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ASTROPOWER LABORATORY REPORT SM-46215-Q2

# DESIGN STUDY OF A CLOUD PATTERN RECOGNITION SYSTEM

Quarterly Progress Report for Period
15 September 1964 to
15 December 1964



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SANTA MONICA/CALIFORNIA

DOUGLAS

Report SM-46215-Q2

# DESIGN STUDY OF A CLOUD PATTERN RECOGNITION SYSTEM

Quarterly Progress Report
For Period 15 September 1964 to 15 December 1964

Contract No. NAS 5-3866
Goddard Space Flight Center
Greenbelt, Maryland

Prepared by

THE ELECTRONICS LABORATORY

N65 21329

MISSILE & SPACE SYSTEMS DIVISION
ASTROPOWER LABORATORY
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Newport Beach, California

SUMMARY

21329

This report documents the work accomplished in the second quarter of the contract on the "Design Study of a Cloud Pattern Recognition System." The iterative design-discriminant analysis learning algorithm is being applied, by means of a computer simulation using an IBM 7094, to the specification of a parallel logic structure required for the automatic recognition of vortices in TIROS cloud cover photographs. The effects of gray scale and noise in the input patterns are being investigated on sample problems using alphabetic characters. Other system design parameters are being investigated using both the cloud cover photographs and the sample problem data.

The gray scale investigation has resulted in the development of design routines that are invariant under linear gray scale transformations. Routines for formatting the digitized cloud patterns for input to the 7094 have been developed, as have techniques for printing out the test data to validate the records. Computer programs have been prepared for design of character recognition systems using the iterative design-discriminant analysis learning algorithm. Some results have been obtained on the effect of variation of system parameters on system performance. Verification of the digitized frames is in progress, as are the editing of the digitized frames and generalization runs in the sample problem investigation. Additional vortex frames have been requested, as only a third of the originally requested set are so far available.

During the next quarter, the currently open tasks are to be completed. Work is to commence on the remaining tasks. Primary emphasis will be on the computer simulation runs.

Author

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# 1.0 INTRODUCTION

## 1.1 Background Discussion

Present processing techniques convert the returned data from the TIROS satellite, and associated communication and tracking system, into an area map with general descriptors of weather conditions in the traversed region. Manual analysis of the high-resolution photographs by trained meteorologists then provides inputs, concerning atmospheric stability, wind flow, storm centers, fronts, etc., to be superimposed on the computer-generated maps. The final weather maps, the results of a merger of computer and manual analysis, are then transmitted to weather centrals providing timely, extensive weather data for user consumption.

This highly automated system is necessitated by the extensive amount of weather data presently being accumulated on a routine basis by the TIROS satellite system. With world wide coverage on a timely basis as the goal of the meteorological satellites, additional satellites will be placed in orbit, further increasing the amount of processing required. As suggested above, much of the data can be processed by computer. The task which defies automatic handling is the recognition of the cloud formations and interpretation of the cloud cover photographs. If a device were developed that could recognize cloud features such as storm centers, cloud streets,cloud fronts, etc., and interpret this data, it is conceivable that future weather forecasting systems could be further automated and the burden placed on the meteorologist alleviated.

Under contract NASw609[1], Astropower investigated the feasibility of performing the recognition task with a self-organizing, parallel logic system categorized as a "forced learning perceptron." Using optical correlation of actual cloud cover negatives and an estimation procedure mechanized on the IBM 7094, the size of the parallel layer required to achieve effective regognition of vortex pattern was to be determined. Program results showed that a "forced learning perceptron" was capable of correctly identifying only 65-70% of the patterns examined. This indicated that poor class separation existed between the vortex and non-vortex patterns, due in part to the inaccuracies in the optical processing and correlation procedures involved, and in part to the inherent overlap of the patterns themselves. To achieve more effective recognition, the design procedure must account for the pattern similarities. To

[1] Report 129-F, "Cloud Pattern Interpretation," Final Report on Contract NASw609, August 1963

accomplish this, the iterative design-discriminant analysis algorithm was developed during the course of NASw609. This design routine would be implemented in a digital computer simulation and the digitized cloud patterns examined directly, thus overcoming the inaccuracies of the optical correlation procedure.

### 1.2 Purpose and Scope of Present Program

The objective of this program is to arrive at the design specifications for a feasibility model of an automatic vortex recognition system. The design effort will be implemented by digital computer simulation of a parallel logic, self-organizing system examining digitized cloud photographs collected by the TIROS weather satellite system. The iterative design-discriminant analysis routine will be used to examine some 1000 such patterns (500 vortex, 500 non-vortex), of various resolutions, with a sufficiently large population of logic units. From this population, the logic units required to perform the recognition task will be selected. The system design then consists of specifying the number of logic units, their weighted input connections, the output weights, and the logic unit threshold to achieve a specified level of performance. Previous to the examination of the cloud data, the effect of gray scale in the input patterns will be determined by comparing the designs achieved on a sample problem (alphabetic character recognition) using both black and white characters and those with gray scale (10 levels).

### 1.3 Task Statement

The work to be performed to arrive at the design specifications for a vortex recognition system can be summarized as follows:

#### 1.3.1 Selection of Tape Data

Obtain copies of digital tapes and determine methods for manipulating the tape data to provide at least 500 vortex and 500 non-vortex patterns. Select a representative sample of alphabetic character data with varying gray scale for the preliminary gray scale investigation.

#### 1.3.2 Gray Scale Investigation

Investigate the effects of gray scale in character recognition. Compare machine designs and performance on black and white patterns as opposed to those with levels of gray.

### 1.3.3 Format Tape Data

The test data, digital tapes and character information, will be screened and transferred to high speed tape in a format suitable for easy access to the IBM 7094 computer.

### 1.3.4 Computer Programs

Computer programs will be designed, written, debugged, and documented to provide the necessary routines for the automatic design of the recognition mechanism in the computer memory, according to an iterative design procedure using the magnetic tape input data as training material. These programs will provide for, but not be limited to, the following:

a. Programs to present the data in full and in part, and with original and with limited resolution, to the recognition mechanism.

b. Generation of logic unit input for the number of logic units to be examined.

c. Implementation of discriminant analysis-iterative design algorithm to examine the logic unit structure and arrive at the required logic unit specifications for effective recognition.

d. Examination of effect on system performance of the various parameters.

e. Programs for allowing the TIROS data to be rotated in the computer.

### 1.3.5 Computer Simulation

The computer simulation will provide the closed loop design algorithm required to examine the pattern data and arrive at the design specifications for the parallel logic interpreter. The simulation routine will consist of, but not be limited to, the following:

a. Determination of suitable logic unit parameters for use with a closed loop learning algorithm.

b. Determination of limiting performance obtainable as a function of machine size for a closed loop algorithm.

c. Determination of the effect on logic unit effectiveness and efficiency by the inclusion of either discriminant analysis or a simplified form of discriminant analysis for logic unit specification (to be accomplished on the sample problem or a sample set of data).

d. Determination of the effect of the number of sample patterns in the "learning population" on terminal performance, both for these patterns and for a "validation sample" of patterns not included in the "learning population" (to be accomplished on a sample problem or a sample set of data).

e. Determination of the minimum resolution required to achieve effective recognition.

f. Establishment of the preliminary design specifications for an automatic vortex or cloud pattern recognition system as a result of the simulated learning routine.

g. Briefly study the system requirements for a complete automatic pattern interpreter system.

### 1.3.6 Preliminary Design Reviews

During the course of the computer simulation program, a continuing review of the preliminary design results will be made and any modifications of the program or examination of various parameters necessary will be made in an effort to achieve the interpreter design.

### 1.3.7 Resolution Investigation

An additional study will be made to determine the boundary of minimum resolution compatible with efficient recognition, for both the tape data and additional photographic data. This will include the following:

a. Tape readout with reduced resolution

b. Photographic processing to obtain estimates of the required resolution.

c. Consultation with other companies.

### 1.3.8 Parallel Logic Interpreter Design Specifications

As a result of the above subtasks, the actual design specifications will be determined. These include the required number of logic units, number of input connections, input connection weights, assignment of input connections to sensory points, weights of connections from logic to response units, and logic and response unit thresholds. In addition, a preliminary study of the hardware required for construction or simulation of the actual interpreter will be performed.

## 1.4 Summary of Work Performed

Nearly all of the computer programs used in the sample problem investigations have been written and debugged. Approximately three dozen useable computer passes have been run. These are primarily design runs. The generalization runs, which form the basis of technique evaluation, are currently in progress.

275 digitized TIROS frames have been received, of which 116 are currently classified as "useable." Many additional nonvortex frames will be culled from the "useable" set. An additional 172 vortex frames have been requested.

The SC-4020 program received has been made compatible with the Douglas monitor system and with the headers of the digitized tapes received. Verification of the digitized frames is in progress. The gray scale reduction programs have been run successfully on the frames received. The rotation and editing routines are being checked out. The flow chart for the main program has been revised to reflect changes in the design techniques. Coding has begun on this program. A satisfactory eigenvector routine has been obtained by modifying a SHARE program.

## 2.0 DATA COLLATION

Two sets of data are required for this study. One set is a collection of hand-printed characters for the preliminary investigation of design parameters. The second set is a collection of digitized TIROS frames for the design of a vortex recognition network. The acquisition of both of these sets of data is essentially complete.

### 2.1 Alphabetic Characters

As described in the first quarterly report*, two sets of 240 hand-written characters each were obtained. Each character was coded as 70-dimensional binary vector. These vectors were keypunched to provide two pattern decks. These decks were designated Deck I-BW and Deck II-BW, and are available both on punch cards and as a Fortran input tape. A program for converting these decks to other gray scale levels has been written. This conversion is accomplished either by applying a linear transformation to the original binary value uniformly over the 7 by 10 input raster, or by applying a different linear transformation to each column of the raster. The modified decks are available only as Fortran input tapes. So far, only one such tape has been generated, the decks being designated Deck I-37 and Deck II-37. (These are binary patterns with gray levels of .3 and .7.)

### 2.2 Cloud Pattern Data

183 TIROS frames containing 39 different vortices, and 184 TIROS frames containing no vortices were selected from negatives supplied by the TIROS Data Utilization Manager, NASA Goddard Space Flight Center. Details of the selection process are described in the first quarterly report. Table I provides a complete listing of these frames. Digitized tapes of the 367 frames were requested from the Institute for Space Studies, New York.

Subsequent to this request, prints of most of these frames were received from the project manager, Mr. J. Silverman of NASA, GSFC. In many cases, the print did not agree with the corresponding negative. The cause of these discrepancies has been found to be the correction of errors in

*Astropower Laboratory Report SM-46215-Q1

TABLE I

VORTEX AND NON VORTEX FRAMES

a) Vortex Frames

| Pass, Mode and Camera Number | Frame No. | No Discrepancies Tape vs Neg and Prints | Sequence # Incorrect | Tiros No. and Station** | Date |
|---|---|---|---|---|---|
| 064 D1 | 4* | | | 6P | 9-23-62 |
| " | 5* | | | " | " |
| " | 6* | | | " | " |
| " | 7* | | | " | " |
| " | 8* | | | " | " |
| " | 9* | | | " | " |
| " | 10* | | | " | " |
| " | 11* | | | " | " |
| " | 12* | | | " | " |
| " | 13* | | | " | " |
| " | 14* | | | " | " |
| " | 15* | | | " | " |
| " | 16* | | | " | " |
| " | 17* | | | " | " |
| " | 18* | | | " | " |
| " | 19* | | | " | " |
| | | | | | |
| 065 T1 | 7* | | X | 6P | 9-22-62 |
| " | 8* | | X | " | " |
| " | 9* | | X | " | " |
| | | | | | |
| 145 T1 | 11* | | X | 6W | 9-28-62 |
| " | 12* | | X | " | " |
| " | 13* | | X | " | " |
| " | 14* | | X | " | " |
| " | 15* | | X | " | " |
| | | | | | |
| | | | | | |

* Digitized Tape Not Available
** P = Point Mugu, W = Wallops Island

TABLE I (CONT'D)

VORTEX AND NON VORTEX FRAMES

a) Vortex Frames

| Pass, Mode and Camera Number | Frame No. | No Discrepancies Tape vs Neg and Prints | Sequence # Incorrect | Tiros No. and Station** | Date |
|---|---|---|---|---|---|
| 484 T1 | 13* | | X | 5P | 7-23-62 |
| " | 14* | | X | " | " |
| " | 15* | | X | " | " |
| " | 16* | | X | " | " |
| " | 17* | | X | " | " |
| " | 18* | | X | " | " |
| | | | | | |
| 596 T1 | 16* | | | 5P | 7-31-62 |
| " | 17* | | | " | " |
| " | 18* | | | " | " |
| " | 19* | | | " | " |
| " | 20* | | | " | " |
| " | 21* | | | " | " |
| " | 22* | | | " | " |
| " | 23* | | | " | " |
| | | | | | |
| 597 T1 | 18* | | | 5P | 7-31-62 |
| " | 19* | | | " | " |
| " | 20* | | | " | " |
| " | 21* | | | " | " |
| " | 22* | | | " | " |
| " | 23* | | | " | " |
| " | 24* | | | " | " |
| " | 25* | | | " | " |
| " | 26* | | | " | " |
| " | 27* | | | " | " |
| " | 28* | | | " | " |
| | | | | | |

* Digitized Tape Not Available

** P = Point Mugu, W = Wallops Island

TABLE I (CONT'D)

VORTEX AND NON VORTEX FRAMES

a) Vortex Frames

| Pass, Mode and Camera Number | Frame No. | No Discrepancies Tape vs Neg and Prints | Sequence # Incorrect | Tiros No. and Station** | Date |
|---|---|---|---|---|---|
| 598 T1 | 24 | X | | 5W | 7-31-62 |
| " | 25 | X | | " | " |
| " | 26 | X | | " | " |
| " | 28 | X | | " | " |
| " | 32 | X | | " | " |
| | | | | | |
| 610 T1 | 27* | | | 5P | 8-1-62 |
| " | 28* | | | " | " |
| " | 29* | | | " | " |
| " | 30* | | | " | " |
| " | 31* | | | " | " |
| " | 32* q | | | " | " |
| | | | | | |
| 611 T1 | 21* | | | 5P | 8-1-62 |
| " | 22* | | | " | " |
| " | 23* | | | " | " |
| " | 24* | | | " | " |
| " | 25* | | | " | " |
| " | 26* | | | " | " |
| " | 27* | | | " | " |
| " | 28* | | | " | " |
| " | 29* | | | " | " |
| | | | | | |
| 615 T1 | 28* | | | 5P | 8-1-62 |
| " | 29* | | | " | " |
| " | 30* | | | " | " |
| " | 31* | | | " | " |
| " | 32* | | | " | " |

* Digitized Tape Not Available
** P = Point Mugu, W = Wallops Island

TABLE I (CONT'D)

VORTEX AND NON VORTEX FRAMES

a) Vortex Frames

| Pass, Mode and Camera Number | Frame No. | No Discrepancies Tape vs Neg and Prints | Sequence # Incorrect | Tiros No. and Station** | Date |
|---|---|---|---|---|---|
| 667 | 12* | | | 5P | 8-5-62 |
| " | 13* | | | " | " |
| " | 14* | | | " | " |
| " | 15* | | | " | " |
| " | 16* | | | " | " |
| " | 27* | | | " | " |
| " | 28* | | | " | " |
| " | 29* | | | " | " |
| " | 30* | | | " | " |
| " | 31* | | | " | " |
| | | | | | |
| 670 T1 | 28* | | | 5W | 8-5-62 |
| " | 29* | | | " | " |
| " | 30* | | | " | " |
| " | 31* | | | " | " |
| | | | | | |
| 681 T1 | 28* | | | 5P | 8-6-62 |
| " | 29* | | | " | " |
| " | 30* | | | " | " |
| " | 31* | | | " | " |
| | | | | | |
| 684 T1 | 30* | | | 5W | 8-6-62 |
| | | | | | |
| 807 D1 | 13* | | | 5W | 8-14-62 |
| " | 14* | | | " | " |
| " | 15* | | | " | " |
| | | | | | |
| | | | | | |

* Digitized Tape Not Available
** P = Point Mugu, W = Wallops Island

TABLE I (CONT'D)

VORTEX AND NON VORTEX FRAMES

a) Vortex Frames

| Pass, Mode and Camera Number | Frame No. | No Discrepancies Tape vs Neg and Prints | Sequence # Incorrect | Tiros No. and Station** | Date |
|---|---|---|---|---|---|
| 813 T1 | 6 | X | | 5P | 8-15-62 |
| " | 7 | X | | " | " |
| " | 8 | X | | " | " |
| " | 9 | X | | " | " |
| " | 10 | X | | " | " |
| | | | | | |
| 921 T1 | 16* | | X | 5W | 8-22-62 |
| " | 17* | | X | " | " |
| " | 18* | | X | " | " |
| " | 19* | | X | " | " |
| " | 20* | | X | " | " |
| " | 21* | | X | " | " |
| | | | | | |
| 922 D1 | 3* | | | 5P | 8-22-62 |
| " | 4* | | | " | " |
| " | 5* | | | " | " |
| | | | | | |
| 926 T1 | 2 | X | | 5P | 8-23-62 |
| " | 3 | X | | " | " |
| " | 4 | X | | " | " |
| | | | | | |
| 951 T1 | 1* | | | 5P | 8-24-62 |
| " | 2* | | | " | " |
| " | 3 | X | | " | " |
| | | | | | |
| 954 T1 | 10* | | | 5W | 8-25-62 |
| " | 11* | | | " | " |
| | | | | | |

* Digitized Tape Not Available
** P = Point Mugu, W = Wallops Island

## TABLE I (CONT'D)

## VORTEX AND NON VORTEX FRAMES

### a) Vortex Frames

| Pass, Mode and Camera Number | Frame No. | No Discrepancies Tape vs Neg and Prints | Sequence # Incorrect | Tiros No. and Station** | Date |
|---|---|---|---|---|---|
| 993 D1 | NA | | | 5P | 8-27-62 |
| " | 2 | X | | " | " |
| " | 3 | X | | " | " |
| | | | | | |
| 998 T1 | 9 | X | | 5P | 8-28-62 |
| " | 10 | X | | " | " |
| " | 11 | X | | " | " |
| " | 12 | X | | " | " |
| | | | | | |
| 1007 D1 | 1* | | | 5P | 8-28-62 |
| " | 2* | | | " | " |
| " | 3* | | | " | " |
| " | 4* | | | " | " |
| " | 5* | | | " | " |
| " | 6* | | | " | " |
| | | | | | |
| 1007 T1 | 26* | | | 5P | 8-28-62 |
| " | 27* | | | " | " |
| " | 28* | | | " | " |
| " | 29* | | | " | " |
| " | 30* | | | " | " |
| " | 31* | | | " | " |
| " | 32* | | | " | " |
| | | | | | |
| 1010 T1 | 4 | X | | 5W | 8-28-62 |
| " | 5 | X | | " | " |
| " | 6 | X | | " | " |
| " | 7 | X | | " | " |

* Digitized Tape Not Available

** P = Point Mugu, W = Wallops Island

## TABLE I (CONT'D)

## VORTEX AND NON VORTEX FRAMES

### a) Vortex Frames

| Pass, Mode and Camera Number | Frame No. | No Discrepancies Tape vs Neg and Prints | Sequence # Incorrect | Tiros No. and Station** | Date |
|---|---|---|---|---|---|
| 1011 T1 | 12 | X | | 5P | 8-28-62 |
| " | 13 | X | | " | " |
| " | 14 | X | | " | " |
| | | | | | |
| 1011 T1 | 17* | | | 5P | 8-28-62 |
| " | 18* | | | " | " |
| " | 19* | | | " | " |
| | | | | | |
| 1012 T1 | 9 | X | | 5P | 8-29-62 |
| " | 10 | X | | " | " |
| | | | | | |
| 1053 T1 | 15 | X | 5W | 8-31-64 | |
| " | 16 | X | | " | " |
| " | 17 | X | | " | " |
| " | 19 | X | | " | " |
| " | 22 | X | " | " | |
| | | | | | |
| 1054 T1 | 16 | X | | 5P | 9-1-62 |
| " | 17 | X | | " | " |
| " | 22 | X | | " | " |
| " | 23 | X | | " | " |
| | | | | | |
| 1096 T1 | 23 | X | | 5P | 9-3-62 |
| " | 25 | X | | " | " |
| " | 26 | X | | " | " |
| " | 27 | X | | " | " |
| | | | | | |
| | | | | | |

* Digitized Tape Not Available
** P = Point Mugu, W = Wallops Island

TABLE I (CONT'D)

VORTEX AND NON VORTEX FRAMES

a) Vortex Frames

| Pass, Mode and Camera Number | Frame No. | No Discrepancies Tape vs Neg and Prints | Sequence # Incorrect | Tiros No. and Station** | Date |
|---|---|---|---|---|---|
| 1133 T1 | 8 | X | | 5W | 9-6-62 |
| " | 9 | X | | " | " |
| " | 10 | X | | " | |
| " | 11 | X | | " | " |
| " | 12 | X | | " | " |
| | | | | | |
| 1134 D1 | 4 | X | | 5P | 9-6-62 |
| " | 5 | X | | " | " |
| " | 6 | X | | " | " |
| " | 7 | X | | " | " |
| " | 8 | X | | " | " |
| " | 9 | X | | " | " |
| | | | | | |
| 1137 D1 | 1 | | X | 5W | 9-6-62 |
| " | 2 | | X | " | " |
| | | | | | |
| 1147 T1 | 5 | X | | 5W | 9-7-62 |
| " | 6 | X | | " | " |
| " | 7 | X | | " | " |
| | | | | | |
| 1204 D1 | 11* | | | 5W | 9-11-62 |
| " | 12* | | | " | " |
| | | | | | |
| 1206 T1 | 18 | | X | 5P | 9-11-62 |
| " | 19 | | X | " | " |
| | | | | | |
| | | | | | |
| | | | | | |

* Digitized Tape Not Available

** P = Point Mugu, W = Wallops Island

TABLE I (CONT'D)

VORTEX AND NON VORTEX FRAMES

b) Non Vortex

| Pass, Mode and Camera Number | Frame No. | No Discrepancies Tape vs Neg and Prints | Sequence # Incorrect | Tiros No. and Station** | Date |
|---|---|---|---|---|---|
| 028 T2 | 16* | | | 6W | 9-20-62 |
| " | 17* | | | " | " |
| " | 18* | | | " | " |
| " | 20* | | | " | " |
| " | 21* | | | " | " |
| | | | | | |
| 034 D1 | 5* | | | 6W | 9-20-62 |
| " | 14* | | | " | " |
| | | | | | |
| 062 T2 | 1 | | X | 5W | 6-23-62 |
| " | 2 | | X | " | " |
| 062 T1 | 18 | X | | " | " |
| " | 19 | X | | " | " |
| " | 31* | | | " | " |
| | | | | | |
| 064 T1 | 2* | | | 6P | 9-22-62 |
| " | 3* | | | " | " |
| " | 4* | | | " | " |
| " | 5* | | | " | " |
| " | 6* | | | " | " |
| " | 7* | | | " | " |
| " | 8* | | | " | " |
| " | 9* | | | " | " |
| " | 10* | | | " | " |
| " | 11* | | | " | " |
| " | 12* | | | " | " |
| " | 13* | | | " | " |
| " | 14* | | | " | " |

* Digitized Tape Not Available

** P=Point Mugu, W=Wallops Island

TABLE I (CONT'D)

VORTEX AND NON VORTEX FRAMES

b) Non Vortex

| Pass, Mode and Camera Number | Frame No. | No Discrepancies Tape vs Neg and Prints | Sequence # Incorrect | Tiros No. and Station** | Date |
|---|---|---|---|---|---|
| 064 T1 | 15* | | | 6P | 9-22-62 |
| " | 16* | | | " | " |
| " | 17* | | | " | " |
| | | | | | |
| 144 T2 | 21 | | X | 6W | 9-27-62 |
| " | 22 | | X | " | " |
| " | 23 | | X | " | " |
| " | 24 | | X | " | " |
| " | 26 | | X | " | " |
| | | | | | |
| 160 T1 | 14 | X | | 5W | 6-30-62 |
| | | | | | |
| 484 T1 | 21* | | | 5P | 7-23-62 |
| " | 22* | | | " | " |
| " | 23* | | | " | " |
| " | 24* | | | " | " |
| " | 25* | | | " | " |
| " | 26* | | | " | " |
| | | | | | |
| 596 T1 | 7* | | | 5P | 7-31-62 |
| " | 8* | | | " | " |
| " | 9* | | | " | " |
| " | 10* | | | " | " |
| " | 11* | | | " | " |
| " | 12* | | | " | " |
| " | 13* | | | " | " |
| " | 14* | | | " | " |
| | | | | | |

* Digitized Tape Not Available

** P=Point Mugu, W=Wallops Island

TABLE I (CONT'D)

VORTEX AND NON VORTEX FRAMES

b) Non Vortex

| Pass, Mode, and Camera Number | Frame No. | No Discrepancies Tape vs Neg and Prints | Sequence # Incorrect | Tiros No. and Station** | Date |
|---|---|---|---|---|---|
| 597 T1 | 1* | | | 5P | 7-31-62 |
| " | 2* | | | " | " |
| " | 3* | | | " | " |
| " | 4* | | | " | " |
| " | 5* | | | " | " |
| " | 6* | | | " | " |
| " | 7* | | | " | " |
| " | 8* | | | " | " |
| " | 9* | | | " | " |
| " | 10* | | | " | " |
| " | 11* | | | " | " |
| | | | | | |
| 610 T1 | 16* | | | 5P | 8-1-62 |
| " | 17* | | | " | " |
| " | 18* | | | " | " |
| " | 19* | | | " | " |
| " | 20* | | | " | " |
| " | 21* | | | " | " |
| | | | | | |
| 611 T1 | 9* | | | 5P | 8-1-62 |
| " | 10* | | | " | " |
| " | 11* | | | " | " |
| " | 12* | | | " | " |
| " | 13* | | | " | " |
| " | 14* | | | " | " |
| " | 15* | | | " | " |
| " | 16* | | | " | " |
| " | 17* | | | " | " |

* Digitized Tape Not Available

** P=Point Mugu, W=Wallops Island

TABLE I (CONT'D)

VORTEX AND NON VORTEX FRAMES

b) Non Vortex

| Pass, Mode and Camera Number | Frame No. | No Discrepancies Tape vs Neg and Prints | Sequence # Incorrect | Tiros No. and Station** | Date |
|---|---|---|---|---|---|
| 615 T1 | 21* | | | 5P | 8-1-62 |
| " | 22* | | | " | " |
| " | 23* | | | " | " |
| " | 24* | | | " | " |
| " | 25* | | | " | " |
| | | | | | |
| 666 T1 | 3* | | | 5W | 8-4-62 |
| " | 5* | | | " | " |
| " | 10* | | | " | " |
| | | | | | |
| 667 | 6* | | | 5P | 8-5-62 |
| " | 7* | | | " | " |
| " | 8* | | | " | " |
| " | 9* | | | " | " |
| " | 10* | | | " | " |
| " | 18* | | | " | " |
| " | 19* | | | " | " |
| " | 20* | | | " | " |
| " | 21* | | | " | " |
| " | 22* | | | " | " |
| | | | | | |
| 681 T1 | 8* | | | 5P | 8-6-62 |
| " | 9* | | | " | " |
| " | 10* | | | " | " |
| " | 11* | | | " | " |
| | | | | | |
| | | | | | |
| | | | | | |

*Digitized Tape Not Available

**P=Point Mugu, W=Wallops Island

TABLE I (CONT'D)

VORTEX AND NON VORTEX FRAMES

b) Non Vortex

| Pass, Mode, and Camera Number | Frame No. | No Discrepancies Tape vs Neg and Prints | Sequence # Incorrect | Tiros No. and Station** | Date |
|---|---|---|---|---|---|
| 684 T1 | 5* | | | 5W | 8-6-62 |
| | | | | | |
| 685 T1 | 16 | X | | 5W | 8-6-62 |
| " | 17 | X | | " | " |
| " | 18 | X | | " | " |
| | | | | | |
| 806 T1 | 5 | X | | 5W | 8-14-62 |
| " | 6 | X | | " | " |
| " | 7 | X | | " | " |
| " | 8 | X | | " | " |
| " | 9* | | | " | " |
| " | 11 | X | | " | " |
| " | 12 | X | | " | " |
| | | | | | |
| 813 D1 | 3* | | | 5P | 8-15-62 |
| " | 4* | | | " | " |
| 813 T1 | 1 | X | | " | " |
| " | 2 | X | | " | " |
| " | 3 | X | | " | " |
| | | | | | |
| 922 D1 | 3* | | | 5P | 8-22-62 |
| " | 4* | | | " | " |
| " | 5* | | | " | " |
| | | | | | |
| 926 T1 | 6 | X | | 5P | 8-23-62 |
| " | 7 | X | | " | " |
| " | 8 | X | | | " |
| | | | | " | " |

*Digitized Tape Not Available

**P=Point Mugu, W=Wallops Island

TABLE I (CONT'D)

VORTEX AND NON VORTEX FRAMES

b) Non Vortex

| Pass, Mode and Camera Number | Frame No. | No Discrepancies Tape vs Neg and Prints | Sequence # Incorrect | Tiros No. and Station ** | Date |
|---|---|---|---|---|---|
| 951 T1 | 7 | X | | 5P | 8-24-62 |
| " | 8 | X | | " | " |
| " | 9 | X | | " | " |
| | | | | | |
| 954 T1 | 23* | | | 5W | 8-25-62 |
| | | | | | |
| 993 T1 | 6 | X | | 5P | 8-27-62 |
| " | 7 | X | | " | " |
| " | 8 | X | | " | " |
| | | | | | |
| 998 T1 | 14 | X | | 5P | 8-28-62 |
| " | 15 | X | | " | " |
| " | 16 | X | | " | " |
| " | 17 | X | | " | " |
| | | | | | |
| 1005 T1 | 19 | X | | 5W | 8-28-62 |
| " | 20 | X | | " | " |
| " | 23 | X | | " | " |
| | | | | | |
| 1007 D1 | 9* | | | 5P | 8-28-62 |
| " | 10* | | | " | " |
| " | 11* | | | " | " |
| " | 12* | | | " | " |
| " | 13* | | | " | " |
| " | 14* | | | " | " |
| | | | | | |
| | | | | | |
| | | | | | |

*Digitized Tape Not Available

** P=Point Mugu, W=Wallops Island

TABLE I (CONT'D)

VORTEX AND NON VORTEX FRAMES

b) Non Vortex

| Pass, Mode, and Camera Number | Frame No. | No Discrepancies Tape vs Neg and Prints | Sequence # Incorrect | Tiros No. and Station** | Date |
|---|---|---|---|---|---|
| 1007 T1 | 17* | | | 5P | 8-28-62 |
| " | 18* | | | " | " |
| " | 19 | X | | " | " |
| " | 20* | | | " | " |
| " | 21* | | | " | " |
| " | 22* | | | " | " |
| " | 23* | | | " | " |
| | | | | | |
| 1011 T1 | NA | | | 5P | 8-28-62 |
| " | 7 | X | | " | " |
| " | 8 | X | | " | " |
| | | | | | |
| 1011 T1 | 22 | X | | 5P | 8-28-62 |
| " | 23* | | | " | " |
| " | 24 | X | | " | " |
| | | | | | |
| 1012 T1 | 2 | X | | 5P | 8-29-62 |
| " | 3 | X | | " | " |
| | | | | | |
| 1054 T1 | 2 | X | | 5P | 9-1-62 |
| " k | 4* | | | " | " |
| " | 5* | | | " | " |
| " | 6* | | | " | " |
| | | | | | |
| 1094 T1 | 1 | X | | 5W | 9-3-62 |
| " | 2 | X | | " | " |
| " | 3 | X | | " | " |
| " | 4 | X | | " | " |

*Digitized Tape Not Available

** P=Point Mugu, W=Wallops Island

TABLE I (CONT'D)

VORTEX AND NON VORTEX FRAMES

b) Non Vortex

| Pass, Mode and Camera Number | Frame No. | No Discrepancies Tape vs Neg and Prints | Sequence # Incorrect | Tiros No. and Station** | Date |
|---|---|---|---|---|---|
| 1094 T1 | 5 | X | | 5W | 9-3-62 |
| " | 6 | X | | " | " |
| " | 7 | X | | " | " |
| " | 8 | X | | " | " |
| " | 10 | X | | " | " |
| " | 11 | X | | " | " |
| " | 14 | X | | " | " |
| " | 15 | X | | " | " |
| | | | | | |
| 1096 T1 | 15 | X | | 5P | 9-3-62 |
| " | 16 | X | | " | " |
| " | 17* | | | " | " |
| " | 18 | X | | " | " |
| | | | | | |
| 1134 D1 | 12 | X | | 5P | 9-6-62 |
| " | 13 | X | | " | " |
| " | 14 | X | | " | " |
| " | 15 | X | | " | " |
| " | 16 | X | | " | " |
| " | 17 | X | | " | " |
| | | | | | |
| 1206 T1 | 22 | | X | 5P | 9-11-62 |
| " | 23 | | X | " | " |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |

*Digitized Tape Not Available

**P=Point Mugu, W=Wallops Island

the panel information on the negatives. These corrections are not indicated in the catalog.

275 digitized frames have been received from the ISS in New York. It has been ascertained that the digitized frames agree with the prints, rather than the negatives. Only 116 frames are from the set requested. 56 of these are frames containing vortices and 60 are non-vortex frames. Table I shows the frames requested, the usable frames received and the incorrect frames with correct headers received. Some digitized frames received also proved "unusable" when it was discovered that TIROS VI frames rather than TIROS V frames should have been requested. Table II is a list of all digitized frames received.

In view of the limited number of vortex frames available, another set of digitized frames were requested. These are all vortex frames, and are listed in Table III.

It is anticipated that the set of non-vortex frames can be expanded, utilizing frames not currently classified as "usable". The number of vortex frames is not adequate. If additional frames cannot be obtained, the sample set will be expanded by translating available frames. Provided that these translations are large relative to the wavelength of the main information frequencies, the resultant patterns will be new to the decision mechanism, which has no inherent translation invariance features. The resulting network design will provide greater translation invariance, at the expense of vortex shape invariance.

TABLE II

FRAMES ON DIGITIZED TAPE

| Tiros | Pass | Seq. No. | Frame Avail-able | Selected Frames |
|---|---|---|---|---|
| 5 | 28 | 1 | 16 | X |
| | | | 17 | X |
| | | | 18 | X |
| 5 | 28 | 2 | 16 | |
| | | | 17 | |
| | | | 18 | |
| | | | 20 | |
| | | | 21 | |
| 5 | 62 | 2 | 1 | |
| | | | 2 | |
| 5 | 62 | 3 | 18 | X |
| | | | 19 | X |
| 5 | 65 | 1 | 1 | |
| | | | 2 | |
| | | | 3 | |
| | | | 4 | |
| | | | 5 | |
| | | | 6 | |
| | | | 7 | |
| | | | 8 | |
| | | | 9 | |
| | | | 10 | |
| 5 | 144 | 1 | 21 | |
| | | | 22 | |
| | | | 23 | |
| | | | 24 | |
| | | | 26 | |

| Tiros | Pass | Seq. No. | Frame Avail-able | Selected Frames |
|---|---|---|---|---|
| 5 | 144 | 2 | 21 | |
| | | | 22 | |
| | | | 23 | |
| | | | 24 | |
| | | | 26 | |
| 5 | 145 | 1 | 11 | |
| | | | 12 | |
| | | | 13 | |
| | | | 14 | |
| | | | 15 | |
| 5 | 145 | 2 | 11 | |
| | | | 12 | |
| | | | 13 | |
| | | | 14 | |
| | | | 15 | |
| 5 | 160 | 1 | 14 | X |
| | 160 | 2 | 14 | |
| 5 | 484 | 1 | 10 | |
| | | | 11 | |
| | | | 12 | |
| | | | 13 | |
| | | | 14 | |
| | | | 15 | |
| | | | 16 | |
| | | | 17 | |
| | | | 18 | |
| | | | 19 | |
| | | | 20 | |

○ = Vortex

X = Frames Being Used

TABLE II (CONT'D)

FRAMES ON DIGITIZED TAPE

| Tiros | Pass | Seq. No. | Frame Avail- able | Selected Frames |
|---|---|---|---|---|
| 5 | 484 | 1 | 21 | |
| 5 | 598 | 1 | 23 | |
| | | | 24 | X |
| | | | 25 | X |
| | | | 26 | X |
| | | | 28 | X |
| | | | 32 | X |
| 5 | 666 | 1 | 3 | |
| | | | 4 | |
| | | | 5 | |
| | | | 6 | |
| 5 | 666 | 2 | 3 | X |
| | | | 4 | |
| | | | 5 | X |
| | | | 6 | |
| 5 | 685 | 1 | 16 | X |
| | | | 17 | X |
| | | | 18 | X |
| 5 | 806 | 1 | 5 | X |
| | | | 6 | X |
| | | | 7 | X |
| | | | 8 | X |
| | | | 11 | X |
| | | | 12 | X |

| Tiros | Pass | Seq. No. | Frame Avail- able | Selected Frames |
|---|---|---|---|---|
| 5 | 813 | 1 | 1 | X |
| | | | 2 | X |
| | | | 3 | X |
| | | | 4 | |
| | | | 5 | |
| | | | 6 | X |
| | | | 7 | X |
| | | | 8 | X |
| | | | 9 | X |
| | | | 10 | X |
| 5 | 921 | 2 | 16 | |
| | | | 17 | |
| | | | 18 | |
| | | | 19 | |
| | | | 20 | |
| | | | 21 | |
| 5 | 926 | 1 | 1 | X |
| | | | 2 | X |
| | | | 3 | X |
| | | | 4 | |
| | | | 5 | |
| | | | 6 | X |
| | | | 7 | X |
| | | | 8 | X |
| | | | 9 | |
| | | | 10 | |
| | | | 11 | |
| | | | 12 | |
| | | | 14 | |
| | | | 16 | |

○ = Vortex

X = Frames Being Used

TABLE II (CONT'D)

FRAMES ON DIGITIZED TAPE

| Tiros | Pass | Seq. No. | Frame Available | Selected Frames |
|---|---|---|---|---|
| 5 | 926 | 1 | 18 | |
| | | | 19 | |
| | | | 20 | |
| | | | 22 | |
| | | | 23 | |
| | | | 24 | |
| | | | 25 | |
| | | | 26 | |
| | | | 28 | |
| | | | 29 | |
| | | | 30 | |
| | | | 31 | |
| 5 | 951 | 1 | 3 | X |
| | | | 7 | X |
| | | | 8 | X |
| | | | 9 | X |
| 5 | 993 | 2 | 2 | X |
| | | | 3 | X |
| | | | 6 | X |
| | | | 7 | X |
| | | | 8 | X |
| 5 | 998 | 1 | 9 | X |
| | | | 10 | X |
| | | | 11 | X |
| | | | 12 | X |
| | | | 14 | X |
| | | | 15 | X |
| | | | 16 | X |
| | | | 17 | X |

| Tiros | Pass | Seq. No. | Frame Available | Selected Frames |
|---|---|---|---|---|
| 5 | 1005 | 2 | 19 | X |
| | | | 20 | X |
| | | | 23 | X |
| 5 | 1007 | 2 | 19 | X |
| 5 | 1010 | 1 | 3 | |
| | | | 4 | X |
| | | | 5 | X |
| | | | 6 | X |
| | | | 7 | X |
| | | | 8 | |
| | | | 9 | |
| | | | 10 | |
| 5 | 1011 | 1 | 1 | |
| | | | 2 | |
| | | | 3 | |
| | | | 4 | |
| | | | 5 | |
| | | | 7 | X |
| | | | 8 | X |
| | | | 12 | X |
| | | | 13 | X |
| | | | 14 | X |
| | | | 22 | X |
| | | | 24 | X |
| | | | 25 | |
| | | | 29 | |
| | | | 30 | |

○ = Vortex

X = Frames Being Used

TABLE II (CONT'D)

FRAMES ON DIGITIZED TAPE

| Tiros | Pass | Seq. No. | Frame Avail-able | Selected Frames |
|---|---|---|---|---|
| 5 | 1012 | 1 | 2 | X |
| | | | 3 | X |
| | | | 4 | |
| | | | 5 | |
| | | | 6 | |
| | | | 7 | |
| | | | 8 | |
| | | | 9 | X |
| | | | 10 | X |
| | | | 11 | |
| | | | 12 | |
| | | | 13 | |
| | | | 14 | |
| | | | 15 | |
| | | | 16 | |
| | | | 17 | |
| | | | 18 | |
| | | | 19 | |
| | | | 20 | |
| | | | 22 | |
| | | | 23 | |
| | | | 24 | |
| | | | 25 | |
| | | | 26 | |
| | | | 29 | |
| | | | 30 | |
| | | | 31 | |

| Tiros | Pass | Seq. No. | Frame Avail-able | Selected Frames |
|---|---|---|---|---|
| 5 | 1053 | 1 | 15 | X |
| | | | 16 | X |
| | | | 17 | X |
| | | | 19 | X |
| | | | 22 | X |
| 5 | 1054 | 1 | 1 | |
| | | | 2 | X |
| | | | 8 | |
| | | | 9 | |
| | | | 10 | |
| | | | 11 | |
| | | | 14 | |
| | | | 15 | |
| | | | 16 | X |
| | | | 17 | X |
| | | | 22 | X |
| | | | 23 | X |
| | | | 24 | |
| | | | 25 | |
| | | | 26 | |
| | | | 27 | |
| | | | 28 | |
| | | | 29 | |
| | | | 30 | |
| | | | 31 | |

◯ = Vortex

X = Frames Being Used

TABLE II (CONT'D)

FRAMES ON DIGITIZED TAPE

| Tiros | Pass | Seq. No. | Frame Avail- able | Selected Frames |
|---|---|---|---|---|
| 5 | 1094 | 1 | 1 | X |
| | | | 2 | X |
| | | | 3 | X |
| | | | 4 | X |
| | | | 5 | X |
| | | | 6 | X |
| | | | 7 | X |
| | | | 8 | X |
| | | | 10 | X |
| | | | 11 | X |
| | | | 14 | X |
| | | | 15 | X |
| | | | 16 | |
| | | | 18 | |
| 5 | 1096 | 1 | 15 | X |
| | | | 16 | X |
| | | | 17 | X |
| | | | 18 | X |
| | | | 19 | X |
| | | | 23 | X |
| | | | 24 | |
| | | | 25 | X |
| | | | 26 | X |
| | | | 27 | X |
| 5 | 1133 | 1 | 8 | X |
| | | | 9 | X |
| | | | 10 | X |
| | | | 11 | X |
| | | | 12 | X |

| Tiros | Pass | Seq. No. | Frame Avail- able | Selected Frames |
|---|---|---|---|---|
| 5 | 1134 | 1 | 4 | |
| | | | 5 | |
| | | | 6 | |
| | | | 7 | |
| | | | 8 | |
| | | | 9 | |
| | | | 10 | |
| | | | 11 | |
| | | | 12 | |
| | | | 13 | |
| | | | 14 | |
| | | | 15 | |
| | | | 16 | |
| | | | 17 | |
| | | | 18 | |
| | | | 19 | |
| | | | 20 | |
| | | | 21 | |
| | | | 22 | |
| | | | 23 | |
| | | | 24 | |
| | | | 25 | |
| | | | 26 | |
| | | | 27 | |
| | | | 28 | |
| | | | 30 | |
| | | | 31 | |
| | | | 32 | |

○ = Vortex

X = Frames Being Used

## TABLE II (CONT'D)

## FRAMES ON DIGITIZED TAPE

| Tiros | Pass | Seq. No. | Frame Avail-able | Selected Frames |
|---|---|---|---|---|
| 5 | 1134 | 2 | 1 | |
| | | | 2 | |
| | | | 3 | |
| | | | 4 | X |
| | | | 5 | X |
| | | | 6 | X |
| | | | 7 | X |
| | | | 8 | X |
| | | | 9 | X |
| | | | 10 | |
| | | | 11 | |
| | | | 12 | |
| 5 | 1137 | 1 | 1 | |
| | | | 2 | |
| 5 | 1147 | 1 | 5 | X |
| | | | 6 | X |
| | | | 7 | X |
| 5 | 1206 | 1 | 14 | |
| | | | 15 | |
| | | | 16 | |
| | | | 17 | |
| | | | 18 | |
| | | | 19 | |
| | | | 20 | |
| | | | 21 | |
| | | | 22 | |
| | | | 23 | |
| | | | 24 | |

| Tiros | Pass | Seq. No. | Frame Avail-able | Selected Frames |
|---|---|---|---|---|
| 5 | 1206 | 1 | 25 | |
| 5 | 1206 | 2 | 6 | |
| | | | 7 | |
| | | | 8 | |
| | | | 9 | |
| | | | 10 | |

○ = Vortex

X = Frames Being Used

## TABLE III

## ADDITIONAL SELECTED VORTEX FRAMES

| Tiros Number | Orbit Number Mode & Camera Number | Frames | Time (GMT) | Date |
|---|---|---|---|---|
| 5 | 017/016 T1 | 3,4 | 1539 | 20 June 1962 |
| ↑ | 056/052 T1 | 7,9 | 0351 | 23 June 1962 |
| | 090/089 T1 | 15, 17, 19 | 1200 | 24 Sept 1962 |
| | 667 D1 | 1, 2, 3 | 0107 | 5 Aug 1962 |
| | 797/797 T1 | 11, 15, 19 | 0430 | 14 Aug 1962 |
| | 799/798 T1 | 9, 11, 13 | 0604 | 14 Aug 1962 |
| | 807 D1 | 12, 13, 14 | 1927 | 14 Aug 1962 |
| | 813/812 T1 | 13, 15 | 0513 | 15 Aug 1962 |
| | 855/855 T1 | 13, 14 | 0351 | 18 Aug 1962 |
| | 870/870 T1 | 11, 13, 15 | 0458 | 19 Aug 1962 |
| | 884/884 T1 | 11, 13 | 0426 | 20 Aug 1962 |
| | 897/896 T1 | 2,3 | 0203 | 21 Aug 1962 |
| | 898/898 T1 | 11, 15, 17 | 0352 | 21 Aug 1962 |
| | 908/907 T1 | 2, 4, 6 | 2033 | 21 Aug 1962 |
| | 912/912 T1 | 11, 15 | 0319 | 22 Aug 1962 |
| | 923/922 T1 | 1, 4 | 2140 | 22 Aug 1962 |
| | 936 D1 | 1, 3, 7 | 1927 | 23 Aug 1962 |
| | 940/939 T1 | 7, 9 | 0207 | 24 Aug 1962 |
| | 950/949 T1 | 23, 25, 26 | 1732 | 24 Aug 1962 |
| | 952/953 T1 | 7, 11, 13, 14, 15 | 0134 | 25 Aug 1962 |
| | 955/955 T1 | 13, 15, 17 | 0320 | 25 Aug 1962 |
| | 963/962 T1 | 23, 25, 27 | 1515 | 25 Aug 1962 |
| | 964 D1 | 2, 4, 6 | 1820 | 25 Aug 1962 |
| | 926 D1 | 24, 26, 27 | 1430 | 26 Aug 1962 |
| | 978/977 T1 | 13, 15, 21 | 1624 | 26 Aug 1962 |
| | 992/991 T1 | 8, 9, 17 | 1545 | 27 Aug 1962 |
| ↓ | 1007/1006 T1 | 27, 29, 31 | 1703 | 28 Aug 1962 |
| 5 | 1007 D1 | 2, 4, 6 | 1820 | 28 Aug 1962 |

## TABLE III (CONT'D)

## ADDITIONAL SELECTED VORTEX FRAMES

| Tiros Number | Orbit Number Mode & Camera Number | | Frames | Time (GMT) | Date |
|---|---|---|---|---|---|
| 5 | 1019/1017 | T1 | 11, 15, 17 | 1066 | 29 Aug 1962 |
| | 1019 | D1 | 12 | 1431 | 29 Aug 1962 |
| | 1020/1020 | T1 | 7, 9, 11 | 1600 | 29 Aug 1962 |
| | 1024/1024 | T1 | 7, 9 | 2250 | 29 Aug 1962 |
| | 1052/1052 | T1 | 1, 2, 3 | 2143 | 31 Aug 1962 |
| | 1062/106 | T1 | 29, 30, 31 | 1305 | 1 Sept 1962 |
| | 1093 | D1 | 2, 3 | 1826 | 3 Sept 1962 |
| | 1107 | D1 | 2, 8, 11 | 1752 | 4 Sept 1962 |
| | 1125/1125 | T1 | 8, 9 | 2329 | 5 Sept 1962 |
| | 1133 | D1 | 9, 10, 11 | 1325 | 6 Sept 1962 |
| | 1140/1140 | T1 | 7, 11, 13 | 0109 | 7 Sept 1962 |
| | 1151 | D1 | 1, 3, 4 | 1953 | 7 Sept 1962 |
| | 1151/1151 | T1 | 23, 25, 27 | 1935 | 7 Sept 1962 |
| | 1163/1162 | T1 | 5, 7, 9 | 1405 | 8 Sept 1962 |
| | 1181/1181 | T1 | 1, 3, 5 | 2153 | 9 Sept 1962 |
| | 1189/1187 | T1 | 20, 21, 22 | 0505 | 10 Sept 1962 |
| | 1193/1192 | T1 | 13, 15, 17 | 1630 | 10 Sept 1962 |
| | 1203/1202 | T1 | 28, 29, 30 | 0915 | 11 Sept 1962 |
| | 1205 | D1 | 9, 10, 12 | 1218 | 11 Sept 1962 |
| | 1224/1224 | T1 | 11, 13, 17 | 2156 | 12 Sept 1962 |
| | 1290/1289 | T1 | 3132 | 1057 | 17 Sept 1962 |
| | 1363/1362 | T1 | 27, 28, 29 | 1318 | 22 Sept 1962 |
| | 1366 | D1 | 6, 8 | 2000 | 22 Sept 1962 |
| | 1463 | D1 | 2, 3, 4 | 1419 | 29 Sept 1962 |
| | 1493/1493 | T1 | 23, 25 | 1500 | 1 Oct 1962 |
| | 1522 | D1 | 7, 9, 10 | 1710 | 3 Oct 1962 |
| | 1534 | D1 | 14, 16 | 1312 | 4 Oct 1962 |
| 5 | 1549/1548 | T1 | 23, 25, 27 | 1245 | 5 Oct 1962 |

TABLE III (CONT'D)

ADDITIONAL SELECTED VORTEX FRAMES

| Tiros Number | Orbit Number Mode & Camera Number | | Frames | Time (GMT) | Date |
|---|---|---|---|---|---|
| 5 | 1562 | D1 | 2, 3, 4 | 1206 | 6 Oct 1962 |
| | 2227/2227 | T1 | 1, 2, 5 | 2052 | 21 Nov 1962 |
| | 2425/2423 | T1 | 21, 23 | 1334 | 5 Dec 1962 |
| | 2439/2437 | T1 | 27, 29, 31 | 1301 | 6 Dec 1962 |
| | 2440 | D1 | 9, 11, 13 | 1757 | 6 Dec 1962 |
| | 2482/2481 | T1 | 25, 27, 29 | 1433 | 9 Dec 1962 |
| 5 | 2569 | D1 | 1, 2 | 1758 | 15 Dec 1962 |

## 3.0 COMPUTER PROGRAMS

The computer programming portion of the Cloud Pattern project encountered a series of frustrating setbacks during this reporting period. The first magnetic tape containing digitized cloud patterns was late in arriving. This caused a delay in getting the pictures transcribed onto Astropower tapes, verified, and categorized. With the arrival of the second magnetic tape from NASA it was discovered that several of the cloud patterns were duplicates of those appearing on the first magnetic tape. To date, our file set of cloud patterns, both vortex and non-vortex patterns, is approximately 60% complete.

NASA furnished Astropower Laboratory with a cloud cover plotting program which renders the digitized TIROS weather data into photographic form. The program makes it possible to obtain either microfilm copies of the original data or hard copy prints. This will facilitate the verification procedure which is necessary in order to insure that the categorization of cloud patterns is done correctly. However, the cloud cover plotting program didn't function as well as was originally anticipated. About 50% of the trouble stemmed from in-house systems' incompatibilities. The remainder of the difficulty was with flaws in the program logic. Unfortunately, the aggregate program difficulties, coupled with "less than ideal" computer turn-around time, proved to have a detrimental effect on the project schedule.

Currently, the programming effort for the cloud pattern project includes three computer programs. These are: (1) CP01 Convert & Repack TIROS Data; (2) CP03 Edit & Rotate Cloud Patterns; and (3) CP05 Cloud Pattern Computer Design. Program CP01 converts the gray scale from a 64 level to a 16 level scale and condenses (repacks) the intensity points so that the entire pattern can be accommodated in the computer at one time.

Program CP03 edits the cloud pattern picture to trim the size down from a 240 x 240 matrix to a 180 x 180 matrix. This editing procedure is expected to eliminate most of the objectionable features, such as horizons, from the pattern set in the majority of cases where such features exist. It will also serve to quadruple the size of this cloud pattern set by rotating the edited input picture through $90^{\circ}$, $180^{\circ}$, and $270^{\circ}$ orientations thus creating four output pictures for each input picture. This program is in the checkout phase.

The cloud pattern computer design program (CP05) is in the process of being coded. It is anticipated that checkout of this program should be under way in the latter part of January.

During the next reporting period it is expected (1) that all requested cloud patterns will have been received, verified, and categorized; (2) that all the required programs will be operational; and (3) that the generation of logic unit specifications will be started.

## 4.0 DESIGN TECHNIQUES

Eight design techniques were described in the first quarterly report. These techniques are to be studied empirically on a sample problem. These investigations were also described in the first quarterly report.

### 4.1 Empirical Studies

During the past quarter, these investigations have been plagued by computer malfunctions resulting in very slow turn around time, persistent program bugs requiring many turn arounds, and system problems resulting in the loss of a number of data tapes and program passes utilizing these tapes. Nearly all of these difficulties seem to be over now, but these investigations are about one month behind schedule. The estimated completion date of this phase of the program is now mid-January. Partial results are presented in this report.

The status of this study is described here. The following computer programs are completely operational.

(1) All control programs required to generate a machine design for a given algorithm and a given sample pattern deck. This includes two main programs and seven subroutines. One of these is a routine which extracts the eigenvalues and eigenvectors of a 10 by 10 matrix in .45 seconds. (At the time of the last quarterly report the lack of a routine which took less than 2-1/2 seconds was a cause of some concern.)

(2) All of the subroutines specific to individual design algorithms. This is eight operational routines.

(3) Three programs used to verify the generality of a given machine design against any of the sample pattern sets in use. These will be combined into a single program in the near future.

(4) The program utilized to generate sample pattern sets of varying gray levels by means of linear transformations on the gray levels of the original pattern decks.

The list of programs not yet debugged includes Fortran IV versions of all programs described in (1) above. System changeover from Fortran II to Fortran IV occurs January 1. Approval has been obtained to continue the Fortran II program if necessary. A program to generate machine designs using several standard perceptron approaches has been written, but is not yet debugged. Machine designs generated by this last program will be used to provide standards by which the generality of the designs produced by the eight algorithms are judged. Without such a standard, the generality of machine design and the generality of sample patterns are completely confounded.

Figures 1 and 2 compare learning rates for the algorithms for one sample problem, Figures 3 and 4 for a second problem. The same sample patterns (Deck I-BW) are used in both problems, but the two classifications of the twelve letters are different. These are Classifications 2 and 3 given in the first quarterly, representing the easier and harder classifications respectively.

In Figures 1 and 3, the number of patterns in the design sample which are misclassified are presented as a function of the number of units in the machine design. Figures 2 and 4 provide average percentage decreases as given by the formula

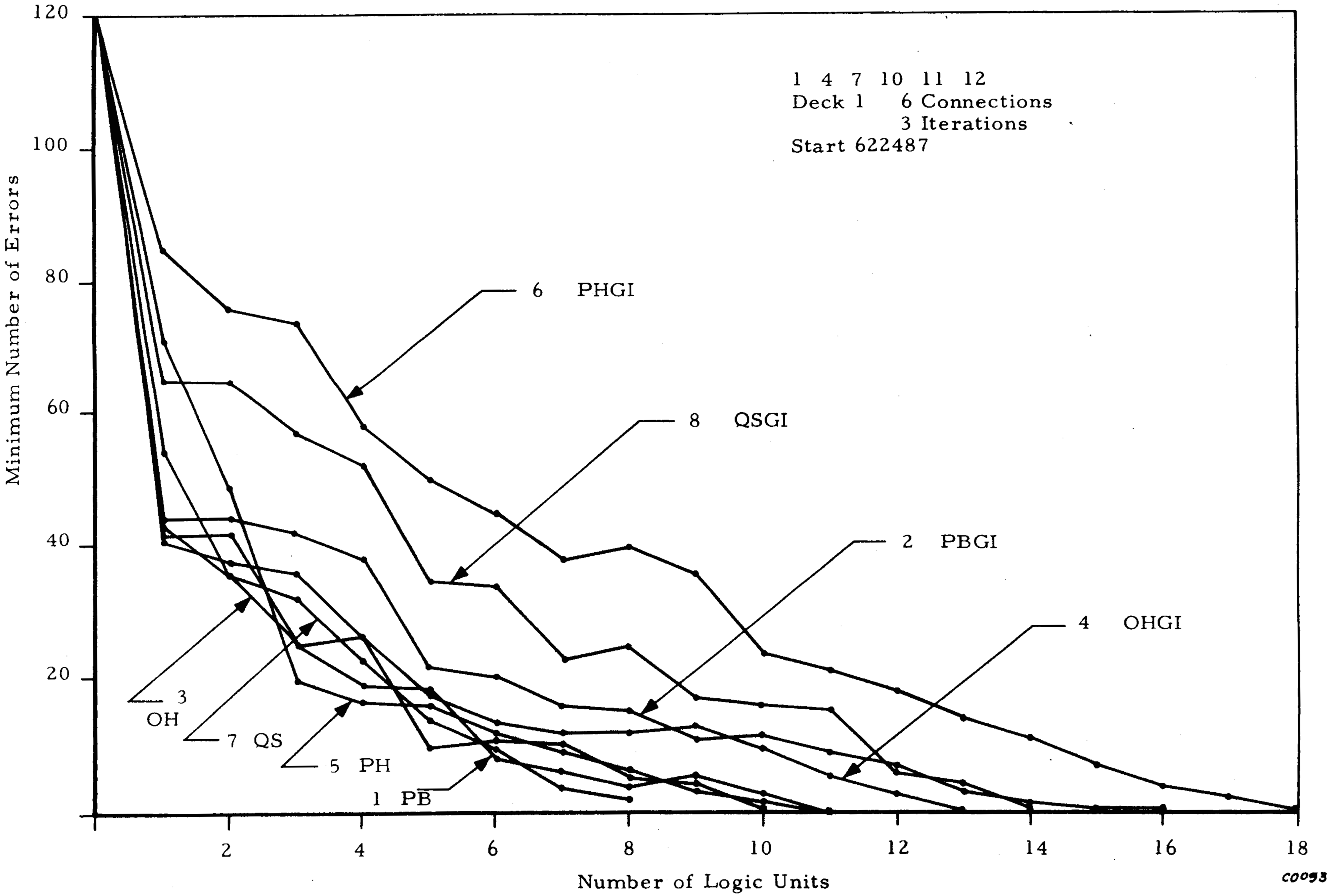
$$APD = 100 - 100 \left(1 - \frac{L}{240}\right)^{1/N}$$

where N is the number of units, L the loss, and 240 the initial loss. For a given number of units this number is monotonic with the loss function, and seems to provide a neater presentation of the data.

In both examples, only the design algorithms were varied. Three iterations were used in each case, as were six-dimensional subspaces for the property filters. Identical starting numbers for the random number generators provided identical collections of subspaces to each design routine. Twenty units were generated for each one included in the machine designs.

The gray invariant version of technique PH (designated PHGI) has one parameter with no analytical basis — the threshold of the logic units. Figures 1 through 4 indicate the desirability of varying this parameter.

The conclusions to be drawn from these figures, other than the desirability of "tuning" technique PHGI, should be quite tentative. The generality of these designs is more important than "learning" rates. Furthermore,



1 4 7 10 11 12
Deck 1 6 Connections
3 Iterations
Start 622487
6 PHGI
8 QSGI
2 PBGI
4 OHGI
3 OH
7 QS
5 PH
1 PB
Minimum Number of Errors
Number of Logic Units
C0093


Figure 1.

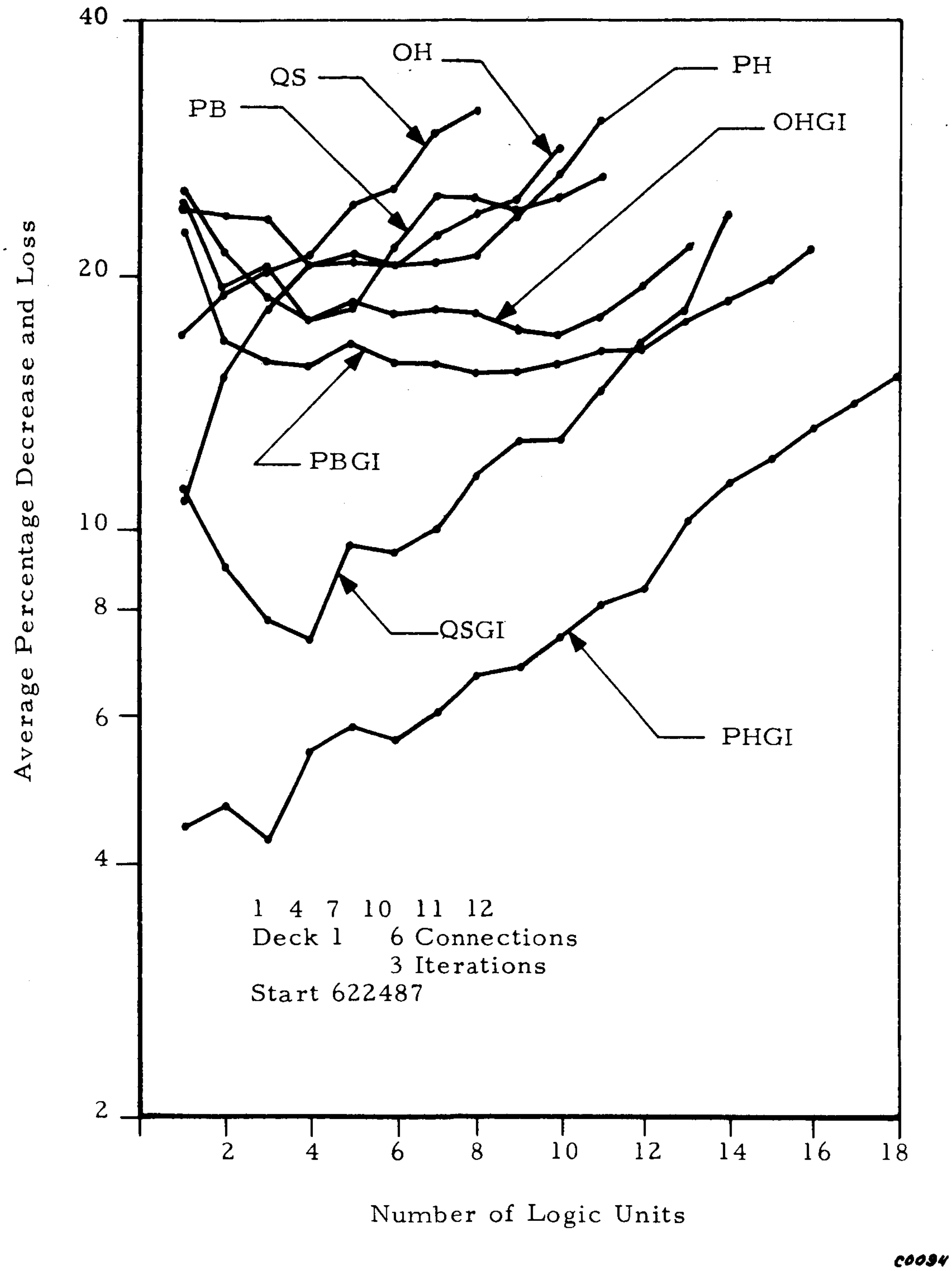

40
20
10
8
6
4
2
Average Percentage Decrease and Loss
2
4
6
8
10
12
14
16
18
Number of Logic Units
OH
QS
PB
PH
OHGI
PBGI
QSGI
PHGI
1 4 7 10 11 12
Deck 1 6 Connections
3 Iterations
Start 622487
C0034

Figure 2

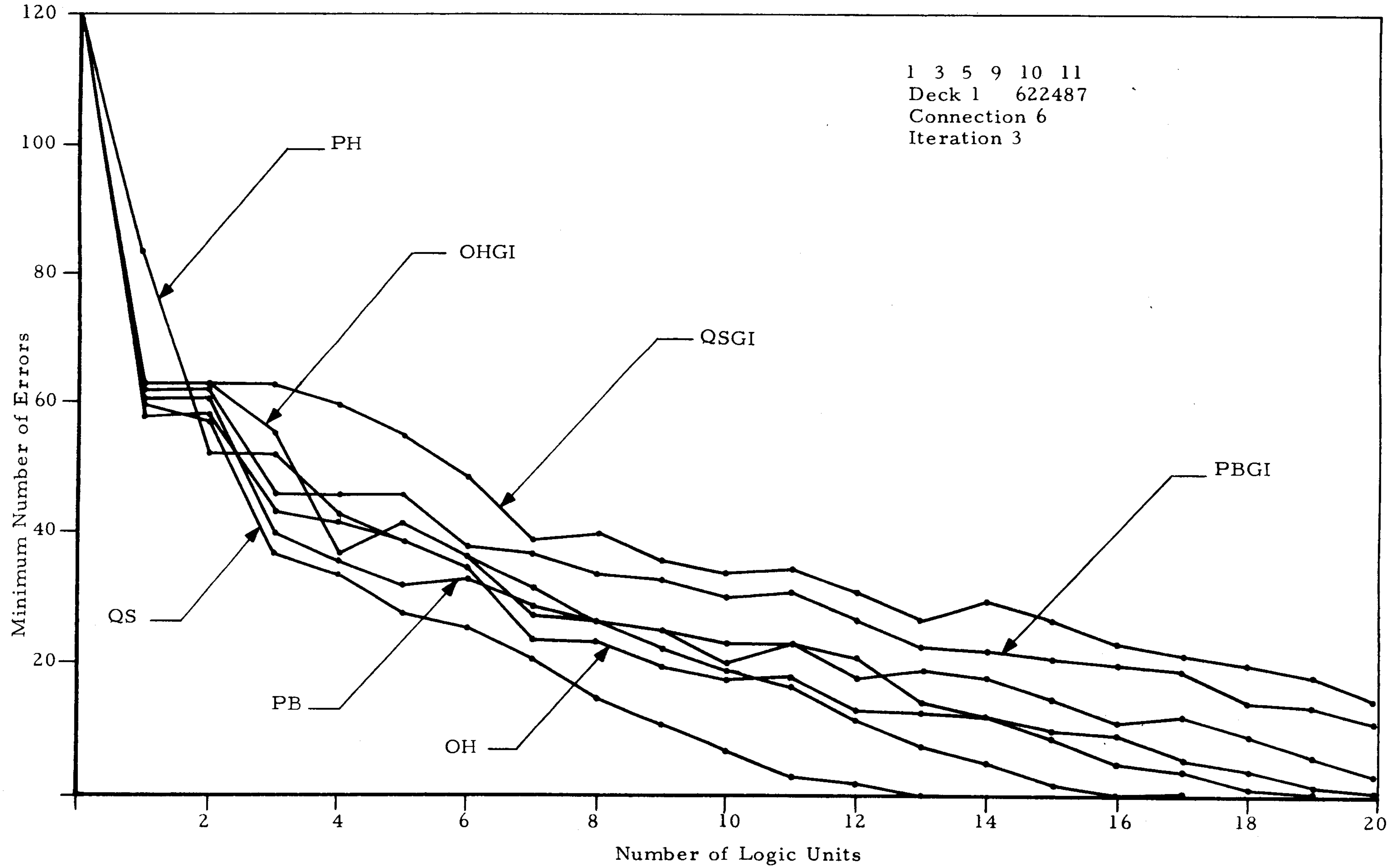
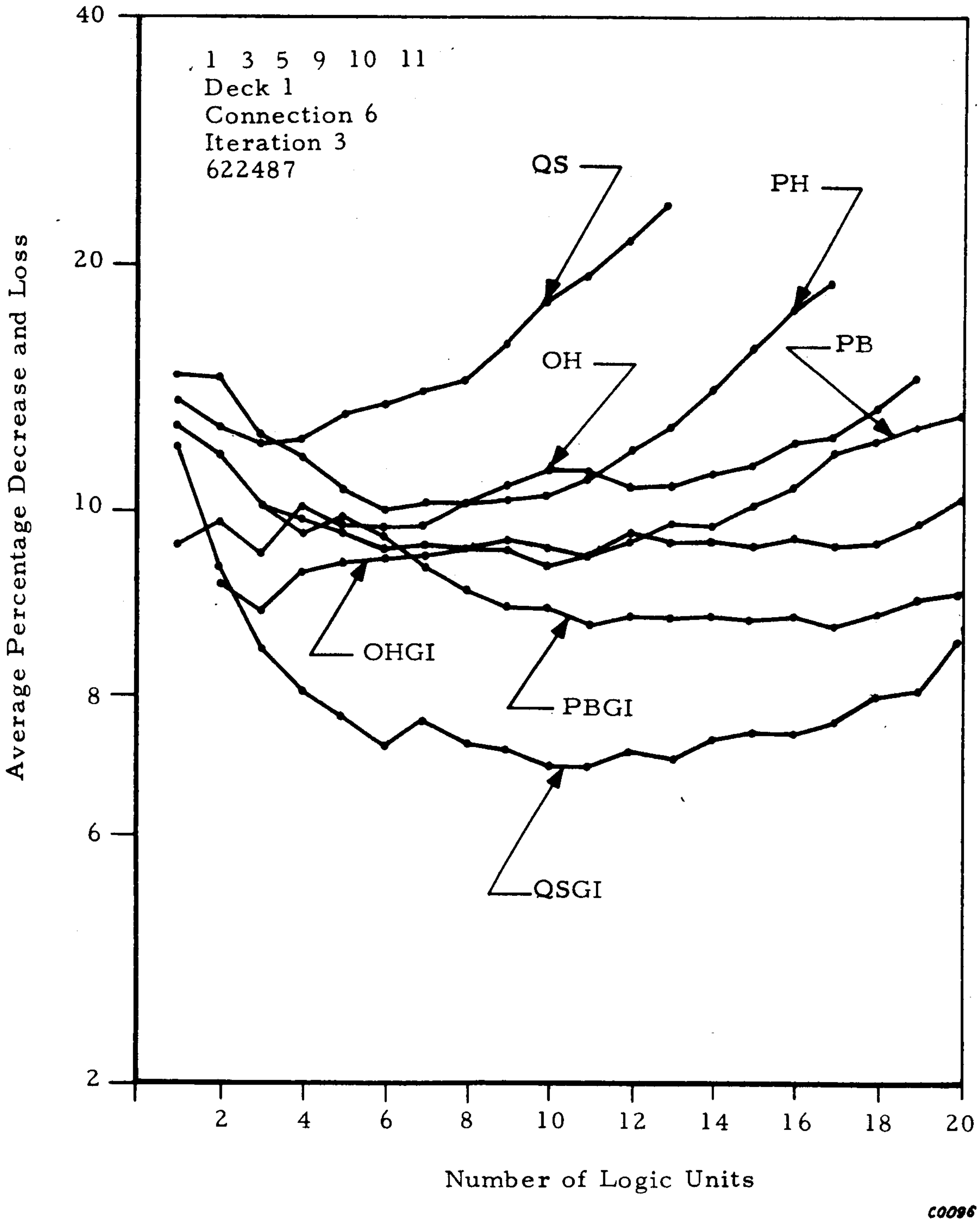

1 3 5 9 10 11
Deck 1 622487
Connection 6
Iteration 3
PH
OHGI
QSGI
PBGI
QS
PB
OH
120
100
80
60
40
20
2
4
6
8
10
12
14
16
18
20
Minimum Number of Errors
Number of Logic Units

Figure 3



40
20
10
8
6
2
1 3 5 9 10 11
Deck 1
Connection 6
Iteration 3
622487
QS
PH
PB
OH
OHGI
PBGI
QSGI
Average Percentage Decrease and Loss
2
4
6
8
10
12
14
16
18
20
Number of Logic Units
C0096


Figure 4

the dimensionality of the subspaces (the number of input connections per logic unit) affects performance. This dimensionality also affects the computer time required for a design and the ease of implementation. The techniques probably should be compared with different dimensionalities reflecting the natural differences in the systems. The OH techniques required 60% more computer time than the PB techniques for the design of the same number of six input units. The PH techniques require 60% more time than the OH techniques, and the QS techniques require 50% more time than the PH techniques. Complexity of implementation is equal for all techniques except PHGI, QS and QSGI. PHGI is somewhat more difficult to implement, while QS and QSGI are considerably more difficult.

As a final consideration, the GI techniques provide an invariance to gray scale transformations. The PH and the QS techniques provide a rejection of spurious (in TIROS frames) clues. These clues are not spurious in separating the sample patterns, however. It is thus to be expected that "learning" rates would be lower in these cases. However, at least for learning rates, this handicap is apparently offset by the more complex decision boundary for the logic units. Technique QS is the most powerful, PH is second best.

Figures 5 and 6 show the effect of varying the number of iterations. Since the method for generating logic units is unimportant in this investigation, technique PB was used to minimize computing time. For the design of an 11-unit machine, computing time increased .15 minutes for each iterative cycle added. The final comparison should await the availability of generality data, although it appears that more than five iterative cycles are unnecessary.

### 4.2 Analytical Investigation

An analytical study of the iterative adjustment of the logic unit output weights is being conducted. It has thus far been necessary to consider two factors providing six cases. First, it must be specified if there is a complete solution, a partial solution, or no solution. The first case corresponds to the existence of a set of output weights which yields perfect classification of the sample patterns. In the second case no complete solution exists, but there exists a set of weights providing correct classification for some patterns, while all other patterns are on the decision boundary. In the third case neither a complete nor a partial solution exists. The second factor is whether the activity vectors of the

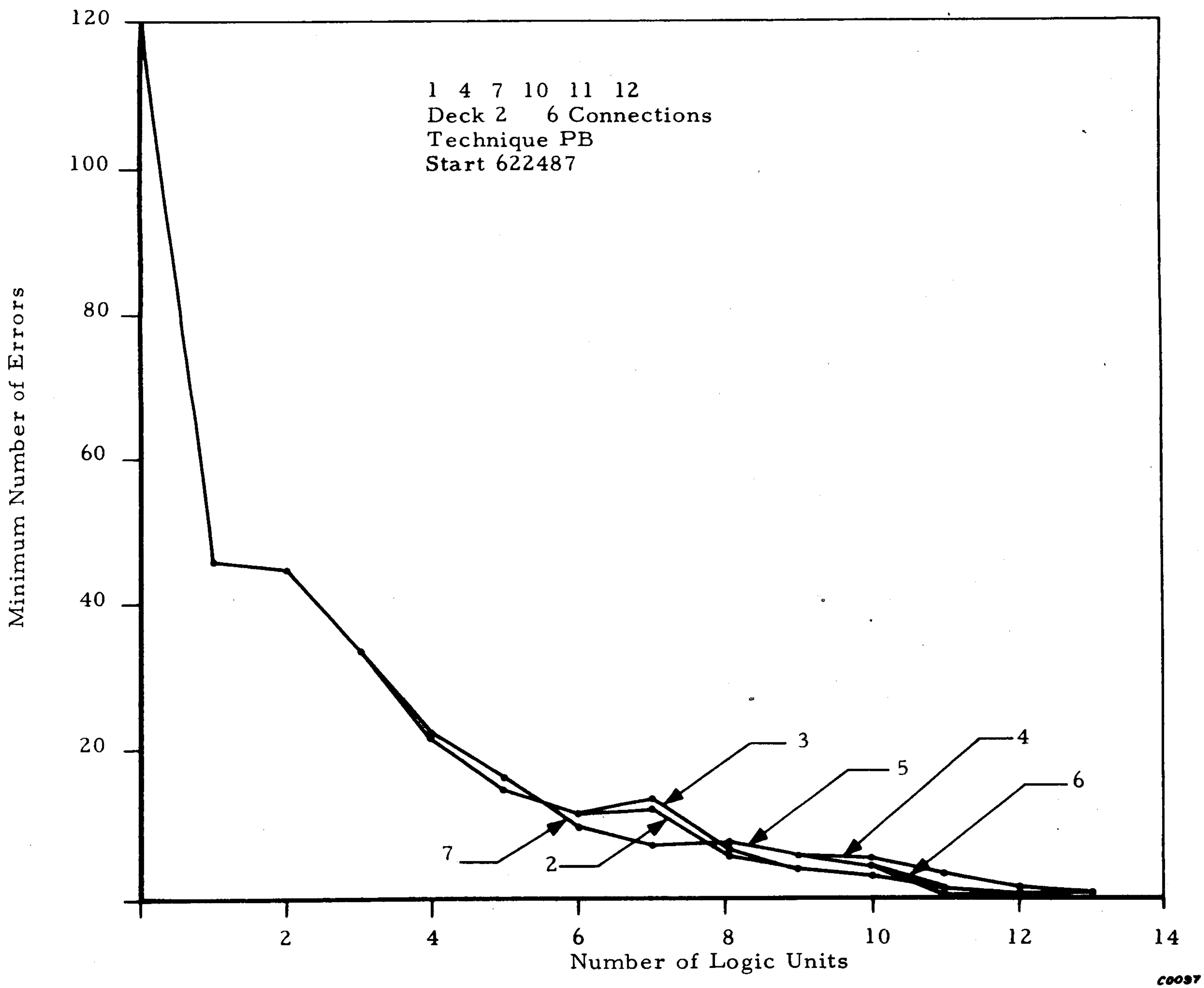

1 4 7 10 11 12
Deck 2 6 Connections
Technique PB
Start 622487
Minimum Number of Errors
120
100
80
60
40
20
2
4
6
8
10
12
14
Number of Logic Units
3
5
4
6
7
2
C0037

Figure 5

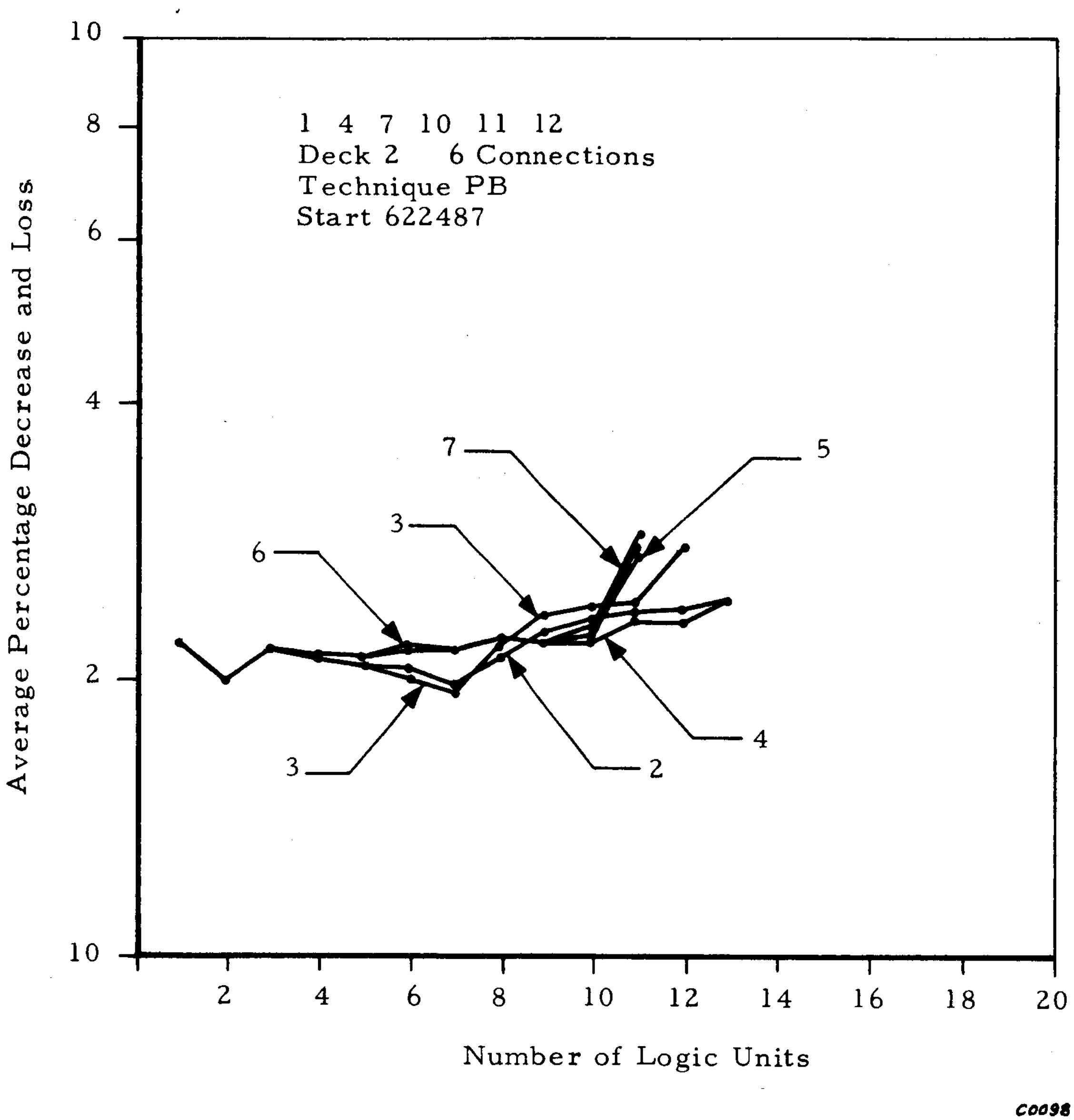

1 4 7 10 11 12
Deck 2 6 Connections
Technique PB
Start 622487
10
8
6
4
2
10
2
4
6
8
10
12
14
16
18
20
7
5
3
6
3
2
4
Average Percentage Decrease and Loss
Number of Logic Units
C0098

Figure 6

logic units are linearly independent or not. While this factor affects the uniqueness of a weight vector giving a specific decison boundary and loss function, intuitively it should not affect the limit of the loss function. It nevertheless has not yet been sidestepped.

In the case that no solution exists, and the activity vectors are independent, it has been shown that the loss function has a minimum value greater than zero, that this minimum is given by a unique, finite weight vector; and that the iterative adjustment process yields this weight vector in the limit. The proof of this is, at the moment, somewhat ponderous. It is anticipated that if results are obtained for some or all of the other five cases, the proofs will become neater. The proof will thus be given in a subsequent report. It is of some interest to note, however, that the well known convergence theorems for perceptrons begin with the assumption that a complete solution exists.

## 5.0 PROGRAM FOR NEXT QUARTER

The program for the next quarter divides that period in half. All currently open tasks are to be completed during the first half of the quarter. Work on the computer simulator and the preliminary design reviews will begin in early February. The resolution investigation will begin early in January.

It is anticipated that the sample problem investigation will be completed by mid-January and documented by the end of that month. The editing routines should be completed by the beginning of January. Verified frames will be then edited. The "unuseable" file of digitized frames will be searched for nonvortex patterns. Additional vortex frames are expected in January. An edited tape of sample patterns is scheduled to be available by the beginning of February. The main simulation program is also scheduled for availability at that time.

Simulation runs are scheduled to begin in February. As results become available from these runs, the preliminary design review will commence. A program for verifying the network design against sample patterns will be written in February to assist in the design review.

## 6.0 NEW TECHNOLOGY

The design-techniques under investigation are expected to constitute a major improvement in the design of decision networks; however, sufficient data are not yet available to document their usefulness or uniqueness. The technique for gray scale invariance seems of particular importance in the design of pattern recognition devices. Again, further results are required to substantiate the analytic studies.