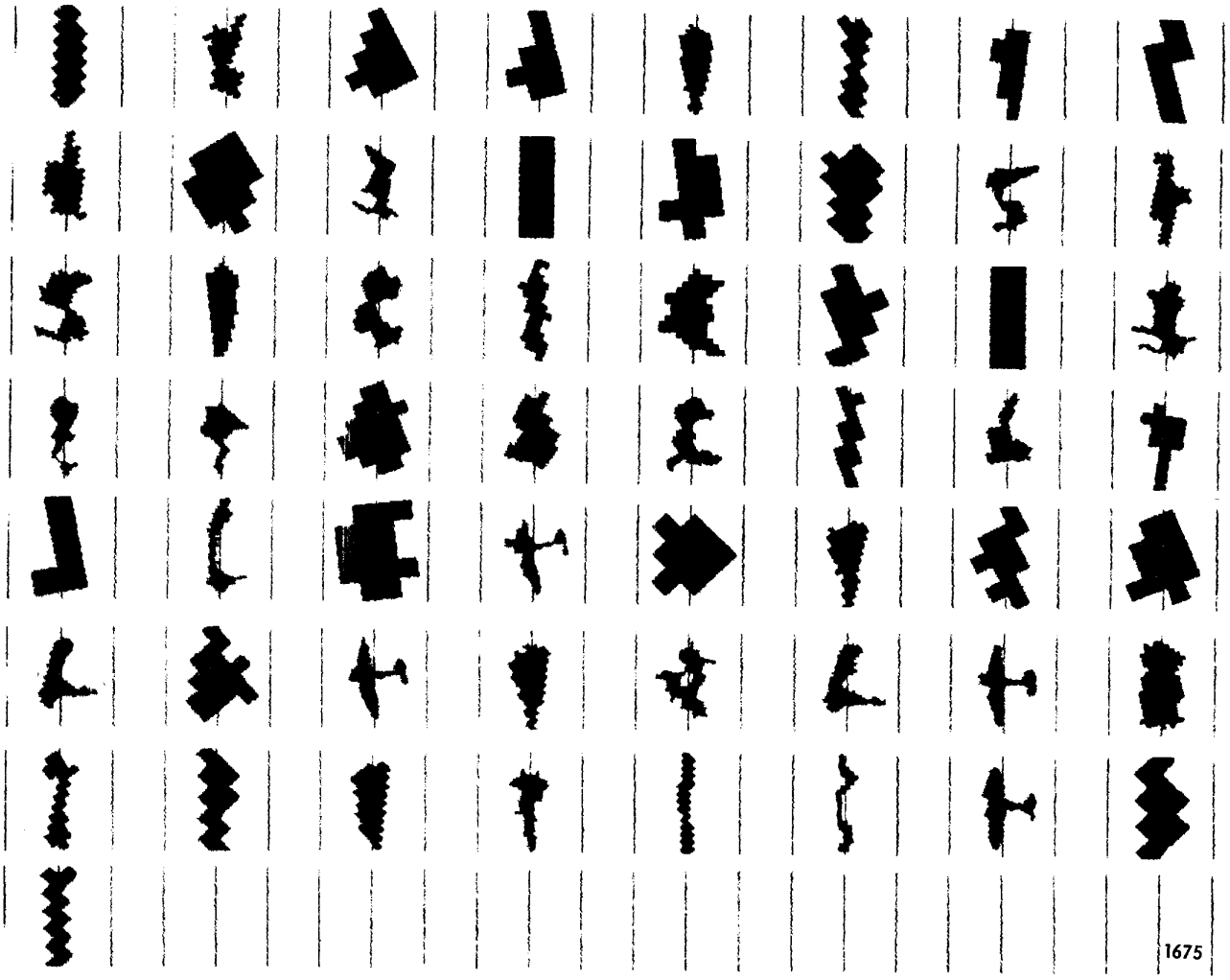
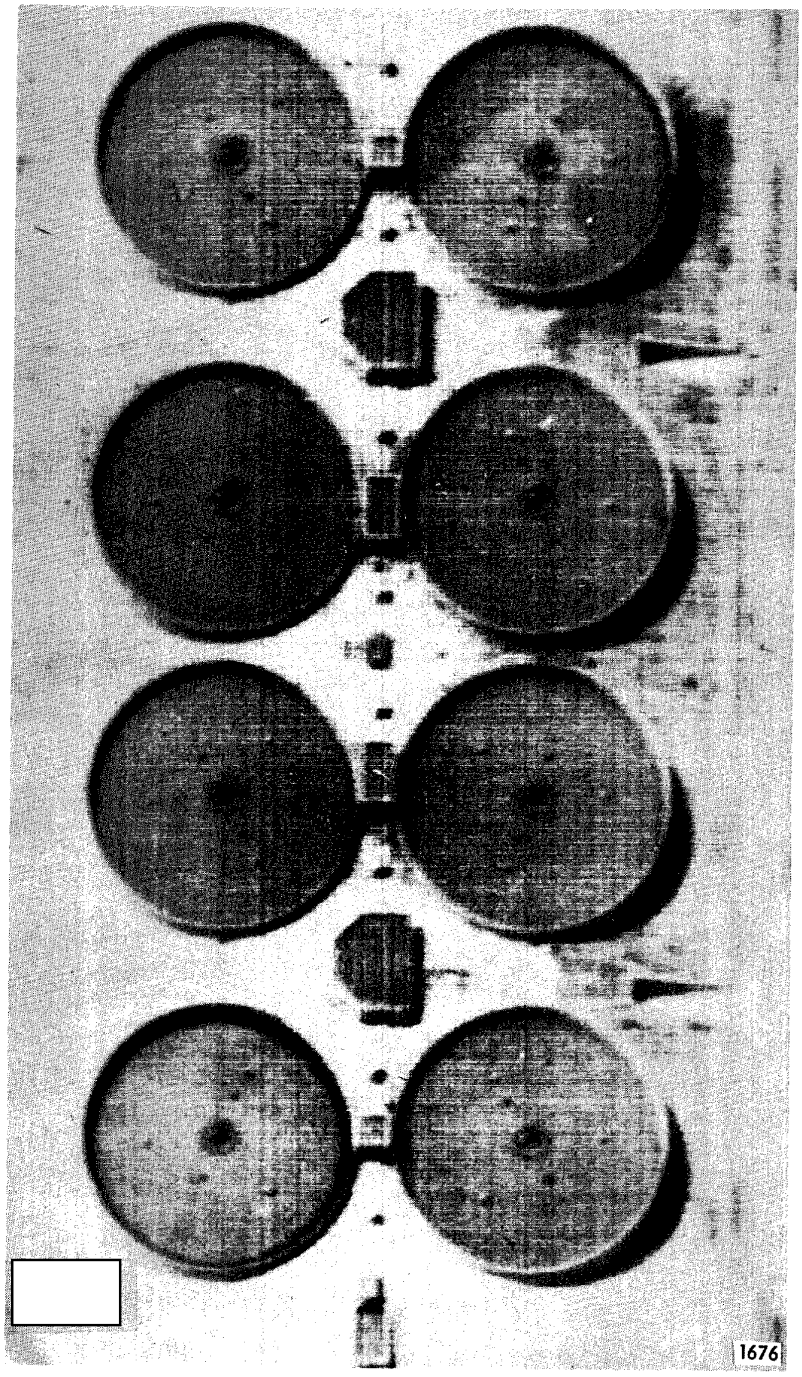


Figure 6 OUTPUT OF STANDARDIZER APPLIED TO FIGURE 5



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Figured 7 ORIGINAL PHOTOGRAPH

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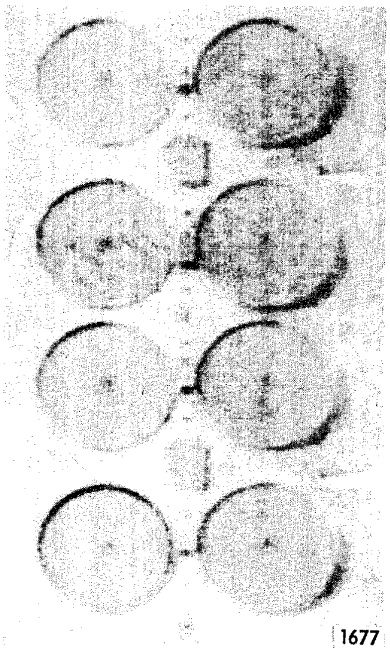

Figure 8 EDITED VERSION OF FIGURE 7

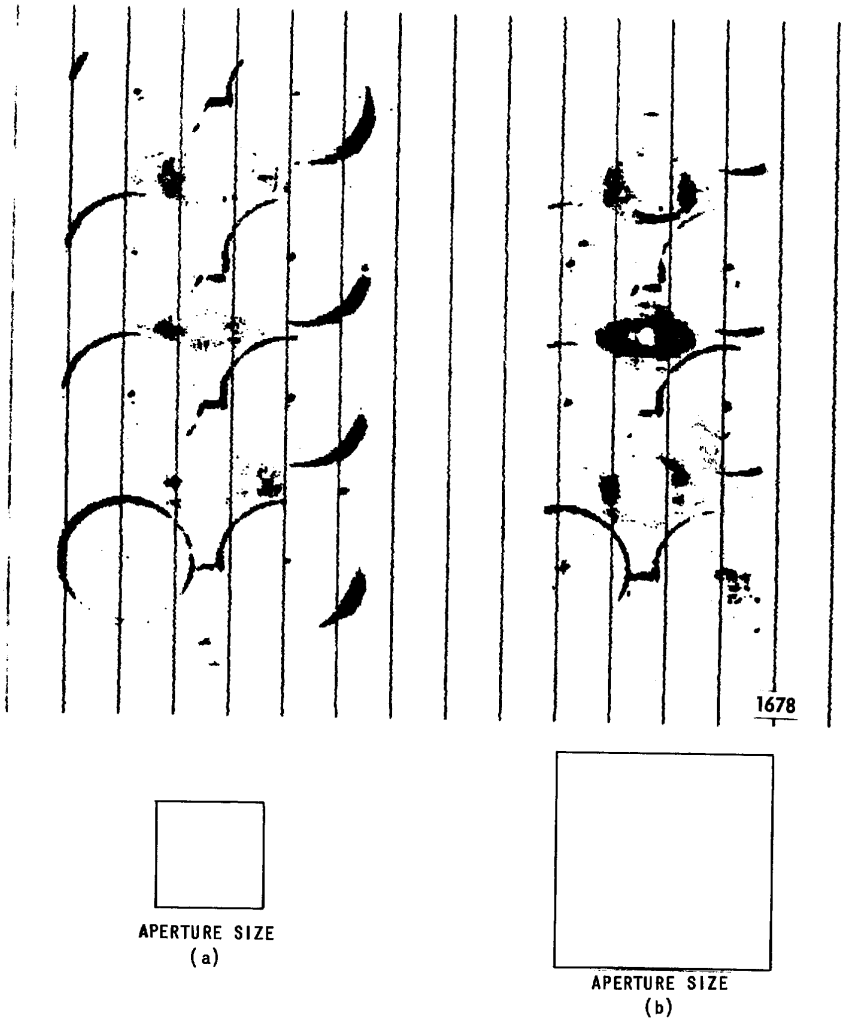

Figure 9 ANNULAR FILTER OUTPUT FOR TWO APERTURE SIZES

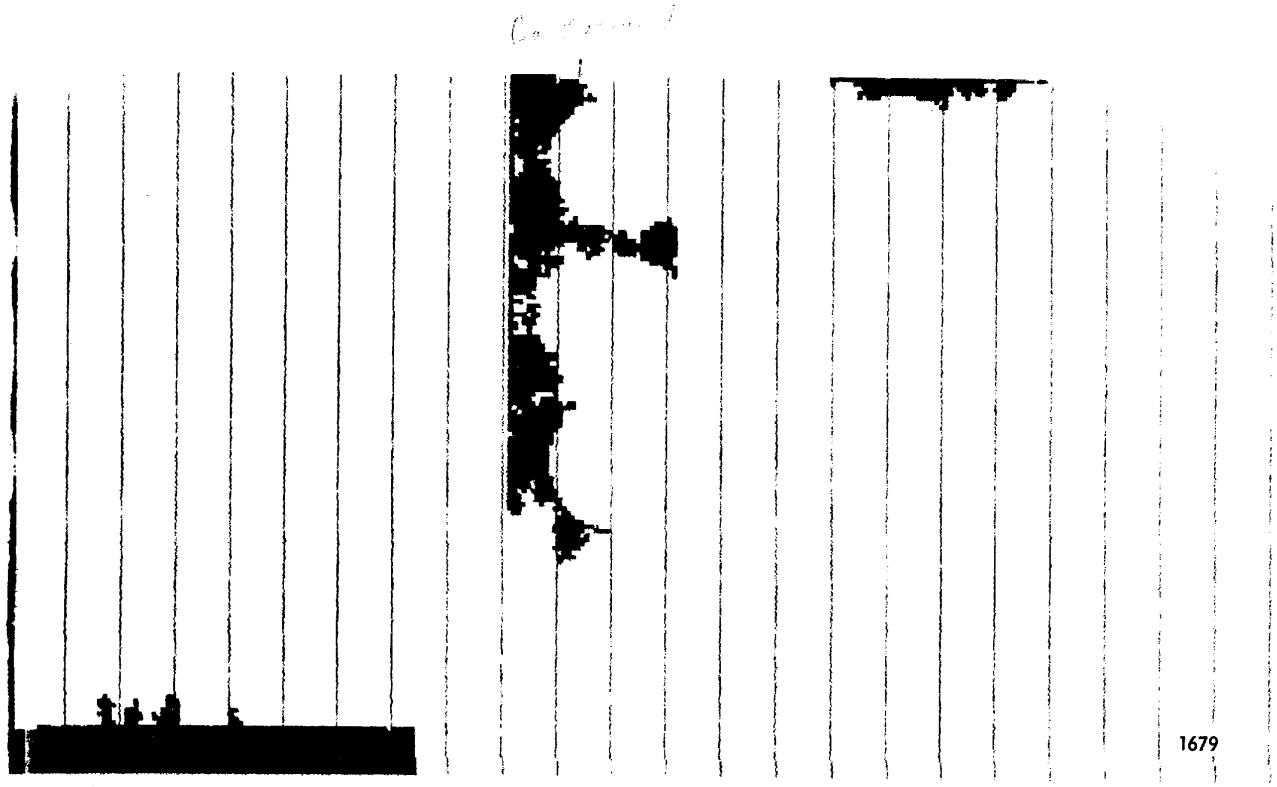

Figure 10(a) OUTPUT OF KOLMOGROV-SMIRNOV FILTER APPLIED TO FIGURE 8

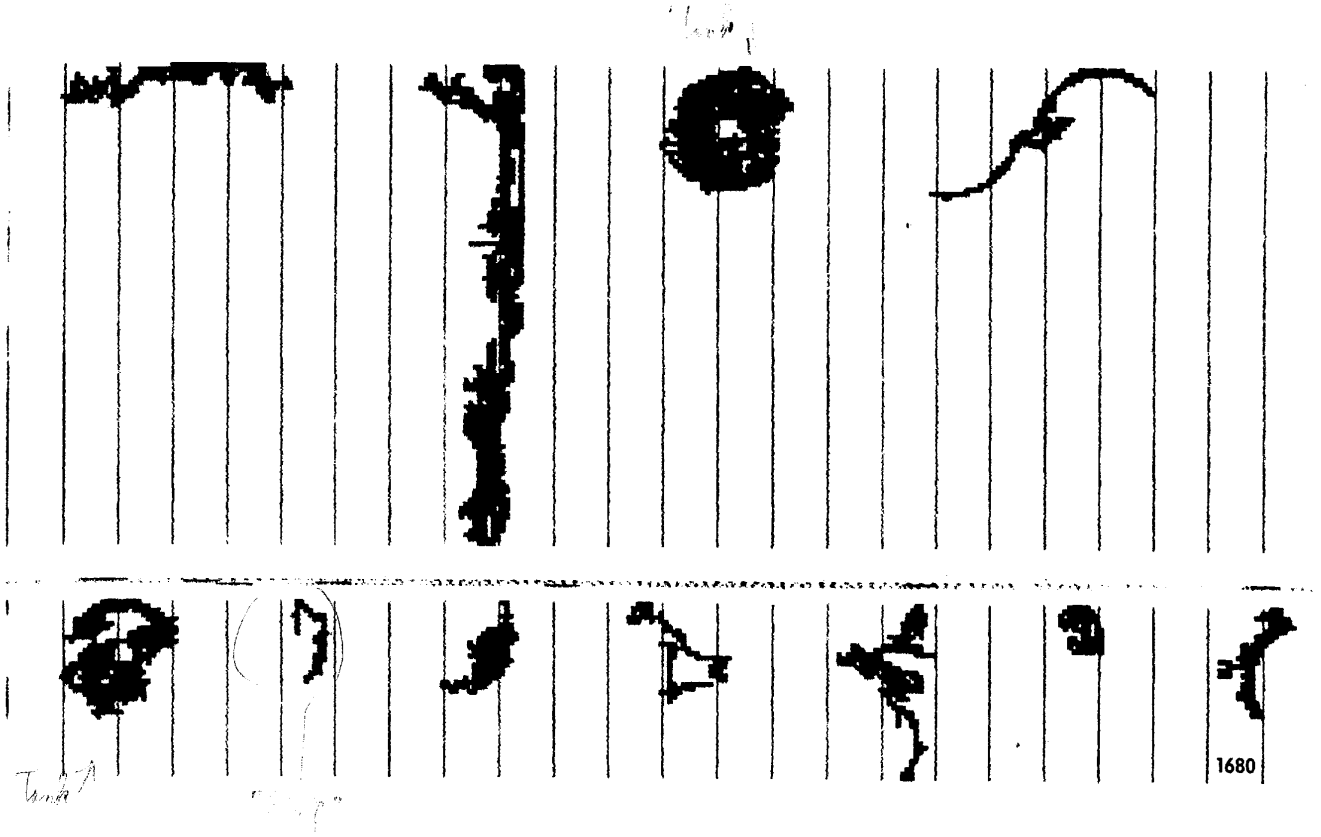

Figure 10(b) OUTPUT OF KOLMOGROV-SMIRNOV FILTER APPLIED TO FIGURE 8

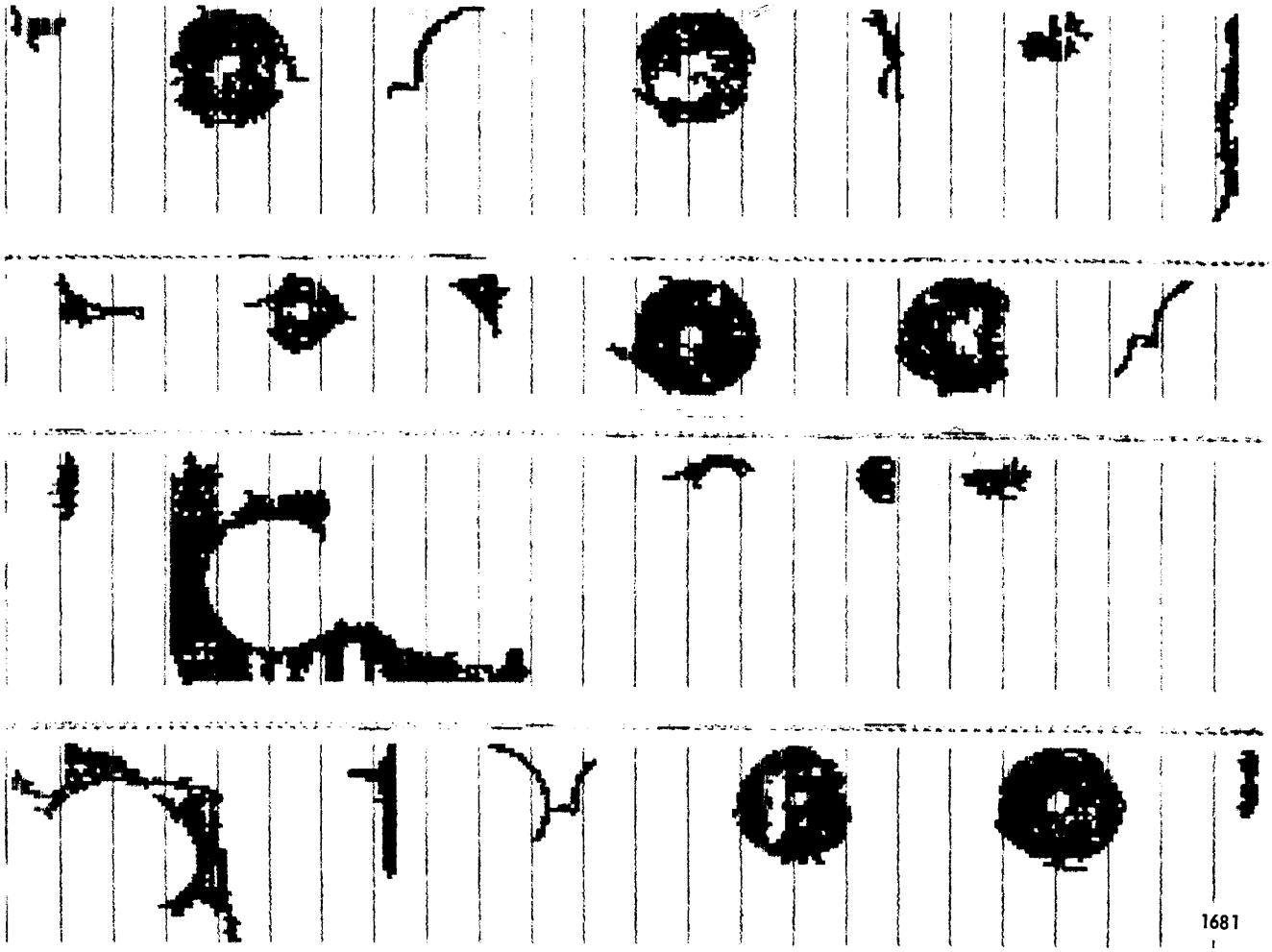

Figure 10(c) OUTPUT OF KOLMOGROV-SMIRNOV FILTER APPLIED TO FIGURE 8

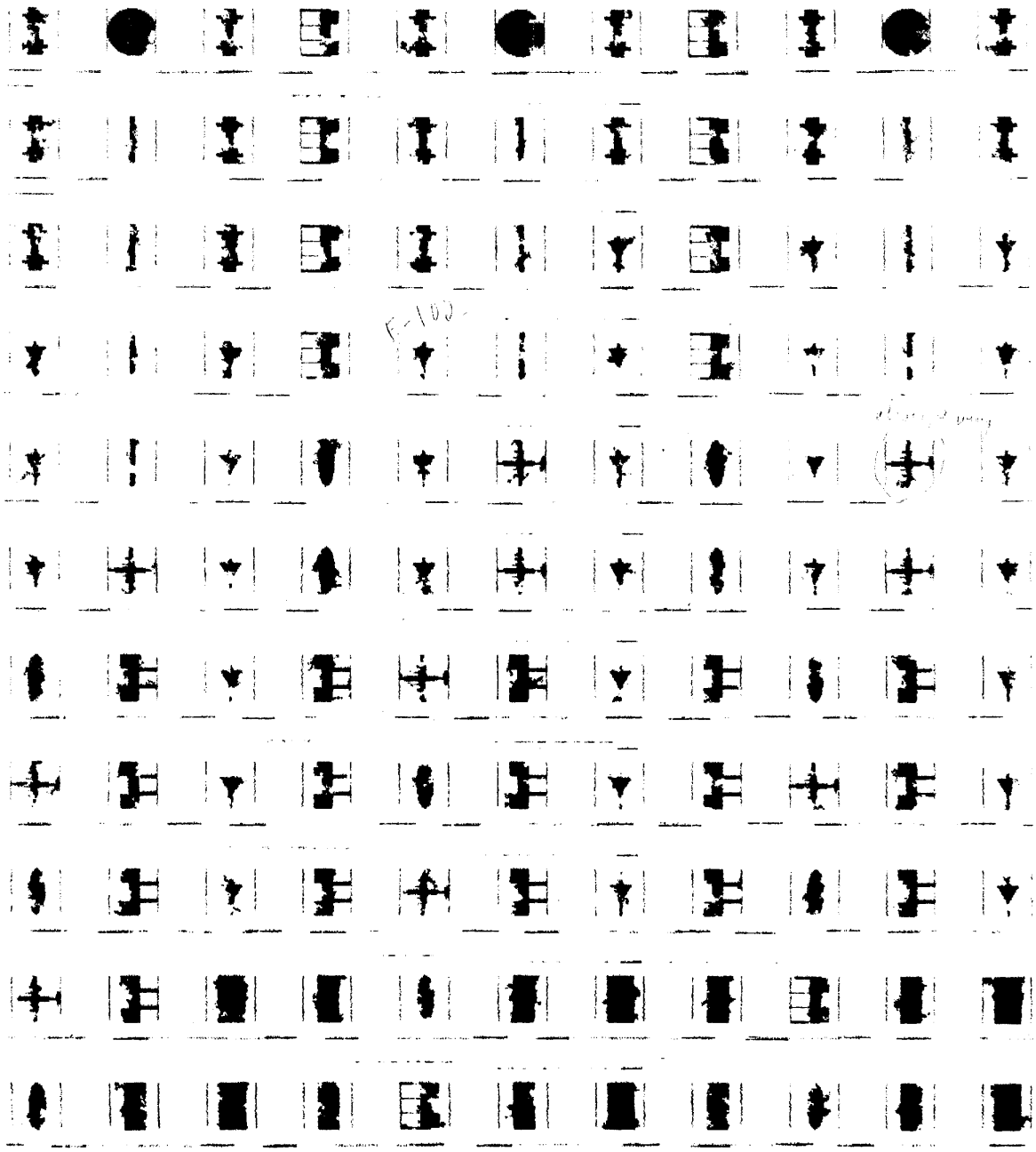

Figure 11 SAMPLE OF OBJECTS USED IN RECOGNITION EXPERIMENTS

1682

Table 2

RESULTS OF RECOGNITION EXPERIMENT

SYNTHESIZED OBJECTS

CORRECT PATTERN CLASSIFICATION	TOTAL NUMBER	NUMBER CORRECTLY CLASSIFIED	NUMBER INCORRECTLY CLASSIFIED	% RECOGNITION
TU 104	60	60	0	100.0
IL 18	60	60	0	100.0
LA 60	60	60	0	100.0
F 102	60	60	0	100.0
SHIPS	60	59	1	98.3
BLDGS.	90	86	4	95.5
TANKS	60	59	1	98.3
OBJECT TOTAL	450	444	6	98.7
OTHER	270	262	8	97.0

OBJECT DETECTION PROBABILITY = .987
FALSE ALARM PROBABILITY = .030

COMPLETE RECOGNITION RESULTS

CORRECT CLASSIFICATION ↓	RECOGNIZED AS: TU 104	IL 18	LA 60	F 102	SHIPS	BLDGS.	TANKS	OTHER	REJECTED
TU 104	60								
IL 18		60							
LA 60			60						
F 102				60					
SHIPS					59				1
BLDGS.						86		4	
TANKS							59	1	
OTHER					2	6		262	

ACTIVITY VECTOR MASK