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SYSTEM DEFINITION AND INVESTIGATION OF THE ON SITE PROCESSING O--ETC(U)

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1 OF 2

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SYSTEM DEFINITION AND INVESTIGATION OF THE ON SITE PROCESSING OF EN ROUTE SENSOR SIGNALS

ADDENDUM INVESTIGATION INTO POSSIBLE EN ROUTE ON SITE BEACON RING AROUND DISCRIMINANTS

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16. Abstract

This report presents the results, conclusions and recommendations of an investigation to determine what, if any, characteristics exist in beacon reply data that could be used to identify false target reports generated by ring around. A specific technique, using run length, is suggested. The technique is evaluated via statistical methods and computer simulation.

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METRIC CONVERSION FACTORS

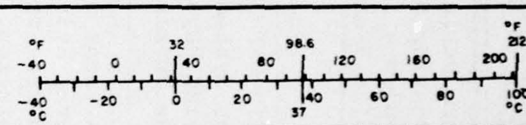
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



PREFACE

This report describes additional work performed by The Johns Hopkins University Applied Physics Laboratory (APL) for the Federal Aviation Administration as a follow-on to the beacon task of contract DOT-FA75WA-3553. The objective of this effort is to identify and evaluate possible discriminants against false targets caused by beacon ring around. The Technical Representative for this effort is Dr. James A. Shannon of Air Traffic Control System Division (ARD-111) of the System Research and Development Service (SRDS).

This report is issued as an addendum to the final report (reference 1) for the initial investigation done under this contract. Errata to reference 1 are listed in Appendix D of this report.

Grateful acknowledgment is made to NAFEC personnel, Mr. Robert Delaney and the technical support crew at the Elwood site, for their cooperation and technical assistance in collecting the required data for the investigation.

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GLOSSARY

ACP	Azimuth Change Pulse (see appendix C.2)
AI	Auxiliary Interpreter (section 4.1.3)
APL	The Johns Hopkins University Applied Physics Laboratory
ARSR	FAA Air Route Surveillance Radar
ARTCC	Air Route Traffic Control Center
ATCBI	Air Traffic Control Beacon Interrogator
CAP	Computer Aided Programming Facility at the Applied Physics Laboratory used to convert 9 track tapes to 7 track tapes
CCC	IBM 9020 Central Computer Complex at the ARTCC
CD	Common Digitizer
CD-Record Tape	A digital tape containing beacon report data recorded at the ARTCC during playback of FR-1800 tapes
CDS	A program that simulates the Common Digitizer processing of beacon replies and outputs beacon reports (Appendix B)
CRT	Cathode Ray Tube
D	A notation used to indicate a tape made by the Auxiliary Interpreter (formerly called a D-machine)
Discriminant	A procedure for classifying reports as true or false
EBCDIC	A binary code equivalent for alphameric characters defined in Appendix A
Elevation Angle	In the context of this report, elevation angle is an angle measured with respect to the beacon interrogator
EOF	End of File mark on a digital computer tape
FAA	Federal Aviation Administration
Features	The qualities measured by the discriminant that distinguish true reports from false reports (run length in particular)
Field	A notation used to indicate a tape made with live beacon video (section 4.2.1.1)

GLOSSARY (cont'd.)

FR-1800	Intermediate band analog recorder used to record the output of the modem receiver at the ARTCC
FR-950	Wide band analog recorder used for recording beacon video
LSB	Least Significant Bit
Mode 2 Tape	A digital tape containing beacon replies and beacon reports extracted by the Auxiliary Interpreter during CD operations at NAFEC (section 4.1.3)
MODEM Lines	Narrow band telephone lines used to transmit digital data from the sensor sites to ARTCC's in the National Airspace System (section 4.1.3)
MTI	Moving Target Indicator
NAFEC	National Aviation Facilities Experimental Center at Atlantic City
NAS	National Airspace System
PPI	Plan Position Indicator
QAS	Site Code for the Angel Peak Site in Nevada
RAPPI	Random Access PPI (Console Unit that permits display of raw, in process, and completed target report data in the CD)
RCA Advisor	Wideband analog recorder used for recording beacon video
RFI	Radar Frequency Interference
RTC	Real Time Clock
Run Length	A measure of the azimuthal extent of a target while in process (see appendix C.2)
T_L	Target leading edge threshold in CD
TRAAP	Target Report Ambiguity Analysis Package
T_T	Target trailing edge threshold in the CD
T_V	Target Report Validation threshold in the CD
VT	A notation used to indicate that a tape was made from a playback of a video tape (section 4.2.1.1)
WWV	Naval Observatory Time broadcast on Station WWV
Zulu Time	Greenwich Mean Time

EXECUTIVE SUMMARY

E.1 Objectives

The subject of this investigation was beacon ring around in the en route air traffic control system. Ring around occurs when interrogations and subsequent replies in interrogator antenna sidelobes and backlobes cause false target reports to be generated over a substantial portion of a complete antenna rotation. This is undesirable because the false reports can potentially confuse the air traffic controller or obscure true targets. This, in turn, can result in a compromise of the safety of en route air traffic. This is discussed in detail in Section 1.

The purpose of this investigation was twofold. The first objective was to identify what, if any, characteristics are present in the on site sensor data that may be used to reduce false target reports generated by ring around and suggest possible false target report discriminants based on these characteristics.

The second objective was to evaluate the proposed false report discriminant(s) via simulation using actual reply data. To accomplish this, a computer simulation was designed and implemented to take reply data as recorded on Auxiliary Interpreter Mode 2 tapes and generate report messages using the CD algorithm. Section 2 summarizes the specific results, conclusions and recommendations pertaining to these two objectives.

E.2 Source of Data

The investigation was conducted using video data collected from two different sites, the Elwood site at the NAFEC facility in Atlantic City, New Jersey and the Angel Peak site near Las Vegas, Nevada. Initially, the investigation was to use data only from commissioned sites. Sufficient data containing examples of ring around were not collected from commissioned sites. Therefore, data was collected at the NAFEC test site in Elwood using a test aircraft that flew radial flight paths directly over the interrogator, thus insuring that ring around occurred.

All of the video data collected was played through the Common Digitizer at Elwood, which is specially equipped with an Auxiliary Interpreter (AI), to provide a record on magnetic tape of target report messages including run length, and corresponding reply data as well. This feature is not available at other sites. Reasonable precautions were made to insure representativeness of the data. Sections 3 and 4 describe the analysis approach and data verification, and summarize the data collected.

E.3 Results and Conclusions

The investigation centered on determination of the Elwood test target characteristics as this was the only target that experienced a sufficient number of ring arounds. It was determined that identification of reports with unusually short run lengths or unusually long run lengths is effective as a false target report discriminant. It was further determined that the tendency of a target to experience ring around is dependent upon the elevation angle of the target relative to the sensor. Targets at higher elevation angles (28^{o} or above at Elwood) experience ring around while others do not.

A discriminant based on run length was implemented in the CD Simulator (see section 6.2.5). Characteristics of this are summarized in Table E-1.

Table E-1 Run Length Discriminant

Reject Reports with Run Length (RL) such that:

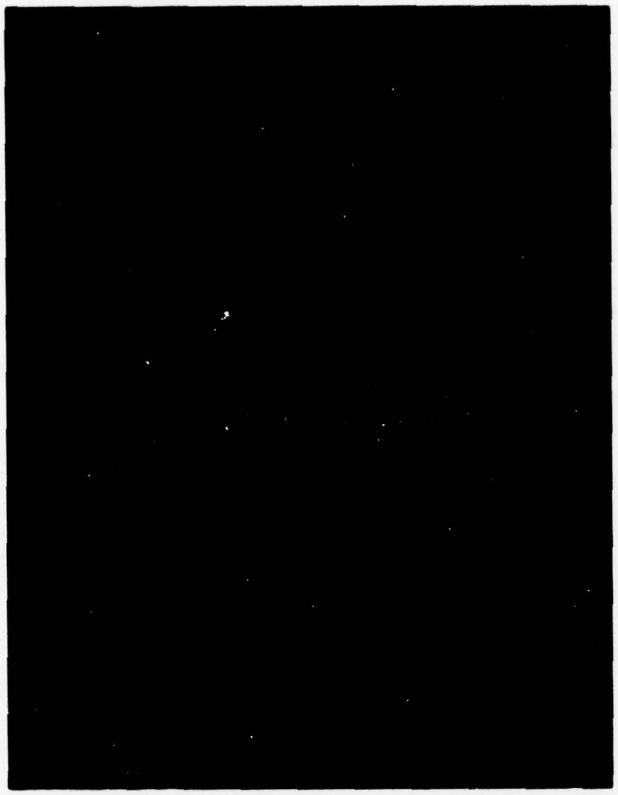
RL $\leq$ 36 ACP's* or RL $\geq$ 104 ACP's

if one of the following conditions are satisified:

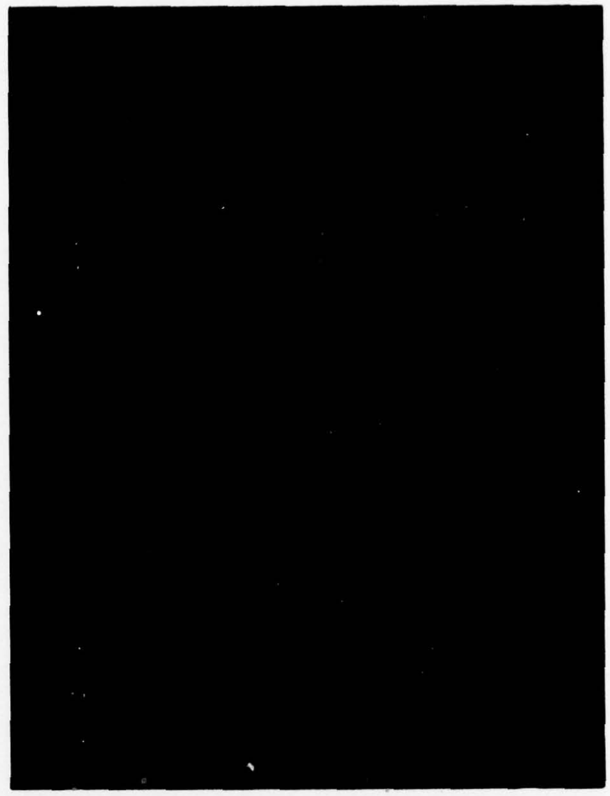
Condition	Report Range	Mode C Present	Elevation Angle
1	$\leq$ 4nmi	No	Any
2	Any	Yes	$\geq 28^{o}$

*ACP is defined in Appendix C, Section C.2.

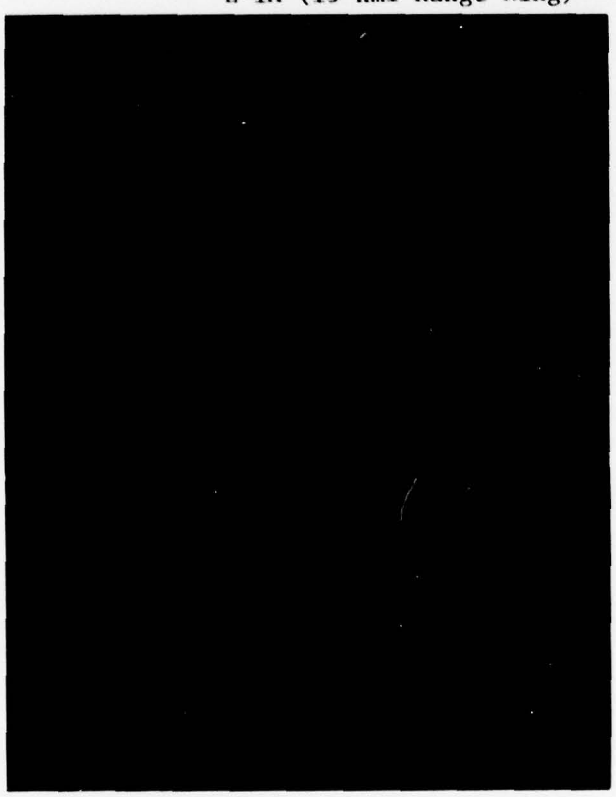
Figure E-1 is a comparison of Elwood test target report data (beacon code 2315) with the discriminant implemented and the same data without the discriminant. An X appears for each target report having the test target beacon code. Figures E-1A and E-1B display scan histories of the test target flight path, from south-southwest to north-northeast. The cumulative effect of several scans of ring around when the target was less than seven nautical miles from the interrogator is evident in E-1A. The reduction in the number of false reports generated is apparent when figure E-1A is compared with figure E-1B. However, the scan history display can be misleading because the scan-to-scan display of the reports, which can be observed during generation of the display, is not evident in a photograph. The air traffic controller is not normally concerned with a scan history but rather the present position and velocity of each aircraft, which is presented on a single scan basis.



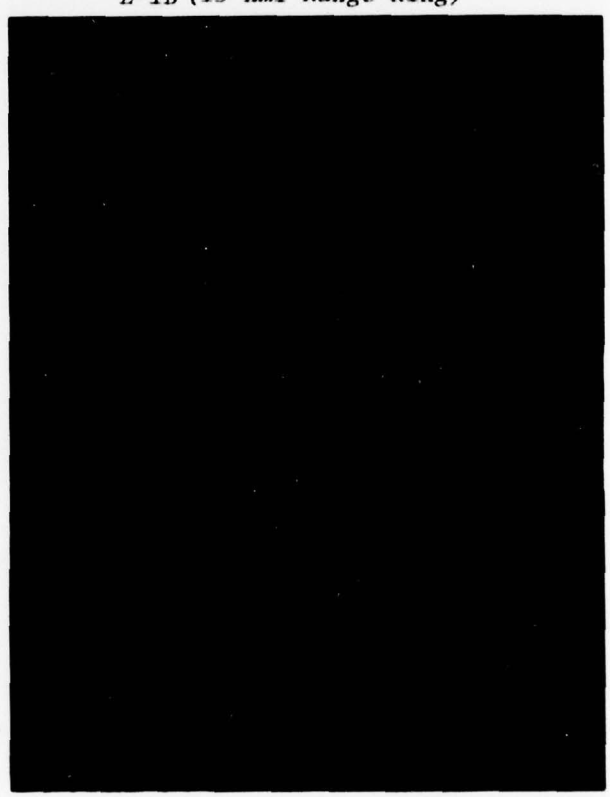
E-1A (15 nmi Range Ring)



E-1B (15 nmi Range Ring)



E-1C (10 nmi Range Ring)



E-1D (10 nmi Range Ring)

Figure E-1 Run Length Discrimination Simulation Results

Figures E-1C and E-1D illustrate the improvement in the display of a single scan. In figure E-1C, the correct report is the single X that is southwest of the interrogator. Eight false reports appear to the northeast. These are reduced to only two false reports by the discriminant. On the air traffic controller's display, the false reports of figure E-1C and their associated data blocks with alphameric information will obscure the region to the northeast resulting in difficulty in identifying other aircraft in this region (the display of other aircraft is suppressed in figure E-1). The discriminant is clearly effective in reducing the number of false reports thus cleaning up the controller's display and enhancing the process of air traffic control.

E.4 Recommendations

The results have shown that identifying target reports with long and short run lengths is an effective way to reduce the number of false reports generated during ring around. Air traffic controllers are highly trained and skilled individuals and rarely misidentify the position of an aircraft even under severe circumstances. However, presentation of ambiguous data to the controller should still be avoided. This will further minimize even the potential of air traffic controller confusion and thereby enhance the safety of en route air traffic. For this reason, it is recommended that the FAA give strong consideration to implementing run length discrimination. Before this can be done, however, the following two steps should be taken:

1) An investigation of run length and elevation angle characteristics should be conducted using data from a representative cross section of commissioned en route sites to permit a more complete understanding of site dependency.

2) The optimal approach to using run length discrimination must be determined. In an ideal situation, run length discrimination would be implemented only when an ambiguity occurs. Tracking of report data, which is done at the Air Route Traffic Control Center (ARTCC), is required to identify target report ambiguities. However, since the computer capacity of the ARTCC is already nearly saturated, it is desirable to implement the discriminant on site. One suggested approach is to identify reports with the discriminant on site by setting a one bit flag in the report message, then pass all the report data to the ARTCC where elimination of the flagged reports could take place after tracking. This approach minimizes any increase in ARTCC processing because only one extra bit of information is passed to the ARTCC. In addition, it avoids elimination of real reports since tracking information can be utilized to recognize when an ambiguity is present.

SECTION 1.0

INTRODUCTION

1.0 INTRODUCTION

This investigation was a continuation of the work begun under contract DOT-FA75WA-3553. The overall objective of the original program was to aid the FAA in enhancing the performance of the National Airspace System (NAS) in the areas of aircraft acquisition, data transfer, and processing of both primary and secondary (Air Traffic Control Radar Beacon System (ATCRBS)) data.

Modification 1 to the original contract expanded the scope of the analysis to include the on site processing of beacon data. This investigation was to analyze the beacon data processing performance of the Common Digitizer (CD) to determine what problems exist that affect or could potentially affect the automation of the en route portion of the National Airspace System (NAS) and, where possible, to make recommendations to alleviate these problems. Reference 1 documents the results, conclusions, and recommendations of the original investigation. Reference 2 is the study plan for the beacon portion of the original effort.

This report, issued as an addendum to Reference 1, documents the additional investigations into the beacon processing performance of the CD and has been completed under Modifications 3 and 4 to the original contract. The study plan for this effort is Reference 3.

1.1 BACKGROUND

The subject of this investigation was the ring around problem. Ring around is a particularly severe form of target report ambiguity. It occurs when an aircraft transponder outputs replies over a substantial portion of an antenna scan, resulting in the generation of several target reports, all at the same range but spread apart in azimuth occurring within a single scan of the antenna.

An example of ring around is presented in Figure 1-1. This photograph was made from the color TV display console using the CD-Record display system developed at the Laboratory and described in Section 8.3 of Reference 1. The CD-Record tape data was obtained by playing beacon video that was recorded on a wide band recorder at the Angel Peak site near Las Vegas, Nevada (site code QAS) through the Common Digitizer at Elwood, N. J. Since the original video was recorded at Angel Peak, a commissioned site, the display of Figure 1 is representative of a commissioned site.

CD-Record Tape Data

Tape Name: QAS-2, FIELD

Time Frame: ~ 30 scans

Range Ring Interval (nmi): 5

Beacon Color: Green

Beacon Symbol: X or Dot

Search Color: None

Search Symbol: None

Flagged Codes

Code	Symbol	Color
0716	X	Green

Display

All Beacon Reports

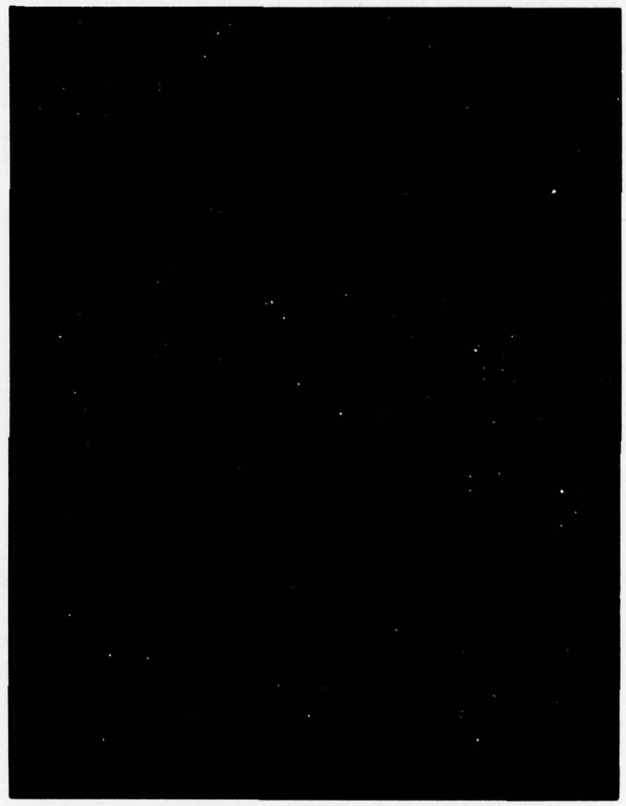


Figure 1-1: Example of Ring Around

The range rings of the display have a 5 nautical mile interval with Angel Peak beacon interrogator at the center of the display. The target that produced the ring around has a beacon code of 0716 and is displayed as a green X. About 30 scans of data are presented so that the target flight path is evident. The target came within about 7.5 nautical miles (slant range) south of the interrogator. The green X's in the northwest and northeast quadrant (mostly northeast) are false reports generated in the antenna sidelobes and backlobe. In the next sections, the adverse affects of the event depicted in Figure 1-1 are discussed.

1.1.1 Adverse Affects of Ring Around

False reports generated by beacon ring around can potentially affect system performance in three areas:

1) System data load
2) Tracker performance
3) Controller performance

Each of these areas is addressed in detail below, with the conclusion that the controller performance is the area most affected by ring around.

1.1.2 System Data Load

There is increasing concern that the present data processing capacity of the IBM 9020 computer system at the Air Route Traffic Control Centers will soon be inadequate to handle the rapidly growing number of en route aircraft. This problem is discussed in detail in Reference 1, Sections 2.3.1 and 3.0. One way to reduce the 9020 data load is to preprocess the report data on site and eliminate false reports which would otherwise have to be processed by the 9020. However, although ring around produces many false reports when it occurs, it does not occur frequently enough to cause a significant increase in the data load of the 9020 systems. For example, during testing at Elwood, a single test target was observed to produce 29 good reports. During the same interval, the test target produced 98 false reports due to ring around (Section 6.2.3.2.4). Assuming that the 29 good reports were produced one per scan, the interval considered was about 29 scans. The average number of beacon reports per scan at a busy en route center is easily 200, so that in 29 scans one may expect about 5800 good reports. Thus, the 98 false reports comprise less than 2% of the data. Thus, although system data load will be reduced by eliminating false beacon reports caused by ring around, the reduction relative to the number of good beacon reports is not large.

1.1.3 Tracker Performance

Targets of interest to the air traffic controller are tracked by the 9020 system at the ARTCC. Usually, when ring around occurs to a target the controller is concerned with, the target involved has already been tracked for many scans prior. On successive scans, the tracker is looking for the report closest to the established track that has the correct beacon code. Normally, when ring around occurs the real report is present along with the false reports and the tracker will correctly identify the real report because it is closest to the already established track.

However, if the controller is attempting to establish contact with a new aircraft or reestablish a dropped track, ring around has the potential to cause a problem as the example of Figure 1-2 shows.

The data, displayed in PPI format, was not tracked by an automated system, but can be tracked visually by associating reports on successive scans. The target of interest in this display, shown as an X symbol, has a beacon code of 1673. This data was collected at the Elwood site. The target flight path starts at about 17.5 nautical miles northeast and ends at 20 nautical miles southwest of the interrogator which is at the center of the display. False reports were produced to the southeast of the interrogator when the target was between 5 and 10 miles northwest due to target replies in or near the antenna backlobe. These reports occurred on successive scans in such a way that they appeared to form a track. Had a controller been attempting to establish contact with a previously untracked or dropped track target while ring around was occurring as it does in this example, the possibility of misidentification of target position would exist. The controller would recognize this and react by requesting the pilot of the aircraft to confirm his heading, and under normal circumstances there would be no further problems. There are times when a controller is requested by a pilot to provide emergency assistance because the pilot is experiencing difficulty such as disorientation or equipment failure, in which case the pilot will not necessarily know his heading, or because of the pressure of the situation, will read his heading incorrectly. Under these conditions, the event depicted in Figure 1-2 could have more serious consequences. Such events do not happen often, but they do happen. Reduction of false reports generated by ring around would, therefore, be a significant step in improving air safety.

1.1.4 Controller Performance

In addition to the problem described above, the presence of ring around on the controller's display is, at the very least, distracting. A data block containing alphamerics will be displayed for each false report

Auxiliary Interpreter Mode 2 Tape Data

Tape Name: Aug 25 Tape 3

Record Number: 0-491

Range Ring Interval: 5 nmi

Beacon Report Color: Green

Beacon Report Symbol: X or Dot

Search Report Color: None

Search Report Symbol: None

Flagged Codes

Code	Symbol	Color
1673	X	Green

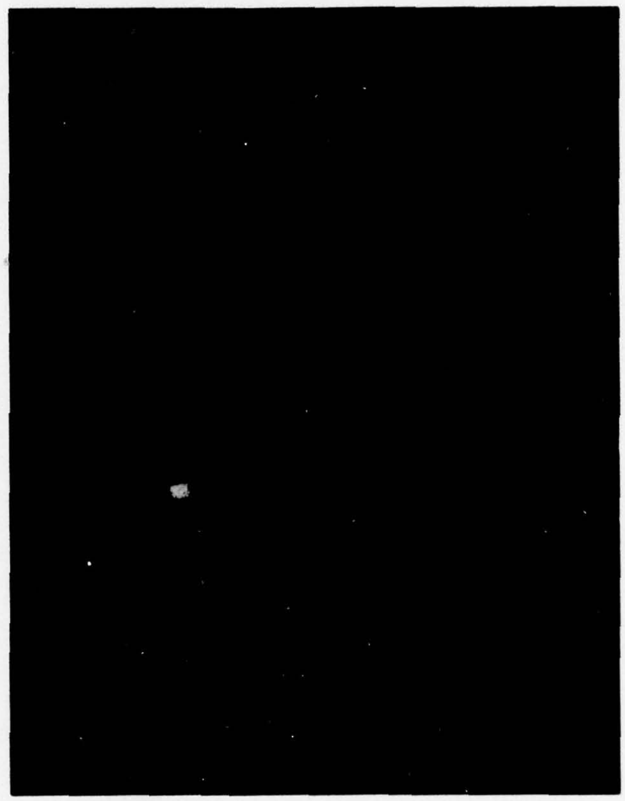


Figure 1-2: False Reports Forming a Track*

*"Tracking" is done visually

appearing on the display causing a portion of the display to be at least partially obscured, and making proper target identification difficult, if not impossible. The controller, of course, is not just concerned with one aircraft, but many, and he is constantly reviewing the entire air traffic situation affecting the sector with which he is concerned. When a controller must devote time to resolving false target ambiguities he necessarily must interrupt his normal procedure, thus reducing efficiency and safety.

1.1.5 Summary of Ring Around Effects

From the above discussion, it is evident that the area of system performance affected most by ring around is controller performance. Ring around partially obscures the controller's display with false reports and alphameric data for each, causing, as a minimum, distractions of the controller's attention. Worse, the presence of false reports can, under certain conditions, make establishing contact with a previously untracked or dropped track aircraft difficult, resulting in a compromise to air safety.

1.2 OBJECTIVES OF THE INVESTIGATION

It appears unreasonably difficult to reduce some ring around problems by further processing of data presently available at the CCC (Reference 4). Other solutions involve sensor modifications. A third solution, the subject of this investigation, is to process additional information available to the CCC for processing.

This investigation had two specific objectives. The first objective was to identify what, if any, characteristics are present in the on-site sensor data that may be used to reduce the ring around problem and propose false target report discriminants utilizing the identified characteristics.

The second objective was to evaluate the discriminants proposed to reduce the ring around problem by this investigation with respect to effectiveness in reducing the problem and overall affect on target report data quality. To aid in accomplishing the second objective, a computer simulation was developed which takes beacon replies from the Auxiliary Interpreter (AI) and, using the CD algorithm, centroids the replies to produce beacon target reports. This was a specific effort recommended in Reference 1. With this simulator, the effects of varying target leading edge threshold (T_L), a target trailing edge threshold (T_T) and the validation threshold (T_V), and the implementation of various additional algorithms such as run length discrimination can be evaluated with actual reply data.

2.0 SUMMARY OF RESULTS, CONCLUSIONS, AND RECOMMENDATIONS

The analysis results are presented in detail in Section 6, with conclusions drawn at appropriate places in the discussion. In this section the results are tied together and overall conclusions made. Next, recommendations based on the conclusions are listed.

2.1 RESULTS AND CONCLUSIONS

2.1.1 Results of Elwood Test Target Analysis

The following conclusions are based on the test target report data (beacon code 2315) collected at Elwood on August 25.

1) All the false reports generated from sidelobe and backlobe returns occurred at elevation angles above 28° relative to the interrogator indicating that the problem is a mismatch between the directional and omnidirectional antenna above this elevation (Section 6.2.3.1) at Elwood.

2) Elimination of target reports with run lengths above and below some predetermined values will be effective in reducing the number of false reports (Section 6.2.3.2).

3) The maximum altitude of the test aircraft was 20,000 feet. Since ring around at Elwood only occurred at elevation angles above 28°, the maximum slant range at which ring around was observed was roughly seven nautical miles. However, since the problem is one of elevation angle, and not range or altitude alone, an aircraft at 40,000 feet should start to exhibit ring around at approximately fourteen nautical miles. Thus, implementing run length discrimination below some predetermined range, such as ten nautical miles, will not be as effective as implementing the discriminant for elevation angles above 28°. Elevation angle can be computed from Mode C altitude data provided by the aircraft transponder (Section 6.2.3.2).

4) All aircraft above 12,000 feet will have a Mode C transponder and thus elevation angle can be computed from slant range and the available altitude data. Aircraft below 12,000 feet are not required to squawk altitude data. Below 12,000 feet, however, the maximum range at which ring around should occur is about 4 nautical miles. Hence, one procedure for implementing the run length discriminant at Elwood would be:

a) If altitude is available implement above 28° elevation,

b) If altitude is not available, implement below four nautical miles slant range.

5) Use of elevation angle information as opposed to a fixed range cutoff for determining when to implement the run length discrimination results primarily in a reduction of the number of real reports eliminated (a very desirable improvement). The effect on the number of false reports eliminated is small (Section 6.2.3.2).

6) Specific examples of an application of run length discrimination are given in Sections 6.2.3 through 6.2.5. These examples illustrate that run length can be an effective discriminant. The actual values for upper and lower run length cutoffs were judiciously chosen to illustrate a point with the data at hand. However, it is not recommended that these cutoff values be used without a more extensive evaluation of the effectiveness.

2.1.2 Elwood Targets of Opportunity (Section 6.2.4)

This part of the investigation was conducted to insure that the test target characteristics and characteristics of targets of opportunity in the Elwood data are consistent. The results indicate that they are consistent.

2.1.3 Angel Peak Data (Section 6.2.6)

The Angel Peak data was considered because of evidence that run length and elevation angle characteristics might be site dependent.

The results are consistent with Elwood in that ring around occurs at higher elevation angles. In the Elwood data a specific elevation angle cutoff was found below which ring around does not occur. The results of the Angel Peak analysis indicate that this cutoff angle may vary from site to site. No evidence was presented to indicate that run length discrimination would not be effective at Angel Peak.

2.2 RECOMMENDATIONS

From this investigation, it has been concluded that:

1) Run length discrimination is effective in reducing the number of false reports generated during ring around, and

2) The tendency of a target to experience ring around is greater as elevation angle increases. This characteristic was present at both Elwood and Angel Peak, but the elevation angles involved were different, indicating site dependency.

Therefore, since run length discrimination has been shown to be a viable technique for decreasing the number of false reports caused by ring around, it is recommended that the FAA investigate further the possibility of implementing a discriminant that identifies potentially false reports based on run length. Two major areas of investigation are recommended:

First, it is recommended that an analysis of run length and elevation angle characteristics be performed on report data collected from commissioned sites. The problem in using targets of opportunity at commissioned sites is that ring around does not occur frequently enough to obtain a good data base from which to extract characteristics, so it would be necessary to provide a test target, as was done in the Elwood data collection (see Section 4.1.5). Video tapes collected at commissioned sites would then be played through the CD at Elwood to produce Mode 2 tapes of beacon replies and target reports with run length. This data would then be analyzed to statistically quantify run length and elevation angle characteristics of the report data. The results would provide a sound data base for designing an algorithm to identify false reports generated during ring around. Since it is expected that site dependency is a factor, collecting data from several different sites will also indicate the properties of parameters, such as actual run length cutoff points and elevation angles, that will be set differently at each site.

The next area of investigation should be directed towards determining how to best integrate run length identification of false reports into the NAS system.

The two approaches most often considered are:

1) Perform run length discrimination at the interrogator site, and

2) Perform run length discrimination at the ARTCC.

The first approach has the advantage that it imposes no additional processing load on the 9020 at the ARTCC. However, as a disadvantage, real reports will occasionally be incorrectly identified as false reports and eliminated. The loss of good reports will occur only rarely, and usually not on successive scans, so that the tracker at the ARTCC will fill in the missing reports with a predicted position for those aircraft being tracked. It should be pointed out that the entire detection and tracking process is statistical in nature, and even with the present system, real reports are occasionally deleted, just due to the nature of statistical processes, with no serious effects on air safety. However, no matter how innocuous the loss of these reports, such losses should be minimized.

The second approach, to pass run length to the ARTCC and perform discriminations there, adds the advantage that tracking prior to elimination of reports can be used to virtually prevent any loss of real reports in controlled air space. The problem associated with this approach is the additional computing load imposed on the 9020 system, which is already nearing capacity.

This leads to a third technique that combines the best aspects of each approach. This is the recommended approach to implementing run length discrimination. The discriminant would be implemented at the interrogator site in the Common Digitizer. Reports identified as false reports (i.e., run length too long or too short) are flagged by setting a single bit in the associated report message. All the report messages, flagged or otherwise, are transmitted to the ARTCC, via the modem lines. In the ARTCC, elimination of reports could then be based on information not available on site, such as tracker data. This approach has the following advantages.

1) On site processing of run length data minimizes the increase in data that the 9020 at the ARTCC must handle. Only one extra bit of information must be processed by the 9020 for each message.

2) Eliminating the reports only after processing in the ARTCC avoids loss of good reports.

3) Air safety is enhanced because the presentation of ambiguous data to the air traffic controller is reduced.

This suggested approach does not indicate what will be done with the additional bit after the report data is passed to the ARTCC. The problem of how to use the discriminant information is non-trivial, and therefore beyond the scope of the present investigation. The many factors involved, such as tradeoffs between processing on site versus processing at the ARTCC, costs, benefits, and approaches to utilizing the demonstrated ability of the discriminant to effectively identify a significant percentage of false reports, make additional investigation necessary if optimal integration into the NAS system is to be accomplished.

3.0 ANALYSIS APPROACH

3.0 ANALYSIS APPROACH

This section presents a summary of the overall analysis approach followed by the details of the specific stages in the investigation. This approach is discussed in detail in Reference 3. Figure 3-1 is a flowchart of the study plan illustrating the significant tasks of the investigation. The corresponding section number for each major task describing that aspect of the investigation is given in the figure.

Initially the investigation was to be conducted utilizing data collected at commissioned en route ARSR sites. However, data collected from the Angel Peak site near Las Vegas, Nevada did not have a sufficient number of occurrences of severe ring around. Consequently, the investigation was expanded to include data collected at the NAFEC test site in Elwood, N.J. while a test target was flying on radials to and from the interrogator. The data collected includes (1) analog recordings of beacon video with known ring around problems, (2) corresponding CD-Records made from real time recorded FR-1800's, (3) CD-Records produced by playing the analog video tapes through the specially equipped CD at Elwood, N.J., and (4) associated AI Mode 2 tapes of beacon replies and reports (including beacon run length).

The integrity of the playback data was verified via comparison of the CD-Records made during playback of analog video with the CD-Records produced from the FR-1800 recorded during the data collection with respect to both statistical characteristics and actual displayed target reports. The comparisons utilized the CD-Record Display Analysis Program and the Target Report Ambiguity Analysis Package (TRAAP). Also, the severity and characteristics of ring around in all the data at the target report level were observed with displays and statistically quantified. Then, using the AI Mode 2 Reply Display Analysis Program, specific examples of ring around were isolated and the beacon reports and corresponding beacon replies were documented. The examples were inspected to determine what, if any characteristics exist in the reply data, that could be used to implement a false target discriminant which would reduce the ring around problem. It was determined at this stage that a discriminant using run length and elevation angle information could potentially be effective in identifying false reports generated during ring around.

The next stage in the investigation was the development of a computer simulation that takes as input the AI Mode 2 replies, centroids them, using the CD algorithms, and outputs beacon target reports. The primary reason for developing the simulator was to simulate the effect of implementing proposed discriminants. In addition, the simulator provided a means for obtaining run length information for the Angel Peak data. Normally, this information appears in the AI Mode 2 data but it was inadvertantly omitted from the Angel Peak data. The simulator generates run length information in the same way that the CD at Elwood does during centroiding of replies.

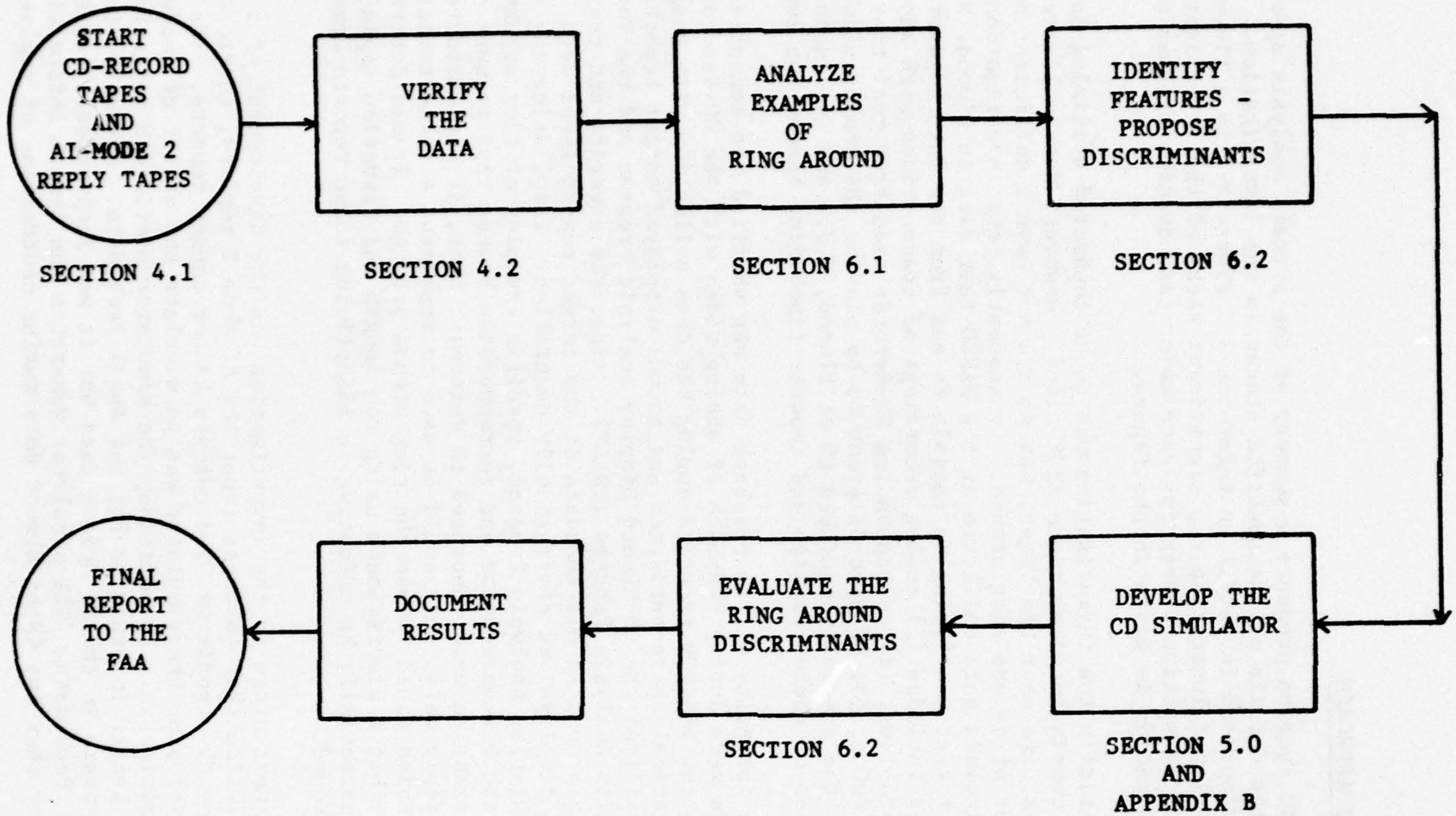


FIGURE 3-1 ANALYSIS APPROACH

Finally, the proposed discriminant was evaluated using statistical tools and the simulator. The results, conclusions, and recommendations which emerged are documented by this report.

4.0 COLLECTION AND VERIFICATION OF DATA

4.0 COLLECTION AND VERIFICATION OF DATA

4.1 DATA COLLECTION

4.1.1 Interrogator Sites Used for Data Collection

Video data for this investigation was provided from two sources, the Angel Peak site near Las Vegas, Nevada (a commissioned site) and the NAFEC site at Elwood, N.J. Originally, the investigation was to be carried out using data from commissioned sites only. However, preliminary results from the Angel Peak data indicated an insufficient number of ring arounds to perform an adequate analysis. For this reason, it was jointly agreed by the FAA and the Laboratory that video data would be recorded at the NAFEC site at Elwood, N.J. while an FAA test aircraft flew patterns that passed directly over the interrogator.

4.1.2 Equipment Configuration for the Angel Peak Data Collection

Figure 4-1 is a block diagram of the equipment used for the data collection at the Angel Peak site. At the Angel Peak site were an Air Traffic Control Beacon Interrogator, a RCA Advisor analog video recorder, and a Common Digitizer (CD). The target reports generated by the CD were transmitted via a modem line, as shown in Figure 4-1, to the Air Route Traffic Control Center (ARTCC) at Los Angeles, where they were recorded on an FR-1800 tape. Time recorded on the FR-1800 tape was the time of day when the tape was made.

4.1.3 Equipment Configuration at NAFEC

Figure 4-2 is a block diagram of the equipment configuration at NAFEC used for the Elwood site data collection and subsequent reduction of both Elwood data and Angel Peak data. The Air Traffic Control Beacon Interrogator (ATC BI), FR-950 video recorder, Common Digitizer (CD), and Auxiliary Interpreter (D-machine or AI) are located at the Elwood site. The ARTCC is located at NAFEC in Atlantic City. The Elwood CD is a special "Enhanced Common Digitizer" which is equipped with an Auxiliary Interpreter (AI). The AI performs several functions, including interaction with the CD during radar processing (see Section 5.2 of Reference 1). The primary function of the AI during collection of data was the extraction of beacon reply information.

The video input to the common digitizer can come from either of two sources. First, the ATC BI may be turned on, and real time video from its receiver inputted to the CD. The alternate video source is the FR-950 analog recorder. Whenever real time video was used, a simultaneous FR-950 analog recording of the beacon video was made.

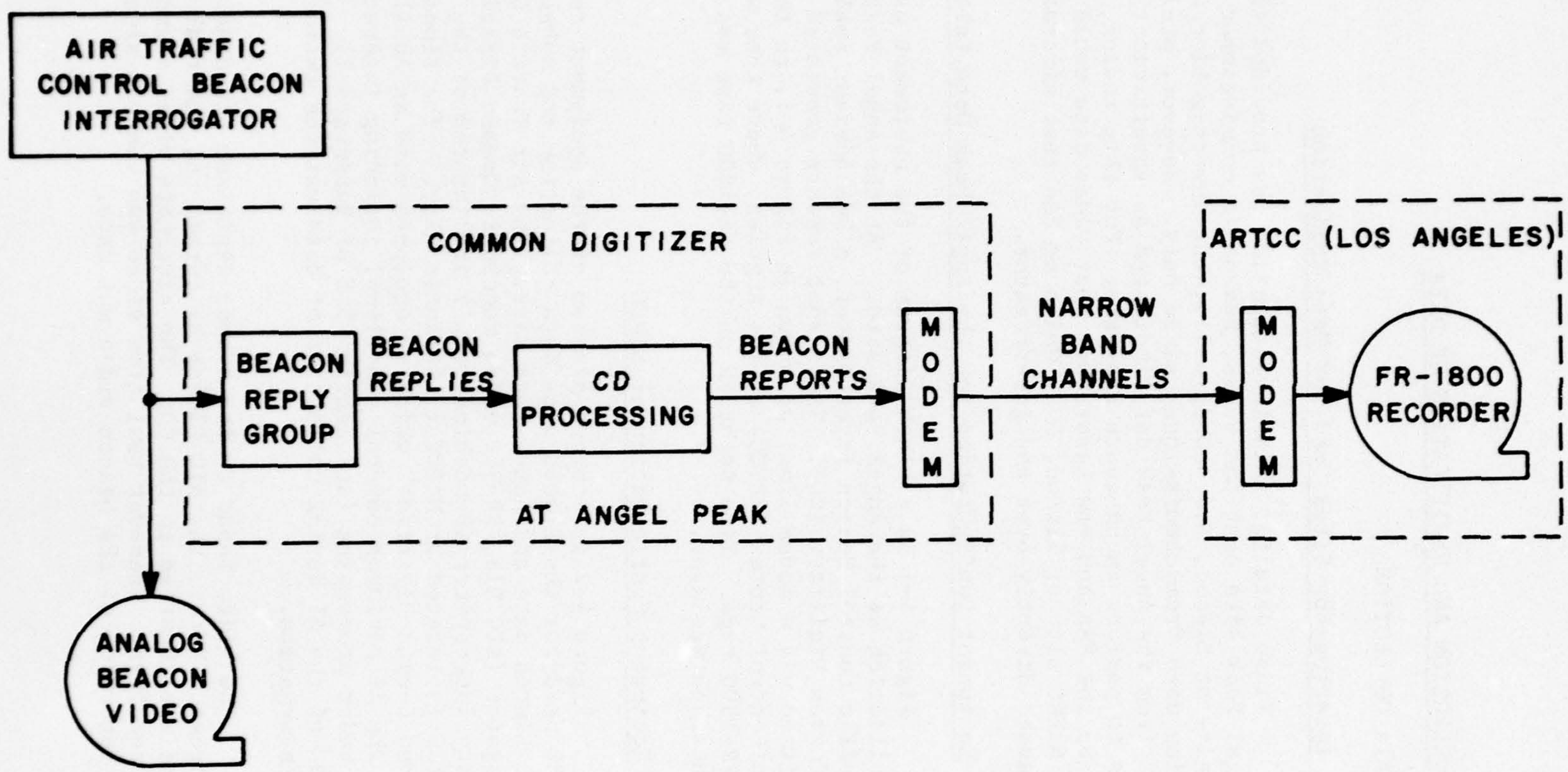


FIGURE 4-1: EQUIPMENT CONFIGURATION AT LAS VEGAS

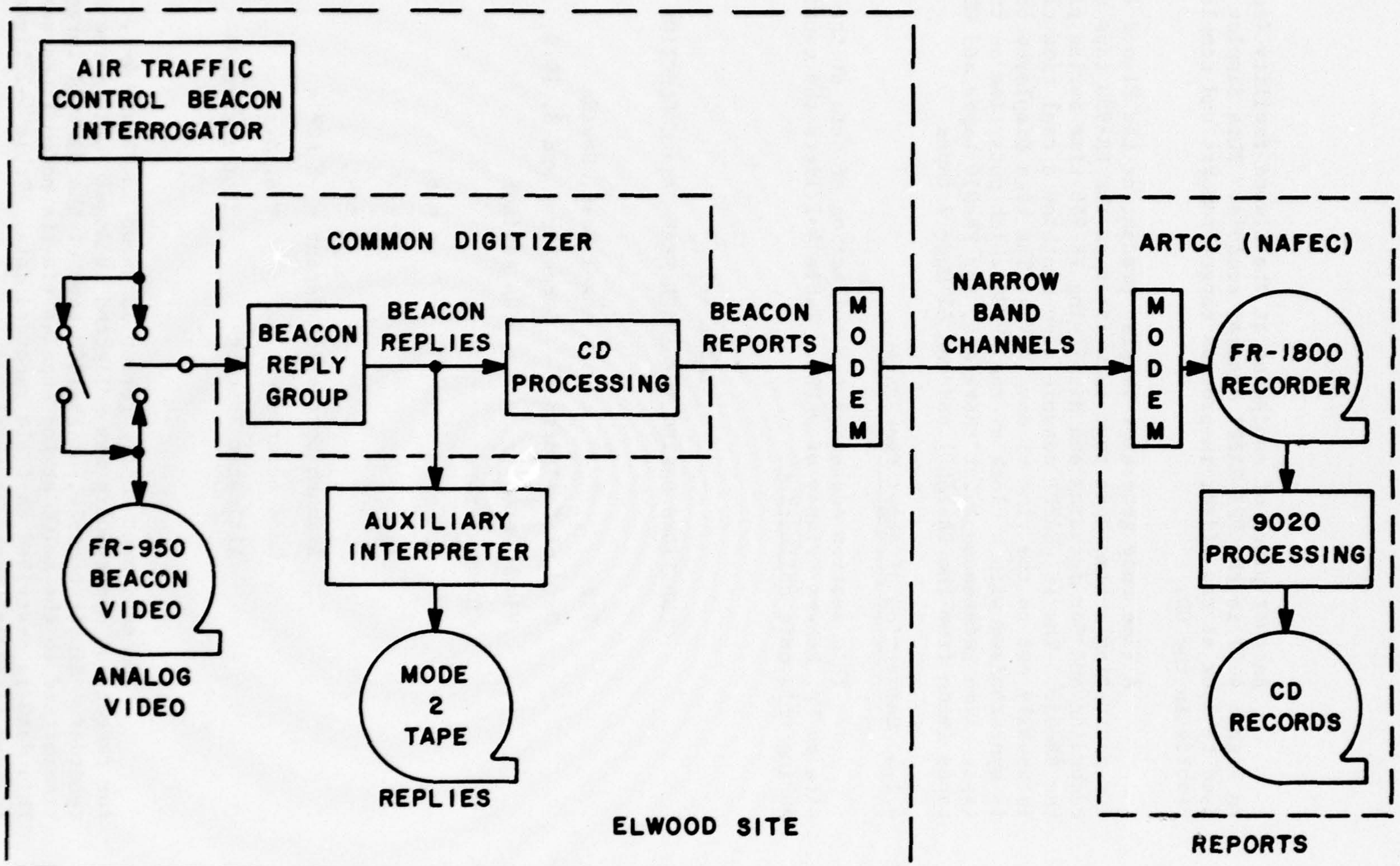


FIGURE 4-2: EQUIPMENT CONFIGURATION AT NAFEC

Another piece of equipment at the Elwood facility (not shown in Figure 4-2) is the PPI-RAPPI display console. This display can be used to look at raw video, in-process target reports and completed target reports in the CD.

A time code generator is also present at the Elwood facility for generating a time code that is written on the FR-950 tape during recording and for decoding and displaying FR-950 time during playback of the FR-950. The PPI-RAPPI console also contains a real time clock which is usually set to the time of day (WWV). The time displayed on the console is synchronized with a clock at the ARTCC which puts time on the FR-1800 tape. Time references exist therefore, for FR-950 tapes and CD Record tapes (made from the FR-1800) and the AI Mode 2 tapes.

4.1.4 Collection of Angel Peak Data

This section addresses the collection of data at the Angel Peak site by Mr. Robert Delaney of NAFEC. Table 4-1 lists the conditions during this data collection.

TABLE 4-1

CONDITIONS DURING THE ANGEL PEAK DATA COLLECTION

Site	-	Angel Peak, Nevada
Date of Collection	-	December 7 and 8, 1976
Video Recorder	-	RCA Advisor
CD-Parameters:		
T_L	=	6
T_T	=	2
T_V	=	4
Azimuth Correction Factor	=	-2 ACP's
Mode Interlace	=	A, A, C
Altimeter Setting		(Not recorded)

The equipment configuration is shown in Figure 4-1. Beacon video for targets of opportunity was collected at Angel Peak on the RCA Advisor recorder. Simultaneously, an FR-1800 tape of the digital target reports transmitted to the ARTCC at Los Angeles via the modem lines was being recorded. This data is described as field recorded data. Table 4-2 lists the RCA Advisor tapes collected at Angel Peak.

TABLE 4-2

RCA ADVISOR VIDEO TAPES COLLECTED AT ANGEL PEAK
December 7 and 8, 1976

Advisor Tape	Date	*Zulu Time Start	End
1	12/8/76	00:07:00	00:33:00
2	12/8/76	01:03:00	01:29:00
3	12/8/76	18:34:00	19:03:00
4	12/7/76	19:54:00	20:12:00

*See glossary

4.1.5 Data Collection at NAFEC

In support of this investigation the FAA conducted data collection operations on August 25 at the ARSR-2/ATC BI-3 site in Elwood, N.J. The purpose of this data collection was to provide beacon reply tape data and corresponding CD-Record data for use on the follow-on investigation.

4.1.5.1 Test Aircraft

The purpose of this data collection was to gather data to be used for investigation of ring around. To insure that sufficient ring arounds occurred, a test aircraft was used. The aircraft, a Convair 880, flew radials to the Elwood site passing directly over the facility. With the test aircraft, the proper geometry for high incidence of ring around could be maintained. The test aircraft beacon code was 2315.

4.1.5.2 Data Collected

The data collection utilized the equipment shown in Figure 4-2. Refer to the figure as necessary. During the run, both beacon video and MTI search radar video were recorded on the FR-950 tapes. MTI video was not recorded for the entire data collection because the radar was turned off during the run to prevent RFI from affecting the AI. In addition, an FR-1800 tape of the data transmitted across the modem lines to the air route traffic control center (ARTCC) was made. The auxiliary interpreter did not function, thus real time Mode 2 reply data was not collected. The loss of real time Mode 2 tape data did not affect the investigation, which utilized playback data.

Following is a list of notes taken during the data collection.

Data Record

Time Synchronization:

The ARTCC time was reported to be synchronized to WWV. Elwood Real Time Clock (RTC) was 18 seconds behind WWV.

FR-1800:

Start Time - Approximately 13:30:00
Stop Time - Approximately 14:54:00

FR-950:

Three tapes were made. The designation, start and stop times are listed. The FR-950 recorder was sometimes halted when the test aircraft was not near the Elwood site.

Tape 77-15	Tape 77-16	Tape 77-17
Start - 13:11:43	Start - 13:43:52	Start - 14:30:47
Stop - 13:31:13	Stop - 13:55:10	Stop - 15:04:00
Start - 13:34:00	Start - 13:58:42	
Stop - 13:43:00	Stop - 14:03:15	
	Start - 14:13:24	
	Stop - Approx. 14:21:55	
	Start - 14:22:55	
	Stop - 14:28:00	

Beacon Interrogator:

The beacon interrogator was on for the entire run. Mode interlace was 3/A, 3/A, C.

ARSR-2:

The ARSR-2 was on at the beginning of the run. It was turned off at 13:54:00.

Run Length Reporting: Was enabled (LSB = 4)

Report Data on Mode 2: Was enabled but AI was not operative

Auxiliary Interpreter: Was not operative

PRF: 360/sec

Scan Rate: 9.61 sec/scan

$T_L = 6$

$T_T = 2$

$T_V = 5$

Azimuth Correction: -4 ACP's

RAPPI Console Listing:

The test target was manually tracked at the RAPPI console with a ball tab cursor. A printout of CD data was obtained for this target as a result of the tracking.

Photography:

Raw beacon video was photographed during the run at a PPI display.

4.1.6 Follow-Up Reduction at NAFEC

The investigation required AI-Mode 2 recordings of reply data and corresponding CD-records. The FR-950 tapes (77-15, 77-16, 77-17) made at Elwood and Advisor Tapes 1 through 4 made at Angel Peak were played through the Elwood CD at a later date. During this playback, AI-Mode 2 data and FR-1800 data were recorded. CD-Records were made at NAFEC from these FR-1800 as well as from the FR-1800 tapes taken during the original data collections at Elwood and Angel Peak. The AI Mode 2 tapes and corresponding CD-Record data were forwarded to the Laboratory for analysis.

During playback of the FR-950 data, the CD parameters T_L, T_V, T_T were $T_L = 6$, $T_T = 2$, $T_V = 5$. Run length reporting was selected during playback of the Elwood video but not during playback of the Angel Peak video.

4.2 DATA RECEIVED AND VERIFICATION THEREOF

This section lists the tapes received by the Laboratory as a result of the Elwood and Angel Peak data collection operations and discusses the results of a review of each data set that was conducted to determine the quality of the data received.

4.2.1 Review of Angel Peak Data

This section documents the data tapes received by the Laboratory as a result of the data collection effort at Angel Peak, Nevada.

4.2.1.1 Tapes Received from the Angel Peak Data Collection

The tapes received are listed in Table 4-3 along with the corresponding video source. The CD-Record "Field" tapes were made from FR-1800 tape data recorded in real time from the modem line at the Los Angeles ARTCC during data collection operations. These tapes contain report data generated by the CD at the Angel Peak site. The RCA Advisor video tape source(s) were also recorded during the data collection, then played through the Elwood CD at a later date to produce the CD-Record tapes (labeled VT for video tape) and Auxiliary Interpreter (AI) Mode 2 tapes listed. The numbers in the tape labels indicate corresponding sets of Field recorded CD-Records, video tape CD-Records, and AI Mode 2 tapes. Each set of 3 tapes with the same number contains corresponding data.

4.2.1.2 9-7 Track Conversion of Angel Peak Data Tapes

The 9 track tapes received from the FAA must be converted to 7 track tapes for processing in the Laboratory computer facility. This facility is discussed in Section 8.3 of Reference 1. The conversion is accomplished in the Laboratory Computer Aided Programming (CAP) facility. Table 4-4 lists nine track tapes and the corresponding seven track tapes.

4.2.1.3 CD-Record Data Quality of Angel Peak Data

The CD-Record tapes were reviewed using the CD-Record Target Report Display and Target Report Ambiguity Analysis Package (TRAAP) which are documented in Section 8.3 of Reference 1. This review was carried out to determine the quality of the recorded data and to insure that instances of beacon ring around are included. The results of the review using the display system are listed in Table 4-5. Under the TIME column of Table 4-5, the start and stop times that are recorded on the tape are listed. The CD-Record field tape times were recorded from a real time clock data during collection operations. The recorded time on the other tapes is the time of day when the corresponding video tape was played through the CD at Elwood. Under the TIME CORRESPONDENCE column, an arbitrarily selected time from each tape is listed under TAPE TIME next to the corresponding real time. The time correspondence for tape CD-Record QAS #1VT was verified during the analysis as indicated by the X in the "verified" column. The time correspondence for the other tapes was provided by NAFEC but was not verified.

TABLE 4-3

TAPES RECEIVED FROM THE ANGEL PEAK DATA COLLECTION

TAPE	VIDEO SOURCE
CD-Record QAS 1, 2 FIELD	Real Time Video
CD-Record QAS 3 FIELD	Real Time Video
CD-Record QAS 4 FIELD	Real Time Video
CD-Record QAS 1 VT	Advisor #1 and 2
CD-Record QAS 2 VT	Advisor #2
CD-Record QAS 3 VT	Advisor #3
CD-Record QAS 4 VT	Advisor #4
AI-Mode 2 QAS 1 D	Advisor #1 and 2
AI-Mode 2 QAS 2 D	Advisor #2
AI-Mode 2 QAS 3 D	Advisor #3
AI-Mode 2 QAS 4 D	Advisor #4

TABLE 4-4

9 AND 7 TRACK TAPE*
CD-Record QAS 1, 2 FIELD
CD-Record QAS 3 FIELD
CD-Record QAS 4 FIELD
CD-Record QAS 1 VT
CD-Record QAS 2 VT
CD-Record QAS 3 VT
CD-Record QAS 4 VT
AI-Mode 2 QAS 1 D
AI-Mode 2 QAS 2 D
AI-Mode 2 QAS 3 D
AI-Mode 2 QAS 4 D

*9 and 7 track tape have the same name

TABLE 4-5

REVIEW OF CD-RECORD TAPES FROM ANGEL PEAK DATA COLLECTION

Tape	Tape Time		Time Correspondence		
	Start	Stop	Tape Time	Real Time	Verified
CD-Record QAS 1, 2 FIELD	-	-	Real Time	-	
CD-Record QAS 3 FIELD	-	-	Real Time	-	
CD-Record QAS 4 FIELD	-	-	Real Time	-	
CD-Record QAS 1 VT	11:12:03	11:37:03	11:16:39:8	00:12:36.3	X
CD-Record QAS 2 VT	14:08:00	14:35:15	01:16:05	14:08:30	
CD-Record QAS 3 VT	16:55:30	17:11:09	18:58:40	16:55:30	
CD-Record QAS 4 VT	17:24:00	17:40:31	19:56:36	17:24:00	

NOTE: Range limit for all data: ~ 2.5 nmi to 256 nmi

The DATA CONTENT column of Table 4-5 indicates the presence of search or beacon data on the tapes. Only beacon data was recorded.

The reason that the Angel Peak video tapes were played through the Elwood CD was to obtain Mode 2 tapes of reply data. This data can only be obtained from the Auxiliary Interpreter that is located at Elwood, N.J. However, since the data must be played through the CD at the Elwood site, it is necessary to verify that the resulting report data out of the Elwood CD corresponds with the reports issued by the Angel Peak CD during the real time processing of the video that was recorded at Angel Peak. Tapes QAS 1 FIELD recorded live during the Angel Peak data collection and the corresponding tape, QAS 1 VT, recorded at NAFEC from the video tape, were selected for this purpose. Figure 4-3 is the resulting display when beacon reports from the CD-Record made from live data, displayed in green, are overlapped with beacon reports made from the corresponding video tape at Elwood, displayed in red. Where red and green overlap, indicating a coincidence of the reports, a yellow color appears. Separate red reports indicate lack of coincidence between the reports. As the figure shows, the data, for the most part, coincides. Differences in jitter and gain settings between the two CD's while processing the data is the most probable cause of differences. Such variations can cause some differences in the ring around patterns observed and should be considered when conclusions are drawn from the data. In particular, a change in gain may cause run length to vary some, but this effect should be small, since the cause of ring around is failure of sidelobe suppression which is not related to CD gain at the video input port.

4.2.1.4 Presence of Ring Around in the Angel Peak Data

CD-Record tapes QAS 1 VT through QAS 4 VT were reviewed for the presence of ring around using the TRAAP system. The term ring around generally refers to a severe case of sidelobe splitting, as it is generated because of transponder interrogation and replies that occur in the interrogator antenna sidelobes. The TRAAP system detects the sidelobe splits and classifies them as such on the basis of the criteria given in Table 4-6.

CD-Record Tape Data

Tape Name: QAS #1 VT
(Playback)

Time Frame: 11:12:03 to 11:37:03*

Ring Range Interval (nmi): 75

Beacon Color: Red

Beacon Symbol: Dot

Search Color: None

Search Symbol: None

CD-Record Tape Data

Tape Name: QAS #1 FIELD
(Real Time)

Time Frame: 00:08:00 to 00:33:00*

Range Ring Interval (nmi): 75

Beacon Color: Green

Beacon Symbol: Dot

Figure 4-3 Comparison of Real Time Data at Angel Peak with Playback Data at Elwood

*Time frames selected to correspond

TABLE 4-6

SIDELOBE DETECTION CRITERIA

A. Range Separation (ΔR): $0 \text{ nmi} \leq \Delta R \leq 0.250 \text{ nmi}$

B. Azimuth Separation ($\Delta\theta$): $3 \leq \Delta\theta \leq 180°$

C. Duplicate, discrete beacon code required

Because only discrete codes are used for this, any cases of sidelobe splitting or ring around that occur for non-discrete beacon code targets are excluded. Thus the number of sidelobe ambiguities detected represents a lower bound on those that are present. The detected sidelobe splits were listed by computer and then inspected. Those ambiguities that consisted only of pairs or triplets that fell within 90° of one another were not considered severe enough to be called ring around. Most of the observed ambiguities were found to fall in this category. However, a few instances were actual cases of ring around. Table 4-7 lists the tapes, the time intervals considered, and the beacon codes for which severe ring around occurred.

TABLE 4-7

RING AROUND IN ANGEL PEAK DATA

Tape	Analysis Time (Tape Time)		Codes of Targets Experiencing Ring Around
	Start	End	
QAS #1 VT	11:12:03	11:37:03	None
QAS #2 VT	14:08:00	14:35:15	0716
QAS #3 VT	16:55:30	17:11:09	2530
QAS #4 VT	17:24:00	17:40:31	3236

Figures 4-4, 4-5, 4-6 and 4-7 are photographs of the CD-Record tape data for tapes QAS 1 VT, QAS 2 VT, QAS 3 VT, and QAS 4 VT displayed over the time intervals in Table 4-7. Only discrete beacon code reports

CD-Record Tape Data

Tape Name: QAS #1 VT

Time Frame: 11:12:03 to 11:37:03

Range Ring Interval (nmi): 10

Beacon Color: Red or Green

Beacon Symbol: X or Dot

Search Color: None

Search Symbol: None

Ambiguities

Min Range Sep (nmi): 0

Max Range Sep (nmi): 0.250

Min Az Sep: 3^{o}

Max Az Sep: 180^{o}

Color: Red

Symbol: X

Duplicate Discrete Only: Yes

Display

Discrete Only

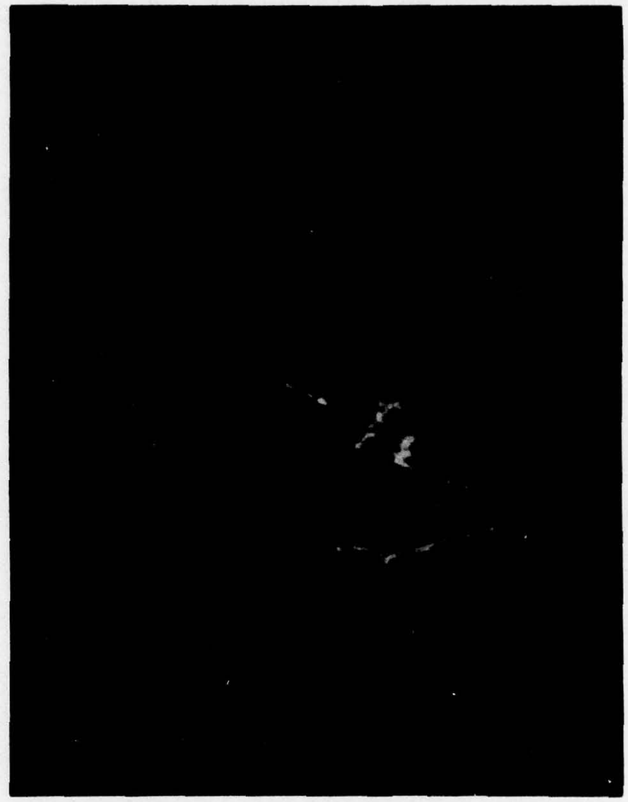


FIGURE 4-4 QAS #1 VT Data

CD-Record Tape Data

Tape Name: QAS #2 VT

Time Frame: 14:08:00 to 14:35:15

Range Ring Interval (nmi): 10

Beacon Color: Red or Green

Beacon Symbol: X or Dot

Search Color: None

Search Symbol: None

Ambiguities

Min Range Sep (nmi): 0

Max Range Sep (nmi): 0.250

Min Az Sep: 3°

Max Az Sep: 180°

Color: Red

Symbol: X

Duplicate Discrete Only: Yes

Display

Discrete Only

FIGURE 4-5 QAS #2 VT Data

CD-Record Tape Data

Tape Name: QAS #3 VT

Time Frame: 16:55:30 to 17:11:09

Range Ring Interval (nmi): 10

Beacon Color: Red or Green

Beacon Symbol: X or Dot

Search Dolor: None

Search Symbol: None

Ambiguities

Min Range Sep (nmi): 0

Max Range Sep (nmi): 0.250

Min Az Sep: 3^{o}

Max Az Sep: 180^{o}

Color: Red

Symbol: X

Duplicate Discrete Only: Yes

Display

Discrete Only

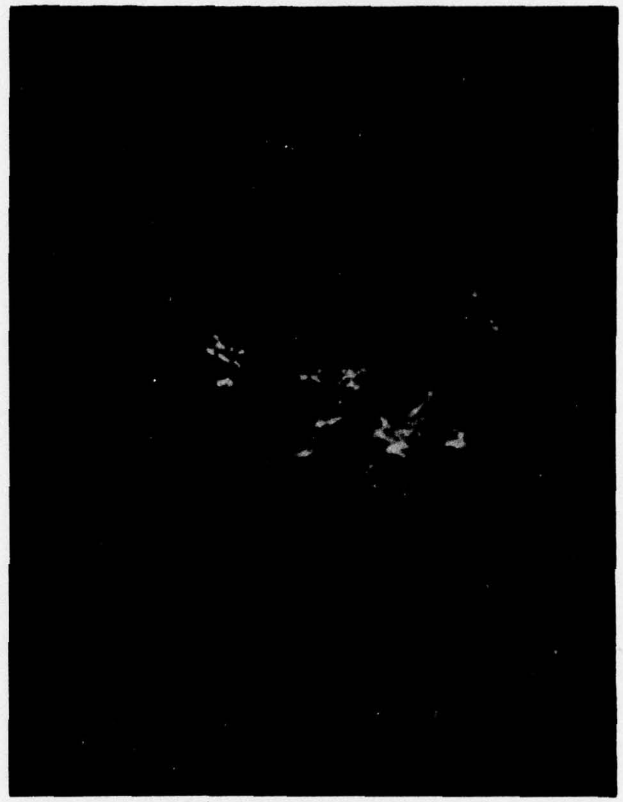


FIGURE 4-6 QAS #3 VT Data

CD-Record Tape Data

Tape Name: QAS #4 VT

Time Frame: 17:24:00 to 17:40:31

Range Ring Interval (nmi): 10

Beacon Color: Red or Green

Beacon Symbol: X or Dot

Search Color: None

Search Symbol: None

Ambiguities

MIN Range Sep (nmi): 0

Max Range Sep (nmi): 0.250

Min Az Sep: 3^{o}

Max Az Sep: 180^{o}

Color: Red

Symbol: X

Duplicate Discrete Only: Yes

Display

Discrete only

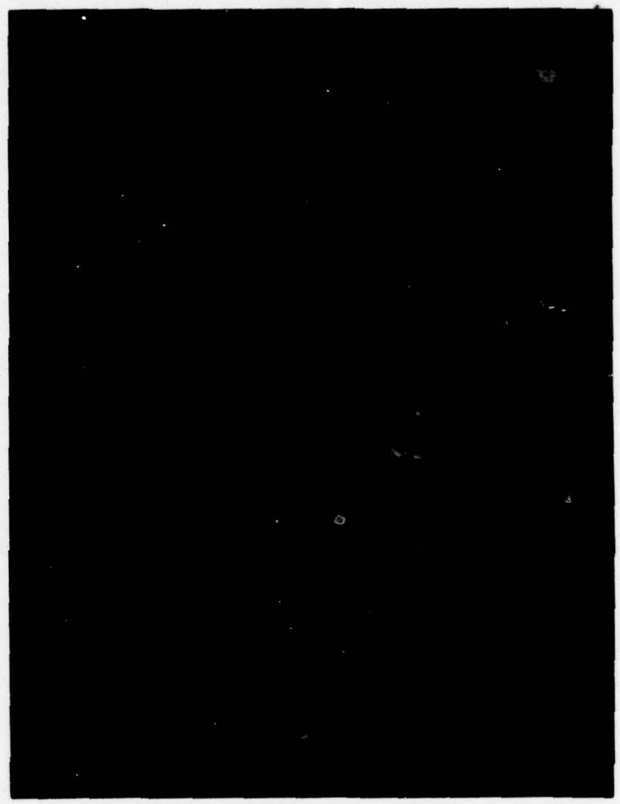


FIGURE 4-7 QAS #4 VT Data

are shown. In this display, normal reports are displayed as green dots. Those reports for which an ambiguity was detected, using the criteria of Table 4-6, are displayed as a red X symbol. The range ring interval in the four figures is 10 nmi. These displays were observed as the reports were put up scan-to-scan, and it was evident that, although many sidelobe type splits occurred (see Section 8.4.3 of Reference 1), few were severe enough to be called ring around, as Table 4-7 shows.

The results of this analysis were shown to the FAA and it was suggested by the FAA that a test aircraft be flown at NAFEC over the Elwood interrogator site to provide more ring around data (see Reference 5). This was done on August 25, 1977.

4.2.1.5 Auxiliary Interpreter Mode 2 Tape Data Quality (Angel Peak Data)

The AI Mode 2 tapes from the Angel Peak data collection were reviewed using the Reply Display described in Section 8.3 of Reference 1. This review was undertaken to insure that the data is good and that replies corresponding to the detected sidelobe splits and ring arounds can be located. The results are listed in Table 4-8.

A recently installed Burroughs modification to the AI allows time to be recorded on the AI Mode 2 tapes (Reference 6). Thus this examination of the time data was not only to determine the time on the tapes, but to insure that time recording was indeed functioning properly. The TIME DATA QUALITY column in Table 4-8 indicates this. The start and end times are listed under the TIME column. These times are tape times and correspond to the tape time on the corresponding CD-Record tapes given in Table 4-5.

The upper and lower cutoff for recording of the report and reply data on the AI Mode 2 tapes is listed in the RANGE LIMITS column of Table 4-8.

Specific items that were checked were report data (beacon, search), presence of reply data, and presence of run length reporting. Appropriate columns appear in Table 4-8. All the AI Mode 2 tapes had beacon only target reports and good reply data, but run length reporting was not implemented.

4.2.2 <u>Review of Elwood Data</u>

This section documents the receipt of data tapes from the August 25 data collection effort at Elwood. These tapes were reviewed for data quality and presence of ring around targets. During the initial review of the data received, it was found that the Mode 2 tape made from FR-950 #77-16 had no report data for the first 452 records which is about 5 minues or

TABLE 4-8

REVIEW OF ANGEL PEAK MODE 2 DATA

Tape	Tape Time (Approximate)		Time Correspondence		Report Data	Reply Data	Run Length	Time Data Quality
	Start	End	Tape Time	Real Time				
QAS 1 D	11:12:03	11:37:03	11:16:40	00:12:36	BCN	Yes	No	Good
QAS 2 D	14:08:00	14:35:15	01:16:05	14:08:30	BCN	Yes	No	Good
QAS 3 D	16:55:30	17:11:09	18:58:40	16:55:30	BCN	Yes	No	Bad
QAS 4 D	17:24:00	17:40:31	19:56:36	17:24:00	BCN	Yes	No	Bad

NOTE: Range limits for all data: ~ 2.5 nmi to 256 nmi.

50 scans. In addition, time data on this tape was bad. This was reported to the FAA and another CD-Record and corresponding Mode 2 tape was made from this FR-950 tape. This tape was found to be adequate and the results of the review addressed here are from the later tapes. (See References 7 and 8).

4.2.2.1 Tapes Received from Elwood Data Collection

The tapes received are listed in Table 4-9, along with the corresponding video source. The CD-Record live tape was made from the FR-1800 tape that recorded the modem line data in real time during the August 25 data collection. The FR-950 sources also recorded during the August 25 data collection were played through the Elwood Common Digitizer (CD to produce the CD-Record tape and Auxiliary Interpreter (AI) Mode 2 tapes listed.

Note that AI Mode 2 tapes 1, 2 and 3 correspond to the CD-Record tapes 1, 2 and 3 respectively, since each corresponding pair is made from the same FR-950 tape. Each pair of tapes was made simultaneously.

4.2.2.2 9-7 Track Conversion of Elwood Data Tapes

The 9 track tapes received from the FAA must be converted to 7 track tapes for processing in the Laboratory computer facility. This facility is discussed in Section 8.3 of Reference 1. The conversion is done in the Laboratory Computer Aided Programming (CAP) facility. The data recorded in nine track tape format physically uses more tape when converted to the seven track tape format. Consequently data recorded on a single nine track tape reel may require two reels when recorded in the seven track format. Table 4-10 lists the nine track tapes and corresponding seven track tapes. As the table shows, AI Mode 2 tapes 1 and 2 each required two reels (designated Part A and Part B) in the seven track format.

4.2.2.3 CD-Record Data Quality of Elwood Data

The CD-Record tapes were reviewed using the CD-Record Target Report Display and Target Report Ambiguity Analysis Package (TRAAP) which are documented in Section 8.3 of Reference 1. This review was carried out to determine the quality of the recorded data and to insure that instances of beacon ring around are included. The results of review using the display system are listed in Table 4-11.

Under the TIME column of Table 4-11, the start and stop times that are recorded on the tape are listed. The CD-Record live tape was recorded from the Elwood clock (synced to WWV time) in real time during the August 25 data collection. The recorded time on the other tapes is the

TABLE 4-9

TAPES RECEIVED
FROM THE ELWOOD DATA COLLECTION

TAPE	VIDEO SOURCE
CD-Record Live	Real Time Video
CD-Record Tape 1	FR-950: 77-15
CD-Record Tape 2	FR-950: 77-16
CD-Record Tape 3	FR-950: 77-17
AI Mode 2 Tape 1	FR-950: 77-15
AI Mode 2 Tape 2	FR-950: 77-16
AI Mode 2 Tape 3	FR-950: 77-17

TABLE 4-10

9-7 TRACK CONVERSION OF ELWOOD DATA

9 TRACK TAPE	7 TRACK TAPE
CD-Record Live	CD-Record Live
CD-Record Tape 1	CD-Record Tape 1
CD-Record Tape 2	CD-Record Tape 2
CD-Record Tape 3	CD-Record Tape 3
AI Mode 2 Tape 1	AI Mode 2 Tape 1 Part A AI Mode 2 Tape 1 Part B
AI Mode 2 Tape 2	AI Mode 2 Tape 2 Part A AI Mode 2 Tape 2 Part B
AI Mode 2 Tape 3	AI Mode 2 Tape 3

TABLE 4-11

REVIEW OF CD-RECORD TAPES FROM THE ELWOOD DATA COLLECTION

Tape	Tape Time		Adapter Codes		Range Limits		Azimuth Offset	Time Correspondence	
	Start	Stop	EBCDIC	Octal	Upper(nmi)	Lower(nmi) (Approximate)		Tape Time	Real Time
Live	13:15:58	14:52:16	72,73,74	173762 173763 173764	256	2.5	None	Real Time	- -
Tape 1	10:57:30	11:25:25	72,73,74	173762 173763 173764	28	2.5	145.5°	11:05:16.6	13:20:7.5
Tape 2	12:39:00	13:06:00	None	None	256	2.5	190.02	12:38:57.3	13:46:13.5
Tape 3	11:31:30	11:45:00	None	None	28	2.5	22.0°	11:38:25.1	14:38:24.9

time of day when the FR-950 tape was played through the CD. Under the TIME CORRESPONDENCE column, an arbitrarily selected time from each tape is listed under TAPE TIME next to the corresponding time of day on August 25 under REAL TIME.

The live tape and tape 1 had adapter codes (Appendix A). These adapter codes should be selected when using the analysis programs, particularly in the case of the live tape as it has data from another site on it as well as the Elwood site data. Use of the adapter code selects only the Elwood data. The codes 72, 73, 74 are recorded as EBCDIC characters on the tape (listed in the EBCDIC column of Table 4-11). The corresponding octal number, determined as described in Appendix A, is listed under OCTAL.

The cutoff ranges are listed under the column designated RANGE LIMITS - Targets above the upper limits and below the lower limits are not recorded. This does not imply that the data was not processed. In the case of the live tape, of course, data is not processed above 256 nmi because this is the maximum range of CD processing in the 1/4 nautical mile range cell mode. However, though CD-Record data was not recorded above 28 nmi for tapes 1, 2 and 3, it was processed in the CD and is present on the corresponding AI Mode 2 tape data.

The real time azimuth data was referenced to true north. However, the recorded azimuth on the FR-950 tapes was with respect to a different zero reference because of a data recording problem that existed. The azimuth offset of the recorded data, with respect to the real time azimuth is listed under the AZIMUTH OFFSET column.

The DATA CONTENT column of Table 4-11 indicates the presence of search or beacon data on the tapes. Only the live tape had both search and beacon data.

4.2.2.4 Presence of Ring Around in Elwood Data

CD-Record tapes 1, 2 and 3 were reviewed for the presence of ring around using the TRAAP system. The term ring around generally refers to a severe case of sidelobe splitting, as it is generated because of transponder interrogation and replies that occur in the interrogator antenna sidelobes. The TRAAP system detects the sidelobe splits and classifies them as such on the basis of the criteria given in Table 4-12.

TABLE 4-12

SIDELOBE DETECTION CRITERIA

A. Range Separation (ΔR): $0 \text{ nmi} \leq \Delta R \leq 0.250 \text{ nmi}$

B. Azimuth Separation ($\Delta\theta$): $3° \leq \Delta\theta \leq 180°$.

C. Duplicate, discrete beacon code required.

Because only discrete codes are used for this, any cases of sidelobe splitting or ring around that occur for non-discrete beacon code targets are excluded. Thus the number of sidelobes detected represents a lower bound on those that are present. Visual observation of the data using the display system revealed, in fact, that a significant number of non-discrete code targets experienced severe ring around.

Table 4-13 lists the tapes, the analysis time interval (in recorded tape time, not real time) and the number of sidelobes detected on each. It is emphasized that this number is a lower bound on the number of sidelobe splits available for analysis.

Figures 4-8, 4-9 and 4-10 are photographs of the CD-Record tape data for tapes 1, 2 and 3 displayed over the time interval indicated in Table 4-11. Only discrete code beacon target reports are displayed. Code 2315 appears as an X symbol, and all others are dots. Duplicate Discrete Code ambiguities with the separation criteria indicated in the figure are in red while all other reports are green. Range rings have a 5 nautical mile interval and are in blue with the Elwood site centered.

4.2.2.5 Auxiliary Interpreter Mode 2 Tape Quality (Elwood Data)

The AI Mode 2 tapes were reviewed using the Reply Display described in Section 8.3 of Reference 1. This review was undertaken to insure that the data is good and that replies corresponding to the detected sidelobe splits and ring arounds can be located. The results are listed in Table 4-14.

A recently installed Burroughs modification to the AI allows time to be recorded on the AI Mode 2 tapes (Reference 6). Thus this examination of the time data was not only to determine the time on the tapes but to insure that time recording was indeed functioning properly. The TIME DATA QUALITY column in Table 4-14 indicates this. The start and end times are listed under the TIME column. These times are tape times and correspond to the tape time on the corresponding CD-Record tapes given in Table 4-11. The correspondence to real time in Table 4-14 is identical to the CD-Record time correspondence given in Table 4-11.

TABLE 4-13

TRAAP ANALYSIS OF CD-RECORD DATA FROM THE ELWOOD DATA COLLECTION

Tape	Analysis Time (Tape Time)		Minimum Sidelobes	Comments
	Start	Stop		
Tape 1	10:57:00	11:25:00	17	Only duplicate discrete codes with range separation less than or equal to 1/4 nmi and azimuth separation greater than 3° are included in this table. Many ring arounds were observed for non-discrete codes as well.
Tape 2	12:39:00	13:06:00	35	
Tape 3	11:31:30	11:45:00	19	

CD-Record Tape Data

Tape Name: Aug 25, Tape 1,A

Time Frame: 10:57:30 - 11:25:00

Range Ring Interval (nmi): 5

Beacon Color: Red or Green

Beacon Symbol: X or Dot

Search Color: None

Search Symbol: None

Ambiguities

Min Range Sep (nmi): 0

Max Range Sep (nmi): 0.250

Min Az Sep: 3°

Min Az Sep: 180°

Color: Red

Symbol: X or Dot

Duplicate Discrete Only: Yes

Flagged Codes

Code	Symbol	Color
2315	X	Selected

Display

Discrete Only

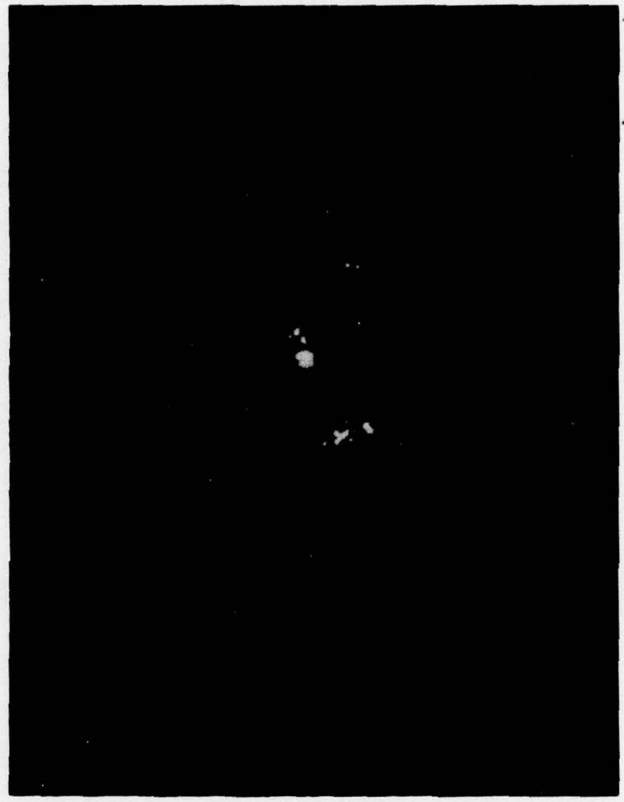


FIGURE 4-8: Display of August 25 CD-Record Tape 1,A Data

CD-Record Tape Data

Tape Name: Aug. 25, Tape 2,A

Time Frame: 12:30:00 - 13:06:00

Range Ring Interval (nmi): 5

Beacon Color: Red or Green

Beacon Symbol: X or Dot

Search Color: None

Search Symbol: None

Ambiguities

Min Range Sep (nmi): 0

Max Range Sep (nmi): 0.250

Min Az Sep: 3^{o}

Max Az Sep: 180^{o}

Color: Red

Symbol: X or Dot

Duplicate Discrete Only: Yes

Flagged Codes

Code	Symbol	Color
2315	X	Red or Green

Display

Discrete Only

FIGURE 4-9: Display of August 25 CD-Record Tape 2,A Data

CD-Record Tape Data

Tape Name: Aug 25, Tape 3

Time Frame: 11:31:30 - 11:45:00

Range Ring Interval (nmi): 5

Beacon Color: Red or Green

Beacon Symbol: X or Dot

Search Color: None

Search Symbol: None

Ambiguities

Min Range Sep (nmi): 0

Max Range Sep (nmi): 0.250

Min Az Sep: 3^{o}

Max Az Sep: 180^{o}

Color: Red

Symbol: X or Dot

Duplicate Discrete Only: Yes

Flagged Codes

Code	Symbol	Color
2315	X	Red or Green

Display

Discrete only

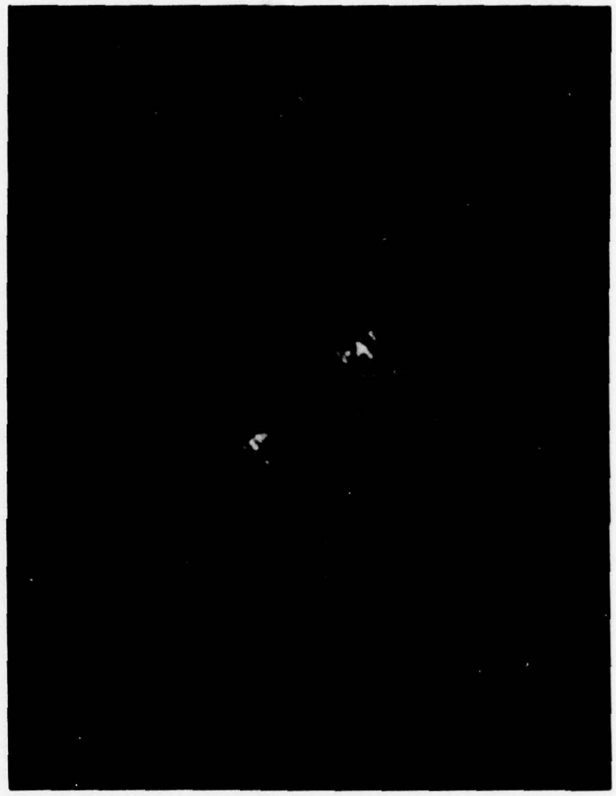


FIGURE 4-10: Display of August 25 CD-Record Tape 3 Data

The upper and lower cutoff for recording of the report and reply data on the AI Mode 2 tapes is listed in the RANGE LIMITS colum of Table 4-14. Note that these range limits differ from the CD-Record data range limits in Table 4-11, in that none of the data was cut off at the 28 nmi limit. This cutoff was implemented in the reply data to prevent overflow of the Auxiliary Interpreter output data buffer. However, the reply data does not appear to have suffered from not having the range cutoff inserted.

The azimuth offset is identical to the offset of the CD-Record data in Table 4-11.

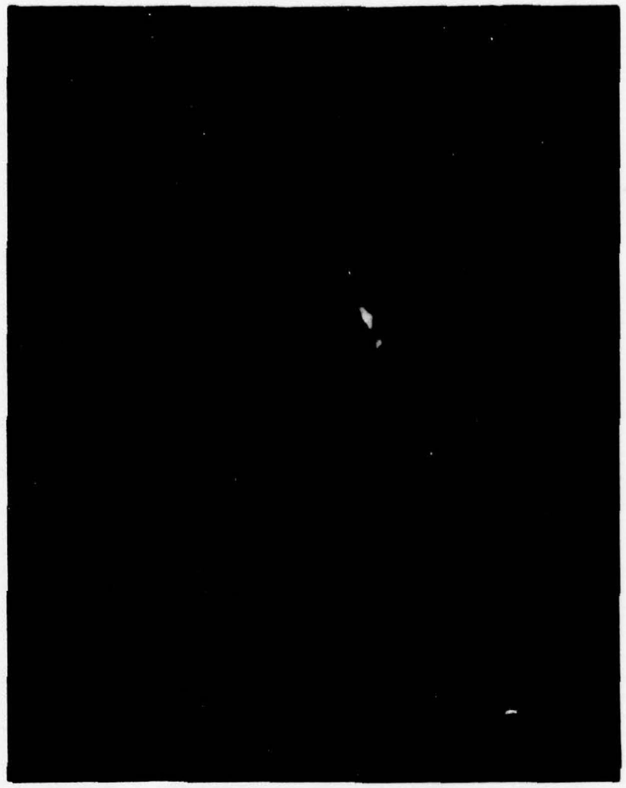
Specific items that were checked were report data (beacon, search) presence of reply data, and presence of run length reporting. Appropriate column appears in Table 4-14. All the AI Mode 2 tapes had beacon only target reports, good reply data, and run length reporting implemented.

TABLE 4-14

REVIEW OF ELWOOD MODE 2 DATA

Tape	Time (Approximate)		Range Limits		Azimuth	Time Correspondence		Report	Reply	Run	Time Data
	Start	Stop	Upper(nmi)	Lower(nmi)	Offset	Tape Time	Real Time	Data	Data	Length	Quality
Tape 1 A & B	10:57:30	11:25:25	256	3	145.5°	11:05:16.6	13:20:7.5	BCN Only	Yes	Yes	Good
Tape 2 A & B	12:39:00	13:06:00	256	3	190.02°	12:38:57.3	13:46:13.5	BCN Only	Yes	Yes	Good
Tape 3	11:31:30	11:45:00	256	3	22.0°	11:38:25.1	14:38:24.9	BCN Only	Yes	Yes	Good

Figure 6-2 Ring Around Example on Elwood Mode 2 Tape 2



Auxiliary Interpreter Mode 2 Tape Data

Tape Name: Aug. 25, Tape 2

Time Frame: 12:42:00

Record Number: 410, 411

Range Ring Interval: 2 nmi

Beacon Report Color: Green

Beacon Report Symbol: X or Dot

Search Report Color: None

Search Report Symbol: None

Beacon Replies

Mode C Color: Blue

Mode C Symbol: Dot

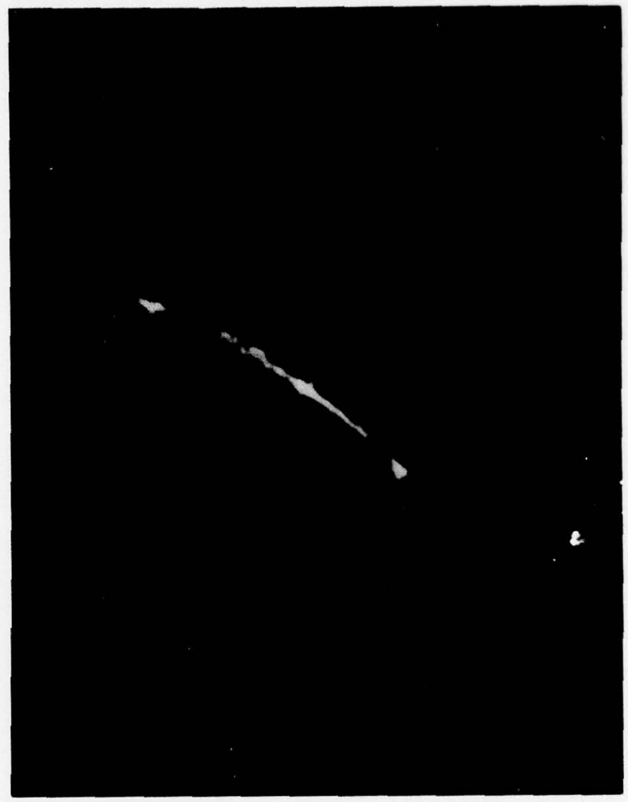
Mode 3/A Color: Red

Mode 3/A Symbol: Dot

Flagged Codes

Code	Symbol	Color
2315	X	Green

Figure 6-3 Ring Around Example on Elwood Mode 2 Tape 2



Auxiliary Interpreter Mode 2 Tape Data

Tape Name: Aug. 25, Tape 2

Time Frame: 12:42:4.4

Record Number: 414, 415, 416

Range Ring Interval: 2 nmi

Beacon Report Color: Green

Beacon Report Symbol: X or Dot

Search Report Color: None

Search Report Symbol: None

Beacon Replies

Mode C Color: Blue

Mode C Symbol: Dot

Mode 3/A Color: Red

Mode 3/A Symbol: Dot

Flagged Codes

Code	Symbol	Color
2315	X	Green

possible discriminant, which will reduce the number of false targets, is to eliminate reports that are very long in run length or very short in run length.

Lead edge threshold T_L might also be a possible discriminant. Increasing the leading edge threshold might be effective in eliminating the false reports with short run lengths, but would be useless against the false reports having very long run lengths.

Another discriminant considered would examine the ratio of mode 3/A hits to the number of opportunities for a 3/A hit while the target report was in process. However, visual inspection of both false and real reports indicates that this ratio is very close to one for nearly all reports, true and false.

Therefore, a discriminant using run length appears to have the most promise of being effective. In the next section, data is statistically assessed to determine the effectiveness of run length discrimination.

6.2 ANALYSIS OF RUN LENGTH CHARACTERISTICS

6.2.1 Introduction

This section documents some significant results and conclusions obtained during investigation to determine a discriminant against false reports generated from ring around. Specifically, an analysis of real and false target report run lengths was performed to determine the merit of a run length discrimination scheme for reducing the number of false reports.

6.2.2 Analysis Procedure

Figure 6-4 illustrates the data reduction procedure used for this analysis. The data used was collected at Elwood, N.J. on August 25, as described in section 4.1. In particular, the data tapes delineated in Table 6-1 were used:

Table 6-1 Data Tapes Used for Test Target Run Length Analysis

1. August 25 AI-Mode 2 Tape 1, Part A
2. August 25 AI-Mode 2 Tape 2, Part A
3. August 25 AI-Mode 2 Tape 3

6.2.2.1 Extraction of Test Target Report Data

Using the Auxiliary Interpreter Mode 2 Tape Reply Display system described in section 8.3 of ref. 1, all test target report data occurring at ranges below 10 nmi was extracted. This range cutoff was used because ring around did not occur beyond this range in this data set.

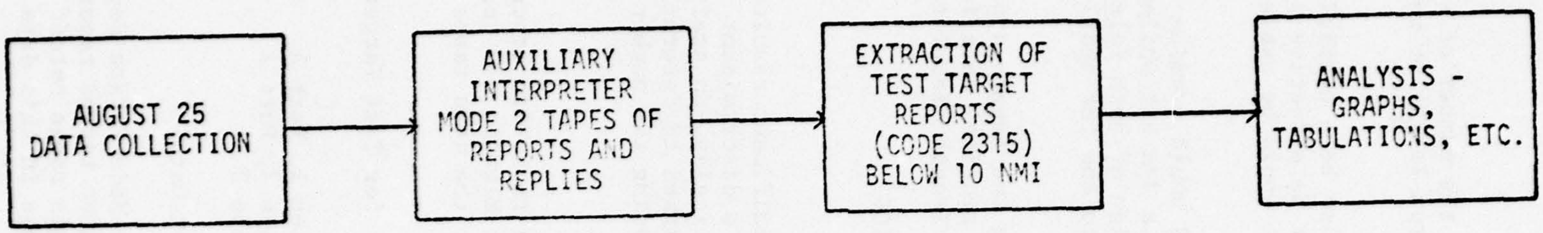


Figure 6-4. DATA REDUCTION PROCEDURE

The following procedure was used to extract the test target data using this display system. For each tape, the report data was displayed in PPI format on the Color TV console. Beacon data was displayed in green symbols. An X symbol was used to distinguish the test target reports (recognizable because of the unique Mode 3/A code assigned, 2315) from all other beacon reports. Fig. 6-5 is an example of the display for tape 3. Approximately 10 scans of data are presented. The test target reports on successive scans can be visually observed to form a track. Reports appearing in an X symbol that are visually correlated with the track are true reports. Reports that appear as an X symbol which do not correlate visually with the track are false. All test target reports in Fig. 6-5 correlate with the track and are real reports. Test target report data below 10 nmi was hooked and the status, true or false, was noted. In Fig. 6-5, a true test target report is being hooked by the red box. Table 6-2 type of data was printed for this report.

Table 6-2. Example of Hooked Report Data

REC	MSG	AZIMUTH	RANGE	RUN LNG	MODE 3A VAL	MODE 3A CODE	MODE C VAL	MODE C ALTITUDE
227	7	229.219	7.500	44	1	2315	1	20,000

The record number (REC) and message number (MSG) uniquely identify the data on the tape so that it may be relocated if necessary. Also given are the range (slant range), azimuth, run length (in ACP's, see section A2 in Appendix A) Mode 3/A code and Mode C altitude. A similar message was printed for each report that was hooked.

Fig. 6-6 is an example of a test target track and test target reports that do not correlate with the track. The test target reports (X symbols) in the upper right corner of the display are false reports generated from antenna sidelobe and backlobe returns. Using the display system, these false reports are easily identified as Figure 6-6 shows.

In some cases, two reports occurred simultaneously which could both be correlated with the track. In such cases, both reports could be called false, both real, or one real and one false. In the cases observed, the run lengths for such reports were shorter than the average run lengths for real reports. Thus, the report with the longer run length was designated the real report and the other false.

6.2.2.2 Summary of Extracted Target Report Data

As Fig. 6-4 shows, the extracted test target report data was subjected to analysis. Appropriate plots and tabulations were made and appear in the next section on results. The extracted data is summarized in Table 6-3.

Auxiliary Interpreter Mode 2 Tape Data

Tape Name: Aug. 25 Tape 3

Time Frame: ~11:33:43

Record Number: 227

Range Ring Interval: 5 nmi

Beacon Report Color: Green

Beacon Report Symbol: X or Dot

Search Report Color: None

Search Report Symbol: None

Flagged Codes

Code	Symbol	Color
2315	X	Green

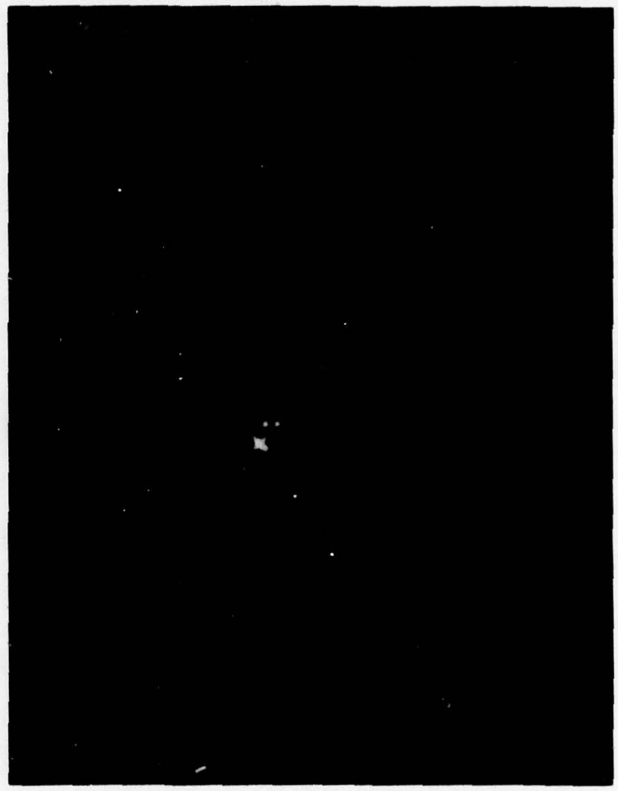


Figure 6-5 Extractions of Test Target Data

Auxiliary Interpreter Mode 2 Tape Data

Tape Name: Aug. 25, Tape 3

Time Frame: ~11:34:12

Record Number:

Range Ring Interval: 2 nmi

Beacon Report Color: Green

Beacon Report Symbol: X or Dot

Search Report Color: None

Search Report Symbol: None

Flagged Codes

Code	Symbol	Color
2315	X	Green

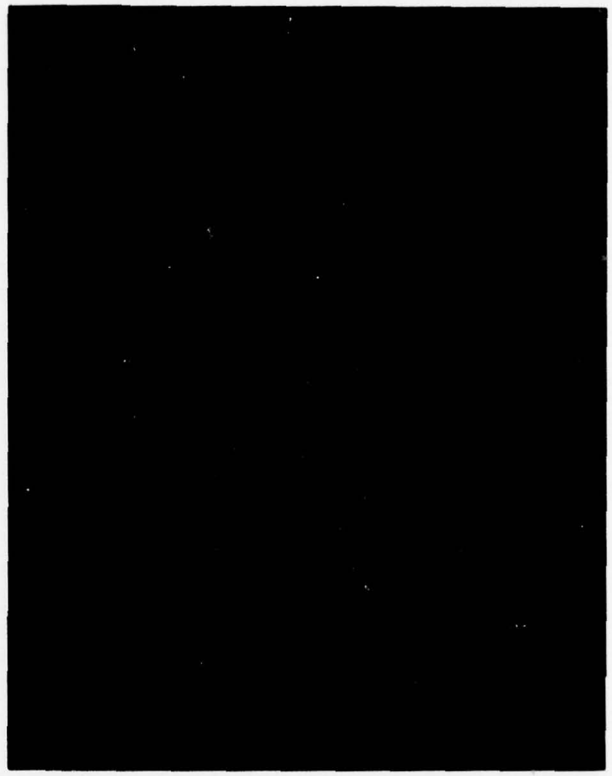


Figure 6-6 Example of Reports that do not Correlate With a Track.

Table 6-3. Test Target Data for Run Length Analysis

Table 6-3a

Tape: Aug. 25 AI-Mode 2 Tape 1, Part A

Altitude (ft)	Real Reports	False Reports
5000	34	0
10000	8	0
20000	0	0

Table 6-3b

Tape: Aug. 25 AI-Mode 2 Tape 2, Part A

Altitude (ft)	Real Reports	False Reports
5000	0	0
10000	19	7
20000	29	48

Table 6-3c

Tape: Aug. 25 AI-Mode 2 Tape 3

Altitude (ft)	Real Reports	False Reports
5000	0	0
10000	0	0
20000	27	44

TOTAL Table 6-3d

Altitude (ft)	Real Reports	False Reports
5000	34	0
10000	27	7
20000	56	92

The tables show that test aircraft was observed at three different altitudes: 5000 feet, 10000 feet and 20000 feet.

The altitudes were determined from the Mode C altitude provided by the aircraft transponder which is accurate to the nearest 100 feet. The actual altitude must be determined by correcting the Mode C altitude for the barometric pressure present at the time the aircraft was flying. The test aircraft altitude varied slightly in some cases from the three nominal altitudes. However, since the recorded barometric pressure for the day cannot account for temperature variations, even the corrected altitudes include errors. Therefore, the altitudes were simply rounded to the nearest 1000 feet.

A listing of the data points and a sample of the altitude correction appear in the Appendix C.

6.2.3 <u>Results</u>

6.2.3.1 Elevation Angle Dependence

This section presents results that indicate an elevation angle above which ring around occurs and below which no ring around occurs. The basis for the conclusion is illustrated with a Range Altitude plot described below.

6.2.3.1.1 Range-Altitude Plot

From Table 6-3d it is observed that at 5000 feet, out of 34 reports observed, all were true. At 10000 feet, 7 false reports and 27 true reports were observed. At 20000 feet, 92 false reports and 56 true reports were observed. From this table it is evident that altitude plays a role in determining when a target will produce ring around. To investigate this further, a Range-Altitude plot was made with all the data points included as shown in Figure 6-7.

The horizontal axis is range in nautical miles. The vertical axis is scaled the same as the horizontal axis, but altitude is indicated in feet, rather than nautical miles. Test target reports were observed at three altitudes, 5000 feet, 10000 feet and 20000 feet, indicated on the vertical axis. The beacon interrogator is at the intersection of the axes.

The elevation at Elwood is near sea level (15-25 feet) and the antenna height is 50-75 feet above the ground. Therefore, the antenna elevation above sea level is less than 100 feet. The aircraft altitudes are above sea level and contain errors which may be on the order of 100 ft. as discussed in Section 6.2.2.2 and Appendix C. Furthermore, 100 ft. difference will not show up in range altitude plot; therefore the elevation of the interrogator is neglected.

Points corresponding to real reports are black, and points corresponding false reports are red. The vertical spreading of the points was done to accommodate the number of points observed and does not indicate deviations from the three altitudes for which data was observed. The range data (example in Table 6-2) is slant range, and the positions of the data points in Figure 6-7 were determined as the intersections of the corresponding altitude and slant range from the interrogator. Slant ranges below about 2.75 nautical miles are not processed by the Common Digitizer and reports are not generated below this range. This cutoff range is shown by an arc representing the locus of points that are 2.75 nautical miles from the interrogator.

6.2.3.1.2 Conclusions from the Range-Altitude Plot

From Figure 6-7 it can be seen that all the false reports occur for targets above 28° elevation (measured from the figure) with the exception of one. The exception was generated from a range split which is not related to ring around type false reports (see section 8 of Ref. 1). Above 60°, no reports occur because the antenna mainbeam and sidelobes are too low to cause interrogation.

It appears that ring around, rather than being related to altitude, is related to elevation angle. Sidelobe suppression is failing above this elevation.

In the past it has been observed that higher altitude targets tend to ring around more frequently than lower altitude targets. From Figure 6-7, it can be seen that ground distance traversed while in the 28° to 60° elevation angle region increases as altitude increases, so that higher altitude targets have more area and therefore more opportunity to ring around than the lower altitude targets. Of course, the occurrence of ring around is also related to range - targets beyond about 15 nmi slant range will not experience ring around ragardless of elevation angle, so that at extremely high altitudes, ring around will not occur.

The ideal solution for ring around is to adjust the radiation pattern of the omnidirectional antenna so that sidelobe suppression is effective above this elevation (28°). This may not be easy to do in practice, however, and so run length discrimination, to be discussed shortly, may be a reasonable alternative.

6.2.3.2 Run Length Characteristics

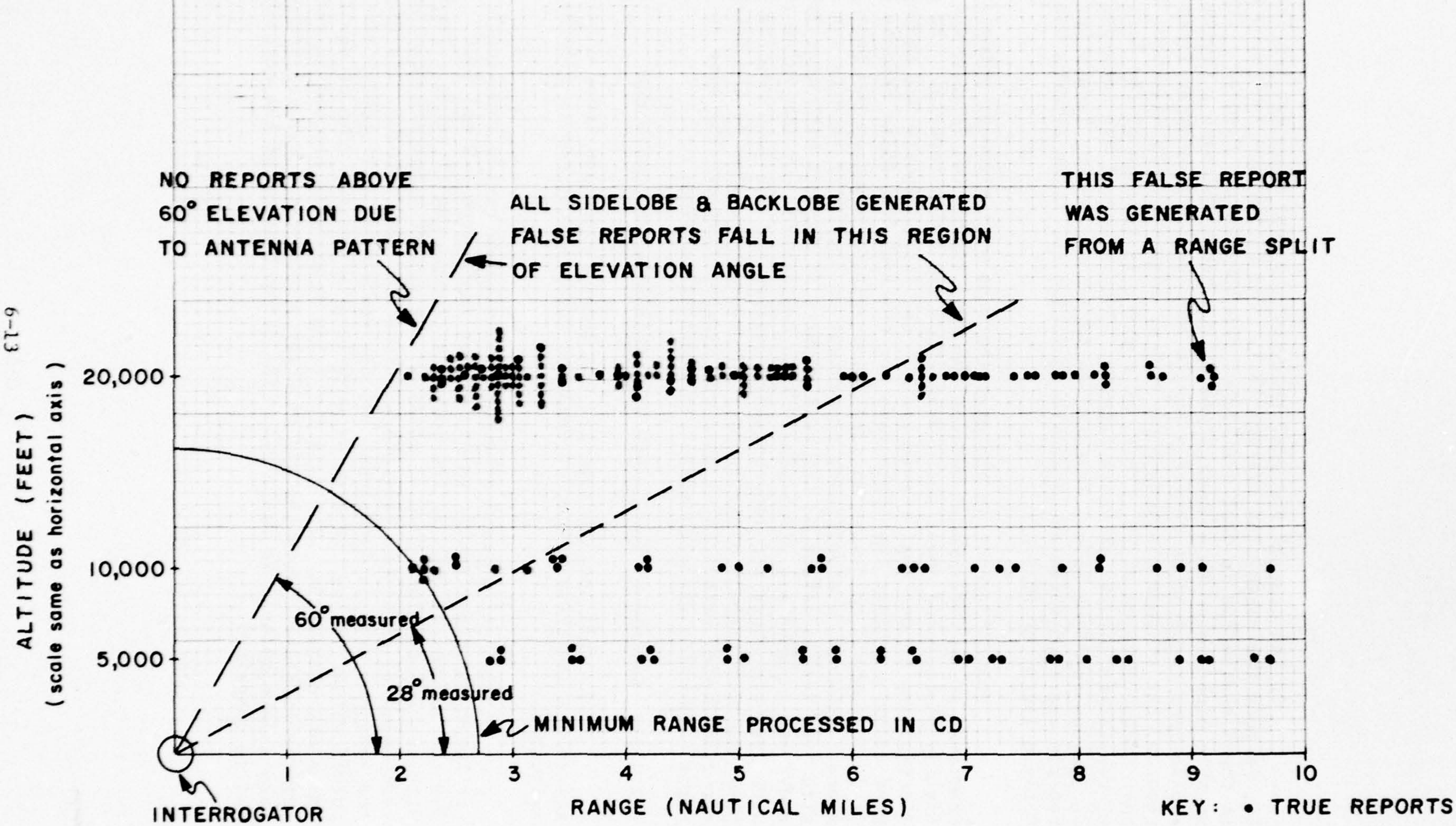
In this section, an investigation of the run length characteristics for true and false reports to determine the viability of using run length as a false target discriminant is addressed. Run length is defined in section C.2 of Appendix C. The approach for this analysis was to examine histograms of run length for real and false reports to see if differences between the run length distributions for real and false reports could be utilized to design an effective false target discriminant.

6.2.3.2.1 Composite Run Length Histograms

Figure 6-8 is a histogram of real and false test target reports below 10 nmi slant range. The horizontal axis is run length in ACP's (see section C.2 in Appendix C)and the vertical axis is number of reports. Run length in the original data and is reported to a least significant bit of 4 ACP's. Consequently, the run length bins are 4 ACP's wide (0-3, 4-7, etc.).

Obviously, the distributions for the real reports differ from the false reports. The real reports peak at 44 with values ranging from 20 to 100. False reports peak at 20 with values ranging from 12 to 252.

FIGURE 6-7 ALTITUDE vs. RANGE



Data Source: Aug 25 Elwood Data
Data Points: Beacon Code 2315 Real & False Reports

Number of Points

Alt (ft)	True	False
5000	34	0
10000	27	7
20000	56	92

In the case of the real reports, the most frequent run lengths, 44, is near the calculated average 49.7. The difference indicates an asymmetry in the distribution in that the higher run lengths are favored. This is reasonable since there is a lower limit on run length because a finite number of replies are required to detect a target but there is no upper limit. For false reports, the average run length of 59.4 is significantly different from the most frequent value of 20. This, of course, is because of the large spread of run length values for false reports. Comparison of the computed standard deviations confirms this. Standard deviation of the run length for the real reports was 14.8 while the standard deviation for false reports was almost 4 times larger at 56.3.

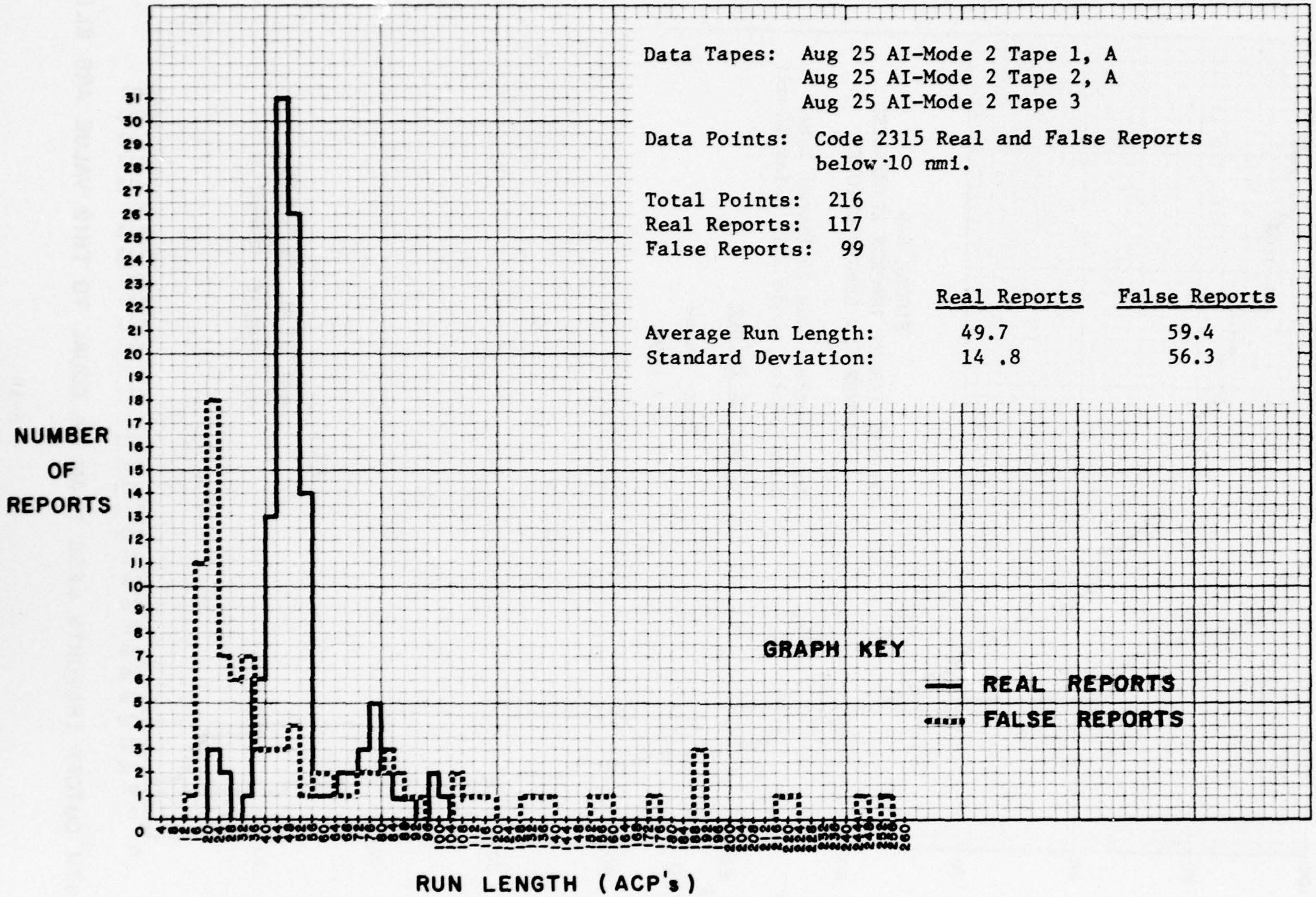
The difference in the distributions will allow an effective discriminant to be implemented because the real report run lengths are more tightly distributed about the average than the false reports. The ideal discriminant is one that eliminates all the false reports but keeps all the good reports. Since the histograms for the true and false reports overlap, it is impossible to design an ideal discriminant based on run length data alone. However, a significant percentage of the false reports can be eliminated with very little effect on the real reports if reports with very long and very short run lengths are eliminated. This would throw out the false reports with long and short run lengths while passing all the good reports because they are more tightly distributed. Unfortunately, some of the false reports are also passed because they have run lengths that are the same as good reports. Specific examples appear in the next section.

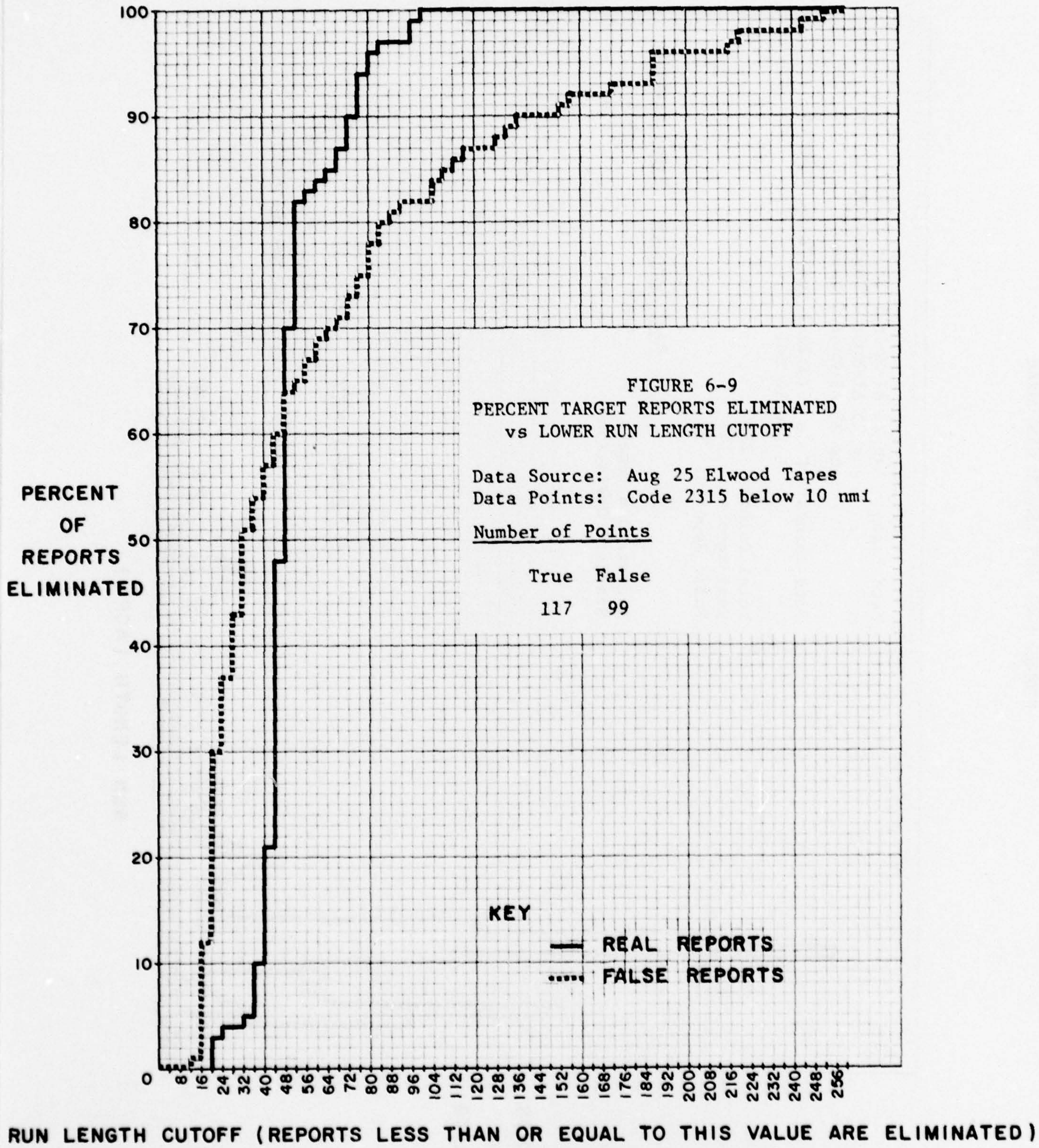
6.2.3.2.2 Example of Run Length Discrimination Effectiveness

In this section specific run length upper and lower cutoff values are chosen and their effect on real and false target report eliminations are evaluated.

Plots of percent of reports eliminated versus run length cutoffs for lower and upper cutoff values appear in Figures 6-9 and 6-10. In Figure 6-9 the horizontal axis is the lower run length cutoff value. Target reports with run lengths less than or equal to the cutoff value are eliminated. The vertical axis gives the percentage versus the cutoff value. In Figure 6-10 the vertical axis is identical, but the horizontal axis represents the upper cutoff value. Target reports with run lengths greater than or equal to this value are eliminated. The data for false reports is plotted in red and real reports in black. With the aid of these plots, two cases are considered. Case 1 is tabulated in Table 6-4. The determination of the entries in Table 6-4 is described.

FIGURE 6-8 RUN LENGTH HISTOGRAM




100
90
80
70
60
50
40
30
20
10
0
PERCENT OF REPORTS ELIMINATED
FIGURE 6-9
PERCENT TARGET REPORTS ELIMINATED
vs LOWER RUN LENGTH CUTOFF
Data Source: Aug 25 Elwood Tapes
Data Points: Code 2315 below 10 nmi
Number of Points
True False
117 99
KEY
REAL REPORTS
FALSE REPORTS
8 16 24 32 40 48 56 64 72 80 88 96 104 112 120 128 136 144 152 160 168 176 184 192 200 208 216 224 232 240 248 256
RUN LENGTH CUTOFF (REPORTS LESS THAN OR EQUAL TO THIS VALUE ARE ELIMINATED)

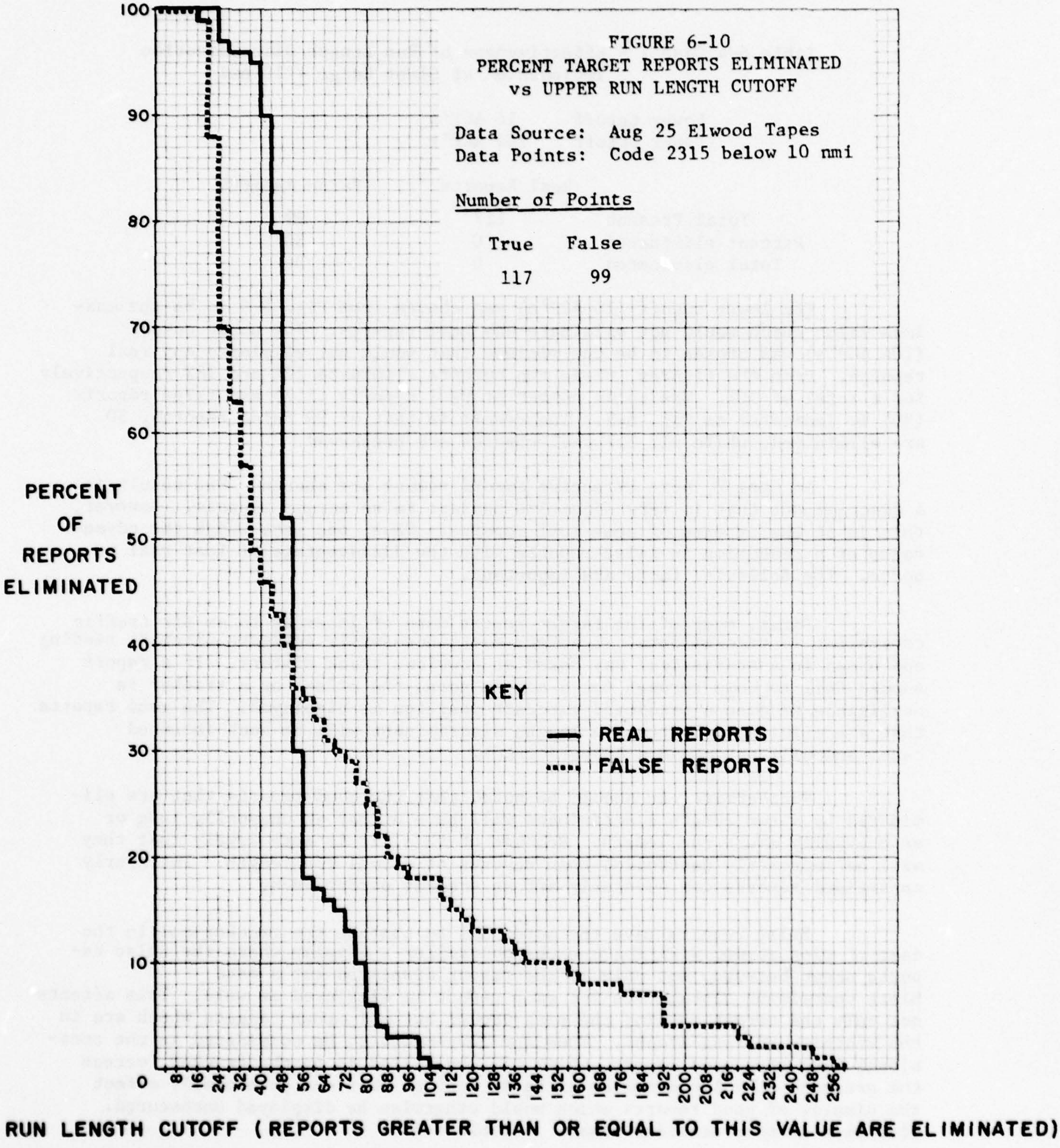


FIGURE 6-10
PERCENT TARGET REPORTS ELIMINATED
vs UPPER RUN LENGTH CUTOFF
Data Source: Aug 25 Elwood Tapes
Data Points: Code 2315 below 10 nmi
Number of Points
True False
117 99
KEY
REAL REPORTS
FALSE REPORTS
PERCENT OF REPORTS ELIMINATED
100
90
80
70
60
50
40
30
20
10
0
8
16
24
32
40
48
56
64
72
80
88
96
104
112
120
128
136
144
152
160
168
176
184
192
200
208
216
224
232
240
248
256
RUN LENGTH CUTOFF (REPORTS GREATER THAN OR EQUAL TO THIS VALUE ARE ELIMINATED)

Table 6-4 Case 1 - Effectiveness of Run Length Discrimination Implemented at Slant Range $\leq$ 10 nmi

Lower Cutoff	16 ACP's
Upper Cutoff	104 ACP's

	Real Reports	False Reports
Total Present	117	99
Percent eliminated	0	30
Total eliminated	0	30

The lower cutoff (16 ACP's) was chosen from Fig. 6-9 to be the maximum value which would not eliminate any real reports. The upper cutoff (104 ACP's) was chosen to be the minimum that would not eliminate any real reports. From the figures, these two cutoffs eliminate 12% and 18% respectively for a total of 30%. The total number of real reports (117) and false reports (99) is indicated on Fig. 6-8. The result is that of 99 false reports, 30 are eliminated, while all 117 real reports are preserved.

In Case 2, more effective cutoff values are chosen. The result is a discriminant that is very effective against false target reports. However, this is at the expense of some real reports. Thus, one must weigh the advantages of a reduction in false reports with the disadvantage of lost real reports. The following facts are important.

First, much of the target report data of interest to an air traffic controller is tracked data. Trackers must necessarily estimate aircraft heading and speed in a statistical way based on previous track history. If a report should fail to come through for a single scan, the effect on a tracker is negligible because a predicted aircraft position is displayed. The good reports that are eliminated by the run length discriminant will be such isolated cases and will not cause a dropped track.

Furthermore, it should be noted that the good reports that are eliminated by a run length discriminant will have either an unusually long or an unusually short run length. Because of this, it is more likely that they will be improperly centroided than reports of normal run length. Improperly centroided reports can adversely affect tracker performance.

False reports have the potential to confuse the tracker and in the case of ring around will obscure the controller's display where the false reports occur because, not only is the report displayed but a data block containing alphamerics for each report is displayed as well. This affects not only the target causing the ring around but all other targets which are in the vicinity of ring around. Thus the compromise to be considered is the occasional loss of a good report, which will be filled in by the tracker, versus the presence of a large number of false reports that can potentially affect the display of good reports which would otherwise be displayed unobscured. With this in mind consider Case 2 in Table 6-5.

Table 6-5 Case 2 - Effectiveness of Run Length Discrimination Implemented at Slant Range ≤ 10 nmi

Lower Cutoff - 36 ACP's
Upper Cutoff - 104 ACP's

	Real Reports	False Reports
Total Present	117	99
Percent eliminated	10	71
Total eliminated	12	72

In Case 2, the upper cutoff remains 104 ACP's but the lower cutoff is increased to 36 ACP's. Now, out of the 99 false reports, 72 are eliminated - a sizeable improvement and a very effective discriminant. However, 12 of the 117 real reports are also lost. As discussed previously, the loss of these reports is not necessarily harmful. However, the idea of eliminating real reports is still politically dsiturbing, if nothing else. The number of real reports that are lost can be further reduced if use is made of elevation angle as shown in the next section.

6.2.3.2.3 Use of Elevation Angle Dependence

In section 6.2.3.1 the dependence of ring around on elevation is shown, Specifically, all ring around in the observed data occurs above 28° elevation. Thus, a ring around discriminant need only be implemented for targets known to be above this elevation angle. This will be just as effective against ring around false reports as a discriminant that does not use elevation angle, but it will reduce the number of real reports that are also subjected to the same discrimination criteria and cause a subsequent reduction in the number of real reports eliminated. In order to assess this quantitatively, a histogram of run length for real and false reports above 28° elevation only was made. This is shown in Fig. 6-11. The number of real and false reports are indicated on the plot. This data is a subset of the data presented in the composite run length histogram of Fig. 6-8. In Figure 6-8 the total real reports were 117. This is dramatically reduced to 29 when the data is restricted to above 28° elevation. On the other hand, of the 99 false reports of Fig. 6-8, 98 are above 28° elevation. The remaining false report was generated by a range split, not ring around (see section 6.2.3.1.2). The significance of this is that while all the ring around generated false reports are still subjected to the discriminant, the number of real reports that are subject to the discriminant is substantially reduced, thereby reducing the opportunities to eliminate real reports. In the next section, an example is presented that shows how the number of real reports lost is reduced while the number of false reports eliminated is almost the same.

6.2.3.2.4 Example of Use of Elevation Angle Data

Figures 6-12 and 6-13 are plots of percent reports eliminated versus lower and upper run length cutoff values. These are identical to plots

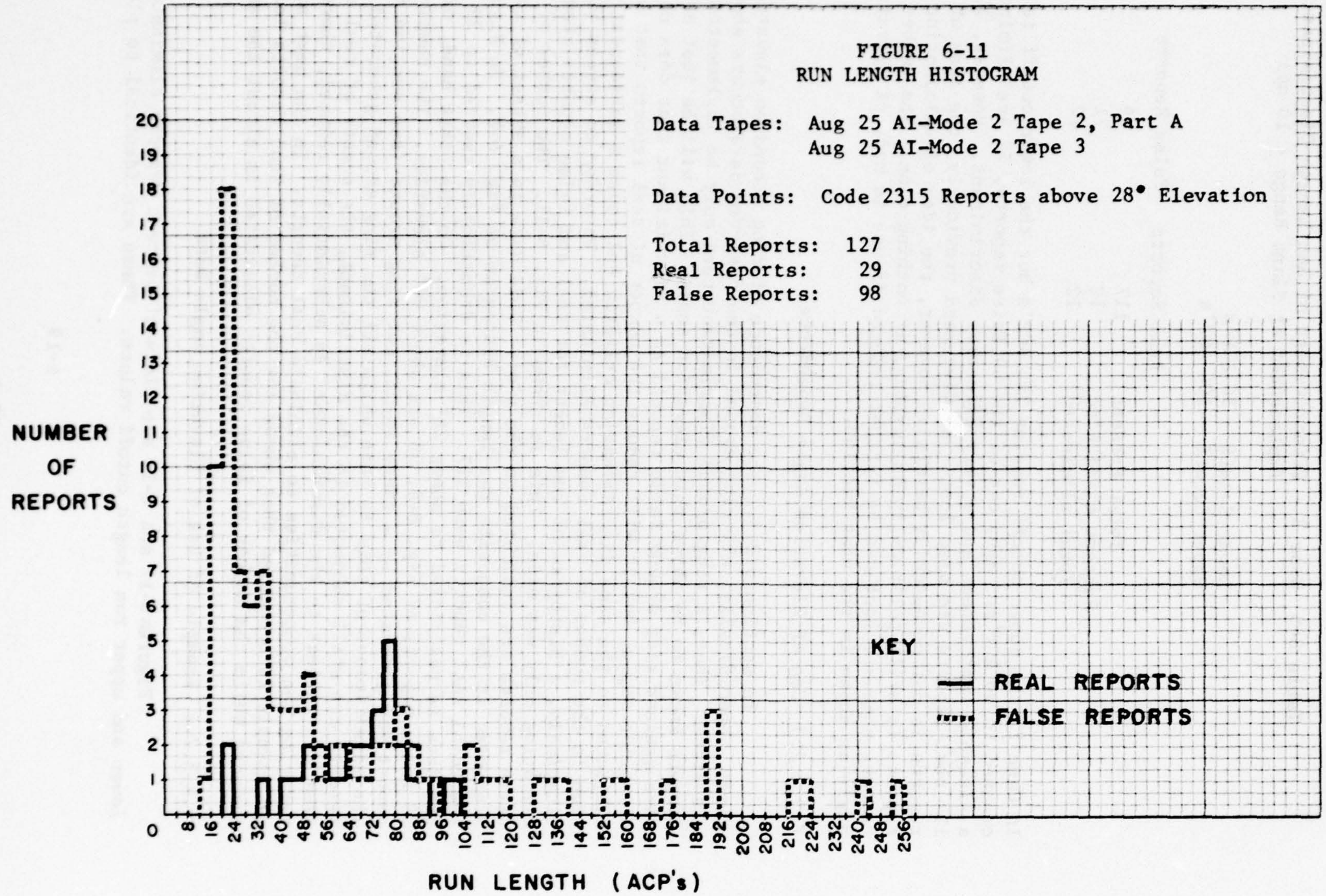


FIGURE 6-11
RUN LENGTH HISTOGRAM

Data Tapes: Aug 25 AI-Mode 2 Tape 2, Part A
Aug 25 AI-Mode 2 Tape 3

Data Points: Code 2315 Reports above 28° Elevation

Total Reports: 127
Real Reports: 29
False Reports: 98

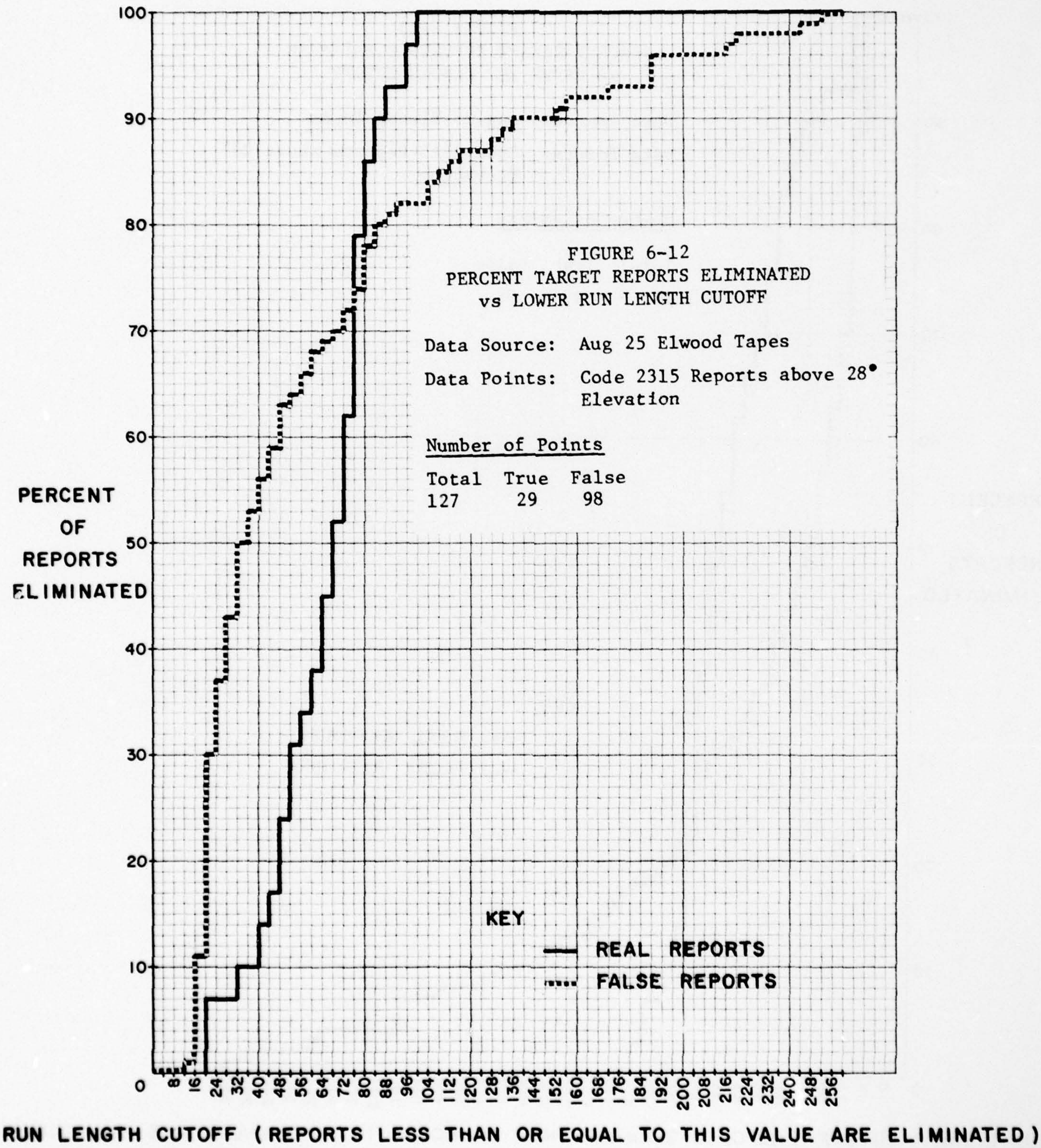


FIGURE 6-12
PERCENT TARGET REPORTS ELIMINATED
vs LOWER RUN LENGTH CUTOFF
Data Source: Aug 25 Elwood Tapes
Data Points: Code 2315 Reports above 28° Elevation
Number of Points
Total True False
127 29 98
KEY
REAL REPORTS
FALSE REPORTS
PERCENT OF REPORTS ELIMINATED
RUN LENGTH CUTOFF (REPORTS LESS THAN OR EQUAL TO THIS VALUE ARE ELIMINATED)
0
10
20
30
40
50
60
70
80
90
100
8 16 24 32 40 48 56 64 72 80 88 96 104 112 120 128 136 144 152 160 168 176 184 192 200 208 216 224 232 240 248 256

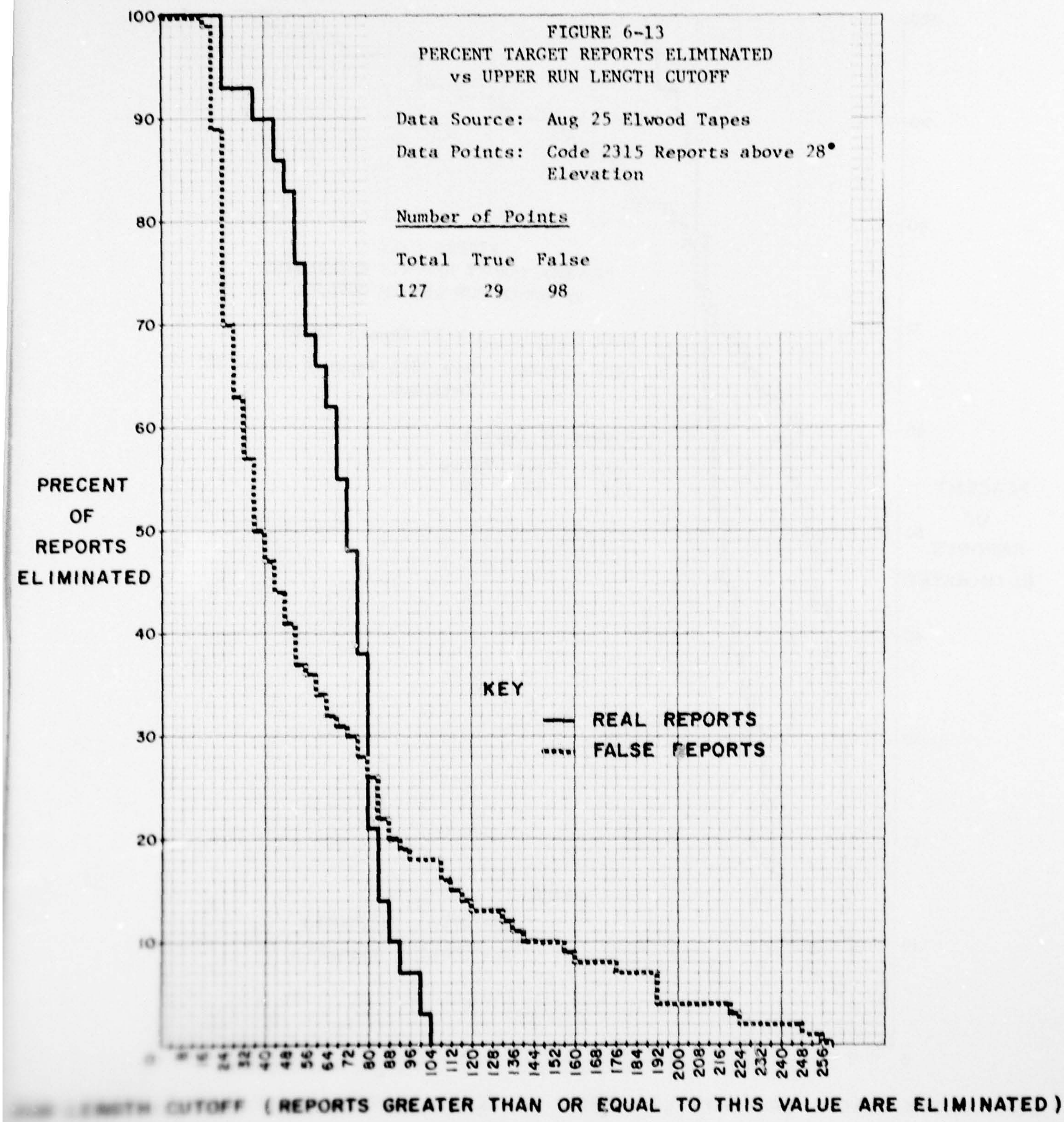


FIGURE 6-13
PERCENT TARGET REPORTS ELIMINATED
vs UPPER RUN LENGTH CUTOFF

of Figures 6-9 and 6-10 describes in section 6.2.3.2.2, except now only reports above 28° elevation are included. These plots were used to evaluate Case 3 shown in Table 6-6.

Table 6-6 Case 3 - Effectiveness of Run Length Discrimination Implemented above 28° Elevation Angle

Lower Cutoff	36
Upper Cutoff	104

	Real Reports	False Reports
Total Present	29	98
Percent eliminated	10	71
Total eliminated	3	70

The run length cutoff values are the same as in Case 2, but now the discriminant is implemented only above 28° elevation angle. In Case 2, 10% of 117 real reports, or 12 total real reports were eliminated. In Case 3, 10% of real reports are still eliminated, but because of the elevation angle restruction, only 29 real reports are present, thus only 3 real reports are eliminated. The bottom line is that only 3 instead of 12 real reports are eliminated. On the other hand, in Case 2, 72 false reports are eliminated and in Case 3, 71 false reports are eliminated. Thus, a significant reduction in the number of real reports eliminated has been achieved while the effectiveness against false reports remains almost unchanged.

6.2.4 Additional Results From Elwood Targets of Opportunity

In this section, an analysis of targets of opportunity in the Elwood data, other than the test target, is presented. This was done to insure that the observations of section 6.2.3 are not unique to the test target, but rather apply to any beacon targets detected by the Elwood sensor.

6.2.4.1 Procedure for Extracting Data for Targets of Opportunity

The three CD-Record tapes from the Elwood data collection listed in Table 6-3 were analyzed for target report ambiguities using the TRAAP program with the detection criteria given below in Table 6-7.

Table 6-7
Ambiguity Detection Criteria

A. Range Separation (ΔR): 0 nmi $\leq \Delta R \leq$ 0.250 nmi
B. Azimuth Separation ($\Delta\theta$): 3 $\leq \Delta\theta \leq$ 180°
C. Duplicate, discrete beacon code required

A list of the target reports associated with each ambiguity detected was outputted by the computer. A typical segment of this listing appears in Table 6-8.

Table 6-8
Typical Listing of Ambiguities
(Aug 25, CD-Record, Tape 2, A)

TIME	RANGE (NMI)	AZIMUTH (DEG)	ALTITUDE (FT)	CODE 3A	
12:58:34.8	6.125	113.027	28200	7067	
12:58:35.1	6.125	123.398	28200	7067	
12:58:35.1	6.125	129.023	28200	7067	
12:58:38.8	5.875	267.100	28300	7067	
12:58:43.1	5.750	67.588	28400	7067	
12:58:43.5	5.750	82.002	28400	7067	
12:58:44.0	5.750	97.207	28400	7067	
12:58:44.5	5.750	114.434	28400	7067	
12:58:44.6	5.750	124.980	0	7067	
12:58:57.0	5.500	227.813	28600	7067	
12:59:0.6	5.500	3.428	28600	7067	
12:59:5.5	5.625	184.395	-1000	7067	Code 7067 Ring Around
12:59:6.0	5.625	203.906	28700	7067	
12:59:10.7	5.750	23.555	28700	7067	
12:59:11.3	5.750	37.090	28700	7067	
12:59:14.4	5.875	182.637	0	7067	
12:59:19.2	6.125	341.104	28800	7067	
12:59:19.6	6.125	353.936	28800	7067	
12:59:19.7	6.125	359.648	28800	7067	
12:59:20.4	6.125	25.488	28800	7067	
12:59:20.5	6.125	29.355	28800	7067	
12:59:20.9	6.125	38.408	28800	7067	
12:59:21.4	6.250	63.018	300	7067	
13:00:25.7	7.625	311.309	10800	4306	Code 4306
13:00:26.2	7.625	331.348	10800	4306	
13:02:28.0	5.250	224.385	20000	2315	
13:02:29.8	5.125	287.842	20000	2315	
13:02:33.5	4.750	69.697	20000	2315	
13:02:37.5	4.500	215.947	20000	2315	Code 2315 Ring Around
13:02:37.7	4.500	227.285	20000	2315	
13:02:38.5	4.375	251.719	20000	2315	
13:02:38.7	4.375	263.496	20000	2315	
13:02:38.9	4.375	271.670	20000	2315	
13:02:39.2	4.375	284.326	21500	2315	

The listings were inspected to determine the beacon codes of those targets experiencing ring around. For example, in Table 6-8, it can be observed that codes 7067, and the test target (code 2315) are experiencing ring around. On the other hand, although code 4036 was associated with a sidelobe type split because of the range and azimuth separation of the two reports, it was not involved in ring around.

On the basis of the inspection performed, targets involved in ring around were selected for analysis. After the targets were selected, and the beacon codes noted, data was extracted from the associated beacon reply tapes for the targets using the procedure given in section 6.2.2.1.

6.2.4.2 Summary of Targets of Opportunity

Using the above procedure data was extracted for the codes listed in Table 6-9.

Table 6-9
Selected Targets of Opportunity

Tape	Beacon Code
Aug 25 AI-Mode 2 Tape 2, A	7067
Aug 25 AI-Mode 2 Tape 3	1673
Aug 25 AI-Mode 2 Tape 3	1711

The data is listed in detail in Appendix C.

6.2.4.3 Confirmation of Elevation Angle Dependence

The minimum elevation angle at which ring around first occurred for each target listed in Table 6-9 is given in Table 6-10.

Table 6-10
Minimum Elevation Angle for Ring Around

Code	Minimum Angle
7067	33°
1673	32°
1711	34°

Data points below these elevation angles were examined, but no false reports were found. Therefore, these results are consistent with the test target results because no ring around occurred below the 28° elevation angle. In the next section, the number of real and false reports above 28° is tabulated and run length characteristics for these reports are discussed.

6.2.4.4 Run Length Characteristics (Targets of Opportunity)

Figure 6-14 is a histogram of run lengths for true and false reports above 28° for the targets listed in Table 6-9. Comparing this with the appropriate histogram data for the test target, Figure 6-11, it can be seen that the distributions are quite similar. In both figures, the most frequently observed run length for false reports was 20 ACP's. The most frequent run length for the test target real report was 76 ACP's. For the targets of opportunity, maximum run length for real reports occur at 52, 56, 72 and 76 ACP's. Visually it can be seen that the distributions for real report run lengths are similar. The difference is easily within normal variations from sample to sample, particularly when it is noted that only 88 points were used in Figure 6-14, while 127 points were used in Figure 6-11.

It is concluded that the run length characteristics for these reports are consistent with those obtained for the test target above 28°, and hence, based on Elwood data, a run length discriminant will be universally applicable to all target reports above 28° at Elwood. In the next section a particular case is examined.

6.2.4.5 Example of Run Length Discriminants Using Targets of Opportunity

Using the data presented in Figure 6-14 for targets of opportunity, the number of target reports eliminated for specific run length cutoff values was determined. The results are listed in Table 6-11.

Table 6-11
Run Length Discrimination above 28°
for Targets of Opportunity

Lower Cutoff 36
Upper Cutoff 104

	Real Reports	False Reports
Total Present	28	60
Percent eliminated	21	55
Number eliminated	6	33

Here over half the false reports are eliminated (33 out of 60) and only 6 real reports out of 28. This example confirms that run length discrimination can be effective in reducing the number of false reports generated as a result of ring around. The difference between these results, and similar results obtained in Table 6-6 for the test target only, is attributed to the sample sizes used in the analyses.

6.2.5 <u>Results of a Simulation of Run Length Discrimination</u>

The run length discrimination scheme discussed in sections 6.2.3.2.4

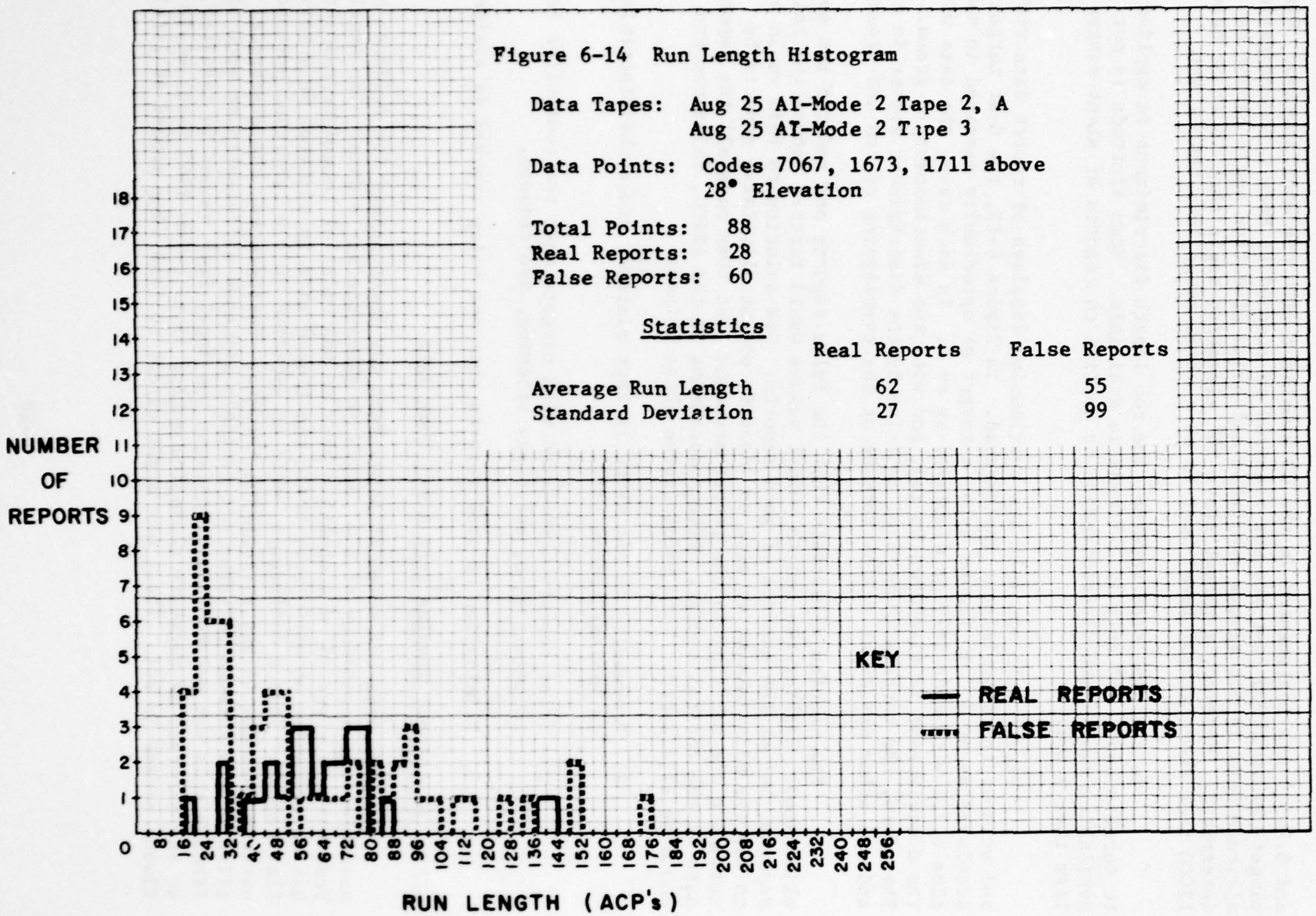


Figure 6-14 Run Length Histogram

Data Tapes: Aug 25 AI-Mode 2 Tape 2, A
Aug 25 AI-Mode 2 Tipe 3

Data Points: Codes 7067, 1673, 1711 above
28° Elevation

Total Points: 88
Real Reports: 28
False Reports: 60

<u>Statistics</u>

	Real Reports	False Reports
Average Run Length	62	55
Standard Deviation	27	99

and 6.2.5.4 was implemented in the CD simulator with one modification. Since targets below 12000 feet are not required to respond to Mode C interrogations, altitude data is not always available and hence elevation angle cannot be determined. However, a target above 28° elevation angle that is at or below 12000 feet above ground level must be at a slant range less than 4 nmi.

In the simulated version, the run length discriminant is applied to targets above 28° only if altitude is available. When altitude is not available, run length discrimination is applied to reports at slant ranges less than 4 nmi.

Figure 6-15 and 6-16 are overlapping displays of report data with and without the discriminant implemented. In figure 6-15, the test target is displayed as an X. In figure 6-16, a target of opportunity examined in section 6.2.4 with code 1673 is displayed as an X. In each case, the data without the discriminant is displayed in red, and with the discriminant in green. Therefore, the targets identified as false by the discriminant appear in red, and all other appear as yellow because of the overlapping of red and green.

The results illustrate that the false reports are reduced but not eliminated. Tighter run length cutoff values would further reduce the false reports, but at the expense of good reports. One solution to this would be to use the discriminant on site to identify potentially false reports by setting a one bit flag in the report messages, but then pass all the report data to the control center. After processing in the ARTCC, false reports could be eliminated. This accomplishes three things:

1) Processing in the ARTCC is kept minimum, since the discriminant is implemented on site.

2) False reports associated with targets that the controller is concerned with, and hence tracking, are reduced.

3) Elimination of good reports that are being tracked is avoided.

6.2.6 Additional Results from Angel Peak Data

The data collected at Angel Peak was investigated for evidence of possible site dependency of run length or elevation angle data. The Angel Peak site is situated on a mountain peak in the midst of rugged terrain and has an elevation of 8860 feet, while the Elwood site is situated in a very flat region. Thus a difference would be expected in the resultant antenna pattern just due to the surrounding terrain. Furthermore, the electrical tilts of the antenna patterns are probably adjusted differently at each site (though this was not confirmed) because the Angel Peak sensor is required to see aircraft at negative elevation angles (i.e. below 8860 feet) while the Elwood sensor is not. Thus, one might expect to find ring around or sidelobe

Auxiliary Interpreter Tape Data

Tape Name: Aug 25-CDS-AI-Mode 2 Tape 3 w/o discriminant *

Time Frame: 11:31:48 - 11:44:00

Record No: 0-1208

Range Ring Interval (nmi): 5

Beacon Color: Red

Auxiliary Interpreter Tape Data

Tape Name: Aug 25-CDS-AI-Mode 2 Tape 3 with discriminant *

Time Frame: 11:31:48 - 11:44:00

Record No: 0-1208

Range Ring Interval (nmi): 5

Beacon Color: Green

Beacon Symbol: X or Dot

Flagged Codes

Code	Symbol	Color
2315	X	Red or Green

Figure 6-15 Simulation of Run Length Discrimination.

* Run Length Discrimination
Reject Reports with Run Length RL such that RL≤36 ACP's or RL≥104 ACP's if one of the following two conditions is also satisfied:

CONDITION	Report Range	Mode C Present	Elevation Angle
1	≤ 4 nmi	No	Any
2	Any	Yes	≥ 28°

Auxiliary Interpreter Tape Data

Tape Name: Aug 25-CDS-AI-Mode 2 Tape 3
w/o discriminant *

Time Frame: 11:31:48 - 11:44:00

Record No: 0-408

Range Ring Interval (nmi): 5

Beacon Color: Red

Auxiliary Interpreter Tape Data

Tape Name: Aug 25-CDS-AI-Mode 2 Tape 3
with discriminant *

Time Frame: 11:31:48 - 11:44:00

Record No: 0-408

Range Ring Interval (nmi): 5

Beacon Color: Green

Beacon Symbol: X or Dot

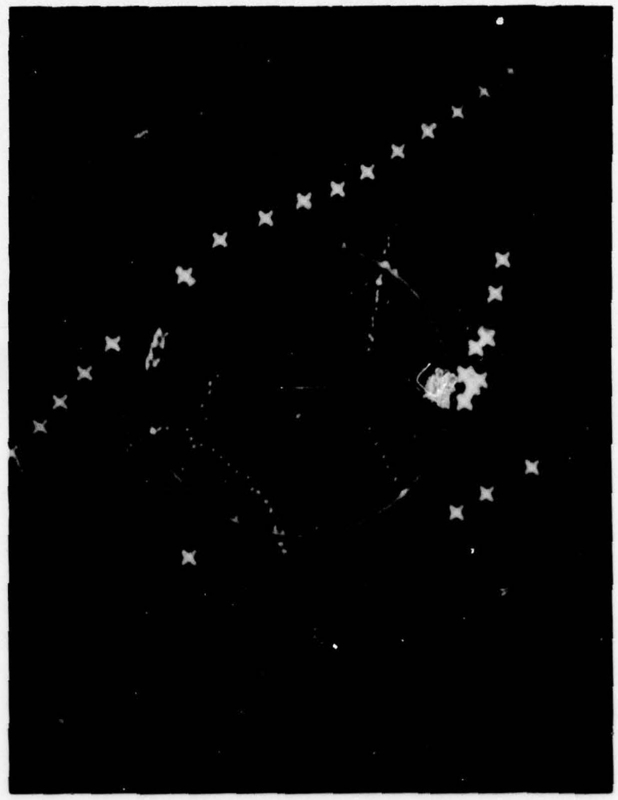


Figure 6-16 Simulation of Run Length Discrimination

Flagged Codes

Code	Symbol	Color
1673	X	Red or Green

* Run Length Discrimination
Reject Reports with Run Length RL such that RL$\leq$36 ACP's or RL$\geq$104 ACP's if one of the following two conditions is also satisfied:

CONDITION	Report Range	Mode C Present	Elevation Angel
1	$\leq$ 4 nmi	No	Any
2	Any	Yes	$\geq$ 28°

problems at a lower physical elevation angle at Angel Peak than at Elwood. For these reasons, it was considered worthwhile to investigate the Angel Peak Data.

6.2.6.1 Extraction of Angel Peak Data

Since run length reporting was not enabled during recording of the Mode 2 tapes from Angel Peak video (see table 4-8), the CD simulator (no discriminant) was utilized to process the reply data and generate new report messages with run length information. The tape selected for this analysis was CDS-QAS #4 D which was made by playing QAS #4 D (see table 4-8) through the simulator. Next, report data for all targets within about 35 nautical miles of the sensor was extracted over an interval of approximately 12 scans and a listing made. An example of the type of data extracted appears in table 6-2. This listing was inspected for evidence of site dependency via comparison of observed characteristics with Elwood results.

6.2.6.2 Discussion of Site Dependency

The data was easily divided into two groups. All the target reports with exception of one had elevation angles with respect to the interrogator ranging from -2.54° to 3.79°. One target, code 3236, had angles ranging from 12° to 19°. The run lengths for the low elevation angle reports were consistent with previous data presented for good reports. However, the run lengths for code 3236 were, with few exceptions, consistently longer. Table 6-12 is a summary of average data.

Table 6-12 Summary of Angel Peak Run Length Characteristics

Targets	Elevation Angle	Number of Points	Average Run Length	Standard Deviation
Code 3236	~12° to 19°	12	79	18
Targets of Opportunity Excluding Code 3236	-2.49 to 4°	157	42	12

NOTES: Tape: CDS-QAS #4 D made by playing QAS #4 D through the CD Simulator.
Reocrd No: 323 to 469
Points: All Reports at Ranges less than 35 nmi.

As the table shows, the average run length for targets at low elevation angles was 42 which is consistent with Elwood data. However, the average run length for the target at the high elevation angle was 79. This observation, that the higher elevation angle target has a longer average run length, is consistent with the Elwood results. This may be seen by looking at the Elwood run length histogram data of figures 6-8 and 6-11. In figure 6-8 all the test target data at Elwood below 10 nautical miles is included regardless of elevation angle. The run length histogram for good reports only peaks at 44 ACP's. In figure 6-11 reports above 28° elevation angle only are included. In this histogram, run length for good reports peaks at 76 ACP's, a shift toward higher run length values. The Angel Peak data is consistent in as much as longer run lengths occur mostly at the high elevation angle. The target at the high elevation angle was also the only one that experienced ring around, though the characteristics of the ring around were difference. In the Elwood data, most of the ring around observed involved false reports displaced up to almost 180° from the true report. In the Angel Peak data, the target, code 3236, was observed to frequently produce sidelobe splits in which three or more false reports were produced with azimuthal separations less than 90° from the true reports. Only when the target was at almost 45° elevation were false reports observed to be separated from the true report by azimuths approaching 180°.

6.2.6.3 Conclusions from Comparison of Angel Peak Data with Elwood Data

This section supports the contention that the occurrence of false reports generated due to sidelobe returns is elevation angle dependent and that these false reports occur more frequently at higher elevation angles. From the Elwood data, a specific elevation angle, 28°, is shown to be a cutoff below which ring around does not occur. Evidence in this section indicates that the nature of this elevation angle is site dependent.

REFERENCES

References

1. "System Definition and Investigation of the On Site Processing of En Route Sensor Signals", Volumes I, II and III, J.W. Thomas, E.C. Wetzlar, L.J. Zitzman APL/JHU Report FP8-E-024, September 1976.

2. "Plan for Analyzing the Beacon Performance of the Common Digitizer", APL/JHU Report FP8-E-009, May 1975.

3. "Program Plan for Common Digitizer Beacon Performance Analysis", APL Document FS-76-208, October 1976.

4. "Indianapolis Ring-a-Round", James Shannon, FAA Memorandum (ARD-111), July 29, 1976.

5. "En Route Investigation Progress Report for August 1977", J.W. Thomas, APL/JHU Internal memorandum F3E-957, September 1977.

6. "Design Data PCD Enhancements", Burroughs Corporation Report #33300-74-2413-D, April 1976.

7. "Review of the August 25 Data Tapes", J.W. Thomas, APL/JHU Momorandum F3E-974, October 1977.

8. "Review of the New August 25 CD-Record Tape 2 and Auxiliary Interpreter Mode 2 Tape 2", J.W. Thomas, APL/JHU Memorandum F3A-77-2-021.

List of APL Memoranda Associated with the Investigation.

1. "Program Specification for Beacon Reply Data Processor/ CD Simulator", J.W. Thomas, APL Memorandum F3E-939, August 1977.

2. "Operational Test for the CDS Program", J.W. Thomas, APL Memorandum F3E-948, August 1977.

3. "August 25 Data Collection at Elwood, N.J. ", J.W. Thomas, APL Memorandum F3E-952, August 1977.

4. "En Route Investigation Progress Report for August 1977," J.W. Thomas, APL Memorandum F3E-957, September 1977.

5. "Telecon with Bob Delaney", J.W. Thomas, APL Memorandum F3E-972, September 1977.

6. "Conversion of Adaptor Codes", J.W. Thomas, APL Memorandum F3E-972, September 1977.

7. "Review of August 25 Data Tapes," J.W. Thomas, APL Memorandum F3E-974, October 1977.

8. "En Route Investigation Progress Report for September 1977", J.W. Thomas, APL Memorandum F3E-975, October 1977.

9. "En Route Investigation Progress Report for October 1977", J.W. Thomas, APL Memorandum F3A-77-2-018, November 1977.

10. "Review of the New August 25 CD Record and Auxiliary Interpreter Mode 2 Tape 2", J.W. Thomas, APL Memorandum F3A-77-2-021, November 1977.

11. "En Route Investigation Progress Report for November 1977", J.W. Thomas, APL Memorandum F3A-77-2-022, December 1977.

12. "Analysis of Run Length Characteristics", J.W. Thomas, APL Memorandum F3A-77-2-028, January 1978.

APPENDIX A

Appendix A (section 4)

Conversion of Adaptor Codes

This documents the method of converting the adaptor codes on CD-Record tapes from EBCDIC format to octal for use in the Target Report Ambiguity Analysis Program (TRAAP).

The adaptor codes on CD-Record tapes are used to identify report data from different sites. Typically, the data from a single site may have one or two or three codes. As an example, Elwood has codes 72, 73 and 74. These numbers are represented on CD-Record tapes in EBCDIC format. Table A-1 lists the binary equivalent for EBCDIC characters. The task at hand is to convert the adaptor code numbers 72, 73 and 74 to octal numbers for use in the TRAAP.

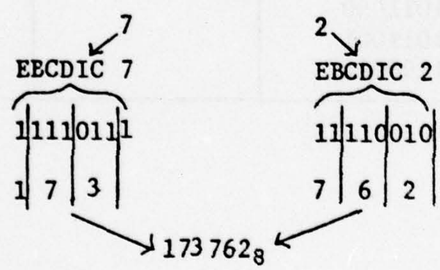
The code 72 consists of two characters, 7 and 2. The binary equivalent for 2 is taken from Table 1:

$$11110010_2$$

Next the binary equivalent for 7 is obtained:

$$11110111_2$$

The two binary representations are written together as illustrated below, divided into groups of three bits from the right and written as an octal number.



In this case the result is

$$72_{EBCDIC} = 173762_8$$

Similarly $73_{EBCDIC} = 173763_8$ and

$$74_{EBCDIC} = 173764_8.$$

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UNCLASSIFIED APL/JHU/FP2-E-034 FAA/RD-77/12-4 NL

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TABLE A-1

CHARACTER TO BINARY EQUIVALENT EBCDIC

Character	Binary Code	Character	Code
0	11110000	T	11100011
1	11110001	U	11100100
2	11110010	V	11100101
3	11110011	W	11100110
4	11110100	X	11100111
5	11110101	Y	11101000
6	11110110	Z	11101001
7	11110111		
A	11000001		
B	11000010		
C	11000011		
D	11000100		
E	11000101		
F	11000110		
G	11000111		
H	11001000		
I	11001001		
J	11010001		
K	11010010		
L	11010011		
M	11010100		
N	11010101		
O	11010110		
P	11010111		
Q	11011000		
R	11011001		
S	11100010		

APPENDIX B

by -

L. A. Biddison

Operation and Data Base Formats of the Common Digitizer Simulator

1.0 Introduction

This memorandum describes the functions of the Common Digitizer Simulator Program and its operating instructions. This includes the correct 32-bit word formats for the data recorded by the Auxiliary Interpreter onto 9-track magnetic tape. Also described is the 30-bit format used in repacking the data onto 7-track mag tapes for the NELIAC computer.

2.0 Functional Description

This section describes the simulation of the CD processing of beacon replies to produce target reports. Part 1 describes the input processing of the beacon reply data recorded on 7-track Auxiliary Interpreter Mode 2 tapes. Part 2 discusses the CD Simulator internal processing to produce target report data, and Part 3 describes the output processing of data onto another 7-track mag tape, in the same format as that of the input tape.

2.1 Input Processing

There are two types of records on the Mode 2 input tapes: beacon reply records and target report records, which occur in consecutive pairs. Each record contains one type of data and is of fixed length. The CD Simulator will process only the reply records from the input tape (ignoring the original target report records). It will build its own reports from the data extracted from the original replies. Input parameters (input tape unit, output tape unit, target leading edge threshold, target trailing edge threshold, validation threshold, range offset and azimuth correction factor) are entered via a punched input card immediately after the program begins execution. See Figure 1 for the input card format. The parameters that are involved in the implementation of a discriminant (to eliminate false target reports generated from ring around) are to be input from the computer console (see Operating Instructions). If the discriminant is not desired, that information is also conveyed via the console. This must be done prior to the execution of the CDS program using console "inspect and change".

The first two words in each magnetic tape record are used as a record header. The first word designates the recording mode (which will always be Mode 2) and the type of data in the record (in this case, beacon reply or target report). The second word contains the time when the last Azimuth Reference Pulse occurred.

Two types of messages comprise the beacon replies: one-word initial sweep messages and two-word beacon reply cells. (See Annex A, page B-12). Following each initial sweep are all the reply messages received during that sweep (see Figure 2). The sweep message contains the initial sweep azimuth (in azimuth change pulses) and the type of interrogation (in this case, either Mode 3/A or Mode C). On Mode 2 tapes there is no correlation between scans and records. Several scans of information could be contained in one record or one scan could span several records.

Since the format of the output data must be the same as that of the input data, the input reply record is immediately dumped onto the output tape. This is done after reading in each reply record and prior to the repacking of its data. Unpacking is necessary because of the rather unusual format of the input data. The Auxiliary Interpreter is interfaced to a 9-track magnetic tape drive that writes records consisting of 32-bit words. The NELIAC computer uses 30-bit words and is interfaced to 7-track tape units. Therefore, the 32-bit words were split into bytes and stored into 30-bit words in the format shown in Annex A (pp. B-14 and B-15). This data will be repacked by the simulator into the 30-bit reply format shown in Annex A (page B-19).

The first word of the header will be stored in MT INPUT(0). The 32-bit time word will now be found in REPLY HEADER TIME(0) and REPLY HEADER TIME (1) (see Annex A, page B-18). The remainder of the reply data is stored from MT INPUT (REPLY START 1) through MT INPUT (END BEACON BUFFER). While initial sweep messages consist of only one word in the 32-bit format, in the MT INPUT buffer they will consist of two 30-bit words, with the second word containing all zeroes. The initial sweep message is unique in that bit 14 of the first cell word and the entire second cell word contain zero. All other 2-word cells are considered to be reply messages. The last message in MT INPUT will occupy the last two words (i.e., they won't be split up at the end of a record). The Master Flowchart is in Figure 4.

2.2 Program Internal Processing

The processing of replies is done by associating the replies with range cells. The maximum range is 256 nmi, and this area is divided into 1024 range bands, each 1/4 nmi in width. An 11-bit sliding window is associated with each range cell. It initially contains all zeroes. For each sweep for which Mode 3/A was interrogated, all 1024 sliding windows are shifted left one bit position. If a Mode 3/A reply was received for a particular range cell in that sweep, bit Ø of its associated sliding window will be set. If no hit fell into that range band, bit Ø will not be set. If the range falls on a cell boundary, it shall be considered to be in the upper range cell. In all cases, the "reply corrected range" is used; that is, the range received from the reply message plus the "range offset" obtained from the punched input card. Every time the windows are processed, the number of hits in each (i.e., the number of bits set in Ø through 11) will be compared to three thresholds. If the number of hits is greater than or equal to T_L (Target Leading Edge Threshold) or T_V (Begin Validate Threshold) that particular target report is said to be "in process". If the number of hits reaches T_V, validation for Mode 3/A and Mode C codes begins on the next sweep. Once validation begins, the code data from the next ungarbled reply is examined. If validation of that mode is not complete for a particular range band, the new code is compared with that saved from the previous sweep associated with that mode. If they agree, the validation of that code (3/A or C) is complete for that range cell. If the information does not agree, the new code replaces the one currently stored for that mode. If validation does not begin, the stored code data is zero. And, if it is completed for a particular mode, the respective validation bit is set.

When the number of hits in the sliding window reaches T_L, the target has reached its lead edge and the corresponding sweep azimuth is saved in a word associated with that range cell. If the number of hits in a sliding window drops to T_T (Target Trailing Edge Threshold), the target report is complete (providing T_L was previously reached for this range band report). If T_L was never reached, yet T_V was, the report is discarded.

Once the report is complete, its center azimuth and run length are calculated. These are saved along with the validation and"ident" bits, the range, Mode 3/A code, and Mode C altitude. These parameters are all recorded at the completion of the reply record processing.

2.3 Output Processing

When the inputted reply record has been processed, the target report data must be repacked and dumped onto the output mag tape in the same format as the Mode 2 tapes. The completed reports will be written in the chronological order of their completion. The reports still in process will be left alone, but the completed reports will be purged. The first message in the record is the two-word header message to indicate data type (target report) and recording Mode 2. The 30-bit report words must be converted into the 32-bit format shown in Annex A (page B-13 and packed in the form shown on pages B-16 and B-17. Each completed report will consist of four 32-bit words. The report record is of fixed length (see Figure 3). Therefore two words of zeroes will be stored at the end of the new report data to indicate its termination. Annex B contains the CD Simulator flowchart and Annex C contains its NELIAC listing.

3.0 Operating Instructions

To operate the CD Simulator Program, one must first boot in the object from block 1 of its mag tape. Then an input card, of the format in Figure 1, must be put into the card reader with two blank cards behind it. Before program execution, location 26000_8 must be set to zero (using console "inspect and change") if no discriminant implementation is desired. Set location 26000_8 to 1 if the discriminant is to apply only to reports for which Mode C altitude has been validated. Set it to 2 if the discriminant is to apply to all completed reports. If the discriminant is to be applied, set the following locations thusly:

26001_8 = altimeter setting in feet, scaled 12;
26002_8 = sensor elevation in feet, scaled Ø;
26003_8 = lower discriminant run length, LSB =4 ACP's;
26004_8 = upper discriminant run length, LSB = 4 ACP's;
26005_8 = range to compare with target slant range (if Mode C altitude is not validated) to determine if the discriminant is to be applied to completed reports, in nmi, scaled Ø.

When this has all been set up, the program can begin execution at location 10000_8. Flip on console KEY 1 to inhibit the mag tape record number printout on the line printer. If KEY 2 is set, the program will halt after writing an "end-of-file" mark onto the output tape. The setting of KEY 3 causes the inhibition of mag tape read-error printouts on the line printer.

FORMAT OF PUNCHED INPUT CARD

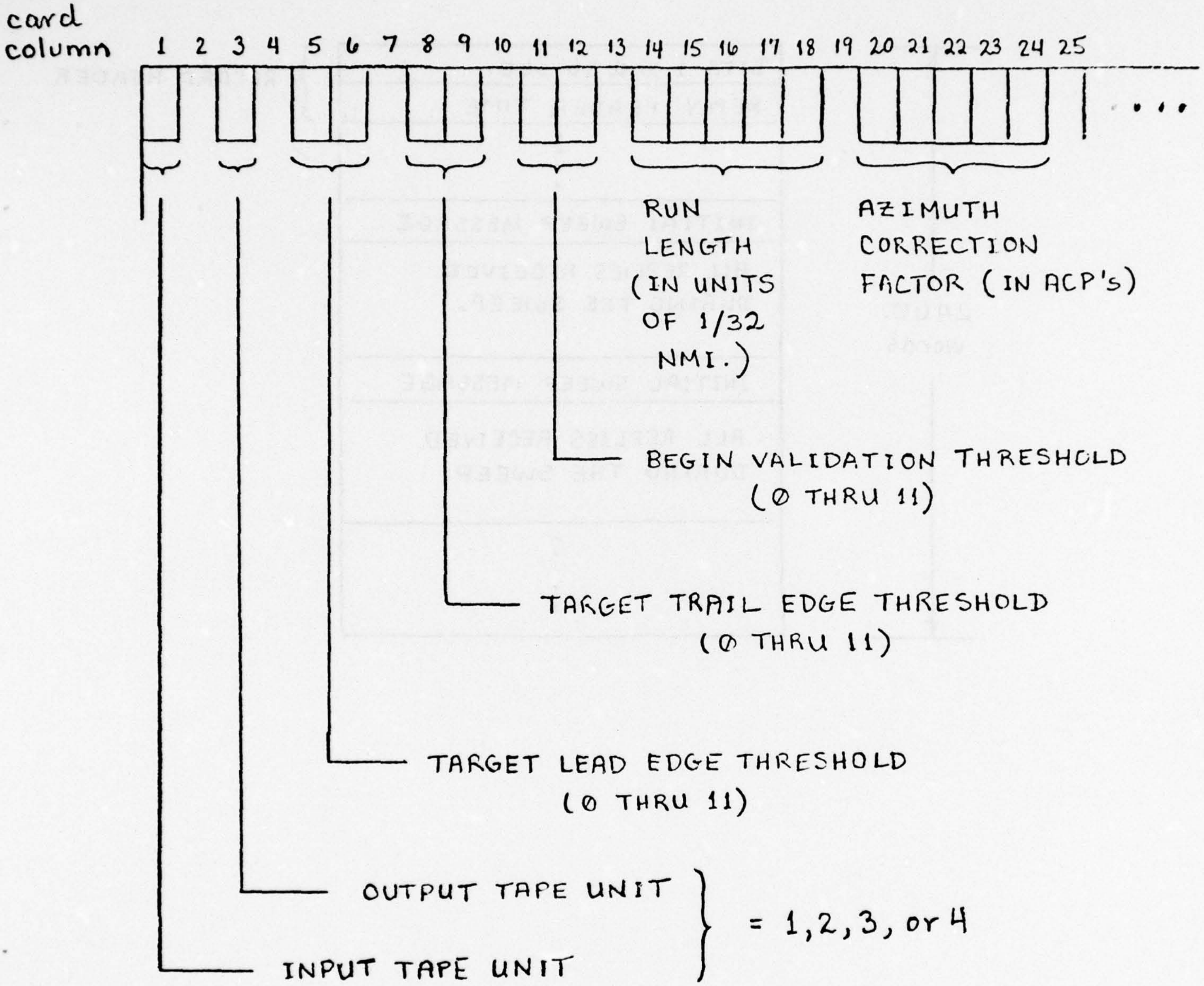


FIGURE 1

BEACON REPLY RECORD MAGNETIC TAPE LAYOUT

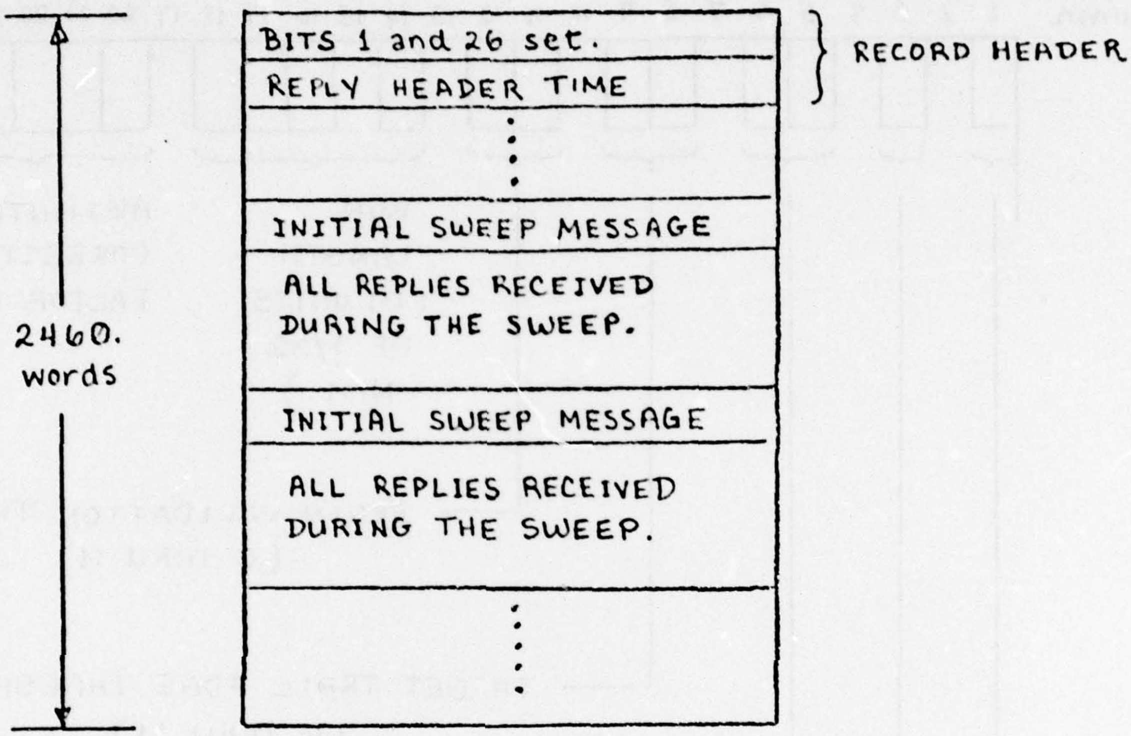


FIGURE 2

TARGET REPORT RECORD MAGNETIC

TAPE LAYOUT

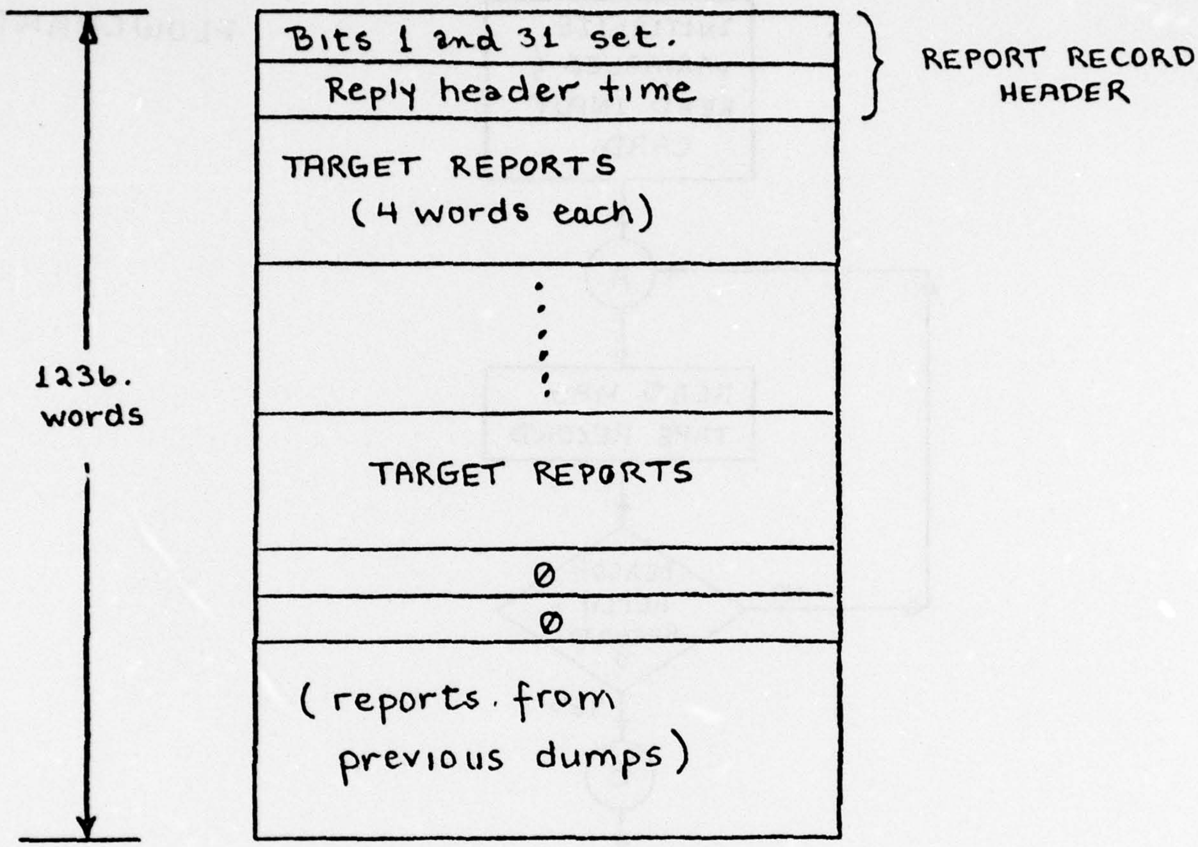
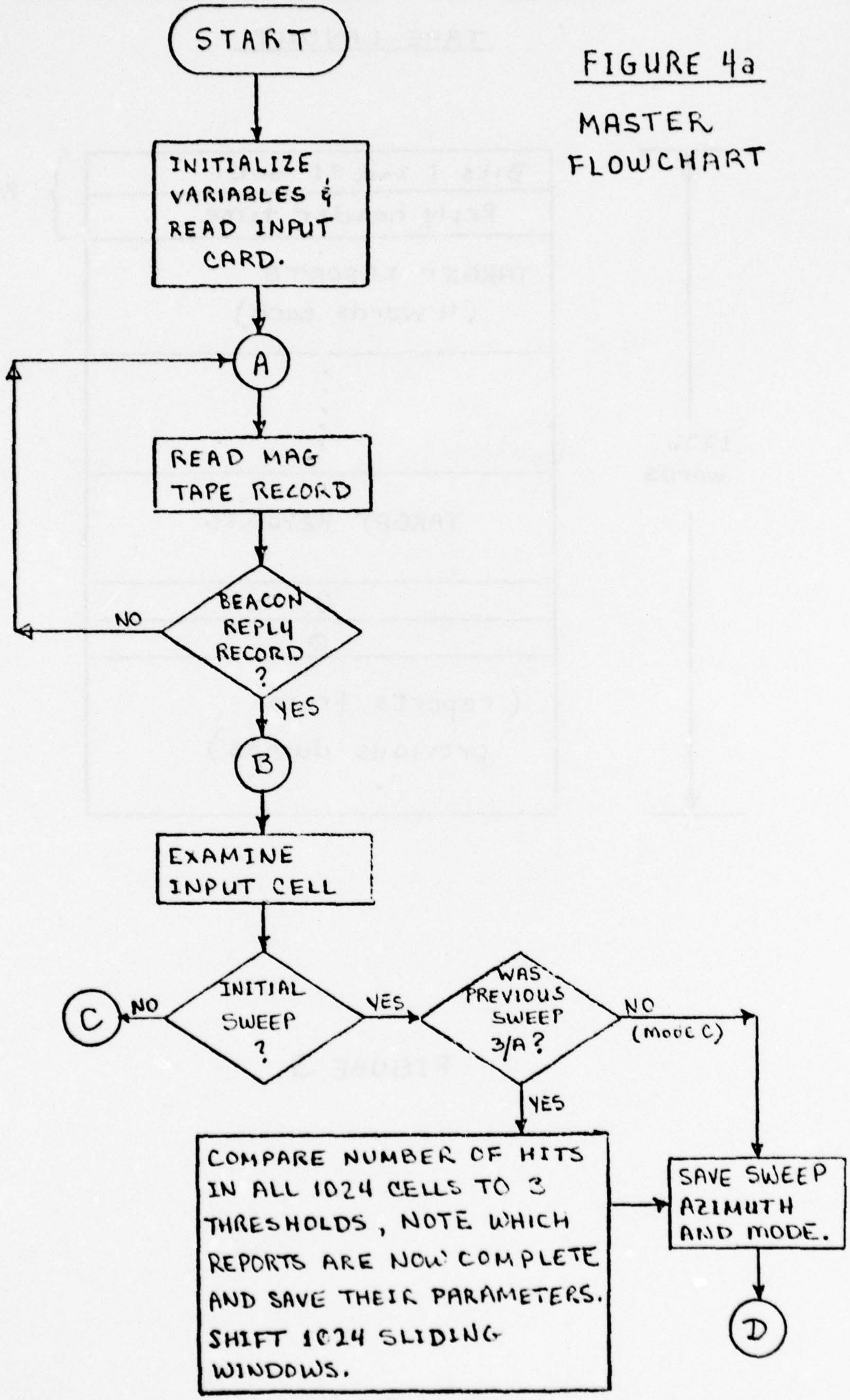


FIGURE 3

FIGURE 4a

MASTER FLOWCHART



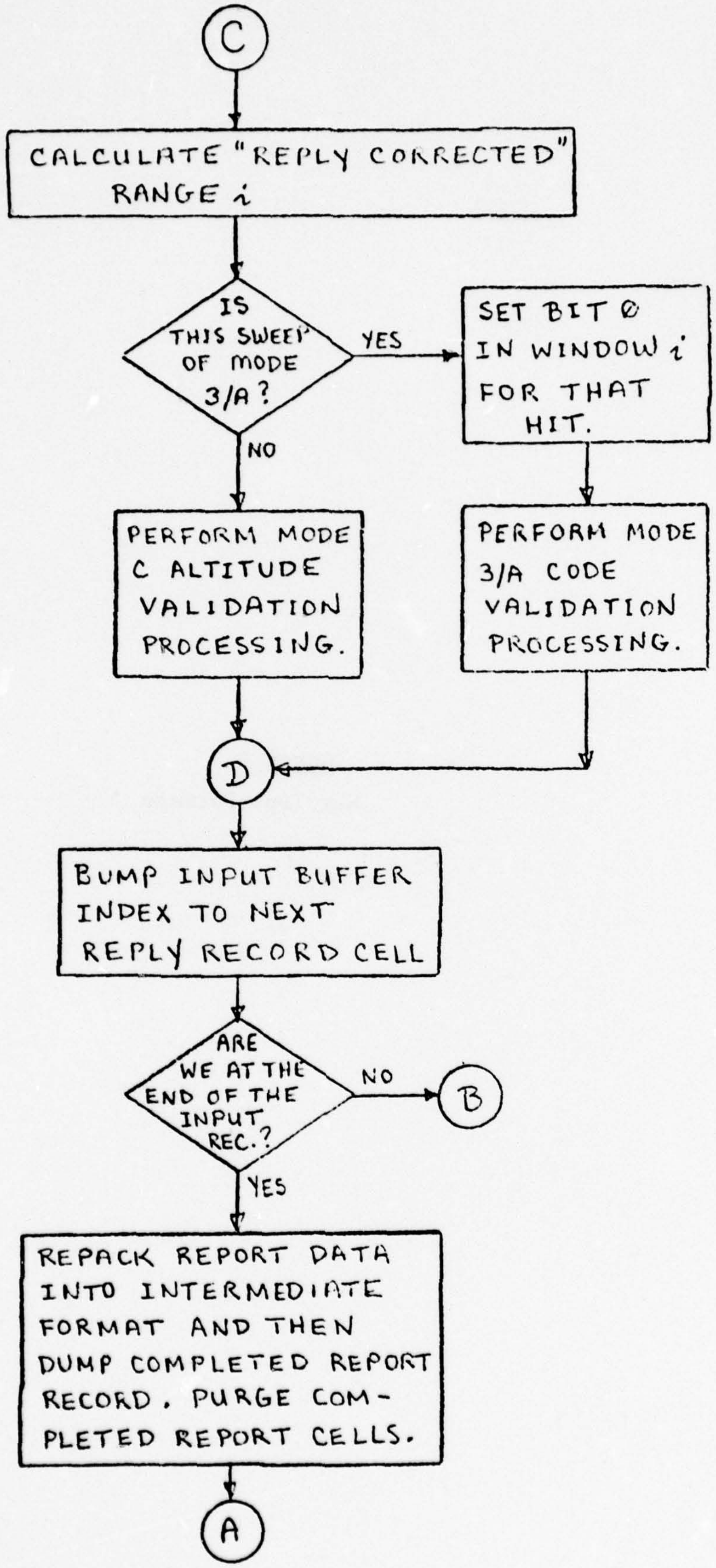

C
CALCULATE "REPLY CORRECTED" RANGE i
IS THIS SWEEP OF MODE 3/A?
YES
SET BIT Ø IN WINDOW i FOR THAT HIT.
NO
PERFORM MODE C ALTITUDE VALIDATION PROCESSING.
PERFORM MODE 3/A CODE VALIDATION PROCESSING.
D
BUMP INPUT BUFFER INDEX TO NEXT REPLY RECORD CELL
ARE WE AT THE END OF THE INPUT REC.?
NO
B
YES
REPACK REPORT DATA INTO INTERMEDIATE FORMAT AND THEN DUMP COMPLETED REPORT RECORD. PURGE COMPLETED REPORT CELLS.
A

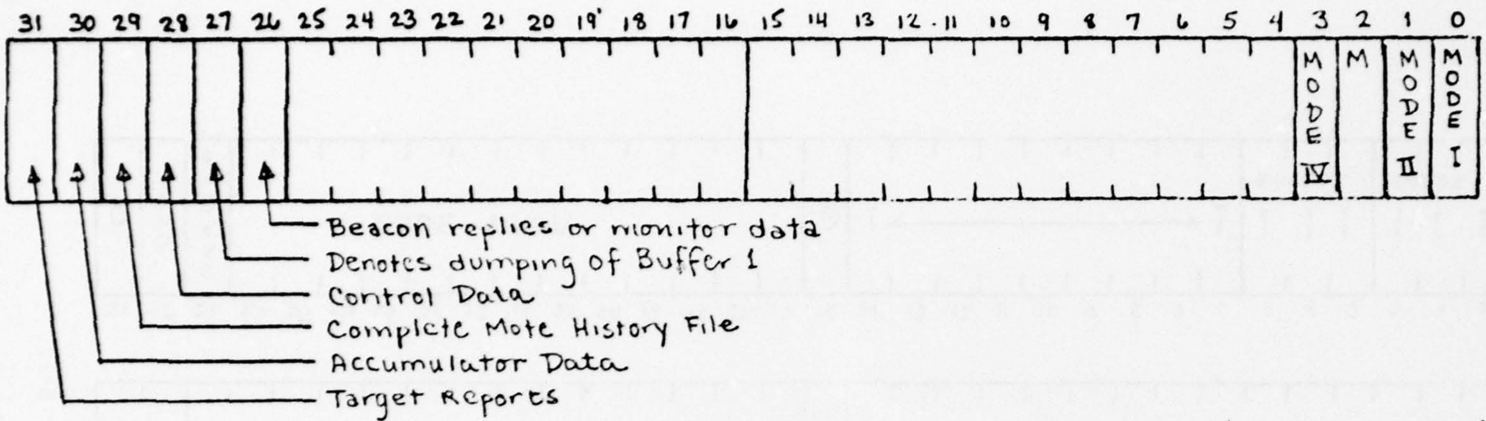
Figure 4b

Annex A

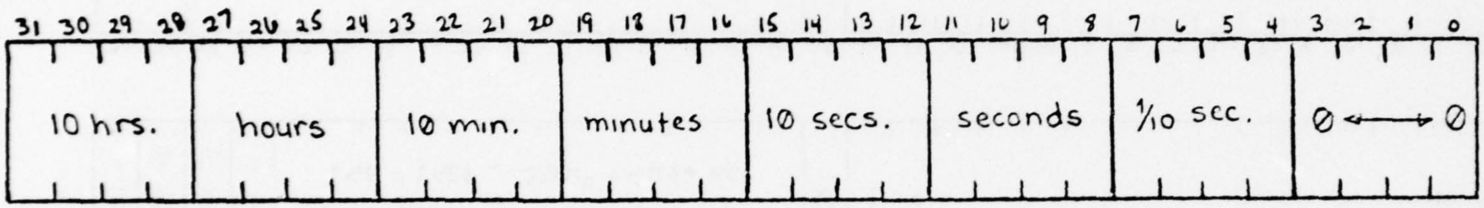
Mag Tape Formats

RECORD HEADER WORDS (32-bit format)

Header Word 1 : `mode and type of data

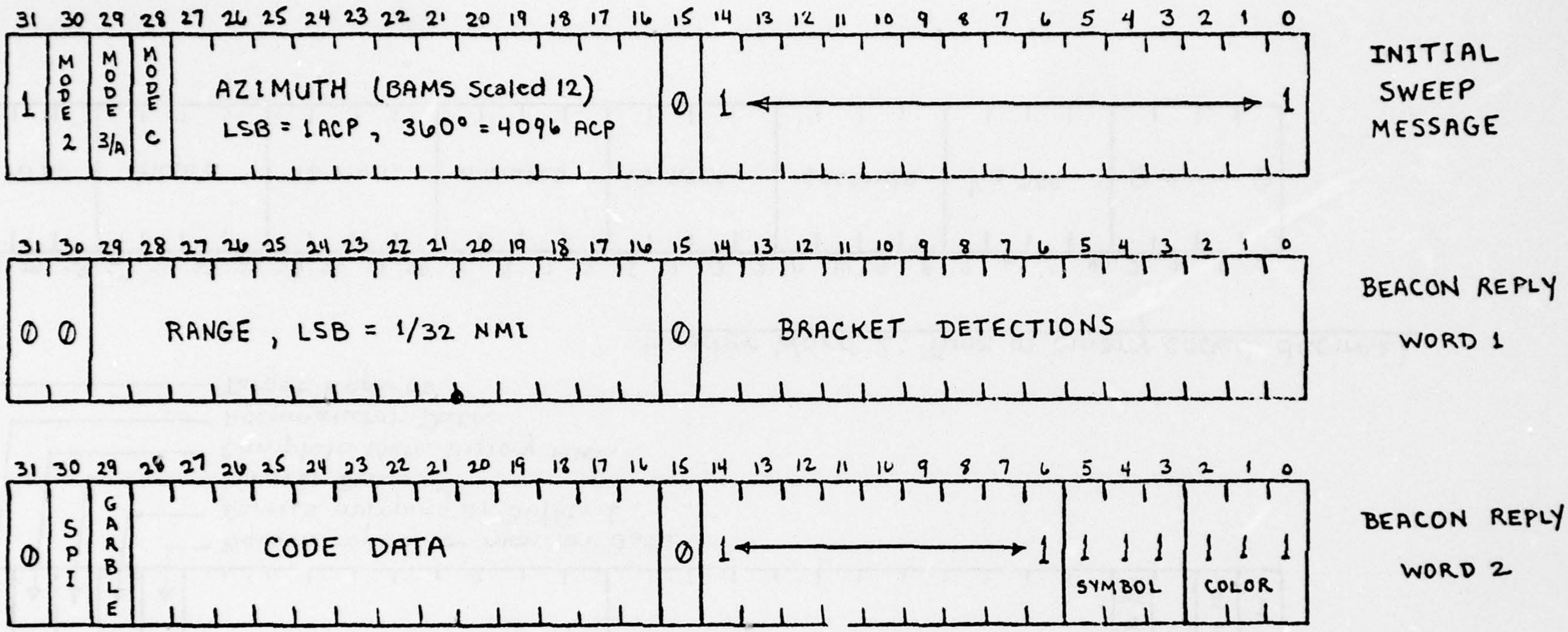


Header Word 2: Time in binary coded decimal



BEACON REPLIES (32-bit format)

Initial Sweep Message and Beacon Reply cell



BEACON TARGET REPORT (32-bit format)

First Word

31	Ø
30	Ø
29	M 3/A XBIT
28	Ø
27	TEST RTQC
26	$\overline{RTQC}$
25	1
24	M 2
23	M 3/A
22	M C
21	IDENT
20	SRCH KEIN FCNCL
19	7700
18	7600
17	FAA
16	AF
15–12	Ø Ø Ø Ø
11–1	RANGE LSB = 1/8 NMI
0	MOTE FLAG

Second Word

31–28	Ø Ø Ø Ø
27–16	AZIMUTH, LSB = 1 ACP BAMS SCALED 12 (360° = 4096 ACP)
15–12	Ø Ø Ø Ø
11–7	RUN LENGTH LSB = 8 ACP
6–0	TIME IN STORAGE LSB = 1/8 SEC.

Third Word

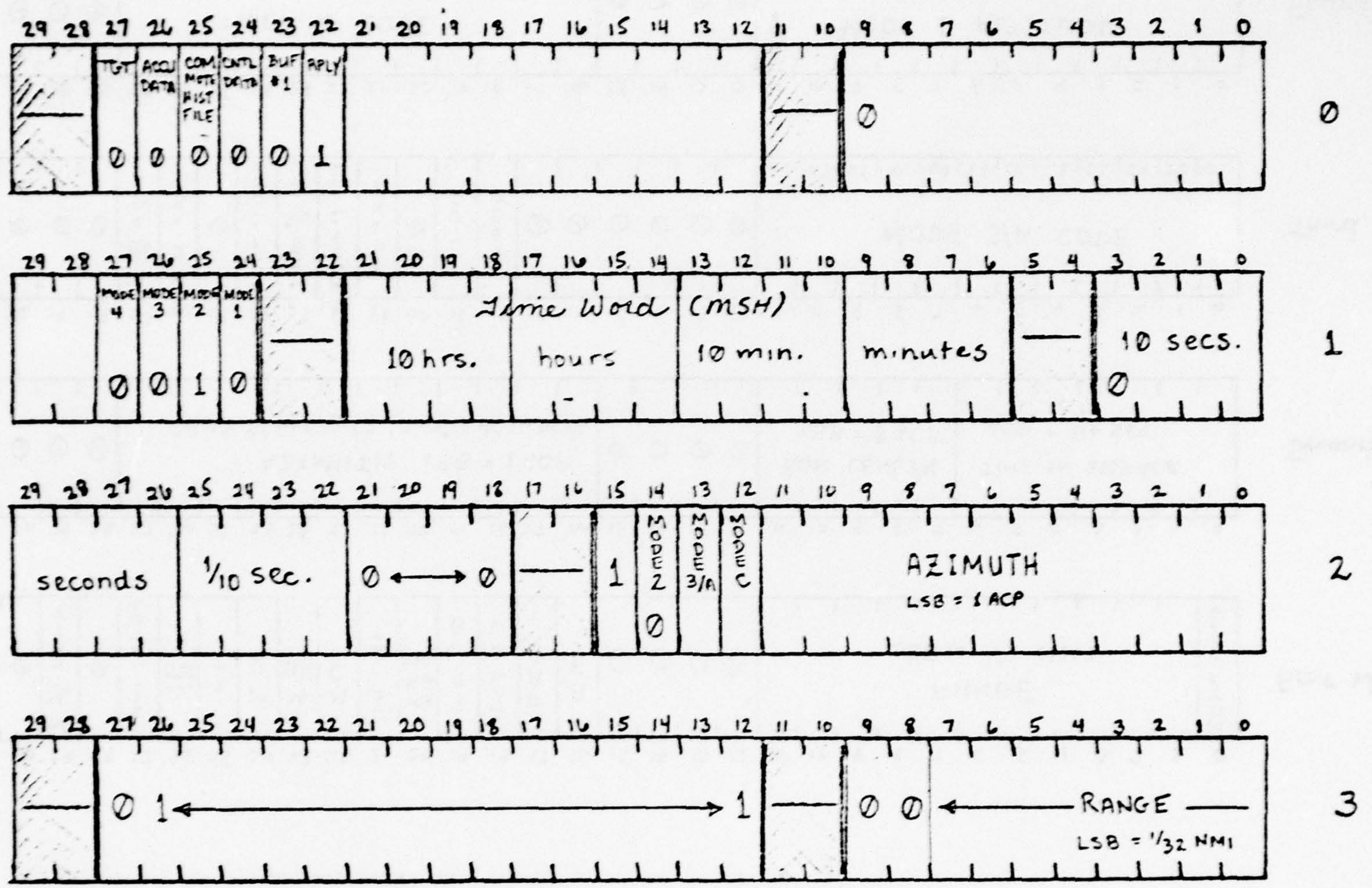
31–28	Ø Ø Ø Ø
27	M 3/A XBIT
26	M 2 XBIT
25	Ø
24	MODE 2 VAL
23	MODE 3/A VAL
22	MODE C VAL
21	IDENT
20	Ø
19	7700
18	7600
17–12	Ø Ø Ø Ø Ø Ø
11–0	MODE 3/A CODE (A4, A2, A1, B4, B2, B1, C4, C2, C1, D4, D2, D1)

Fourth Word

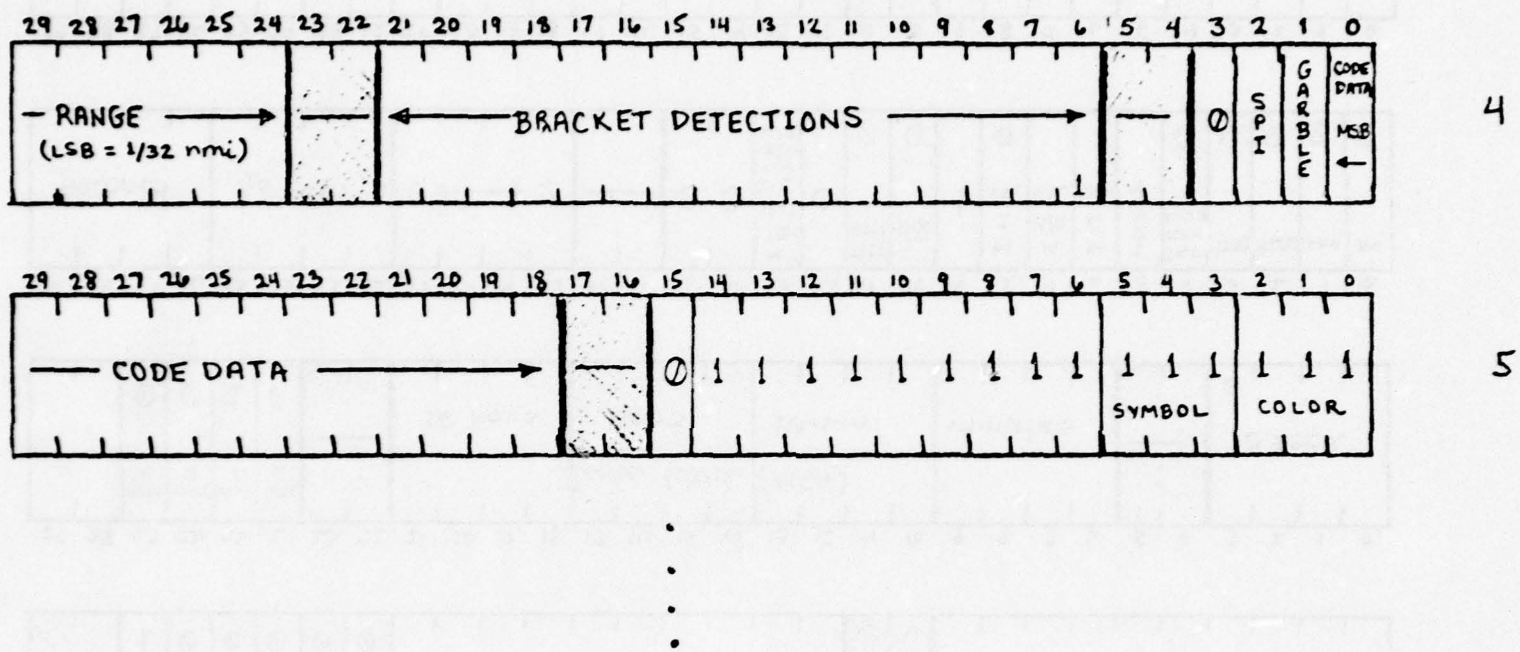
31–28	Ø Ø Ø Ø
27–16	MODE 2 CODE (D4, C1, A1, C2, A2, C4, A4, B1, D1, B2, D2, B4)
15–12	Ø Ø Ø Ø
11	ALT SIGN
10–0	MODE C ALTITUDE LSB = 100 FT.

INTERMEDIATE PACKING (as appears on mag tape) OF REPLY DATA

from 32-bit words into 30-bit word format:

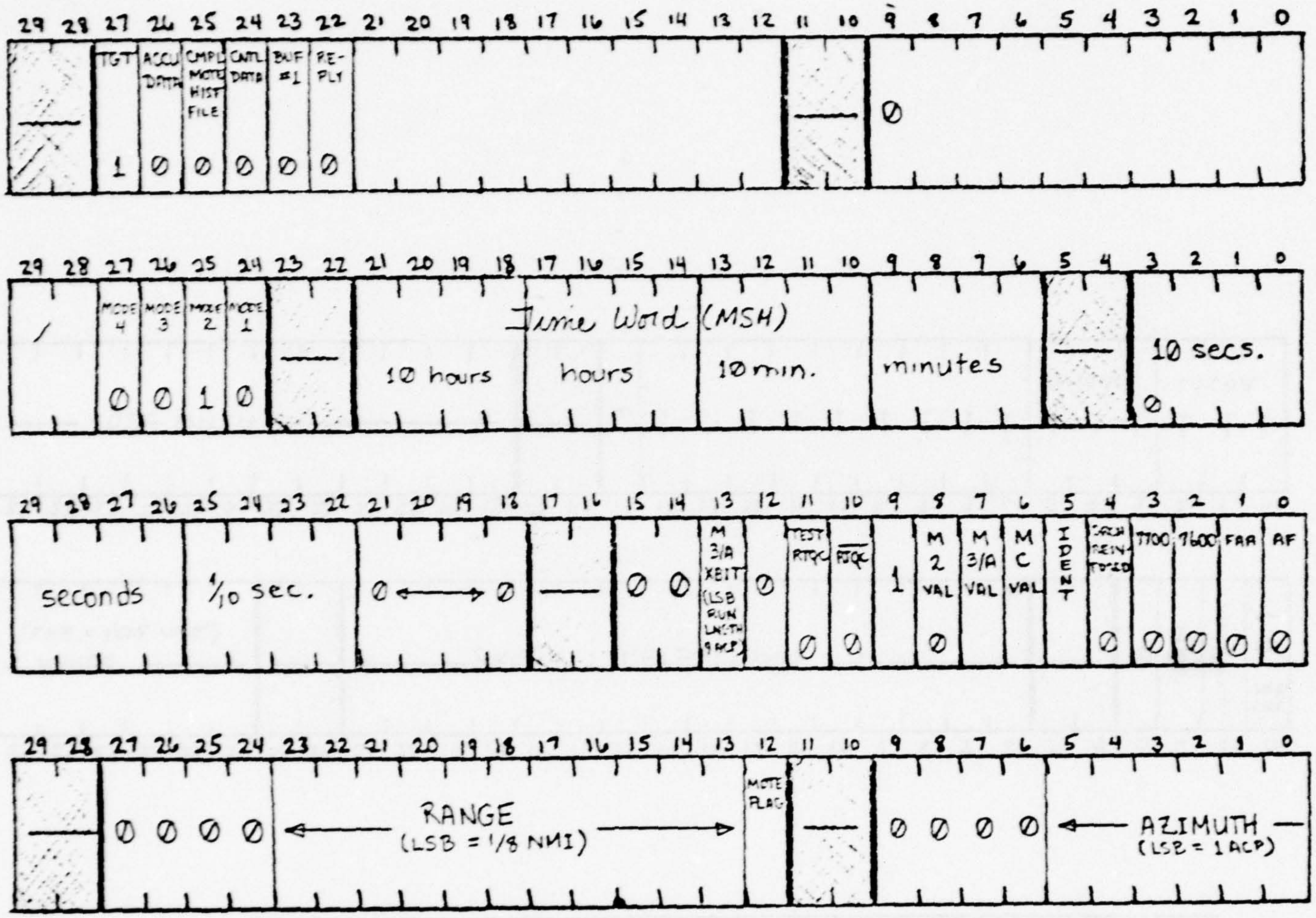


Intermediate packing of REPLY RECORD DATA (cont'd.)

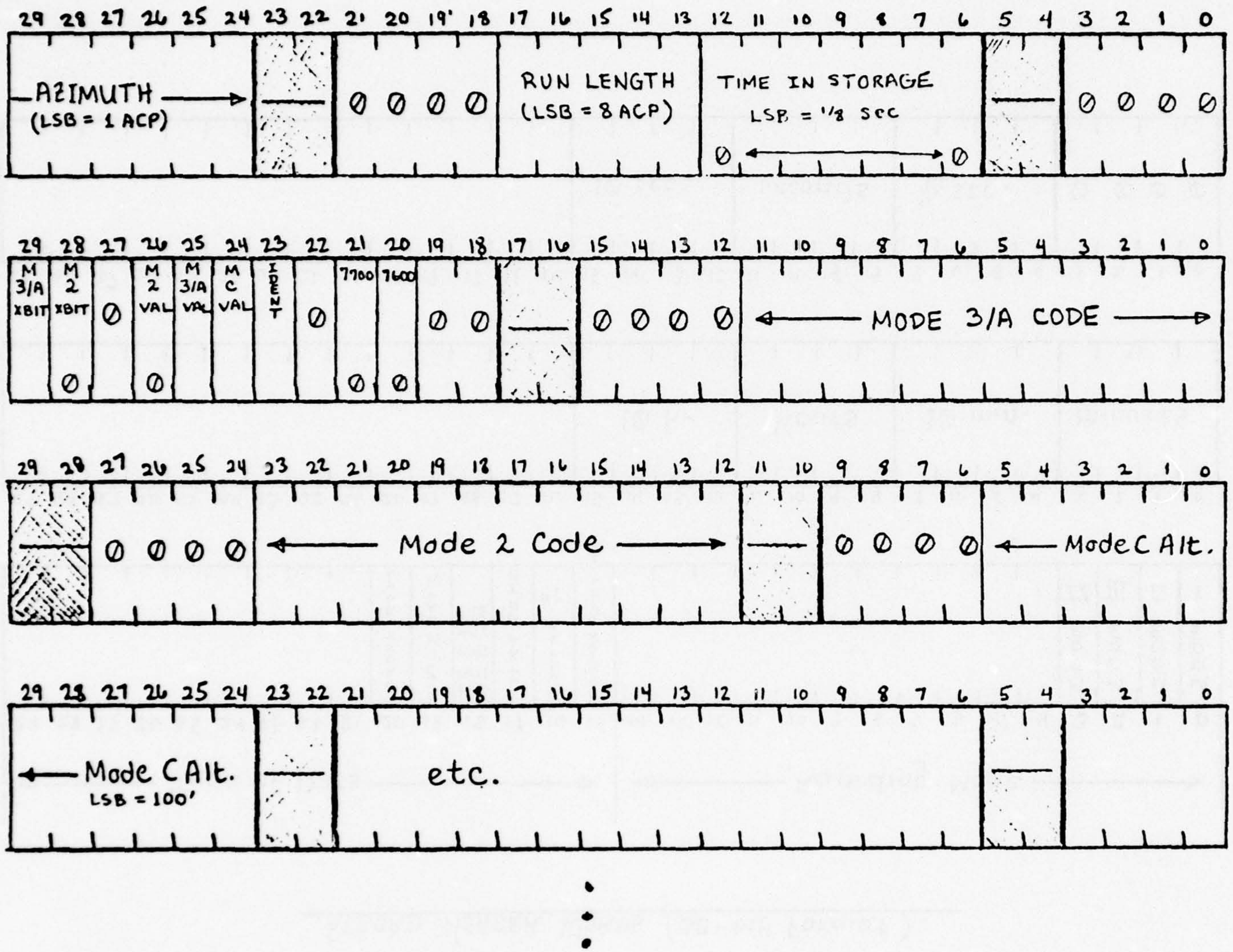


INTERMEDIATE PACKING (as appears on mag tape) of TARGET REPORT RECORD

DATA from 32-bit words into 30-bit format:



Intermediate packing of TARGET REPORT RECORD DATA (cont'd.)



RECORD HEADER WORDS (30-bit Format)

RECORD HEADER WORD 1

Bits 29–21	20	19	18	17	16	15	Bits 14–4	3	2	1	0
← Type of Data →							← Recording Mode →				
	TARGET RPTS	ACCUM. DATA	COMPLETE MOTE HIST. FILE	CNTRL DATA	BUFFER #1	BEACON REPLIES		MODE IV	MODE III	MODE II	MODE I

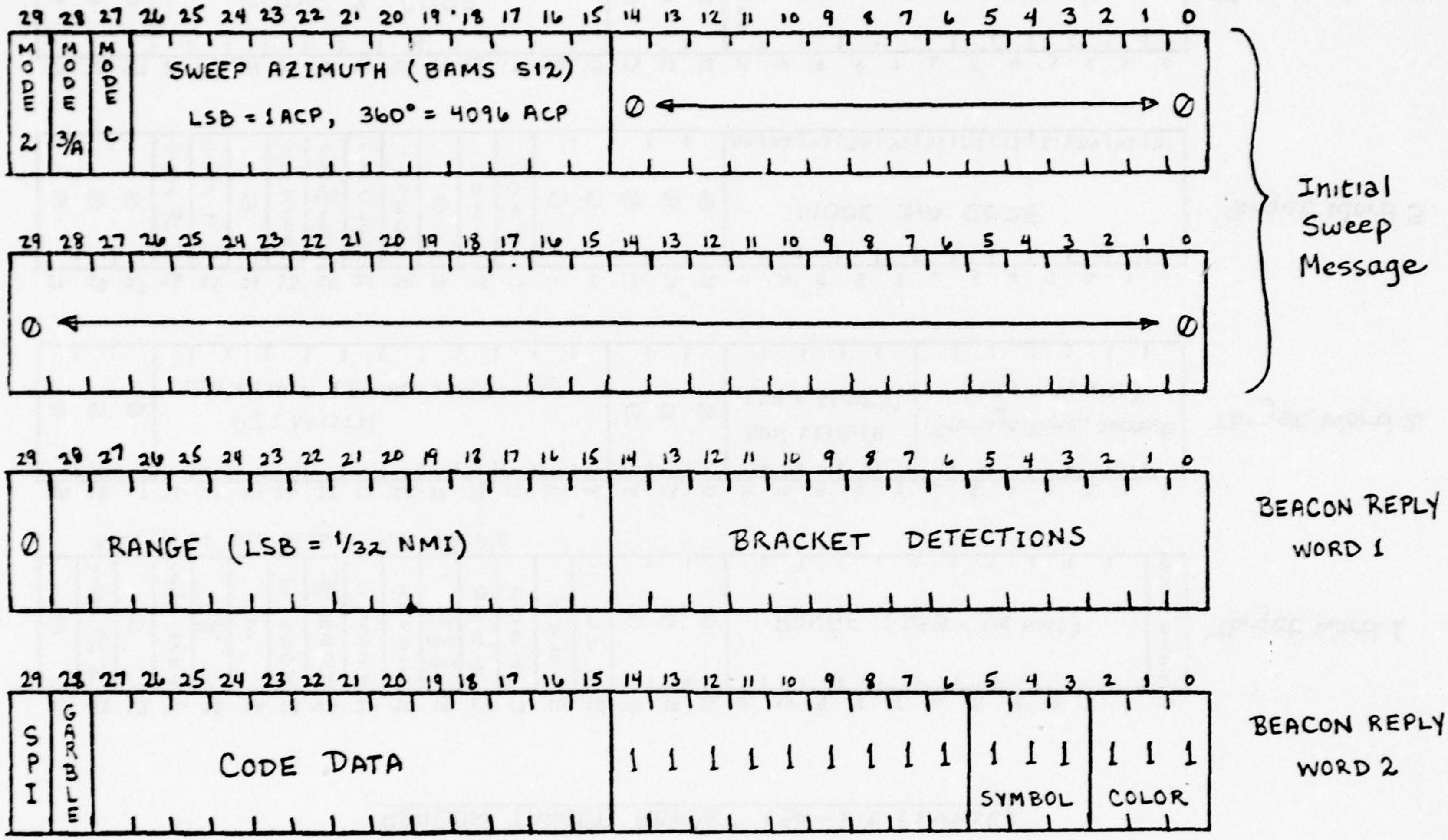
RECORD HEADER WORD 2 (TIME WORD):

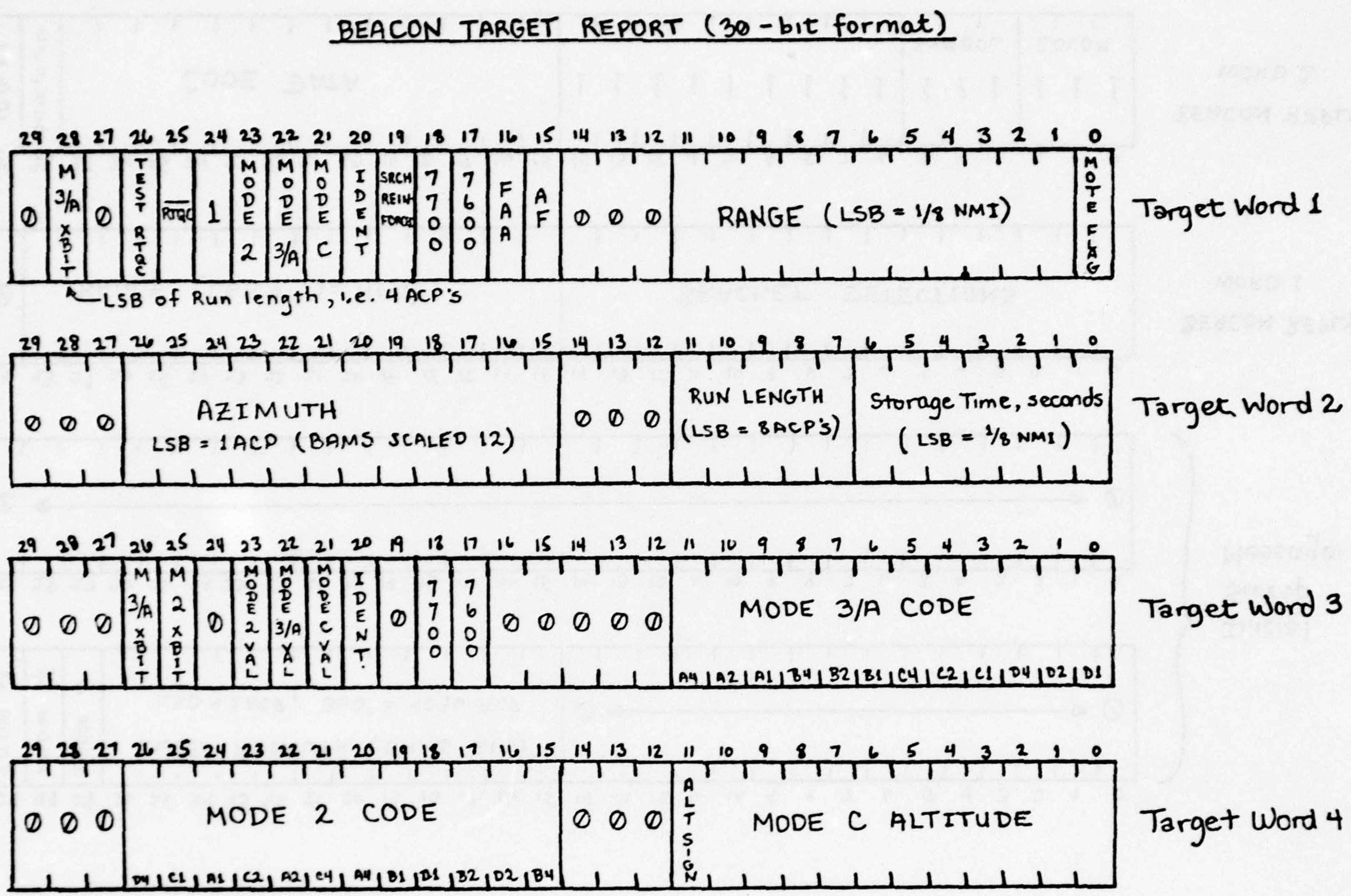
Bits 29–16	Bits 15–12	Bits 11–8	Bits 7–4	Bits 3–0
	10 hr.	hours	10 min.	minutes
	10 secs.	seconds	1/10 sec.	0 0 0 0

SAVED IN "REPLY HEADER TIME" AND "REPLY HEADER TIME[1]" RESPECTIVELY.

BEACON REPLIES (30-bit format)

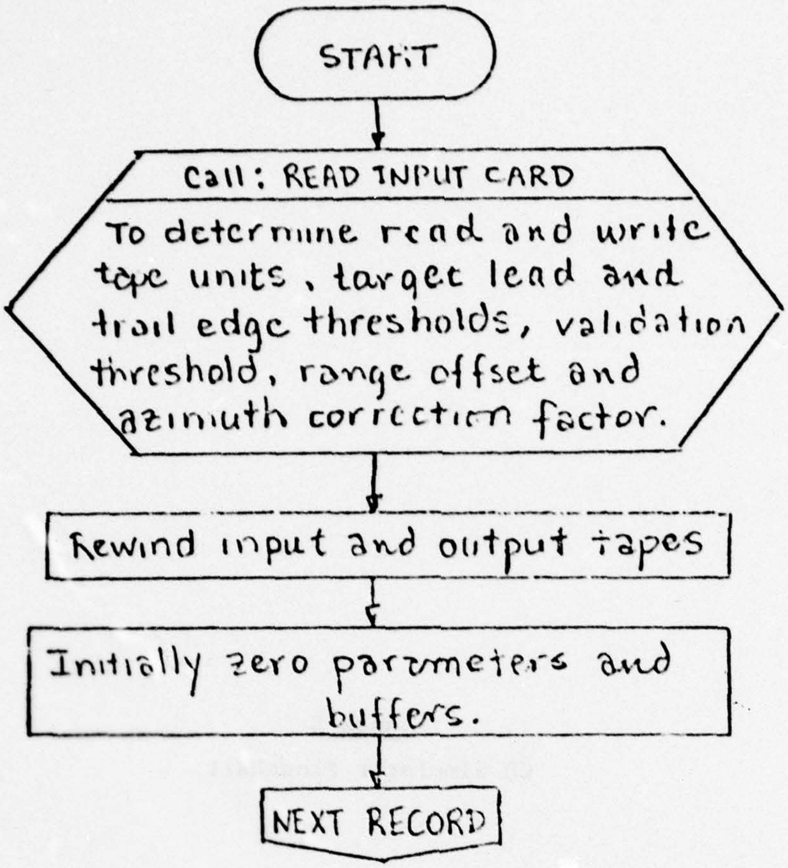
Initial Sweep Message and Beacon Reply Cells

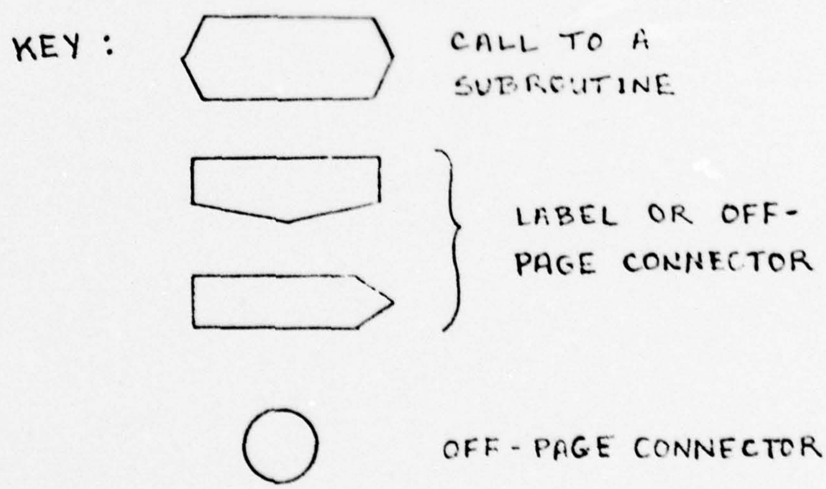


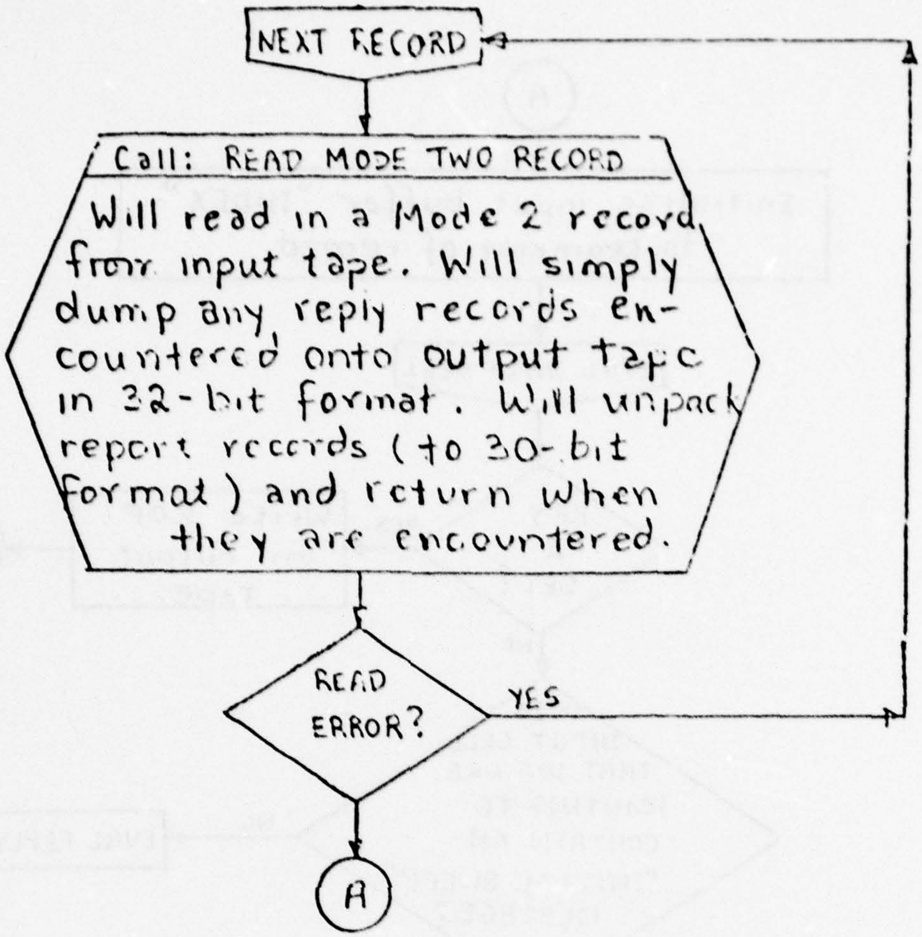

BEACON TARGET REPORT (30-bit format)
29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0
Ø
M 3/A X BIT
Ø
TEST RTQC
RTQC
1
MODE 2
MODE 3/A
MODE C
IDENT
SRCH REIN FORCED
7700
7600
FAA
AF
Ø Ø Ø
RANGE (LSB = 1/8 NMI)
MOTE FLAG
Target Word 1
LSB of Run length, i.e. 4 ACP'S
Ø Ø Ø
AZIMUTH
LSB = 1ACP (BAMS SCALED 12)
Ø Ø Ø
RUN LENGTH
(LSB = 8ACP'S)
Storage Time, seconds
(LSB = 1/8 NMI)
Target Word 2
Ø Ø Ø
M 3/A X BIT
M 2 X BIT
Ø
MODE 2 VAL
MODE 3/A VAL
MODE C VAL
IDENT.
Ø
7700
7600
Ø Ø Ø Ø Ø
MODE 3/A CODE
A4 A2 A1 B4 B2 B1 C4 C2 C1 D4 D2 D1
Target Word 3
Ø Ø Ø
MODE 2 CODE
D4 C1 A1 C2 A2 C4 A4 B1 D1 B2 D2 B4
Ø Ø Ø
ALT SIGN
MODE C ALTITUDE
Target Word 4

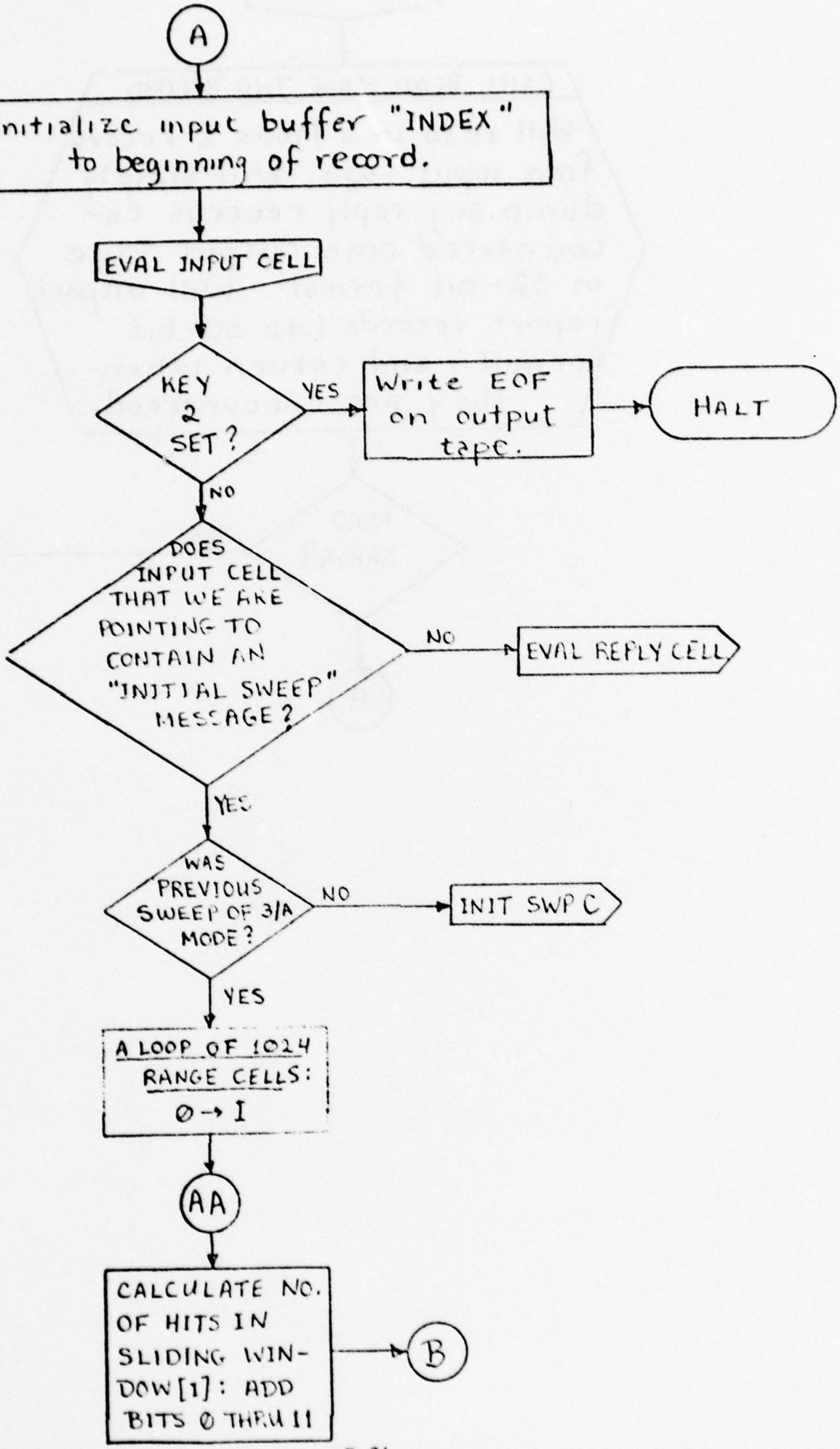
Annex B

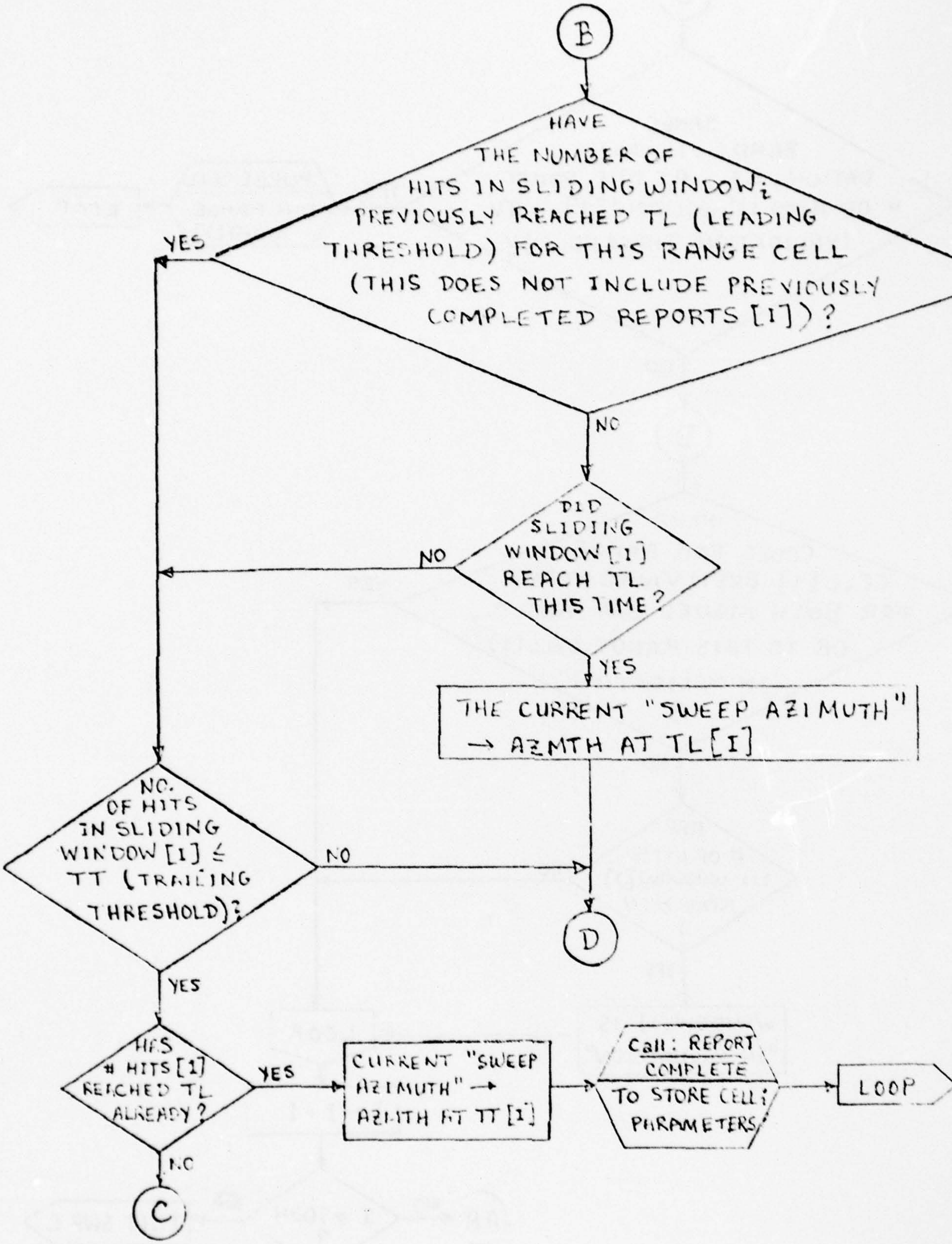
CD Simulator Flowchart

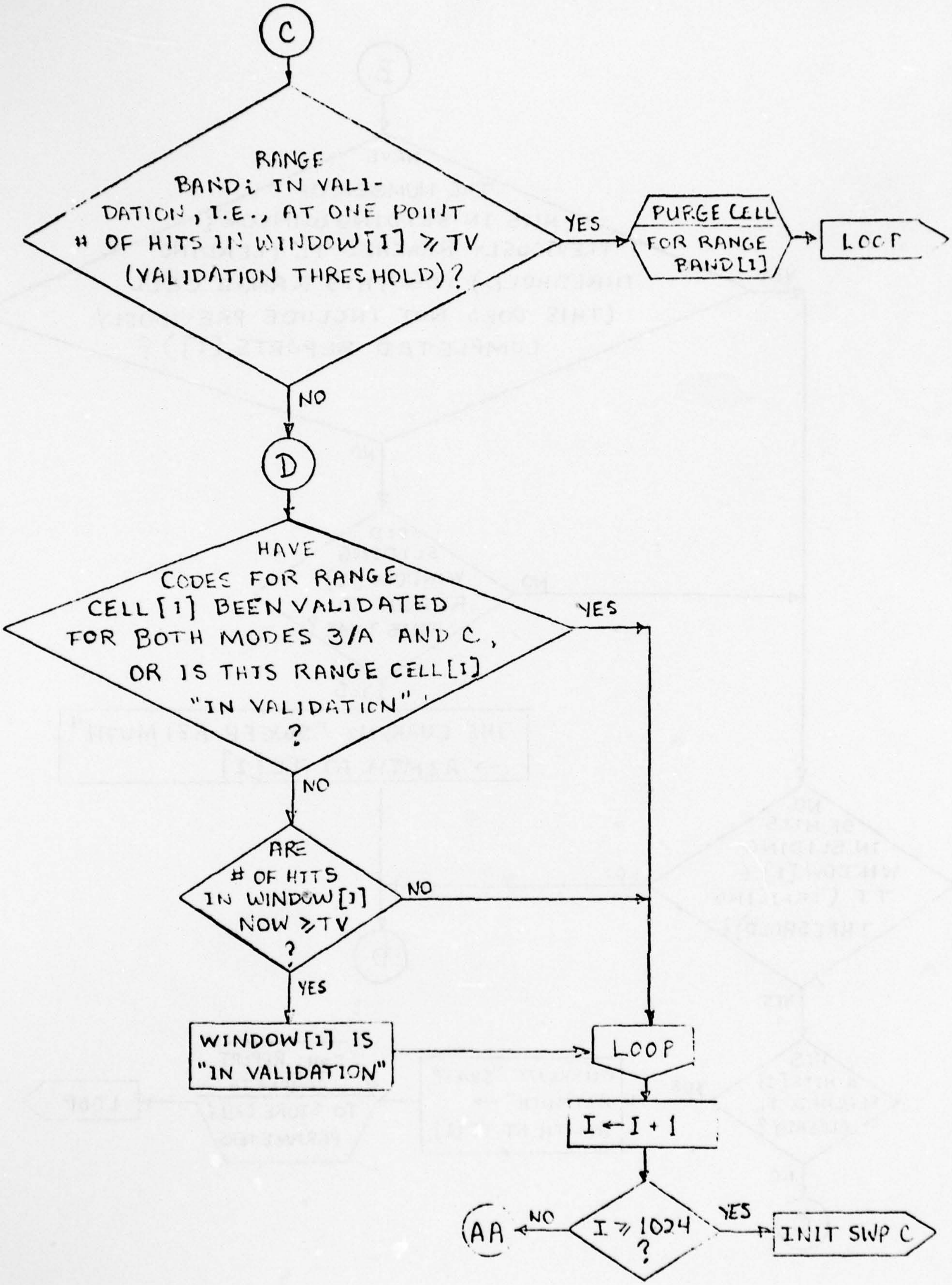

START
Call: READ INPUT CARD
To determine read and write tape units, target lead and trail edge thresholds, validation threshold, range offset and azimuth correction factor.
Rewind input and output tapes
Initially zero parameters and buffers.
NEXT RECORD

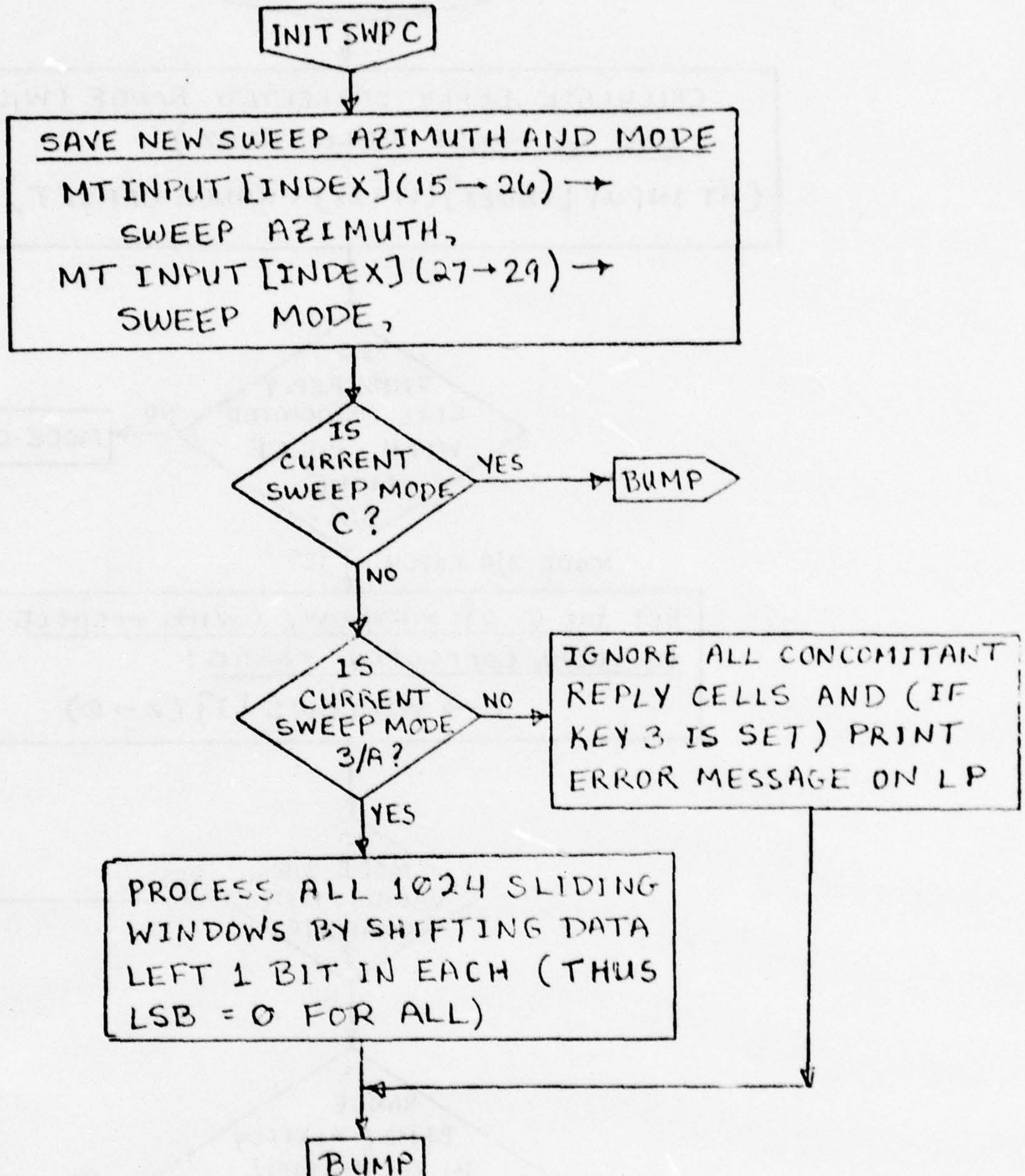

KEY:
CALL TO A SUBROUTINE
LABEL OR OFF-PAGE CONNECTOR
OFF-PAGE CONNECTOR

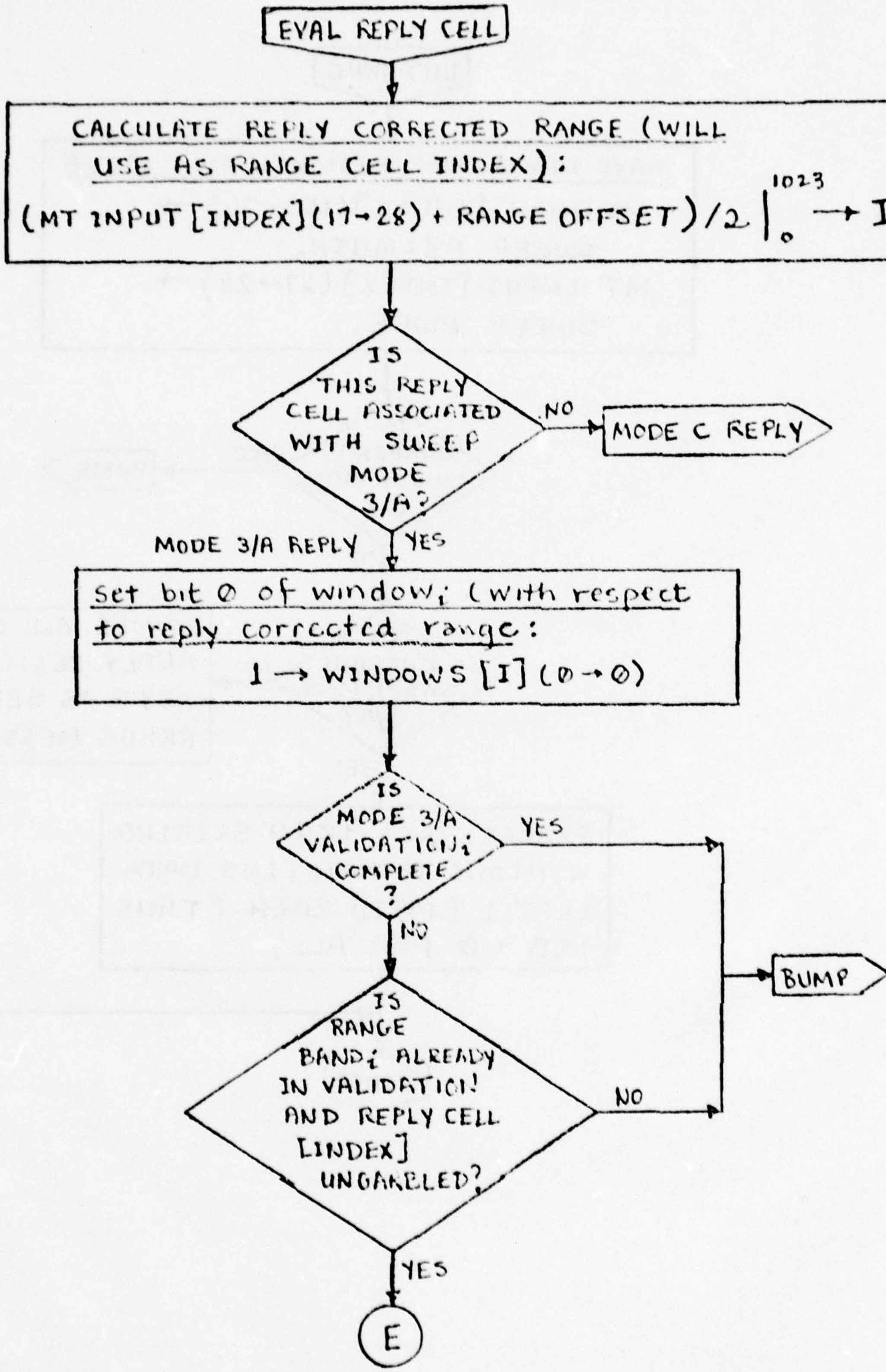

NEXT RECORD
Call: READ MODE TWO RECORD
Will read in a Mode 2 record from input tape. Will simply dump any reply records encountered onto output tape in 32-bit format. Will unpack report records (to 30-bit format) and return when they are encountered.
READ ERROR?
YES
A


A
Initialize input buffer "INDEX" to beginning of record.
EVAL INPUT CELL
KEY 2 SET?
YES
Write EOF on output tape.
HALT
NO
DOES INPUT CELL THAT WE ARE POINTING TO CONTAIN AN "INITIAL SWEEP" MESSAGE?
NO
EVAL REPLY CELL
YES
WAS PREVIOUS SWEEP OF 3/A MODE?
NO
INIT SWP C
YES
A LOOP OF 1024 RANGE CELLS:
0 → I
AA
CALCULATE NO. OF HITS IN SLIDING WINDOW[I]: ADD BITS 0 THRU 11
B

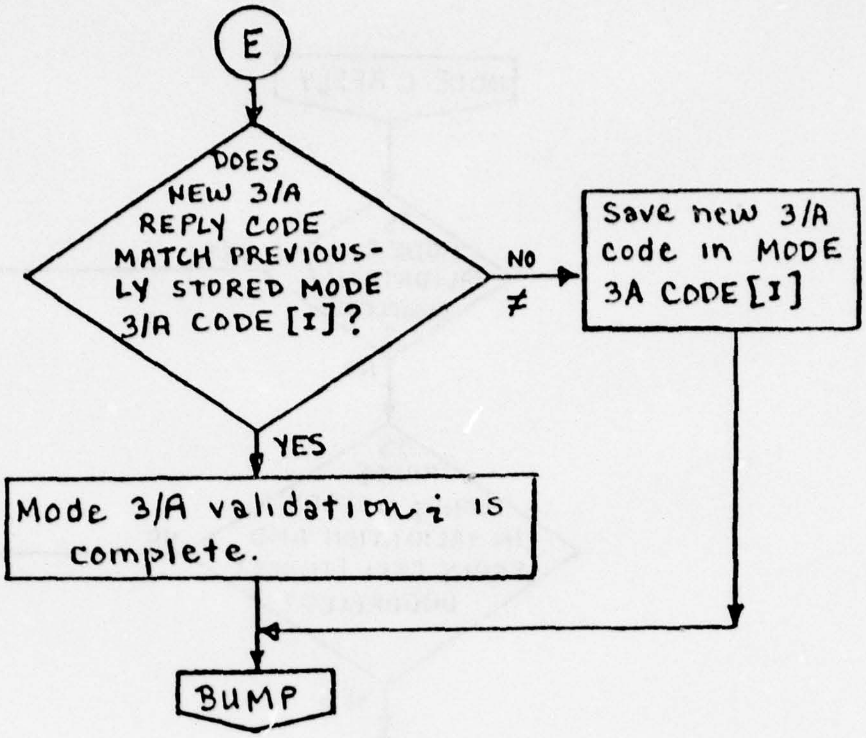

B
HAVE THE NUMBER OF HITS IN SLIDING WINDOW_i PREVIOUSLY REACHED TL (LEADING THRESHOLD) FOR THIS RANGE CELL (THIS DOES NOT INCLUDE PREVIOUSLY COMPLETED REPORTS [I])?
YES
NO
DID SLIDING WINDOW [I] REACH TL THIS TIME?
NO
YES
THE CURRENT "SWEEP AZIMUTH" → AZMTH AT TL [I]
NO. OF HITS IN SLIDING WINDOW [I] ≤ TT (TRAILING THRESHOLD)?
NO
YES
D
HAS # HITS [I] REACHED TL ALREADY?
YES
NO
C
CURRENT "SWEEP AZIMUTH" → AZMTH AT TT [I]
Call: REPORT COMPLETE TO STORE CELL PARAMETERS
LOOP

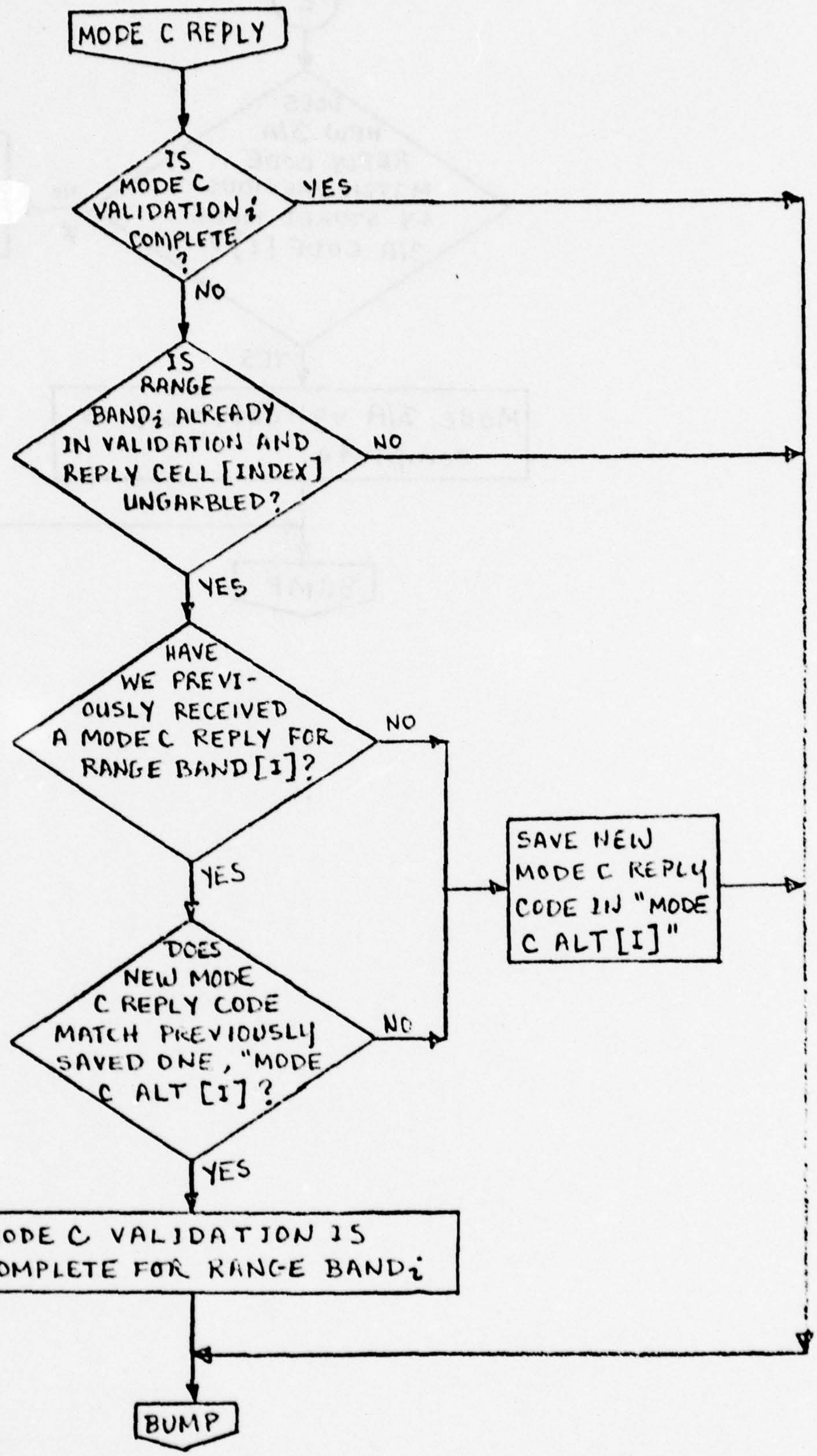

C
RANGE BANDi IN VALIDATION, I.E., AT ONE POINT # OF HITS IN WINDOW[I] ≥ TV (VALIDATION THRESHOLD)?
YES
PURGE CELL FOR RANGE BAND[I]
LOOP
NO
D
HAVE CODES FOR RANGE CELL[I] BEEN VALIDATED FOR BOTH MODES 3/A AND C, OR IS THIS RANGE CELL[I] "IN VALIDATION" ?
YES
NO
ARE # OF HITS IN WINDOW[I] NOW ≥TV ?
NO
YES
WINDOW[I] IS "IN VALIDATION"
LOOP
I←I+1
I ≥ 1024 ?
NO
AA
YES
INIT SWP C

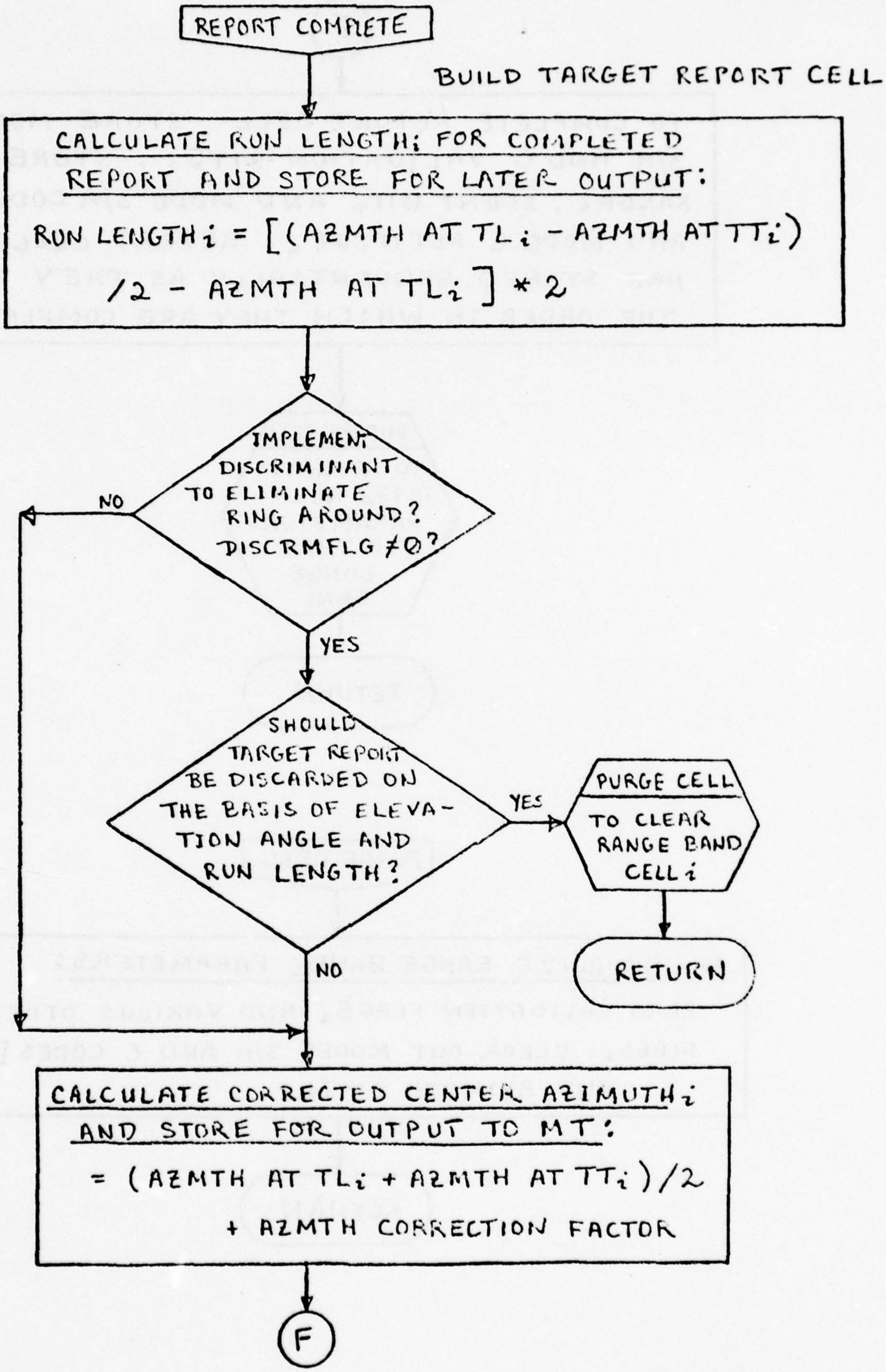

INIT SWPC
SAVE NEW SWEEP AZIMUTH AND MODE
MT INPUT [INDEX] (15 → 26) → SWEEP AZIMUTH,
MT INPUT [INDEX] (27 → 29) → SWEEP MODE,
IS CURRENT SWEEP MODE C?
YES
BUMP
NO
IS CURRENT SWEEP MODE 3/A?
NO
IGNORE ALL CONCOMITANT REPLY CELLS AND (IF KEY 3 IS SET) PRINT ERROR MESSAGE ON LP
YES
PROCESS ALL 1024 SLIDING WINDOWS BY SHIFTING DATA LEFT 1 BIT IN EACH (THUS LSB = 0 FOR ALL)
BUMP

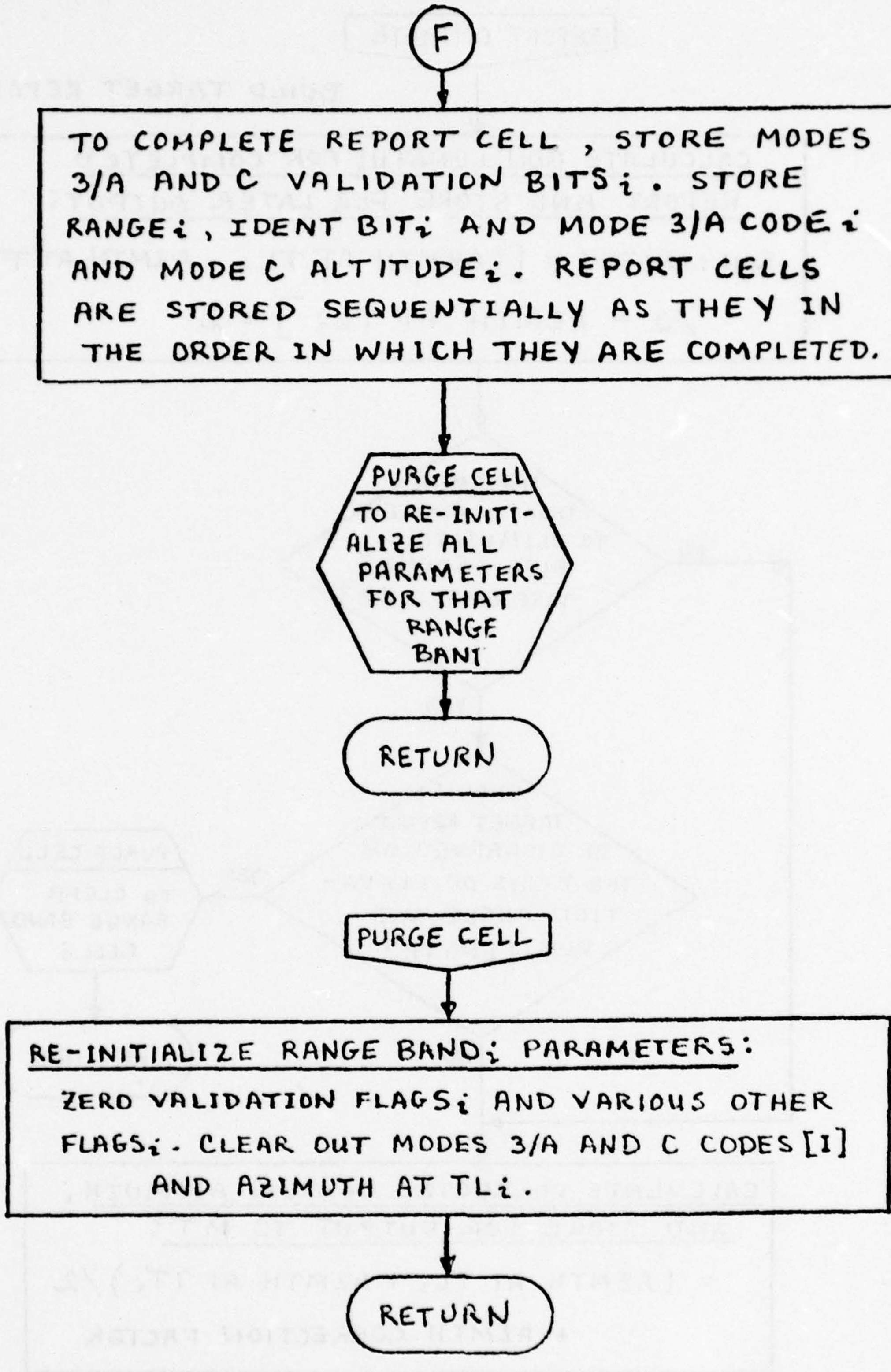


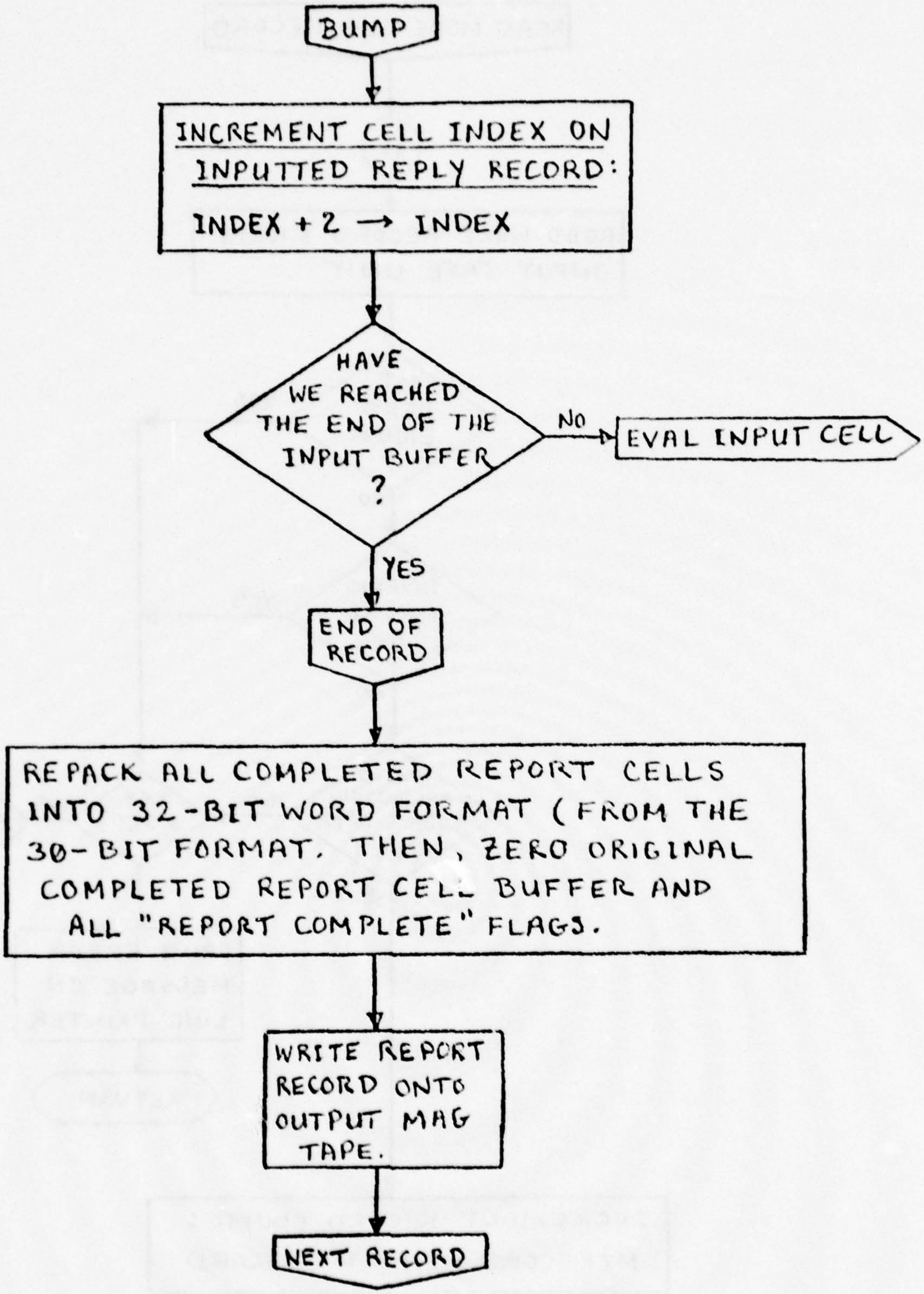
EVAL REPLY CELL
CALCULATE REPLY CORRECTED RANGE (WILL USE AS RANGE CELL INDEX):
(MT INPUT [INDEX](17→28) + RANGE OFFSET)/2 |₀^1023 → I
IS THIS REPLY CELL ASSOCIATED WITH SWEEP MODE 3/A?
NO
MODE C REPLY
MODE 3/A REPLY
YES
Set bit Ø of window_i (with respect to reply corrected range:
1 → WINDOWS [I] (Ø → Ø)
IS MODE 3/A VALIDATION_i COMPLETE?
YES
NO
BUMP
IS RANGE BAND_i ALREADY IN VALIDATION AND REPLY CELL [INDEX] UNGARBLED?
NO
YES
E

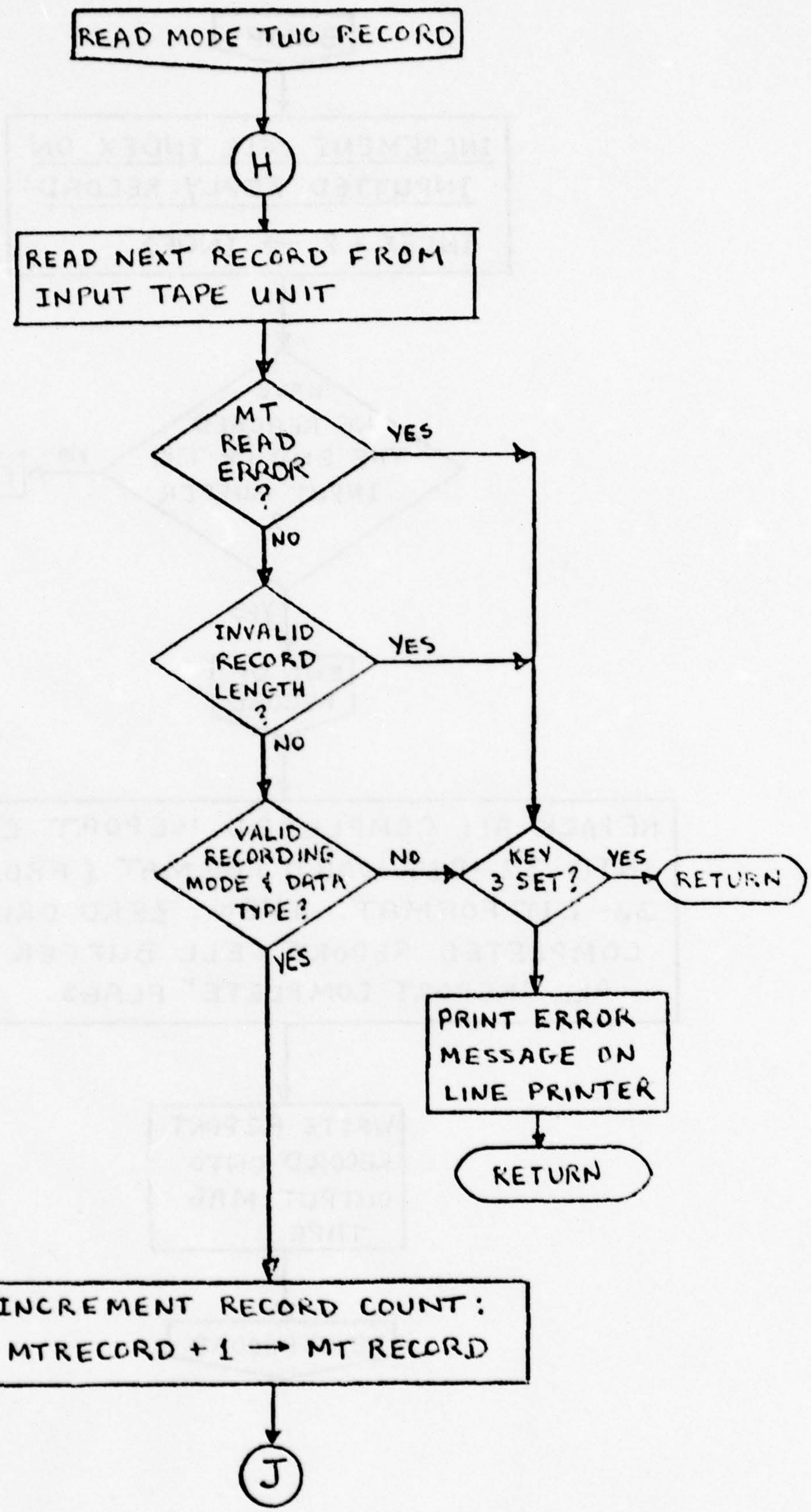

E
DOES NEW 3/A REPLY CODE MATCH PREVIOUS-LY STORED MODE 3/A CODE [I]?
NO
≠
Save new 3/A code in MODE 3A CODE [I]
YES
Mode 3/A validation i is complete.
BUMP

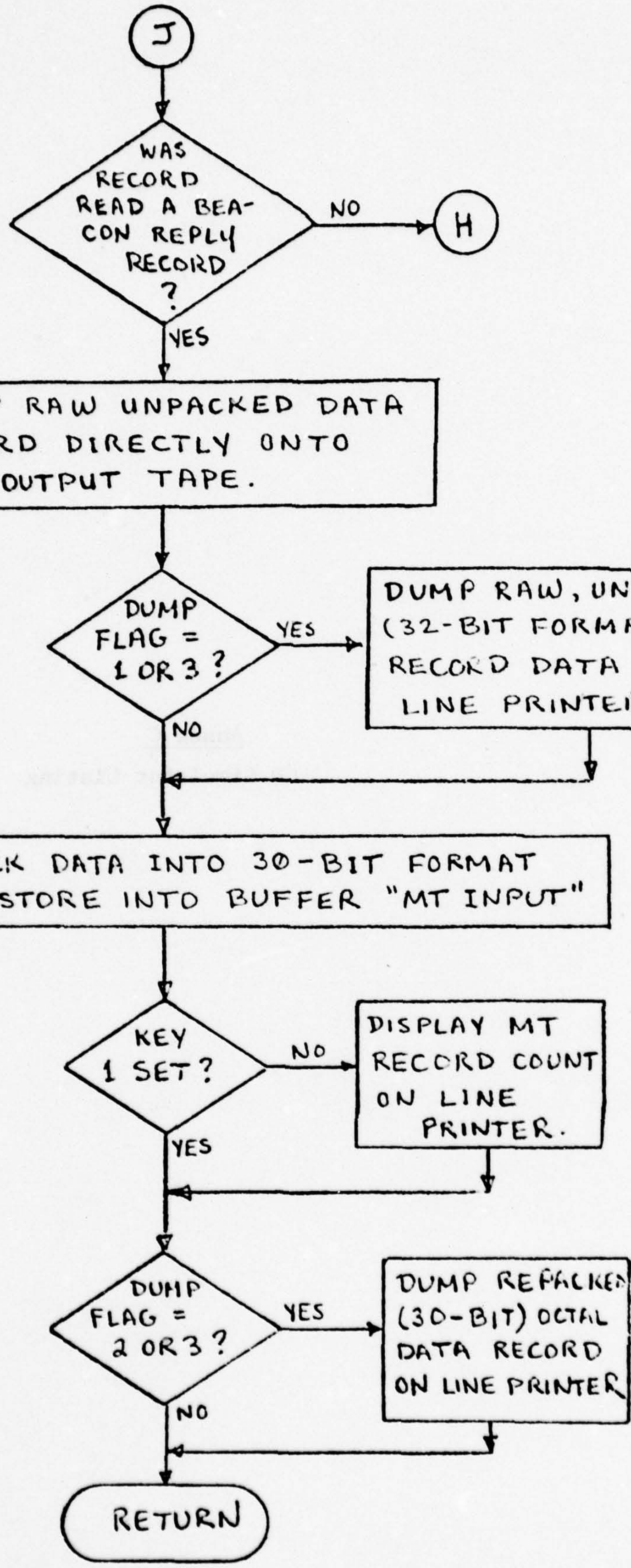

MODE C REPLY
IS MODE C VALIDATION$_i$ COMPLETE ?
YES
NO
IS RANGE BAND$_i$ ALREADY IN VALIDATION AND REPLY CELL [INDEX] UNGARBLED?
NO
YES
HAVE WE PREVIOUSLY RECEIVED A MODE C REPLY FOR RANGE BAND[I]?
NO
YES
SAVE NEW MODE C REPLY CODE IN "MODE C ALT[I]"
DOES NEW MODE C REPLY CODE MATCH PREVIOUSLY SAVED ONE, "MODE C ALT [I]?
NO
YES
MODE C VALIDATION IS COMPLETE FOR RANGE BAND$_i$
BUMP


REPORT COMPLETE
BUILD TARGET REPORT CELL
CALCULATE RUN LENGTH; FOR COMPLETED REPORT AND STORE FOR LATER OUTPUT:
RUN LENGTH i = [(AZMTH AT TL i - AZMTH AT TT i) /2 - AZMTH AT TL i] * 2
IMPLEMENT DISCRIMINANT TO ELIMINATE RING AROUND? DISCRMFLG ≠ 0?
NO
YES
SHOULD TARGET REPORT BE DISCARDED ON THE BASIS OF ELEVATION ANGLE AND RUN LENGTH?
YES
NO
PURGE CELL
TO CLEAR RANGE BAND CELL i
RETURN
CALCULATE CORRECTED CENTER AZIMUTH i AND STORE FOR OUTPUT TO MT:
= (AZMTH AT TL i + AZMTH AT TT i)/2 + AZMTH CORRECTION FACTOR
F


F
TO COMPLETE REPORT CELL, STORE MODES 3/A AND C VALIDATION BITSi. STORE RANGEi, IDENT BITi AND MODE 3/A CODEi AND MODE C ALTITUDEi. REPORT CELLS ARE STORED SEQUENTIALLY AS THEY IN THE ORDER IN WHICH THEY ARE COMPLETED.
PURGE CELL
TO RE-INITI-ALIZE ALL PARAMETERS FOR THAT RANGE BANI
RETURN
PURGE CELL
RE-INITIALIZE RANGE BANDi PARAMETERS:
ZERO VALIDATION FLAGSi AND VARIOUS OTHER FLAGSi. CLEAR OUT MODES 3/A AND C CODES [I] AND AZIMUTH AT TLi.
RETURN


BUMP
INCREMENT CELL INDEX ON INPUTTED REPLY RECORD:
INDEX + 2 → INDEX
HAVE WE REACHED THE END OF THE INPUT BUFFER ?
NO
EVAL INPUT CELL
YES
END OF RECORD
REPACK ALL COMPLETED REPORT CELLS INTO 32-BIT WORD FORMAT (FROM THE 30-BIT FORMAT. THEN, ZERO ORIGINAL COMPLETED REPORT CELL BUFFER AND ALL "REPORT COMPLETE" FLAGS.
WRITE REPORT RECORD ONTO OUTPUT MAG TAPE.
NEXT RECORD


READ MODE TWO RECORD
H
READ NEXT RECORD FROM INPUT TAPE UNIT
MT READ ERROR ?
YES
NO
INVALID RECORD LENGTH ?
YES
NO
VALID RECORDING MODE & DATA TYPE ?
NO
YES
KEY 3 SET?
YES
RETURN
PRINT ERROR MESSAGE ON LINE PRINTER
RETURN
INCREMENT RECORD COUNT: MTRECORD + 1 → MT RECORD
J


J
WAS RECORD READ A BEACON REPLY RECORD ?
NO
H
YES
DUMP RAW UNPACKED DATA RECORD DIRECTLY ONTO OUTPUT TAPE.
DUMP FLAG = 1 OR 3 ?
YES
DUMP RAW, UNPACKED (32-BIT FORMAT) OCTAL RECORD DATA ONTO LINE PRINTER.
NO
UNPACK DATA INTO 30-BIT FORMAT AND STORE INTO BUFFER "MT INPUT"
KEY 1 SET ?
NO
DISPLAY MT RECORD COUNT ON LINE PRINTER.
YES
DUMP FLAG = 2 OR 3 ?
YES
DUMP REPACKED (30-BIT) OCTAL DATA RECORD ON LINE PRINTER
NO
RETURN

Annex C

CD Simulator Listing

```
3(COMMENT:   FLOWCHART 01,  [00234],  18 JAN  1977 )

:
(: C D SIMULATOR OPERATING INSTRUCTIONS)

(: KEY 1 - TO INHIBIT MT RECORD NUMBER PRINTOUT)

(: KEY 2 - WRITE EOF ON OUTPUT TAPE AND HALT)

(: KEY 3 - INHIBIT MT ERROR PRINTOUTS)

(: PC IS 10000.; HAVE INPUT CARD IN READER)

(: LOCATION 26000.IS DISCRMFLG -  = 0 IF NO DISCRIMINANTS; )

(:  = 1 IF ONLY FOR REPORTS WITH MODE C VALIDATED; )

(:  = 2 IF WANT DISCRIMINANT FOR ALL COMPLETED REPORTS)

(: FOLLOWING LOCATIONS SET IFF YOU WISH TO IMPLEMENT DISCRIMINANT)

(: LOC. 26001.IS ALTIMTR SET - ALTIMETER SETTING IN S12 FEET)

(: LOC. 26002.IS SENSOR ELEV - IN SO FEET)

(: LOC. 26003.IS RUNLL - LOWER RUN LENGTH FOR DISCR. COMPARE, 4ACP)

(: LOC. 26004.IS RUNLU - UPPER RUN LENGTH FOR DISCR. COMPARE, 4ACP)
```

```
(: LOC. 26005.IS DISCRNGE - RANGE TO COMPARE WITH SLANT RANGE)

(: IF USING DISCRIMINANTS AND MODE C NOT VALIDATED, IN SO NMI)
 COMMENT IS: . .                                                    30000
```

```
3(COMMENT:   FLOWCHART 02,  [00100],  18 JAN  1977 )

WINDOWS:                                                                30000
{ BIT 10(10 → 10), BIT 9(9 → 9), BIT 8(8 → 8), BIT 7(7 → 7),
BIT 6(6 → 6), BIT 5(5 → 5), BIT 4(4 → 4), BIT 3(3 → 3),
BIT 2(2 → 2), BIT 1(1 → 1), BIT 0(0 → 0) }(1024),
COMPLETED 1 RPRT BUF(1024),
COMPLETED 2 RPRT BUF(1024),
COMPLETED 3 RPRT BUF(1024),
COMPLETED 4 RPRT BUF(1024), SWEEP AZIMUTH,
MODE 3A CODE(1024),
MODE C ALT(1024), ; DIMN1: . .
```

```
3(COMMENT:   FLOWCHART 03,  [00112],  18 JAN  1977 )

PARAMS: { AZMTH AT TL(0 → 11)                                    50000
  }(1024),

OUTPUT BUF:                                                      52000
{ OT1A(12 → 27), OT1B(0 → 9) },

OUTPUT 1 BUF:                                                    52001
{ OT1C(24 → 29), OT2A(6 → 21), OT2B(0 → 3) },

OUTPUT 2 BUF:                                                    52002
{ OT2C(18 → 29), OT3A(0 → 15) }(1240),
TEMP OUT BUF(3000),

FLAGS:                                                           62222
{ IN PROCESS FLG(0 → 0), VALID 3A COMPLETE(1 → 1),
VALID C COMPLETE(2 → 2), IN VALIDATION(3 → 3),
TL REACHED FLG(4 → 4), IDENT BIT(5 → 5),
RPT COMPLETE FLG(6 → 6), C CODE FLG(7 → 7) }(1024), ;
DIMN2: . .                                                       64222
```

```
7(COMMENT:   FLOWCHART 04,  [00014],  18 JAN  1977 )
LIBRARY = ( READ INPUT CARD, ARC TAN, SQUARE ROOT,  ); . .
```

```
6(COMMENT:   FLOWCHART 05,  [00023],  18 JAN  1977 )

OCT DUMP:                                                    04471
0 04471a.

MAG TAPE ALTERNATE:                                          7720C
0 7720Ca.

MAG TAPE:                                                    77212
0 77212a.

PRINT:                                                       02273
0 02273a. . .
```

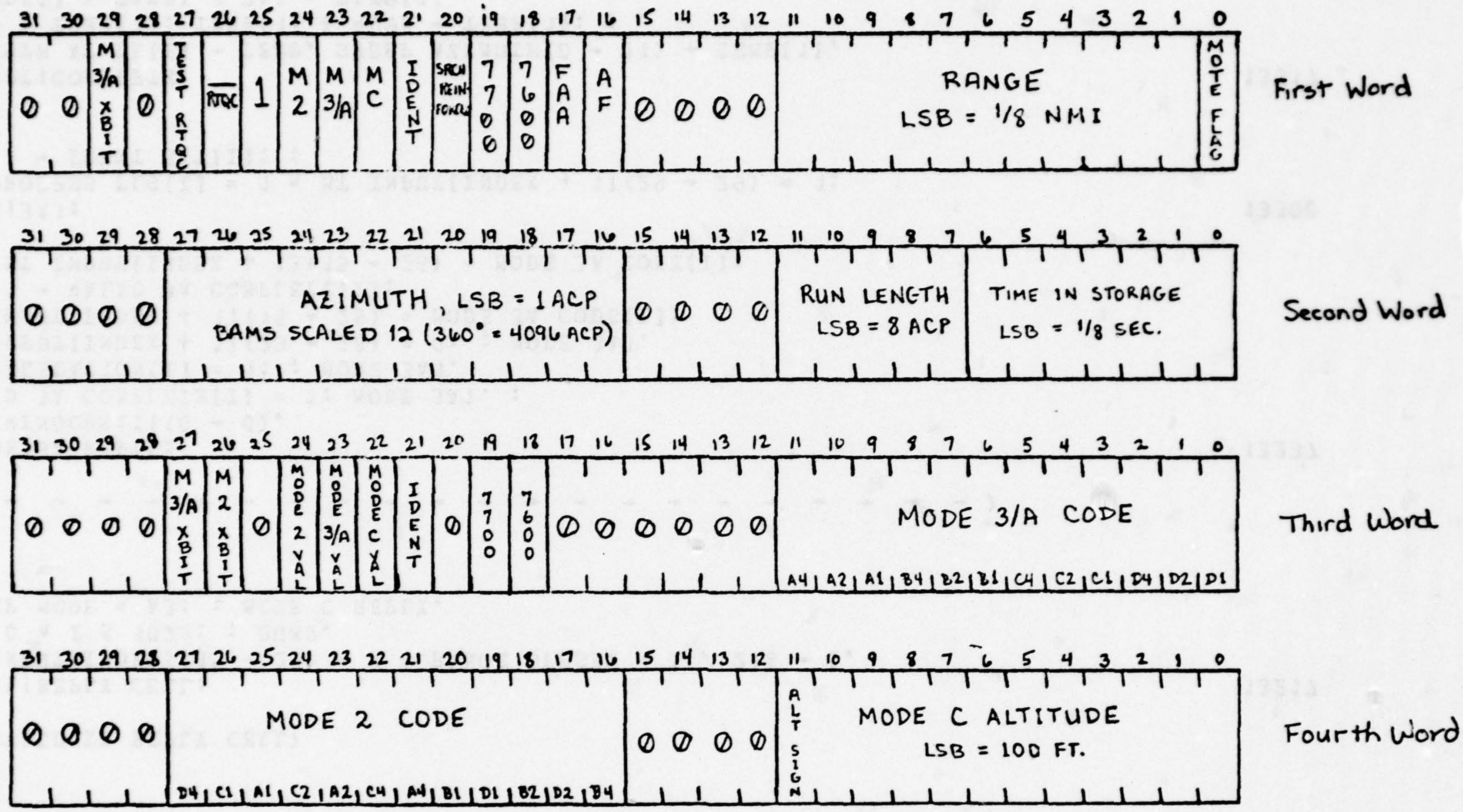
```
3(COMMENT:   FLOWCHART 06,  [02527],  18 JAN  1977 )

WRITE = 8, TAPE DRIVE, OUT TAPE DRIVE, INDEX|, SWEEP|MODE,
TL|, TT|, TV|, RANGE|OFFSET, AZMTH|CORR FCTR, A3| = 2, C| = 1,
DISCRMPLG = { 26000ₙ },
ALTIMTR|SET = { 26001ₙ },
SENSOR|ELEV = { 26002ₙ },
RUNLL| = { 26003ₙ },
RUNLU| = { 26004ₙ },
DISCRNGE| = { 26005ₙ },
DELTA|H, RS|, RG|, ALTCORR|,

[DISCR|FMT:
 * DISCRMPLG =  * I1, |2| * ALTIMETER SET =  * S6. 2,
 * FT * |2| * SENSOR ELEV =  * I2,  * FT * - /  * RUNLL =  * I3,
 * ACPS * |2| * RUNLU =  * I3,  * ACPS * |2| * DISCRNGE =  * I1,  *
NMI *  /  / ],
TEMP(6),

[INITIALIZATION|FORMAT:
I1, |1|I1, |1|I2, |1|I2, |1|I2, |1|I5, |1|I5, ],
MODE C CODE, BAD|SWEEP FLAG,

[MODE ERR FORMAT:

 * SWEEP MODE NEITHER 3A NOR C:
SKIP TO NEXT SWEEP *  / ], X,

D1:                                                                   12562
SIGN|,
HUNDREDS(8) = 0, 2, 0, 1,  - 2, 0,  - 1, 0,

GRAY|CODE:                                                            12573
{ D|2(7 → 7), D|4(6 → 6), A|1(5 → 5), A|2(4 → 4), A|4(3 → 3),
B|1(2 → 2), B|2(1 → 1), B|4(0 → 0), C|1(2 → 2), C|2(1 → 1),
C|4(0 → 0) },
ALTITUDE, ;

TAPE IO(TYPE, BN, UNIT, MODE, BEGIN, END, G):
{ TYPE → I, BN → J, UNIT → K, MODE → L, BEGIN → N, END → M, 12730ₙG,
```

```
MAG TAPE,  },
(: )

(: - - - - - - - - - - - - - - - - - - - - - - )

(: CD SIMULATOR INITIALIZATION)

START|:                                                             12616
READ INPUT CARD(INITIALIZATION FORMAT; TAPE DRIVE, OUT
 TAPE DRIVE, TL, TT, TV, RANGE OFFSET, AZMTH CORR FCTR, )
DISCRMFLG = 0: ; RUNLL * 4 → TEMP, RUNLU * 4 → TEMP[1],
    PRINT(DISCR FMT, DISCRMFLG, ALTIMTR SET, 12, SENSOR
    ELEV, TEMP, TEMP[1], DISCRNGE);
OUT TAPE DRIVE = 3: 4 → OUT TAPE DRIVE;
    OUT TAPE DRIVE = 4: 8 → OUT TAPE DRIVE; ; ;
TAPE DRIVE = 3: 4 → TAPE DRIVE;
    TAPE DRIVE = 4: 8 → TAPE DRIVE; ; ;
TAPE IO(1, 0, TAPE DRIVE, 2, 0, 0, 0),
TAPE IO(1, 0, OUT TAPE DRIVE, 2, 0, 0, 0),
0 → SWEEP MODE → SWEEP AZIMUTH → MT RECORD → BAD SWEEP FLAG,
I = 0(1)1023{ 0 → WINDOWS[I] → FLAGS[I] →
COMPLETED 1 RPRT BUF[I] → COMPLETED 2 RPRT BUF[I] →
COMPLETED 3 RPRT BUF[I] → COMPLETED 4 RPRT BUF[I] →
MODE 3A CODE[I] → MODE C ALT[I] → AZMTH AT TL[I],  },
I = 0(1)1241{ 0 → OUTPUT BUF[I],  },
I = 0(1)2999{ 0 → TEMP OUT BUF[I],  },
0 → CARRY OVER, 77₈ → FRESH START,

NEXT|RECORD:                                                        13001
0 → READ REPORTS, 1 → READ REPLIES, 0 → PROBLEM CODE,
READ MODE TWO RECORD,
PROBLEM CODE = 0: ; NEXT RECORD.
0 → X, REPLY START I → INDEX,
(: )

(: - - - - - - - - - - - - - - - - - - - - - - )
```

```
(: EVALUATE INPUT CELL)

 EVAL|INPUT CELL:                                                    13013
[KEY 2 < WRITE EOF > , ],
MT INPUT[INDEX](14 → 14) = 0 ∩ MT INPUT[INDEX + 1] = 0:
    C → BAD SWEEP FLAG;
    BAD SWEEP FLAG = 1: BUMP. ;
    EVAL REPLY CELL.
SWEEP MODE = A3: ; INIT SWP C.

INIT|SWP A:                                                          13035
I = C(1)1023{ BIT 0[I] + BIT 1[I] + BIT 2[I] + BIT 3[I] +
BIT 4[I] + BIT 5[I] + BIT 6[I] + BIT 7[I] + BIT 8[I] +
BIT 9[I] + BIT 10[I] → L,
TL REACHED FLG[I] = 1: MODE 3A2. ;
L ≥ TL: 1 → TL REACHED FLG[I] → IN PROCESS FLG[I],
    SWEEP AZIMUTH → AZMTH AT TL[I]; ;

MODE|3A2:                                                            13112
L ≤ TT: ; AROUND.
TL REACHED FLG[I] = 1: REPORT COMPLETE;
    IN VALIDATION[I] = 1: PURGE CELL; ; ;

AROUND|:                                                             13131
VALID 3A COMPLETE[I] = 1 ∩ VALID C COMPLETE[I] = 1:
    INIT SWP B. ;
IN VALIDATION[I] = 1: INIT SWP B. ;
L ≥ TV: 1 → IN VALIDATION[I] → IN PROCESS FLG[I]; ;
INIT|SWP B:  },                                                      13164

INIT|SWP C:                                                          13166
MT INPUT[INDEX](15 → 26) → SWEEP AZIMUTH,
MT INPUT[INDEX](27 → 29) → SWEEP MODE = A3:
    I = 0(1)1023{ WINDOWS[I] * 2↑1 → WINDOWS[I],
    C → WINDOWS[I](0 → 0),  },
    BUMP. ;
SWEEP MODE = C: BUMP. HELP.
(: )
```

```
GLOBAL    ALPHABETIC NAME LIST DUMP                                  18 JAN  1977

06 ALTITUDE          3 12574         06 HUNDBEDS          3 12563         07 RPKERRFORMAT      0 14570
05 ARCTAN            0 10315         03 IDENTBIT          3 62222 05 05   03 RPTCOMPLETEFLG    3 62222 06 06
03 AZMTHATTL         3 50000 00 11   03 INPROCESSFLG      3 62222 00 00   05 SQUAREROOT        0 10150
07 BACKSPACE1RECOR   0 15505         03 INVALIDATION      3 62222 03 03   02 SWEEPAZIMUTH      3 42000
02 BIT0              3 30000 00 00   04 LIBRARY           3 10040         07 TAPEBACKSPACE     0 15462
02 BIT1              3 30000 01 01   05 LOCAL             3 10403         06 TAPEDRIVE         3 12453
02 BIT10             3 30000 10 10   05 MAGTAPEALTERNAT   0 77200         06 TAPEIO            0 12604
02 BIT2              3 30000 02 02   05 MAGTAPE           0 77212         07 TAPEREWIND        0 15500
02 BIT3              3 30000 03 03   02 MODECALT          3 44001         06 TEMP              3 12525
02 BIT4              3 30000 04 04   06 MODECCODE         3 12544         03 TEMPOUTBUF        3 54332
02 BIT5              3 30000 05 05   06 MODERRFORMAT      0 12546         03 TLREACHEDFLG      3 62222 04 04
02 BIT6              3 30000 06 06   02 MODE3ACODE        3 42001         03 VALID3ACOMPLETE   3 62222 01 01
02 BIT7              3 30000 07 07   07 MTINPUT           3 66000         03 VALIDCCOMPLETE    3 62222 02 02
02 BIT8              3 30000 08 08   07 MTRECORD          3 14513         02 WINDOWS           3 30000
02 BIT9              3 30000 09 09   05 OCTDUMP           0 04471         06 WRITE             3 12452
07 BYPASS1RECORD     0 15512         03 OT1A              3 52000 12 27   06 X                 3 12561
07 CARRYOVER         3 14507         03 OT1B              3 52000 00 09
03 CCODEFLG          3 62222 07 07   03 OT1C              3 52001 24 29
06 CLOCK             3 00160         03 OT2A              3 52001 06 21
02 COMPLETED1RPRTB   3 32000         03 OT2B              3 52001 00 03
02 COMPLETED2RPRTB   3 34000         03 OT2C              3 52002 18 29
02 COMPLETED3RPRTB   3 36000         03 OT3A              3 52002 00 15
02 COMPLETED4RPRTB   3 40000         03 OUTPUTBUF         3 52000
07 COUNTDIGITS       3 14514         03 OUTPUT1BUF        3 52001
06 DECODEALTITUDE    0 14167         03 OUTPUT2BUF        3 52002
02 DIMN1             0 46001         06 OUTTAPEDRIVE      3 12454
03 DIMN2             0 64222         03 PARAMS            3 50000
06 DISCRMFLG         3 26000         05 PRINT             0 02273
06 D1                3 12562         07 PROBLEMCODE       3 14506
07 ENDBEACONBUFFER   3 14472         05 READINPUTCARD     0 10757
05 FIXTOFLOATING     0 12142         07 READREPORTS       3 14457
03 FLAGS             3 62222         07 READREPLIES       3 14460
07 FRESHSTART        3 14512         07 RECCOUNTFORMAT    0 14607
07 FRESHSTART0       3 14512 00 00   07 REPLYHEADERTIME   3 14455
07 FRESHSTART1       3 14512 01 01   07 REPLYSTARTI       3 14510
```

BEACON TARGET REPORT (32-bit format)



```
(: - - - - - - - - - - - - - - - - - - - - - - )


(: EVALUATE REPLY CELL)

 EVAL|REPLY CELL:                                                    13217
MT INPUT[INDEX](15 - 28) - K + RANGE OFFSET - I / 2↑3 - I,
I ≥ 0 ∩ I ≤ 1023: ; BUMP.
SWEEP MODE = A3: ; MCDE C REPLY.
(: )


(: - - - - - - - - - - - - - - - - - - - - - - )

 MODE|3A REPLY:                                                      13237
1 - WINDOWS[I](0 - 0),
VALID 3A COMPLETE[I] = 1: MODE 3A1. ;
IN VALIDATION[I] = 1: ; MODE 3A1.
MT INPUT[INDEX + 1](28 - 28) = 0: ; MODE 3A1.
MT INPUT[INDEX + 1](15 - 26) = MODE 3A CODE[I]:
    1 - VALID 3A COMPLETE[I];
    MT INPUT[INDEX + 1](15 - 26) - MODE 3A CODE[I];

MODE|3A1:                                                            13300
IN PROCESS FLG[I] = 1 ∩ MT INPUT[INDEX + 1](29 - 29) = 1:
    1 - IDENT BIT[I]; ;
BUMP.

REPORT|COMPLETE:                                                     13317
( AZMTH AT TL[I] - TEMP, SWEEP AZIMUTH(0 - 11) - TEMP[1],
TEMP > TEMP[1]: TEMP[1] + 4096 - TEMP[1]; ;
(TEMP[1] + TEMP) / 2↑1 - TEMP[1],
(TEMP[1] - TEMP) / 2↑1 - TEMP[2],
DISCRMFLG = 0: DISCRMEND. ;
I - TEMP, (TEMP * 60) / 1. 0B2 - RS,
VALID C COMPLETE[I] = 1: ; DISCRM2.
MODE C ALT[I] - MODE C CODE, DECODE ALTITUDE,
ALTITUDE < 0: ALTITUDE + 1 - ALTITUDE; ;
```

```
ALTITUDE < 0: DISCRM2. ;
((ALTIMTR SET - 29. 92B12) * 925) / 1. CB12 - SENSOR ELEV →
DELTA H / 100 → DELTA H + ALTITUDE → ALTCORR,
RS * RS - ALTCORR * ALTCORR → TEMP,
SQUARE ROOT(TEMP) → RG,
ARCTAN(ALTCORR, RG) → TEMP * 360 → TEMP,
TEMP ≥ 28. 0B15: DISCRM3. DISCRMEND.

DISCRM2|:                                                              13436
DISCRMFLG = 2: ; DISCRMEND.
DISCRNGE * 60 → TEMP ≥ RS: ; DISCRMEND.

DISCRM3|:                                                              13446
PUNLL < TEMP[2] ∩ TEMP[2] < RUNLU: DISCRMEND. R2.

DISCRM|END:                                                            13455
TEMP[2](1 → 5) → TEMP → COMPLETED 2 RPRT BUF[X](7 → 11),
TEMP[2](0 → 0) → TEMP → COMPLETED 1 RPRT BUF[X](28 → 28),
1 → COMPLETED 1 RPRT BUF[X](24 → 24),
VALID 3A COMPLETE[I] → COMPLETED 1 RPRT BUF[X](22 → 22),
VALID C COMPLETE[I] → COMPLETED 1 RPRT BUF[X](21 → 21),
I → COMPLETED 1 RPRT BUF[X](2 → 11),
TEMP[1] + AZMTH CORR FCTR → TEMP[1],
TEMP[1] > 4095: TEMP[1] - 4096 → TEMP[1]; ;
TEMP[1] > 4095: TEMP[1] - 4096 → TEMP[1]; ;
TEMP[1] → COMPLETED 2 RPRT BUF[X](15 → 26),
VALID 3A COMPLETE[I] → COMPLETED 3 RPRT BUF[X](22 → 22),
VALID C COMPLETE[I] → COMPLETED 3 RPRT BUF[X](21 → 21),
IDENT BIT[I] → COMPLETED 3 RPRT BUF[X](20 → 20),
MODE 3A CODE[I] → COMPLETED 3 RPRT BUF[X](0 → 11),
C CODE FLG[I] = 1: ; R1.
MODE C ALT[I] → MODE C CODE, DECODE ALTITUDE,
ALTITUDE < 0: ALTITUDE + 1 → ALTITUDE; ;
ALTITUDE → COMPLETED 4 RPRT BUF[X](0 → 11),

R1|:                                                                   1361C
1 → RPT COMPLETE FLG[X], X + 1 → X,

R2|:                                                                   13616
PURGE CELL, },
```

```
PURGE|CELL:                                                              1362C
[ 0 → IDENT BIT[I] → TL REACHED FLG[I] → IN PROCESS FLG[I] →
AZMTH AT TL[I] → VALID 3A COMPLETE[I] →
VALID C COMPLETE[I] → C CODE FLG[I] → MODE 3A CODE[I] →
MODE C ALT[I] → IN VALIDATION[I], ],
(: )

(: → → → → → → → → → → → → → → → → → → → → → → → → → → → → → → → → )

 MODE|C REPLY:                                                           13671
VALID C COMPLETE[I] = 1: MODE C1. ;
IN VALIDATION[I] = 1: ; MODE C1.
MT INPUT[INDEX + 1](28 → 28) = 0:
    C CODE FLG[I] = 1: ; 1 → C CODE FLG[I],
        MT INPUT[INDEX + 1](15 → 26) → MODE C ALT[I],
        MODE C1. ;
    MODE C1.
MT INPUT[INDEX + 1](15 → 26) = MODE C ALT[I]:
    1 → VALID C COMPLETE[I];
    MT INPUT[INDEX + 1](15 → 26) → MODE C ALT[I];

MODE|C1:                                                                 13744
IN PROCESS FLG[I] = 1 ∩ MT INPUT[INDEX + 1](29 → 29) = 1:
    1 → IDENT BIT[I]; ;
BUMP.
(: )

(: → → → → → → → → → → → → → → → → → → → → → → → → → → → → → → → → )

 END|OF RECORD:                                                          13763
100000₈ → TEMP OUT BUF, 2 → TEMP OUT BUF[1],
REPLY HEADER TIME(0 → 15) → TEMP OUT BUF[2],
REPLY HEADER TIME[1](0 → 15) → TEMP OUT BUF[3], 4 → J,
I = 0(1)1023( RPT COMPLETE FLG[I] = 1:
    COMPLETED 1 RPRT BUF[I](15 → 29) → TEMP OUT BUF[J],
    COMPLETED 1 RPRT BUF[I](0 → 14) → TEMP OUT BUF[J + 1],
    J + 2 → J,
```

```
    COMPLETED 2 RPRT BUF[I](15 → 29) → TEMP OUT BUF[J],
    COMPLETED 2 RPRT BUF[I](0 → 14) → TEMP OUT BUF[J + 1],
    J + 2 → J,
    COMPLETED 3 RPRT BUF[I](15 → 29) → TEMP OUT BUF[J],
    COMPLETED 3 RPRT BUF[I](0 → 14) → TEMP OUT BUF[J + 1],
    J + 2 → J,
    COMPLETED 4 RPRT BUF[I](15 → 29) → TEMP OUT BUF[J],
    COMPLETED 4 RPRT BUF[I](0 → 14) → TEMP OUT BUF[J + 1],
    J + 2 → J,
    C → RET COMPLETE FLG[I] → COMPLETED 1 RPRT BUF[I] →
    COMPLETED 2 RPRT BUF[I] → COMPLETED 3 RPRT BUF[I] →
    COMPLETED 4 RPRT BUF[I]; ;  },
J > 2052: 2052 → J: ;
C → TEMP OUT BUF[J] → TEMP OUT BUF[J + 1] →
TEMP OUT BUF[J + 2] → TEMP OUT BUF[J + 3], J + 4 → J, 0 → K → I,

REPACK|:                                                          14061
TEMP OUT BUF[K] → OT1A[I],
TEMP OUT BUF[K + 1](6 → 15) → OT1B[I],
TEMP OUT BUF[K + 1](0 → 5) → OT1C[I],
TEMP OUT BUF[K + 2] → OT2A[I],
TEMP OUT BUF[K + 3](12 → 15) → OT2B[I],
TEMP OUT BUF[K + 3](0 → 11) → OT2C[I],
TEMP OUT BUF[K + 4] → OT3A[I], I + 3 → I,
K + 5 → K < J: REPACK. ;
OUTPUT BUF8 + 1233 → TEMP,
TAPE IO(WRITE, 11111s, OUT TAPE DRIVE, 2, OUTPUT BUF8, TE
MP, 2), NEXT RECORD.
(: )


(: → → → → → → → → → → → → → → → → → → → → → →)

 BUMP|:                                                           14162
INDEX + 2 → INDEX ≥ END BEACON BUFFER: END OF RECORD.
    EVAL INPUT CELL.

DECODE ALTITUDE:                                                  14167
{ MODE C CODE(0 → 2) → GRAY CODE,
HUNDREDS[GRAY CODE] → ALTITUDE,
```

```
MODE C CODE(3 → 10) → GRAY CODE,
D2 + D4 + A1 + A2 + A4 + B1 + B2 + B4 → SIGN,
SIGN(0 → 0) = 0: ALTITUDE →  → ALTITUDE; ;
D2 = D4: 0 → D4; 1 → D4;
D4 = A1: 0 → A1; 1 → A1;
A1 = A2: 0 → A2; 1 → A2;
A2 = A4: 0 → A4; 1 → A4;
A4 = B1: 0 → B1; 1 → B1;
B1 = B2: 0 → B2; 1 → B2;
B2 = B4: 0 → B4; 1 → B4;
GRAY CODE * 5 - 10 + ALTITUDE → ALTITUDE,
MODE C CODE(11 → 11) → D1,  },
(: )

(:  → → → → → → → → → → → → → → → → → → → → )

 HELP|:                                                       14432
[KEY 3 < HELP1 > , ], PRINT(MODE ERR FORMAT, ),

HELP1|:                                                       14436
1 → BAD SWEEP FLAG, BUMP.

WRITE|EOF:                                                    14441
TAPE IO(7, 0, OUT TAPE DRIVE, 2, 0, 0, 0), THE|END: . .
```

LOCAL NAME REFERENCES - FLOWCHART 06

LIMITS: 10000 - 14454

ADDRESS	K	NAME	REFERENCED BY								
12455	3	INDEX	13012	13015	13021	13167	13173	13220	13256	13263	13275
			13305	13704	13722	13727	13741	13751	14163		
12456	3	SWEEPMODE	12744	13032	13176	13213	13234				
12457	3	TL	12626	13073							
12460	3	TT	12630	13113							
12461	3	TV	12632	13151							
12462	3	RANGEOFFSET	12634	13223							
12463	3	AZMTHCORRFCTR	12636	13522							
12464	3	A3	13033	13177	13235						
12465	3	C	13214								
12466	3	DELTAH	13375	13401							
12467	3	RS	13351	13404	13405	13444					
12470	3	RG	13420	13423							
12471	3	ALTCORR	13403	13410	13412	13421					
12472	0	DISCRFMT	12647								
12533	0	INITIALIZATIONF	12616								
12545	3	BADSWEEPFLAG	12747	13024	13026	14437					
12562	3	SIGN	14223	14225	14430						
12573	3	GRAYCODE	14172	14173	14201	14203	14205	14207	14211	14213	14215
			14217	14221	14233	14237	14245	14252	14254	14260	14266
			14273	14275	14301	14307	14314	14316	14322	14330	14335
			14337	14343	14351	14356	14360	14364	14372	14377	14401
			14405	14413	14420	14422					
12616	0	START	10000								
13001	0	NEXTRECORD	13007	14161							
13013	0	EVALINPUTCELL	14165								
13035	0	INITSWPA	-								
13112	0	MODE3A2	13071	13074							
13131	0	AROUND	13114	13123							
13164	0	INITSWPB	13142	13147	13152						
13166	0	INITSWPC	13034								
13217	0	EVALREPLYCELL	13031								

ADDRESS	K	NAME	REFERENCED BY						
13237	0	MODE3AREPLY	-						
13300	0	MODE3A1	13247	13254	13261	13273			
13317	0	REPORTCOMPLETE	13122						
13436	0	DISCRM2	13356	13365					
13446	0	DISCRM3	13435						
13455	0	DISCRMEND	13344	13434	13440	13445	13454		
13610	0	R1	13575						
13616	0	R2	13453						
13620	0	PURGECELL	13130	13616					
13671	0	MODECREPLY	13236						
13744	0	MODEC1	13675	13702	13707	13725	13737		
13763	0	ENDOFRECORD	14166						
14061	0	REPACK	14136						
14162	0	BUMP	13030	13212	13216	13233	13316	13762	14440
14432	0	HELP	13215						
14436	0	HELP1	14432						
14441	0	WRITEEOF	13013						
26001	3	ALTIMTRSET	12653	13370					
26002	3	SENSORELEV	12657	13374					
26003	3	RUNLL	12642	13446					
26004	3	RUNLU	12645	13452					
26005	3	DISCRNGE	12665	13442					

```
3(COMMENT:   FLOWCHART 07,  [01670],  18 JAN  1977 )

REPLY HEADER TIME(2),
MT INPUT = ( 66000a ),
READ REPORTS = 0, READ REPLIES = 0, RE|READ COUNT,
DUMP|FLAG = 0, XPER|INFO, LAST|ADDRESS, OFF|SET = 2048,
END|I,
VALID|REC LENGTH(3) = 6, 1236, 2460, END BEACON BUFFER,
S|ECONDS(2), SAVEM|,

RPK|ERROR DATA:                                                        14476
( RPK|ER SV I,   ),
RPK ER|SV J,

PROB|VALUES:                                                           14500
( S|TATUS,  ),
SKIP|COUNT, RECORD|LENGTH, RECORDING|MODE, DATA|TYPE,
E|OF = 0, PROBLEM CODE, CARRY OVER, REPLY START I,
FIRST|WORD,

FRESH START:                                                           14512
( FRESH START 0(0 - 0), FRESH START 1(1 - 1),  ) = 77a,
MT RECORD, COUNT DIGITS = 8,

(PROBLEM|FORMAT:
|2| * READ PROBLEM INFORMATION *  /  / |2| * 1. STATUS FLAGS * |
3|I1,  / |2| * 2. SKIP COUNT * |3|I3,
 / |2| * 3. RECORD LENGTH * |3|I5,
 / |2| * 4. RECORDING MODE * |3|I2,  / |2| * 5. DATA TYPE * |3|I2,
 / |2| * 6. END OF FILE * |3|I1,  / |2| * PROBLEM I. D.  * |3|I1,  /
 /  / ],

(RPK ERR FORMAT:
|2| * REPACK ERROR *  / |2| * 1. VALUE OF I * |2|I3,
 / |2| * 2. VALUE OF J * |2|I3,  /  / ],

(REC COUNT FORMAT:
 * MACHINE TAPE RECORD * |3|I4,  /  / ],

WORD|B1:                                                               14616
```

```
{ B|1A(12 → 27), B|1B(0 → 8) },

WORD|B2:                                                        14617
{ B|1C(24 → 29), B|2A(6 → 21), B|2B(0 → 2) },

WORD|B3:                                                        14620
{ B|2C(18 → 29), B|3A(0 → 15) },

WORD|B4:                                                        14621
{ B|3B(12 → 26), B|4A(0 → 9) },

WORD|B5:                                                        14622
{ B|4B(24 → 29), B|4C(6 → 20), B|5A(0 → 3) },

WORD|B6:                                                        14623
{ B|5B(18 → 29), B|5C(0 → 14) },

MISH:                                                           14624
{ TEST|BIT(15 → 15), UPPER|DATA(0 → 14) }(5),

LISH:                                                           14631
{ LOWER|DATA(0 → 14) }(5), ;

READ|MODE TWO RECORD:                                           14636
{ READ REPORTS + READ REPLIES = 0: EXIT NOW. ;

READ|A RECORD:                                                  14642
3 → RE READ COUNT,

RE|READ LOOP:                                                   14644
4 → I, TAPE DRIVE → K, 2 → L, MT INPUT„ + OFFSET → N + 2459 → M,
127CC„2, MAG TAPE ALTERNATE, [SAVE Q < XFER INFO > , ],
XFER INFO(0 → 14) → LAST ADDRESS - MT INPUT„ - OFFSET + 1 →
RECORD LENGTH, OFFSET → M, MT INPUT[M](22 → 27) → DATA TYPE,
MT INPUT[M + 1](24 → 27) → RECORDING MODE,
XFER INFO(15 → 29) → STATUS,
STATUS(2 → 2) = 1:
   RE READ COUNT - 1 → RE READ COUNT ≤ 0: 2 → PROBLEM CODE,
      SKIP COUNT + 1 → SKIP COUNT, PROBLEM EXIT.
      BACKSPACE, RE READ LOOP. ; ;
```

```
STATUS = 0: ; 1 → PROBLEM CODE, PROBLEM EXIT.
I = C(1)2( RECORD LENGTH = VALID REC LENGTH[I]:
    CHECK HEADER. ; ),
3 → PROBLEM CODE, PROBLEM EXIT.

CHECK|HEADER:                                                          14737
RECORDING MODE = 2:
    DATA TYPE = 1: OK HEADER. ;
    DATA TYPE = 3: OK HEADER. ;
    DATA TYPE = 40₈: OK HEADER. ;
    5 → PROBLEM CODE, PROBLEM EXIT.
    RECORDING MODE = 0 ∩ RECORD LENGTH = 6: 1 → EOF,
        6 → PROBLEM CODE; 5 → PROBLEM CODE;
    PROBLEM EXIT.

OK|HEADER:                                                             14774
MT RECORD + 1 → MT RECORD,
DATA TYPE(0 → 0) = 1 ∩ READ REPLIES = 1:
    MT INPUT₈ + OFFSET → TEMP, M → SAVEM,
    TAPE IO(WRITE, 11111₈, OUT TAPE DRIVE, 2, TEMP, LAST
    ADDRESS, 2), SAVEM → M, OK DATA. READ A RECORD.

OK|DATA:                                                               15031
DUMP FLAG = 1 ∪ DUMP FLAG = 3: RAW DATA DUMP. REPACK.

RAW|DATA DUMP:                                                         15040
MT INPUT₈ + OFFSET → TEMP, OCT DUMP(TEMP, LAST ADDRESS),

RE|PACK:                                                               15050
MT INPUT[M + 1] → SECONDS, MT INPUT[M + 2] → SECONDS[1], 0 → J,

BEACON|REPLIES:                                                        15055
DATA TYPE(0 → 0) = 1: 2049 → END BEACON BUFFER,
    OFFSET + 2454 → END I,
    I = OFFSET(6)END I( MT INPUT[I] → WORD B1,
    MT INPUT[I + 1] → WORD B2, MT INPUT[I + 2] → WORD B3,
    MT INPUT[I + 3] → WORD B4, MT INPUT[I + 4] → WORD B5,
    MT INPUT[I + 5] → WORD B6, B1A → MSH, B1B → LSH(6 → 14),
    B1C → LSH(0 → 5), B2A → MSH[1], B2B → LSH[1](12 → 14),
    B2C → LSH[1](0 → 11), B3A → MSH[2], B3B → LSH[2],
```

```
    B4A → MSH[3](6 → 15), B4B → MSH[3](0 → 5), B4C → LSH[3],
    B5A → MSH[4](12 → 15), B5B → MSH[4](0 → 11), B5C → LSH[4],
    K = 0(1)4( TEST BIT[K] = 1: 0 → MT INPUT[J](0 → 14),
        UPPER DATA[K] → MT INPUT[J](15 → 29), J + 1 → J,
        END BEACON BUFFER + 1 → END BEACON BUFFER,
        J ≥ I: REPACK ERROR. ;
        0 → MT INPUT[J];
        LOWER DATA[K] → MT INPUT[J](0 → 14),
        UPPER DATA[K] → MT INPUT[J](15 → 29);
    J + 1 → J,  },  },
    INITIALIZE REPLY SYMBOL AND COLOR, DONE PACK. ;

DONE|PACK:                                                          15244
DISPLAY MT RECORD COUNT, RECORDING MODE → MT INPUT,
DATA TYPE(0 → 14) → MT INPUT(15 → 29),
SECONDS[1](18 → 29) → REPLY HEADER TIME[1],
SECONDS[0](0 → 3) → TEMP → REPLY HEADER TIME[1](12 → 15),
SECONDS[0](6 → 21) → REPLY HEADER TIME,
DUMP FLAG = 2 ∪ DUMP FLAG = 3: PACKED DATA DUMP. EXIT NOW.

PACKED|DATA DUMP:                                                   15276
J + MT INPUT, → LAST ADDRESS, OCT DUMP(MT INPUT,
LAST ADDRESS), EXIT NOW.

PROBLEM|EXIT:                                                       15307
[KEY 3 < PROB1EXT > , ],
PRINT(PROBLEM FORMAT, STATUS, SKIP COUNT, RECORD LENGTH
, RECORDING MODE, DATA TYPE, EOF, PROBLEM CODE, ),

PROB1|EXT:                                                          15331
0 → EOF,

REPACK|ERROR:                                                       15332
I → RPK ER SV I, J → RPK ER SV J, [KEY 3 < RPK1ERR > , ],
PRINT(RPK ERR FORMAT, RPK ER SV I, RPK ER SV J, ),

RPK1|ERR:                                                           15344
0 → EOF, EXIT|NOW:  ),

BACK|SPACE:                                                         15346
```

```
{ 2 → I, 1 → J, TAPE DRIVE → K, MAG TAPE ALTERNATE,
[SAVE Q < XFER INFO > , ],
XFER INFO(15 → 29) = 0: ; 7 → PROBLEM CODE, PROBLEM EXIT.  },

INITIALIZE|REPLY SYMBOL AND COLOR:                                  15362
{ FRESH START 0 = 1:
    I = 2(1)END BEACON BUFFER{ MT INPUT[I](14 → 14) = 0 ∩
    MT INPUT[I + 1] = 0: 0 → CARRY OVER → FRESH START 0,
        I → REPLY START I, CHECK REPLY END. ;  },
    EXIT NOW. ;
CARRY OVER = 1 ∩ MT INPUT[2](14 → 14) = 1: 1 → I,
    FIRST WORD → MT INPUT[1]; 2 → I;
I → REPLY START I,

REPLY|LOOP:                                                         15425
MT INPUT[I](14 → 14) = 0 ∩ MT INPUT[I + 1] = 0:
    CHECK REPLY END. ;
7 → MT INPUT[I + 1](3 → 5), 7 → MT INPUT[I + 1](0 → 2),

CHECK|REPLY END:                                                    15443
I + 2 → I,
I < END BEACON BUFFER: REPLY LOOP. ;
I = END BEACON BUFFER: 1 → CARRY OVER,
    END BEACON BUFFER - 1 → END BEACON BUFFER,
    MT INPUT[I] → FIRST WORD; 0 → CARRY OVER;  },

TAPE BACKSPACE:                                                     15462
{ 77₈ → FRESH START, 2 → I, MT RECORD - 1 → MT RECORD,

COMM|EXIT:                                                          15467
1 → J, TAPE DRIVE → K, 2 → I, 12700₈2, MAG TAPE ALTERNATE,
DISPLAY MT RECORD COUNT, 77₈ → FRESH START,  },

TAPE REWIND:                                                        15500
{ 0 → MT RECORD, 1 → I, COMMON,  },

BACKSPACE 1 RECORD:                                                 15505
{ MT RECORD - 1 → MT RECORD, 2 → I, COMMON,  },

BYPASS 1 RECORD:                                                    15512
```

```
{ MT RECORD + 1 → MT RECORD, 3 → I, COMMON,  },

COM|MON:                                                          15517
{ 1 → J, TAPE DRIVE → K, 2 → L, 12700₈2, MAG TAPE ALTERNATE,
DISPLAY MT RECORD COUNT, 77₈ → FRESH'START,  },

DISPLAY|MT RECORD COUNT:                                          15531
{ [KEY 1 < NO PRINT MT > , ],
PRINT(REC COUNT FORMAT, MT RECORD, ), NO|PRINT MT:  }, . .
```

LOCAL NAME REFERENCES - FLOWCHART 07

LIMITS: 10000 - 15540

ADDRESS	K	NAME	REFERENCED BY						
14461	3	REREADCOUNT	14643	14706					
14462	3	DUMPFLAG	15031	15034	15267	15272			
14463	3	XFERINFO	14657	15353					
14464	3	LASTADDRESS	14661	15022	15045	15300	15303		
14465	3	OFFSET	14647	14663	14666	15004	15040	15064	15066
14466	3	ENDI	15065	15240					
14467	3	VALIDRECLENGTH	14730						
14473	3	SECONDS	15051	15256	15264				
14475	3	SAVEM	15007	15027					
14476	3	BPKERRORDATA	15332	15337					
14477	3	BPKERSVJ	15333	15341					
14500	3	PROBVALUES	14700	14702	14721	15312			
14501	3	SKIPCOUNT	14714	15314					
14502	3	RECORDLENGTH	14665	14727	14761	15316			
14503	3	RECORDINGMODE	14676	14737	14757	15245	15320		
14504	3	DATATYPE	14672	14742	14745	14750	14776	15056	15322
14505	3	EOF	14765	15324	15331	15344			
14511	3	FIRSTWORD	15420	15456					
14515	0	PROBLEMFORMAT	15310						
14616	3	WORDB1	15072	15107	15113				
14617	3	WORDB2	15074	15127	15133				
14620	3	WORDB3	15076	15146					
14621	3	WORDB4	15100	15152	15156				
14622	3	WORDB5	15102	15172	15176				
14623	1	B5C	15210						
14623	3	WORDB6	15104						
14624	1	UPPERDATA	15220	15233					
14624	3	MSH	15111						
14631	1	LOWERDATA	15231						
14631	3	LSH	15117	15124					
14636	0	READMODETWORECO	13005						
14642	0	READARECORD	15003						

ADDRESS	K	NAME	REFERENCED BY					
14644	0	REREADLOCP	14720					
14737	0	CHECKHEADER	14731					
14774	0	OKHEADER	14744	14747	14752	14756		
15031	0	OKDATA	15030					
15040	0	RAWDATADUMP	15037					
15050	0	REPACK	15036					
15055	0	BEACCNREPLIES	-					
15244	0	DONEPACK	15060	15243				
15276	0	PACKEDDATADUMP	15275					
15307	0	PROBLEMEXIT	14715	14725	14736	14755	14773	15360
15331	0	PROB1EXT	15307					
15332	0	REPACKERROR	15226					
15344	0	RPK1ERR	15334					
15345	0	EXITNOW	14641	15274	15306	15406		
15346	0	BACKSPACE	14717					
15362	0	INITIALIZEREPLY	15242					
15425	0	REPLYLOCP	15446					
15443	0	CHECKREPLYEND	15403	15432				
15467	0	COMMEXIT	-					
15517	0	COMMON	15503	15510	15515			
15531	0	DISPLAYMTRECORD	15244	15474	15525			

18 JAN 1977

SEQ NR	ROUTINE NAME	OBJ PROGRAM		FLOWCHART	ENTRANCE		
01		30000	27777	0C234		H	01 / 18
C2	DIMN1	30000	46000	00100		H	01 / 18
03	DIMN2	50000	64221	00112		H	01 / 18
04		10040	10043	00014		H	01 / 18
05	OCTDUMP			00023		H	01 / 18
C6	TAPEIO	12452	14454	02527	10000	H	C1 / 18
07		14455	15540	C1670		H	01 / 18

```
GLOBAL     NUMERICAL NAME LIST DUMP                                    18 JAN  1977

00 CLOCK              3 00160          07 TAPEBACKSPACE     0 15462          03 OT2C                3 52002 18 29
05 PRINT              0 02273          07 TAPEREWIND        0 15500          03 OUTPUT2BUF          3 52002
05 OCTDUMP            0 04471          07 BACKSPACE1RECOR   0 15505          03 TEMPOUTBUF          3 54332
04 LIBRARY            3 10040          07 BYPASS1RECORD     0 15512          03 CCODEFLG            3 62222 07 07
05 SQUAREROOT         0 10150          06 DISCRMFLG         3 26000          03 RPTCOMPLETEFLG      3 62222 06 06
05 ARCTAN             0 10315          02 BIT0              3 30000 00 00    03 IDENTBIT            3 62222 05 05
05 LOCAL              3 10403          02 BIT1              3 30000 01 01    03 TLREACHEDFLG        3 62222 04 04
05 READINPUTCARD      0 10757          02 BIT2              3 30000 02 02    03 INVALIDATION        3 62222 03 03
05 FIXTOFLOATING      0 12142          02 BIT3              3 30000 03 03    03 VALIDCCOMPLETE      3 62222 02 02
06 WRITE              3 12452          02 BIT4              3 30000 04 04    03 VALID3ACOMPLETE     3 62222 01 01
06 TAPEDRIVE          3 12453          02 BIT5              3 30000 05 05    03 INPROCESSFLG        3 62222 00 00
06 OUTTAPEDRIVE       3 12454          02 BIT6              3 30000 06 06    03 FLAGS               3 62222
06 TEMP               3 12525          02 BIT7              3 30000 07 07    03 DIMN2               0 64222
06 MODECCODE          3 12544          02 BIT8              3 30000 08 08    07 MTINPUT             3 66000
06 MODEERRFORMAT      0 12546          02 BIT9              3 30000 09 09    05 MAGTAPEALTERNAT     0 77200
06 X                  3 12561          02 BIT10             3 30000 10 10    05 MAGTAPE             0 77212
06 D1                 3 12562          02 WINDOWS           3 30000
06 HUNDREDS           3 12563          02 COMPLETED1RPRTB   3 32000
06 ALTITUDE           3 12574          02 COMPLETED2RPRTB   3 34000
06 TAPEIO             0 12604          02 COMPLETED3RPRTB   3 36000
06 DECODEALTITUDE     0 14167          02 COMPLETED4RPRTB   3 40000
07 REPLYHEADERTIME    3 14455          02 SWEEPAZIMUTH      3 42000
07 READREPORTS        3 14457          02 MODE3ACODE        3 42001
07 READREPLIES        3 14460          02 MODECALT          3 44001
07 ENDBEACONBUFFER    3 14472          02 DIMN1             0 46001
07 PROBLEMCODE        3 14506          03 AZMTHATTL         3 50000 00 11
07 CARRYOVER          3 14507          03 PARAMS            3 50000
07 REPLYSTARTI        3 14510          03 OT1B              3 52000 00 09
07 FRESHSTART1        3 14512 01 01    03 OT1A              3 52000 12 27
07 FRESHSTART0        3 14512 00 00    03 OUTPUTBUF         3 52000
07 FRESHSTART         3 14512          03 OT2B              3 52001 00 03
07 MTRECORD           3 14513          03 OT2A              3 52001 06 21
07 COUNTDIGITS        3 14514          03 OT1C              3 52001 24 29
07 RPKERRFORMAT       0 14570          03 OUTPUT1BUF        3 52001
07 RECCOUNTFORMAT     0 14607          03 OT3A              3 52002 00 15
```

GLOBAL ALPHABETIC NAME LIST DUMP 18 JAN 1977

```
06 ALTITUDE          3 12574
05 ARCTAN            0 10315
03 AZMTHATTL         3 50000 00 11
07 BACKSPACE1RECOR   0 15505
02 BIT0              3 30000 00 00
02 BIT1              3 30000 01 01
02 BIT10             3 30000 10 10
02 BIT2              3 30000 02 02
02 BIT3              3 30000 03 03
02 BIT4              3 30000 04 04
02 BIT5              3 30000 05 05
02 BIT6              3 30000 06 06
02 BIT7              3 30000 07 07
02 BIT8              3 30000 08 08
02 BIT9              3 30000 09 09
07 BYPASS1RECORD     0 15512
07 CARRYOVER         3 14507
03 CCODEFLG          3 62222 07 07
00 CLOCK             3 00160
02 COMPLETED1RPRTB   3 32000
02 COMPLETED2RPRTB   3 34000
02 COMPLETED3RPRTB   3 36000
02 COMPLETED4RPRTB   3 40000
07 COUNTDIGITS       3 14514
06 DECODEALTITUDE    0 14167
02 DIMN1             0 46001
03 DIMN2             0 64222
06 DISCRMFLG         3 26000
06 D1                3 12562
07 ENDBEACONBUFFER   3 14472
05 FIXTOFLOATING     0 12142
03 FLAGS             3 62222
07 FRESHSTART        3 14512
07 FRESHSTART0       3 14512 00 00
07 FRESHSTART1       3 14512 01 01
06 HUNDREDS          3 12563
03 IDENTBIT          3 62222 05 05
03 INPROCESSFLG      3 62222 00 00
03 INVALIDATION      3 62222 03 03
04 LIBRARY           3 10040
05 LOCAL             3 10403
05 MAGTAPEALTERNAT   0 77200
05 MAGTAPE           0 77212
02 MODECALT          3 44001
06 MODECCODE         3 12544
06 MODEERRFORMAT     0 12546
02 MODE3ACODE        3 42001
07 MTINPUT           3 66000
07 MTRECORD          3 14513
05 OCTDUMP           0 04471
03 OT1A              3 52000 12 27
03 OT1B              3 52000 00 09
03 OT1C              3 52001 24 29
03 OT2A              3 52001 06 21
03 OT2B              3 52001 00 03
03 OT2C              3 52002 18 29
03 OT3A              3 52002 00 15
03 OUTPUTBUF         3 52000
03 OUTPUT1BUF        3 52001
03 OUTPUT2BUF        3 52002
06 OUTTAPEDRIVE      3 12454
03 PARAMS            3 50000
05 PRINT             0 02273
07 PROBLEMCODE       3 14506
05 READINPUTCARD     0 10757
07 READREPORTS       3 14457
07 READREPLIES       3 14460
07 RECCOUNTFORMAT    0 14607
07 REPLYHEADERTIME   3 14455
07 REPLYSTARTI       3 14510
07 RPKERRFORMAT      0 14570
03 RPTCOMPLETEFLG    3 62222 06 06
05 SQUAREROOT        0 10150
02 SWEEPAZIMUTH      3 42000
07 TAPEBACKSPACE     0 15462
06 TAPEDRIVE         3 12453
06 TAPEIO            0 12604
07 TAPEREWIND        0 15500
06 TEMP              3 12525
03 TEMPOUTBUF        3 54332
03 TLREACHEDFLG      3 62222 04 04
03 VALID3ACOMPLETE   3 62222 01 01
03 VALIDCCOMPLETE    3 62222 02 02
02 WINDOWS           3 30000
06 WRITE             3 12452
06 X                 3 12561
```

ADDRESS	K	NAME	REFERENCED BY								
14167	0	DECODEALTITUDE	13361	13600							
14455	3	REPLYHEADERTIME	13773	15266							
14457	3	READREPORTS	13001	14640							
14460	3	READREPLIES	13003	14637	15001						
14472	3	ENDBEACONBUFFER	14164	15062	15223	15404	15445	15450	15454		
14506	3	PROBLEMCODE	13004	13006	14713	14724	14735	14754	14767	14772	15326
			15357								
14507	3	CARRYOVER	12776	15376	15407	15453	15460				
14510	3	REPLYSTARTI	13011	15402	15424						
14512	3	FRESHSTART	13000	15364	15401	15464	15476	15527			
14513	3	MTRECORD	12746	14774	15466	15501	15506	15513	15535		
14514	3	COUNTDIGITS	-								
14570	0	RPKERRFORMAT	15335								
14607	0	RECCOUNTFORMAT	15533								
15462	0	TAPEBACKSPACE	-								
15500	0	TAPEREWIND	-								
15505	0	BACKSPACE1RECOR	-								
26000	3	DISCRMFLG	12637	12651	13343	13436					
30000	3	WINDOWS	12751	13037	13041	13043	13045	13047	13051	13053	13055
			13057	13061	13063	13202	13204	13207	13242		
32000	3	COMPLETED1RPRTB	12753	13521	14041						
34000	3	COMPLETED2RPRTB	12754	13464	14042						
36000	3	COMPLETED3RPRTB	12755	13570	14043						
40000	3	COMPLETED4RPRTB	12756	13607	14044						
42000	3	SWEEPAZIMUTH	12745	13106	13171	13324					
42001	3	MODE3ACODE	12757	13265	13277	13564	13663				
44001	3	MODECALT	12760	13357	13576	13664	13724	13731	13743		
46001	0	DIMN1	-								
50000	3	PARAMS	12763	13111	13321	13640					
52000	3	OUTPUTBUF	12767	14065	14073						
52001	3	OUTPUT1BUF	14106	14114							
52002	3	OUTPUT2BUF	14127								
54332	3	TEMPOUTBUF	12773	13766	14010	14015	14022	14027	14052	14061	
62222	3	FLAGS	12752	13066	13100	13105	13116	13125	13132	13137	13144
			13156	13163	13244	13251	13272	13301	13315	13353	13502
			13510	13544	13552	13560	13572	13614	13623	13630	13635

ADDRESS	K	NAME	REFERENCED BY									
			13645	13652	13657	13667	13672	13677	13711	13720	13736
			13745	13761	14003	14035					
64222	0	DIMN2	-								
66000	3	MTINPUT	13016	15071	15227	15246	15371	15426	15455		
77200	0	MAGTAPPALTERNAT	14656	15352	15473	15524					
77212	0	MAGTAPE	12614								

APPENDIX C (section 6)

C.1 Altitude Correction

Following is the procedure for correcting Mode C altitude for actual barometric pressure.

A. Compute

$\Delta H = [(B-29.92) \times 925]$ to nearest 100 feet

where

B = barometric pressure (inches of mercury)

ΔH = altitude correction in feet

B. Compute

$H_c = H + \Delta H$

where

H is Mode C altitude (feet)

H_c is corrected altitude (feet)

The barometric pressure on August 25, 1977, when the Elwood data was collected was 30.19. This gives ΔH of 200 feet.

The following table lists Mode C altitudes observed for the test target, corrected altitudes, and altitude used for the analysis.

Mode C Altitude (ft.)	Corrected Altitude	Used in Analysis
4800	5000	5000
9800	10000	10000
20000	20200	20000
20100	20300	20000

C.2 Run Length

Run length is a measure of the extent in azimuth over which replies were received and used to generate a target report expressed in Azimuth Change Pulses (ACP's). There are 4096 ACP's per revolution. A detailed discussion of reply centroiding and run length appears in section 8.1.2 and 8.5.2 of reference 1. The relevant information appears here.

Run length is calculated by the Common Digitizer during centroiding of in process beacon reports. First, the uncorrected center azimuth is computed as follows:

$$\text{UNCORRECTED CENTER AZIMUTH} = [\text{AZ START} + \text{AZ STOP})/2] \qquad \text{eq. A-1}$$

where

AZ START = Azimuth in ACP's when the leading edge threshold T_L was reached.

AZ STOP = azimuth in ACP's when the trailing edge threshold T_T was reached.

UNCORRECTED CENTER AZIMUTH = the uncorrected target report center azimuth in ACP's.

The division is accomplished by summing the AZ START and AZ STOP and shifting the result right one bit. Thus the fractional part of the result (1/2) if it exists, is truncated and the UNCORRECTED CENTER AZIMUTH is always an integer. Run length is then computed by the Common Digitizer.

$$\text{RUN LENGTH} = (\text{UNCORRECTED CENTER AZIMUTH} - \text{AZ START}) \times 2 \qquad \text{eq. A-2}$$

where

RUN LENGTH = target report run length in ACP's.

Finally, the RUN LENGTH computed in equation A-2 is shifted right by 2 bits, so that the lower 2 bits are truncated and the least significant bit (LSB) represents 4 ACP's. This is the result that is recorded on the Mode 2 tapes as run length, before being printed out as in Table 2.

The data in the run length field on the Mode 2 tapes is multiplied by 4 before being printed as in Table 2 so that the result is expressed in ACP's. Since truncation was used in the computations, the following is true:

$$RL_{RECORDED} \leq RL_{ACTUAL} \leq RL_{RECORDED} + 3 \qquad \text{eq. A-3}$$

where

$RL_{RECORDED}$ = the run length recorded on the Mode 2 tapes expressed in ACP's.

RL_{ACTUAL} = the run length that would be given by equation A-2 if truncation were not used.

C.3 Table C-1 is a list of the actual data points used in the analysis. These were extracted as described in Section 6.2.2.1 of the report.

TABLE C-1

Data Point List

Tape: Aug. 25, AI-Mode 2 Tape 3 Beacon Code: 2315
Range: ≤ 10 nmi

Tape Record	Message Number	Azimuth	Range	Run Length	Altitude	Status True or False	28^o or Above	Comments
207	10	227.637	8,500	52	20,000	T		
227	7	229.219	7.500	44	20,000	T		
239	23	74.004	6.875	20	20,000	F	X	
245	9	230.361	6.500	60	20,000	T	X	
255	4	25.313	6.125	112	20,000	F	X	
257	15	63.721	6.000	20	20,000	F	X	
257	23	70.225	6.000	20	20,000	F	X	
263	6	232.383	5.500	72	20,000	T	X	
269	23	16.523	5.250	40	20,000	F	X	
275	15	96.416	5.000	60	20,000	F	X	
279	16	234.932	4.750	80	20,000	T	X	
287	13	23.115	4.375	36	20,000	F	X	
289	1	31.729	4.375	72	20,000	F	X	
289	20	46.143	4.375	44	20,000	F	X	
289	26	52.471	4.375	28	20,000	F	X	
293	2	69.873	4.375	216	20,000	F	X	
293	5	97.295	4.250	20	20,000	F	X	
293	10	113.027	4.250	20	20,000	F	X	
293	12	121.465	4.250	20	20,000	F	X	
297	11	240.117	4.000	88	20,000	T	X	
351	15	28.740	3.875	76	20,000	T	X	
359	1	218.232	4.125	60	20,000	F	X	
359	9	227.285	4.125	104	20,000	F	X	

TABLE C-1

Data Point List

Tape: Aug. 25, AI-Mode 2 Tape 3 Beacon Code: 2315
Range: ≤ 10 nmi

Tape Record	Message Number	Azimuth	Range	Run Length	Altitude	Status True or False	28° or Above	Comments
367	22	35.596	4.500	64	20,000	T	X	
373	4	172.178	4.750	68	20,000	F	X	
385	8	38.320	5.250	76	20,100	T	X	
401	20	246.885	5.750	92	20,100	F	X	
401	26	254.443	5.875	52	20,100	F	X	
401	31	261.123	5.875	76	20,100	F	X	
405	15	39.463	6.250	76	20,100	T	X	
421	13	40.342	7.125	48	20,100	T	X	
437	6	40.254	8.125	48	20,100	T		
451	23	39.902	9.250	44	20,100	T		
877	11	65.391	9.250	48	20,000	T		
891	25	64.863	8.250	48	20,000	T		
907	7	64.336	7.375	40	20,000	T		
921	16	63.545	6.375	40	20,000	T	X	
925	8	200.830	6.000	20	20,000	F	X	
925	12	217.266	6.000	84	20,000	F	X	
935	30	50.098	5.500	16	20,000	F	X	
937	17	62.930	5.500	80	20,000	T	X	
941	4	218.320	5.125	32	20,000	F	X	
955	9	187.910	4.500	16	20,000	F	X	
955	14	199.863	4.500	56	20,000	F	X	
957	2	221.660	4.375	24	20,000	F	X	
957	11	236.514	4.375	28	20,000	F	X	

TABLE C-1

Data Point List

Tape: Aug. 25 AI-Mode 2 Tape 3 Beacon Code: 2315
Range: ≤ 10 nmi.

Tape Record	Message Number	Azimuth	Range	Run Length	Altitude	Status True or False	28° or Above	Comments
957	12	242.227	4.375	16	20,000	F	X	
959	12	260.156	4.375	252	20,000	F	X	
969	7	62.666	4.000	100	20,000	T	X	
1029	12	87.891	4.000	84	20,000	F	X	
1029	14	95.098	4.125	36	20,000	F	X	
1029	15	98.701	4.125	16	20,000	F	X	
1029	20	134.561	4.125	20	20,000	F	X	
1033	13	240.732	4.250	96	20,000	T	X	
1035	1	256.465	4.375	16	20,000	F	X	
1043	6	21.445	4.625	188	20,000	F	X	
1043	11	35.420	4.625	20	20,000	F	X	
1049	8	240.820	5.000	72	20,000	T	X	
1057	22	23.467	5.375	24	20,000	F	X	
1059	9	35.508	5.375	36	20,000	F	X	
1061	9	75.322	5.500	80	20,000	F	X	
1061	12	87.100	5.500	108	20,000	F	X	
1061	14	96.328	5.625	32	20,000	F	X	
1065	10	240.293	5.250	20	20,000	T	X	
1065	12	240.557	5.875	68	20,000	T	X	
1073	24	33.486	6.250	16	20,000	F	X	
1077	1	82.881	6.375	72	20,000	F	X	
1081	2	240.293	6.875	44	20,000	T	X	
1095	13	240.381	7.750	52	20,000	T		

TABLE C-1

Data Point List

Tape: Aug. 25 AI-Mode 2, Tape 3 Beacon Code: 2315

Range: $\leq$ 10 nmi.

Tape Record	Message Number	Azimuth	Range	Run Length	Altitude	Status True or False	28° or Above	Comments
1118	5	240.381	8.750	48	20,000	T		
1132	8	240.469	9.750	48	20,000	T		

TABLE C-1

Data Point List

Tape: Aug. 25 AI-Mode 2, Tape 2, Part A — Beacon Code: 2315
Range: $\lesssim$ 10 nmi.

Tape Record	Message Number	Azimuth	Range	Run Length	Altitude	Status True or False	28^{o} or Above	Comments
251	15	233.613	9.875	40	9800	T		
269	8	233.525	9.125	44	9800	T		
287	6	233.525	8.375	44	9800	T		
303	26	233.613	7.500	44	9800	T		
321	15	233.965	6.750	48	9800	T		
337	27	236.250	6.000	96	9800	T		
355	14	234.492	5.250	48	9800	T		
373	27	234.932	4.500	44	9800	T		
391	26	235.547	3.750	52	9800	T		
411	2	237.393	3.000	52	9800	T	X	
415	1	20.303	2.750	64	9800	F	X	
415	9	35.068	2.750	188	9800	F	X	
415	16	46.582	2.750	24	9800	F	X	
509	16	202.061	2.750	172	9800	F	X	
511	15	251.191	2.750	104	9800	F	X	
517	3	45.967	3.000	56	9800	T	X	
523	10	160.400	3.250	44	9800	F	X	
527	16	252.598	3.500	20	9800	F	X	
533	2	47.021	3.750	48	9800	T		
547	16	47.813	4.500	48	9800	T		
563	13	48.428	5.250	52	9800	T		
579	6	48.779	6.000	52	9800	T		
593	10	49.043	6.875	52	9800	T		

TABLE C-1

Data Point List

Tape: Aug. 25 AI-Mode 2, Tape 2, Part A   Beacon Code: 2315

Range: ≤ 10 nmi

Tape Record	Message Number	Azimuth	Range	Run Length	Altitude	Status True or False	28° or Above	Comments
607	13	49.131	7.625	48	9800	T		
621	21	49.219	8.375	44	9800	T		
637	1	49.307	9.250	48	9800	T		
1149	6	111.270	9.375	40	20,000	T		
1165	5	105.293	8.875	48	20,000	T		
1181	1	98.877	8.250	48	20,000	T		
1175	3	91.055	7.875	48	20,000	T		
1209	7	82.529	7.625	52	20,000	T		
1223	5	74.707	7.500	36	20,000	T		
1237	15	64.160	7.500	44	20,000	T		
1253	1	54.932	7.500	52	20,100	T		
1267	6	46.143	7.500	48	20,100	T		
1281	29	37.617	7.750	44	20,100	T		
1313	1	24.170	8.875	44	20,100	T		
1327	16	20.303	9.750	36	20,100	T		
1494	12	268.594	8.875	48	20,100	T		
1510	4	268.330	7.875	52	20,100	T		
1534	6	58.359	6.500	48	20,100	F	X	
1534	12	69.082	6.500	88	20,100	F	X	
1536	21	112.939	6.375	156	20,100	F	X	
1540	12	267.275	6.000	64	20,100	T	X	
1550	6	55.283	5.625	188	20,100	F	X	
1550	10	70.664	5.500	44	20,100	F	X	

TABLE C-1

Data Point List

Tape: Aug. 25, AI-Mode 2, Tape 2, Part A Beacon Code: 2315
Range: ≤ 10 nmi.

Tape Record	Message Number	Azimuth	Range	Run Length	Altitude	Status True or False	28° or Above	Comments
1552	10	96.416	5.500	40	20,100	F	X	
1552	27	135.439	5.375	20	20,100	F	X	
1556	6	266.660	5.125	68	20,100	T	X	
1564	26	50.098	4.750	244	20,100	F	X	
1568	4	101.162	4.625	80	20,100	F	X	
1568	16	120.146	4.625	136	20,100	F	X	
1568	18	129.023	4.625	28	20,000	F	X	
1570	4	149.678	4.625	24	20,000	F	X	
1570	5	153.193	4.500	20	20,000	F	X	
1572	6	263.848	4.375	32	20,000	T	X	Azimuth Split
1572	7	268.242	4.375	28	20,000	F	X	
1580	4	38.848	4.125	20	20,000	F	X	
1580	11	31.465	4.125	12	20,000	F	X	
1580	19	50.098	4.125	28	20,000	F	X	
1582	3	67.412	4.000	56	20,000	F	X	
1582	10	76.201	4.000	32	20,000	F	X	
1582	28	94.219	4.000	32	20,000	F	X	
1584	2	108.018	4.000	16	20,000	F	X	
1590	28	94.219	4.000	32	20,000	F	X	
1642	16	147.305	4.250	16	20,000	F	X	
1644	3	190.371	4.250	20	20,000	F	X	
1644	7	202.764	4.250	48	20,000	F	X	
1644	9	209.355	4.375	32	20,000	F	X	

TABLE C-1

Data Point List

Tape: Aug. 25, AI-Mode 2, Tape 2, Part A   Beacon Code: 2315
Range: ≤ 10 nmi.

Tape Record	Message Number	Azimuth	Range	Run Length	Altitude	Status True or False	28° or Above	Comments
1646	10	285.557	4.500	132	20,000	F	X	
1648	1	301.553	4.500	24	20,000	F	X	
1648	4	304.629	4.500	20	20,000	F	X	
1648	6	308.496	4.500	20	20,000	F	X	
1656	17	83.760	4.750	72	20,000	T	X	
1662	5	289.336	5.250	20	20,000	F	X	
1662	6	293.555	5.250	40	20,000	F	X	
1672	8	83.936	5.625	76	20,000	T	X	
1676	18	285.645	6.125	20	20,000	F	X	
1686	22	84.375	6.500	52	20,000	T	X	
1702	4	84.111	7.500	44	20,000	T		
1716	8	84.111	8.500	48	20,000	T		
2258	12	68.115	5.625	76	20,000	T	X	
2262	4	224.385	5.250	48	20,000	F	X	
2264	15	287.842	5.125	80	20,000	F	X	
2272	21	69.697	4.750	84	20,000	T	X	
2276	8	215.947	4.500	128	20,000	F	X	
2276	13	227.285	4.500	76	20,000	F	X	
2278	7	251.719	4.375	152	20,000	F	X	
2278	11	263.496	4.375	32	20,000	F	X	
2278	17	271.670	4.375	48	20,000	F	X	
2280	2	284.326	4.375	24	20,000	F	X	
2280	21	312.627	4.250	28	20,000	F	X	

TABLE C-1

Data Point List

Tape: Aug. 25, AI-Mode 2, Tape 2, Part A Beacon Code: 2315
Range: ≤ 10 nmi.

Tape Record	Message Number	Azimuth	Range	Run Length	Altitude	Status True or False	28° or Above	Comments
2280	2	284.326	4.375	24	20,000	F	X	
2288	8	70.664	4.125	20	20,000	T	X	Azimuth Split
2288	12	75.410	4.125	16	20,000	F	X	
2344	22	24.258	6.250	16	20,000	F	X	
2346	6	36.475	6.250	220	20,000	F	X	
2348	9	83.936	6.375	116	20,000	F	X	
2352	3	240.820	6.750	48	20,000	T	X	
2364	15	241.523	7.750	48	20,000	T		
2378	6	241.523	8.625	44	20,000	T		
2390	8	241.787	9.625	36	20,000	T		Range Split
2390	9	243.457	9.750	16	20,000	F		

TABLE C-1

Data Point List

Tape: Aug. 25 , AI-Mode 2, Tape 1, Part A Beacon Code: 2315
Range: ≤ 10 nmi.

Tape Record	Message Number	Azimuth	Range	Run Length	Altitude	Status True or False	28° or Above	Comments
13	13	336.357	9.250	44	4800	T		
27	3	336.709	8.500	48	4800	T		
51	145	337.324	7.875	44	4800	T		
63	18	337.588	7.125	40	4800	T		
77	17	337.764	6.375	48	4800	T		
91	10	337.852	5.750	44	4800	T		
105	13	338.027	5.000	44	4800	T		
119	11	338.379	4.375	40	48000	T		
133	11	338.555	3.625	40	4800	T		
147	11	338.555	3.000	52	4800	T		
267	23	156.182	3.000	24	4800	T		
285	12	155.127	3.625	40	4800	T		
307	1	155.566	4.250	20	4800	T		
323	14	154.512	5.000	40	4800	T		
339	7	154.424	5.625	44	4800	T		
361	20	154.336	6.375	40	4800	T		
377	7	154.160	7.000	44	4800	T		
391	30	154.248	7.750	36	4800	T		
407	24	154.336	8.375	36	4800	T		
423	18	154.512	9.125	44	4800	T		
441	10	155.215	9.750	36	4800	T		
1116	19	186.855	7.375	44	4800	T		
1130	5	186.680	6.625	44	4800	T		

TABLE C-1

Data Point List

Tape: Aug. 25, AI-Mode 2, Tape 1, Part A   Beacon Code: 2315
Range: ≤ 10 nmi.

Tape Record	Message Number	Azimuth	Range	Run Length	Altitude	Status True or False	28° or Above	Comments
1142	20	186.680	5.875	40	4800	T		
1156	13	186.680	5.125	40	4800	T		
1170	5	186.768	4.375	44	4800	T		
1186	30	186.680	3.625	44	4800	T		
1310	6	339.785	2.875	24	4800	T		
1370	3	1.143	5.875	44	4800	T		
1384	7	1.318	6.625	44	4800	T		
1398	12	1.055	7.375	44	4800	T		
1412	14	0.967	8.125	44	4800	T		
1426	12	0.967	8.875	44	4800	T		
1440	14	0.967	9.625	44	4800	T		
2258	11	309.287	8.750	48	9800	T		
2276	4	309.375	8.000	40	9800	T		
2292	7	309.111	7.250	44	9800	T		
2310	1	308.760	6.625	48	9800	T		
2326	3	308.232	5.875	48	9800	T		
2344	7	307.969	5.125	52	9800	T		
2362	7	307.617	4.500	48	9800	T		
2380	6	307.178	3.750	52	9800	T		

TABLE C-1

Data Point List

Tape: Aug. 25 , AI-Mode 2, Tape 3 Beacon Code: 1711

Range: ≤ 10 nmi.

Tape Record	Message Number	Azimuth	Range	Run Length	Altitude	Status True or False	28° or Above	Comments
477	7	305.684	9.375	40	10,100	T		
491	23	304.541	8.375	40	10,300	T		
507	9	303.047	7.375	44	10,400	T		
523	8	301.201	6.375	48	10,500	T		
569	20	288.721	3.625	44	11,400	T		
579	19	77.959	3.375	16	11,500	F		
581	2	129.551	3.250	20	11,500	F		
585	16	275.977	3.000	76	11,600	T		
593	19	29.268	2.875	84	11,600	F		
593	33	43.594	2.875	48	11,600	F		
595	10	51.416	2.750	108	11,600	F		
595	24	64.160	2.750	60	11,700	F		
597	11	113.291	2.750	64	11,700	F		
597	13	122.695	2.750	44	11,700	F		
597	15	128.584	2.750	44	11,700	F		
637	15	301.377	2.875	16	12,200	F		
637	26	314.121	2.875	88	12,200	F		
639	5	321.152	2.875	24	12,200	F		
639	16	332.314	2.875	28	12,200	F		
649	4	169.365	3.250	84	12,300	T		
665	1	156.709	3.875	68	12,400	T		
681	6	148.711	4.750	48	12,500	T		
697	12	142.734	5.625	44	12,800	T		

TABLE C-1

Data Point List

Tape: Aug. 25, AI-Mode 2, Tape 3 Beacon Code: 1711
Range: ≤ 10 nmi.

Tape Record	Message Number	Azimuth	Range	Run Length	Altitude	Status True or False	28^o or Above	Comments
713	10	138.955	6.500	40	13,100	T		
729	8	136.318	7.500	48	13,500	T		
743	23	134.033	8.500	44	13,900	T		
759	10	132.188	9.500	44	14,200	T		

TABLE C-1

Data Point List

Tape: Aug. 25, AI-Mode 2, Tape 2 Beacon Code: 7067
Range: ≤ 10 nmi.

Tape Record	Message Number	Azimuth	Range	Run Length	Altitude	Status True or False	28° or Above	Comments
1856	11	299.092	9.5	48	27,000	T		
1882	2	80.068	8.250	20	27,400	F		
1882	16	90.527	8.250	172	27,400	F		
1884	12	124.541	8.125	48	27,400	F		
1884	17	136.934	8.125	112	27,500	F		
1890	1	291.709	7.750	76	27,600	T		
1898	15	86.309	7.375	20	27,700	F		
1902	2	137.197	7.375	48	27,700	F		
1906	1	286.084	7.000	52	27,800	T		
1914	5	65.391	6.750	20	27,900	F		
1920	12	277.734	6.375	56	28,100	T		
1930	18	81.211	6.125	92	28,200	F		
1932	11	99.844	6.125	40	28,200	F		
1934	2	113.027	6.125	132	28,200	F		
1934	9	123.398	6.125	72	28,200	F		
1934	11	129.023	6.125	28	28,200	F		
1936	13	267.100	5.875	40	28,300	T		
1946	24	67.588	5.750	16	28,400	F		
1948	9	82.002	5.750	20	28,400	F		
1950	1	97.207	5.750	148	28,400	F		
1950	16	114.434	5.750	148	28,400	F		
1950	19	124.980	5.750	20	28,400	F		
1954	3	248.555	5.625	140	28,400	T		

TABLE C-1

Data Point List

Tape: Aug. 25 , AI-Mode 2, Tape 2

Range: ≤ 10 nmi.

Beacon Code: 7067

Tape Record	Message Number	Azimuth	Range	Run Length	Altitude	Status True or False	28° or Above	Comments
1970	5	227.813	5.500	52	28,600	T		
1976	7	3.428	5.500	28	28,600	F		
1986	2	184.395	5.625	56	28,600	T		
1986	5	203.906	5.625	96	28,700	F		
1994	17	23.555	5.750	24	28,700	F		
1996	21	37.090	5.750	92	28,700	F		
2002	21	182.637	5.875	16	28,700	T		
2008	22	341.104	6.125	40	28,800	F		
2010	11	353.936	6.125	68	28,800	F		
2010	14	359.648	6.125	24	28,800	F		
2012	13	25.488	6.125	28	28,800	F		
2012	16	29.355	6.125	28	28,800	F		
2014	15	38.408	6.125	124	28,800	F		
2016	6	63.018	6.250	20	28,800	F		
2020	15	169.717	6.375	28	28,800	T		
2038	19	163.037	7.000	48	28,700	T		
2058	1	156.797	7.750	60	28,700	T		
2074	15	153.457	8.625	28	28,600	T		
2092	1	149.238	9.625	36	28,600	T		

TABLE C-1

Data Point List

Tape: Aug. 25, AI-Mode 2, Tape 3 — Beacon Code: 1673

Range: ≤ 10 nmi.

Tape Record	Message Number	Azimuth	Range	Run Length	Altitude	Status True or False	28° or Above	Comments
112	6	26.016	9.750	52	24,100	T		
125	21	22.061	8.875	40	24,200	T		
143	2	17.051	7.875	44	24,400	T		
161	9	9.844	7.125	68	24,600	T		
169	1	161.191	6.750	36	24,600	F		
171	2	213.135	6.750	48	24,700	F		
179	14	0.615	6.500	72	24,700	T		
197	3	348.311	6.000	72	24,900	T		
221	6	86.572	5.625	40	25,100	F		
221	7	85.078	5.750	80	25,100	F		
221	9	96.592	5.750	24	25,100	F		
221	12	102.480	5.750	56	25,100	F		
223	1	106.699	5.625	136	25,100	T		
231	11	315.088	5.750	56	25,200	T		
241	2	90.264	5.750	80	25,300	F		
241	5	103.271	5.750	20	25,300	F		
247	21	298.037	5.875	64	25,400	T		
257	30	76.992	6.125	92	25,500	F		
259	2	87.275	6.125	72	25,500	F		
259	10	136.406	6.125	24	25,500	F		
259	12	147.568	6.125	24	25,500	F		
265	3	284.414	6.375	72	25,600	T		
275	6	71.104	6.625	28	25,700	F		

TABLE C-1

Data Point List

Tape: Aug. 25, AI-Mode 2, Tape 3 Beacon Code: 1673

Range: ≤ 10 nmi.

Tape Record	Message Number	Azimuth	Range	Run Length	Altitude	Status True or False	28° or Above	Comments
275	8	75.234	6.625	44	25,700	F		
277	2	127.969	6.750	44	25,700	F		
281	5	275.219	7.000	76	25,800	T		
291	11	64.248	7.375	100	25,900	F		
293	11	119.795	7.500	20	26,000	F		
297	19	266.748	7.750	64	26,000	T		
307	18	57.744	8.125	88	26,100	F		
309	16	108.809	8.250	16	26,200	T		
313	18	261.387	8.625	52	26,200	T		
329	7	257.344	9.625	52	26,400	T		
-	-	-	-	-	-	-		

Appendix D - Errata to Reference 1

Reference 1 is the APL report issued to the FAA under Contract DOT-FA75WA-3553 in September 1976. The ring around investigation was conducted as a follow-on to this contract, and the final report for the ring around investigation is issued as an addendum to reference 1. Errata to reference 1 are listed in this appendix.

Errata to reference 1:

1) Page 8-5, Section 8.1.2, Paragraph 2, Sentence 1 should read:

   In operation, an interrogation pulse-group transmitted from the ATC BI via the antenna triggers each airborne transponder that is capable of responding to the mode interrogated and located in the direction of the antenna mainbeam within 256 nmi of the antenna.

2) Page 8-10, first paragraph, lines 4 and 8: Change the "one thousand" to "1024".

3) Page 8-23, first paragraph, line 5: Change "Group I" to "Group II".

4) Page 8-29, Section 8.2.2, first paragraph, line 4: Change ARSR-7 to ARSR-2.

5) Page 8-156, Equation 8-1: Should read
   RUN LENGTH = (UNCORRECTED CENTER AZIMUTH - AZ START) X 2

6) Page 8-156, Paragraph 2, line 5: Change "Section 8.12" to "Section 8.1.2".

7) Page 8-160, Table 8.23, under column labeled "RUN LNG": The number here should be 24 instead of $\theta\gamma$.