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UNCLASSIFIED MTR-79W00158 FAA-RD-80-7 NL

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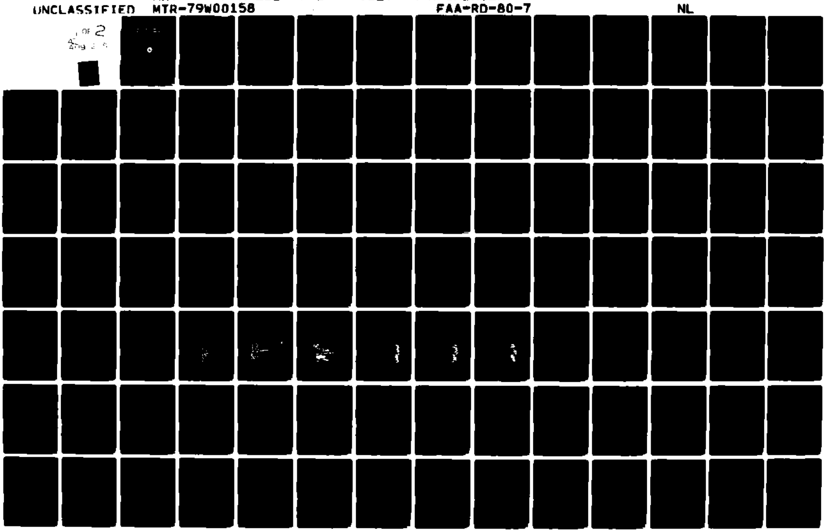

Report No. FAA-RD-80-7

LEVEL II (12)

# Results of an Active Beacon Collision Avoidance Experiment Conducted in the Los Angeles Airspace

AD A096285

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MAY 1979

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16. Abstract


The Active BCAS test bed equipment, which had been tested both at NAFEC and at Washington, D.C., was upgraded to include the Whisper-Shout technique for garble reduction and the DABS mode for high integrity BCAS-to-BCAS operation. The test bed was then flown in the environment of the Los Angeles TCA and of the Orange County Airport. A comparison was then made under various levels of traffic, and with various system features. As a result of all of the tests on the feasibility equipment, general performance results are predicted and improvements for future designs are given.


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# METRIC CONVERSION FACTORS

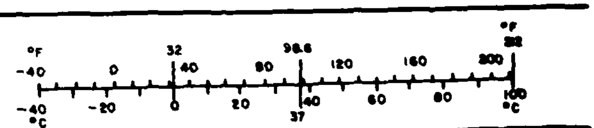
## Approximate Conversions to Metric Measures

| 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 |



## CONCLUSIONS

The major characteristic that first appeared in the Washington tests--that the correlation of clear (not overlapped) replies is only 78%--was confirmed in the Los Angeles flights. This low reply probability appears to be present only for BCAS, not ARTS. It is not strongly influenced by the transmitter power level nor by the interrogation-suppression protocol.

As surmised at the end of the Washington tests this characteristic was attributed to a combination of multipath and the shielding of the ATCRBS target aircrafts' antenna by its fuselage. Further tests made with a combination of the BCAS aircraft and the M.I.T. Lincoln Laboratory's Airborne Measurements Facility (AMF) confirmed this theory and added a quantitative understanding of the phenomenon. From that, the suggestion of using Whisper/Shout to reduce the effects of multipath arose. This and other steps appear to offer fruitful potential for further improvements.

An important conclusion that can be drawn from the Los Angeles flight test data is that the performance of the DABS mode against diversity transponders is of high integrity and is not degraded by the large population of ATCRBS equipped aircraft that were present. Since DABS is garble free, any number of interrogators and transponders could be flown with no degradation of the DABS performance. However, the DABS fruit and ATCRBS suppressions caused by a large number of DABS interrogations could possibly interfere with the ground ATCRBS system. This problem was examined in Reference 8, where an interference limiting algorithm is described which precludes such possibility. Performing the error correction in software is wasteful of computer resources, and is not considered advisable.

Technical conditions under which the ATCRBS mode of the test-bed system is effective also were shown; namely, that the level of traffic be about as represented by the Washington, D.C. area or less, and that the other aircraft be within the altitude range of 2000 ft below to 5000 ft above the BCAS aircraft. The former condition is a characteristic of the ATCRBS mode's dependence on traffic density, the latter condition is a characteristic of the non-diversity antenna system that is deployed on the present transponder equipped fleet. Stressing the ATCRBS mode in the Los Angeles area, the measured effectiveness of the test-bed system for the set of one-on-one encounters flown was found to drop from about 100% to about 80%. At the same time a minor change in the algorithm was found which would preclude the generation of a large number of false alarms (alarms caused by phantom tracks). Specific improvements to the experimental equipment are noted for guidance to obtain a higher level of performance for future equipment.

## RECOMMENDATIONS

The improvements, beyond the test-bed feasibility equipment, listed below are some of the measures that should next be explored both to improve the detection capability and to reduce the number of false alarms.

1. Improve the IF response.

2. Revise the application of Whisper/Shout to alleviate multipath rather than synchronous garble.

3. Require a track confidence level of at least 75% before using it in threat detection.

4. When a reply is in the clear, place a high degree of confidence in it and short-cut the track establishment and altitude correction procedures.

5. Reduce the track blooms by limiting the number of new tracks permitted to start simultaneously at approximately the same range.

6. Accommodate the possibility of a slightly non-periodic interrogation sequence to accommodate some degree of overloading.

7. Include an estimate of altitude rate when starting new tracks.

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# 1. INTRODUCTION

## 1.1 History

The omnidirectional, ATCRBS form of active BCAS system was first proposed by the MITRE Corporation in 1975 (Reference 1). It was decided that NAFEC would build and test such a system with MITRE furnishing technical assistance. This task was completed later that year, and it was tested and improved through 1977. The results of flights at NAFEC and in the Washington, D.C. area are described in subsequent reports by NAFEC and MITRE (References 2 and 3).

In 1977, a DABS capability was added to the Active BCAS, with MITRE and the M.I.T. Lincoln Laboratory furnishing the technical assistance on the ATCRBS and DABS modes respectively (References 4, 5 and 6). This system is the one that was flown during February and May 1978 in Los Angeles and whose performance is described in this report.

In 1978, M.I.T. Lincoln Laboratory was given the task of developing and constructing an improved version of the Active BCAS, packaged so that it could be flown under operational conditions, but functionally derived from the Active BCAS test bed. In other words, the Active BCAS that will be produced should perform at least as well as that given in this report.

## 1.2 Rationale for Testing in Los Angeles

The BCAS flight tests at NAFEC and in the Washington area (ATCRBS mode) showed that the Active BCAS had regions of weak coverage, but it never missed a simulated collision (one-on-one encounter with 400 ft altitude separation between aircraft). The areas of weak coverage were in regions that under many conditions would not prevent a 25 second alarm before collision. However, the traffic was not dense enough for the

Whisper/Shout degarbling technique (Reference 3) to show any meaningful improvement over the basic BCAS. Since Los Angeles has the highest density of aircraft in the world, it was felt that the limits of BCAS performance in synchronous garble could best be determined there.

The environment at Los Angeles is characterized by a mean density of 8 altitude reporting aircraft within 10 nmi, peaking up to 19. The fruit rate averaged at about 20,000 fruit/sec, but on occasion went above 30,000 fruit/sec. The average number of overlapping replies was 2.4 (peaking to 10) when all aircraft within 10 nmi were included. Within 5 nmi, the average number of overlaps was 1.8, with a peak of 10.

While it is not intended that active BCAS would operate unconstrained in a very high density environment, the tests in Washington and Los Angeles were run to ascertain the limits of technical performance. As contrasted to technical performance, operation as an element of the ATC system includes many other considerations that are not treated in this report.

## 1.3 Test Bed Configuration

### 1.3.1 DABS

The DABS portion of Active BCAS acquires and tracks DABS targets, and coordinates escape maneuvers. Squitters from the DABS transponders on the test aircraft permit acquisition; DABS interrogations via DPSK modulation permit both tracking and communication of intent. The algorithms used were an early form designed by M.I.T. Lincoln Laboratory and are described in Reference 5.

The DABS mode shared the airborne computer with the ATCRBS mode and occupied about half of the computer storage and computational capacity (a significant part of those resources were devoted to error correction in software, an expedient used in the test bed only).

### 1.3.2 ATCRBS

The ATCRBS mode tested in Los Angeles was essentially the same as that tested in Washington and NAFEC, except that it shared the computer with DABS for some of the flights. One operational mode, used in most of the May flights, was to interrogate only (no tracking) while in the air and to record the reply buffers. The tracking was performed later on the ground so that the amount of computer time required could be assessed independently of the inherent performance.

#### 1.3.2.1 Targets

Two different types of tests were conducted while operating in the ATCRBS mode. In one series of tests one-on-one encounters were flown against an FAA test aircraft. That aircraft was tracked both by its ATCRBS returns and by its DABS returns.

In other tests targets of opportunity were tracked at all altitudes and ranges up to 12 nmi. These tracks were compared with ARTS tracks to obtain a quantitative measure of the ATCRBS performance.

#### 1.3.2.2 Power Programming via Whisper/Shout

A technique to reduce synchronous garble, called Whisper/Shout was used in most of the tests. Data for Basic ATCRBS without Whisper/Shout, was also collected on all flights. In the February tests the accompanying electronically controllable attenuator burned out, precluding the collection of any Whisper/Shout data. The design was subsequently altered somewhat and, in the May tests, data on Whisper/Shout was collected.

#### 1.3.2.3 Interrogation Power

The interrogation power used in the February tests was more than 2 kW out of the BCAS interrogator, the same as used in the Washington flights. The power used in most of the May flights was reduced to what was considered a more reasonable level of 630 Watts at the transmitter. On May 10 data was taken at both 630 Watts and 315 Watts so that the effect of transmitter power could be studied.

#### 1.3.2.4 Program Variations

The program variables studied were real-time operation vs. non-real-time, ATCRBS alone vs. ATCRBS/DABS combined, and ATCRBS track size.

The non-real-time operations were run with track file sizes of 75, 100, and 200 tracks to determine the effect of computer size. In all the non-real-time cases, the tracker was allowed to take as much time as needed between track updates, but the time needed was a strong function of the size of the track file.

#### 1.3.2.5 Suppression On Top Antenna

During the Washington area flight tests a suppression was issued on the top antenna a few microseconds before the lower antenna interrogation. Some analysis indicated that this could possibly cause a lack of response by some aircraft below the BCAS aircraft. Therefore, the suppression was eliminated for most of the Los Angeles flights, but it was reinstalled for a few flights to study its effect.

## 1.4 Test Scenarios

### 1.4.1 Two Aircraft Tests

Two-aircraft one-on-one encounters were flown both directly over LAX, and in the general aviation environment of Orange County and were conducted in the February 1978 series. In these flights both aircraft had BCAS equipment on board and flew at each other head-on, or at right angles, with an altitude separation of 400 ft. The two aircraft flew at 7500 ft over LAX and about 3500 ft in Orange County. In most of these tests, both aircraft used DABS transponders so that they could be tracked via the DABS mode as well as ATCRBS. Due to a DABS transponder failure, some of the tests were flown with ATCRBS only, which fortuitously allowed a comparison between one system with DABS and ATCRBS modes sharing the computer, and one sytem with ATCRBS only.

### 1.4.2 Single Aircraft Tests

The single aircraft tests consisted of "figure-eights" over LAX, and were performed in May of 1978. It was during these tests that most of the parameter variations were conducted. Whisper/Shout was run, overall power variation was tried, and the suppression on the top antenna was varied. During most of these flights, only the reply buffers were recorded, with the tracking performed later. By doing this, we were able to evaluate the effect of track file size and Whisper/Shout, all on the same data.

### 1.4.3 Fruit Rate

The fruit rate, as seen by the BCAS receiver was recorded on each flight. This was accomplished by interrogating in Mode D, which practically nc transponder answers with a code burst. The "replies" recorded during this interval thus represent an upper bound on fruit. Figure 1-1 is a plot of the fruit rate, averaged

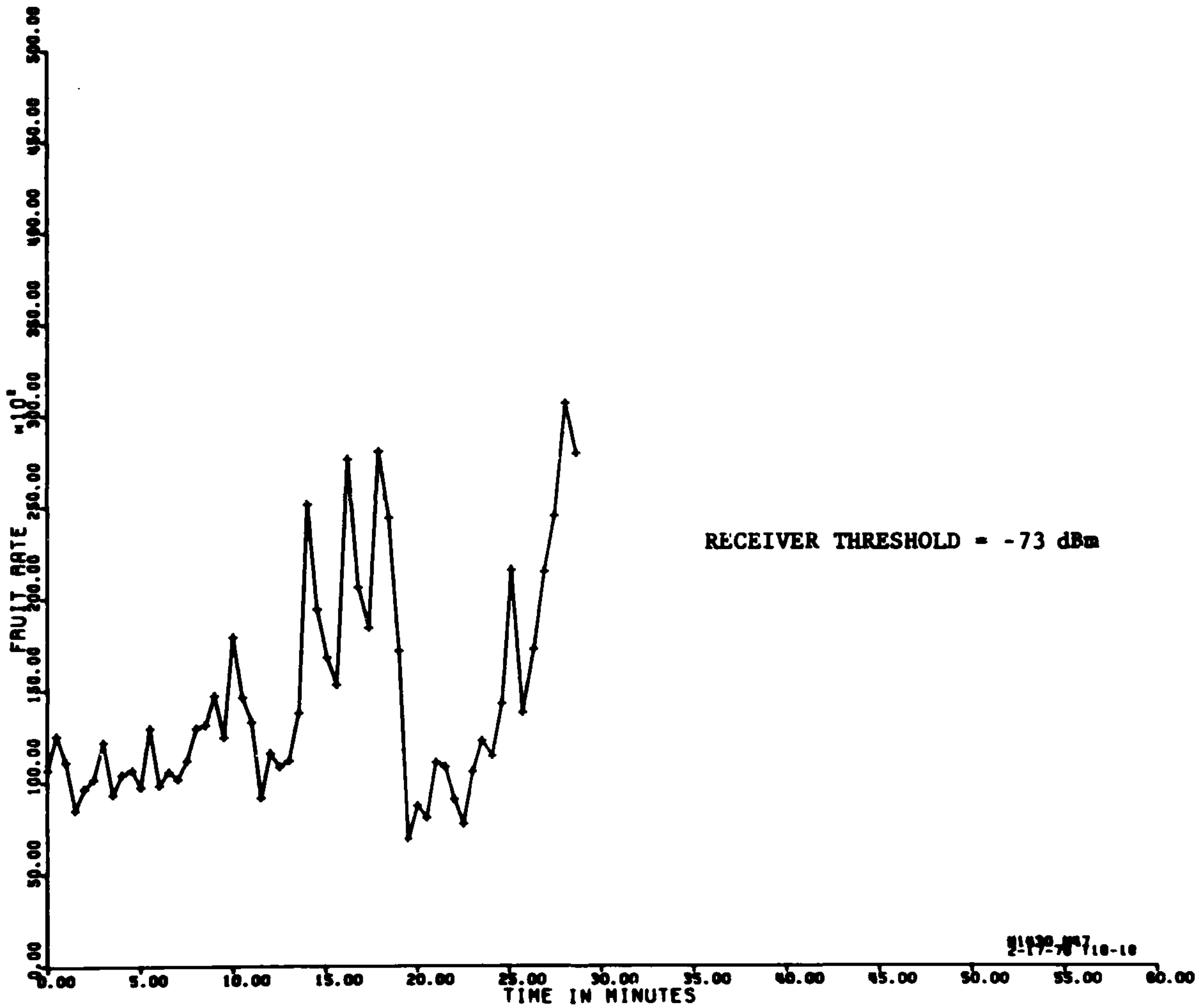


**FIGURE 1-1**
**AIRBORNE ATCRBS FRUIT RATE AVERAGED OVER 30 SEC**

over 30 seconds, for part of the February 17 flight. It can be seen that the fruit rate is quite variable, and is quite dependent on where in the Los Angeles basin the test aircraft is. Figure 1-1 includes two passes directly over LAX airport (at approximately 16 minutes and 25 minutes).

### 1.4.4 Receiver

The receiver used in these flight tests was an RT-868A/APX-76 with its sensitivity set to -73 or -76 dBm (depending on the flight). This receiver was followed by a slightly modified version of the video quantizer used in the DABS sensor, for extraction of range and reply code. This receiver performed both DABS and ATCRBS detection.

The major deficiency of the receiver was its slow rise and fall time of about .5 microseconds. This in itself is not bad, but the DABS sensor was designed to work with a receiver having a rise and fall time of less than .1 microsecond. As a consequence, the leading and trailing edge declarations of the sensor were not quite as intended. This should improve in future versions of the hardware.

The cabling losses between the interrogator and the antennas were 4.9 dB for the top antennas, and 3 dB for the lower antenna. These losses result in the following characteristics of the 630 Watt transmitter and the -73 dBm receiver, as seen at the antenna:

| Antenna: | Top | Bottom |
|---|---|---|
| Power: | 200 Watts | 316 Watts |
| Sensitivity: | -68 dBm | -70 dBm |

## 2. PERFORMANCE

### 2.1 DABS Performance

For the two-aircraft tests flown in February, in most cases DABS transponders were on both aircraft. One of the transponders performed poorly (that on board aircraft N49) and failed near the end of the tests. For this reason, the DABS performance in Figure 2-1, is displayed only for the properly operating unit. This figure shows the fraction of encounters for which the DABS mode had a track, at all ranges up to 12 nmi. Only closing encounters were used so that the time to establish track would be correctly discounted. The 12 nmi limit was arbitrarily chosen as the maximum range at which BCAS would track. Thus, the range limitation is not due to power limitations, since the interrogations were over 2 kW, but due to the algorithm cutoff at 12 nmi. In all cases, the aircraft had an airspeed of 175 knots. It can be seen that the DABS mode, when working against a properly operating DABS transponder, is 90% effective out to 10 nmi and at least 95% effective out to 8 nmi.

Figures 2-2 through 2-6 show some typical charts of the DABS operation. Figure 2-2 shows the number of DABS aircraft tracked as the test aircraft goes through its figure eight flight path. Two encounters are shown here; the target was tracked when within 12 nmi in both cases. Figure 2-3 shows the squitters received for the same time interval. Most of the squitters were false, caused by ATCRBS fruit combining to look like a DABS preamble, these squitters were removed from consideration because the confidence of the reply, as detected by the DABS sensor, was too low.

Figure 2-4 shows the squitters which were accepted by the system. When the two aircraft were far apart (from time 0 to 10 minutes) most of the squitters were from BCAS's own transponder,

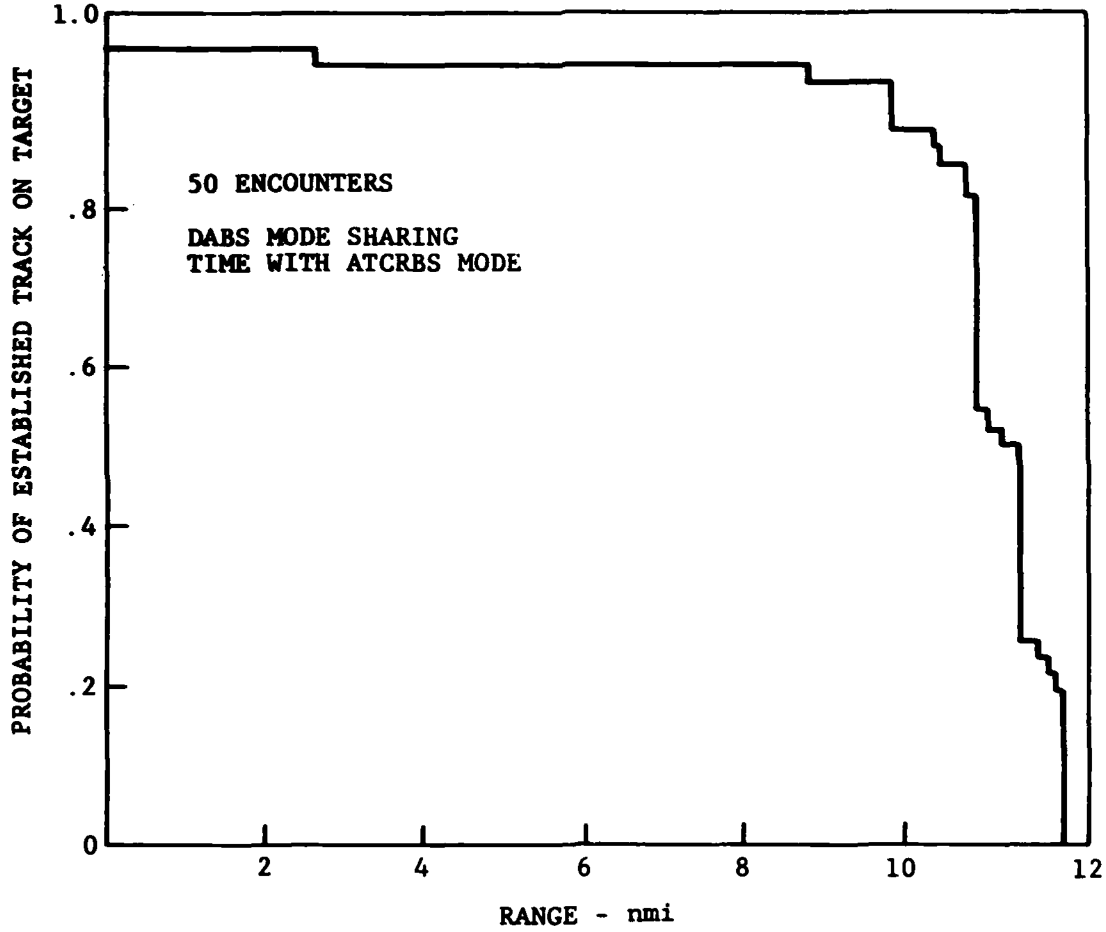


FIGURE 2-1
DABS PERFORMANCE FOR ONE-ON-ONE ENCOUNTERS
IN THE LOS ANGELES BASIN

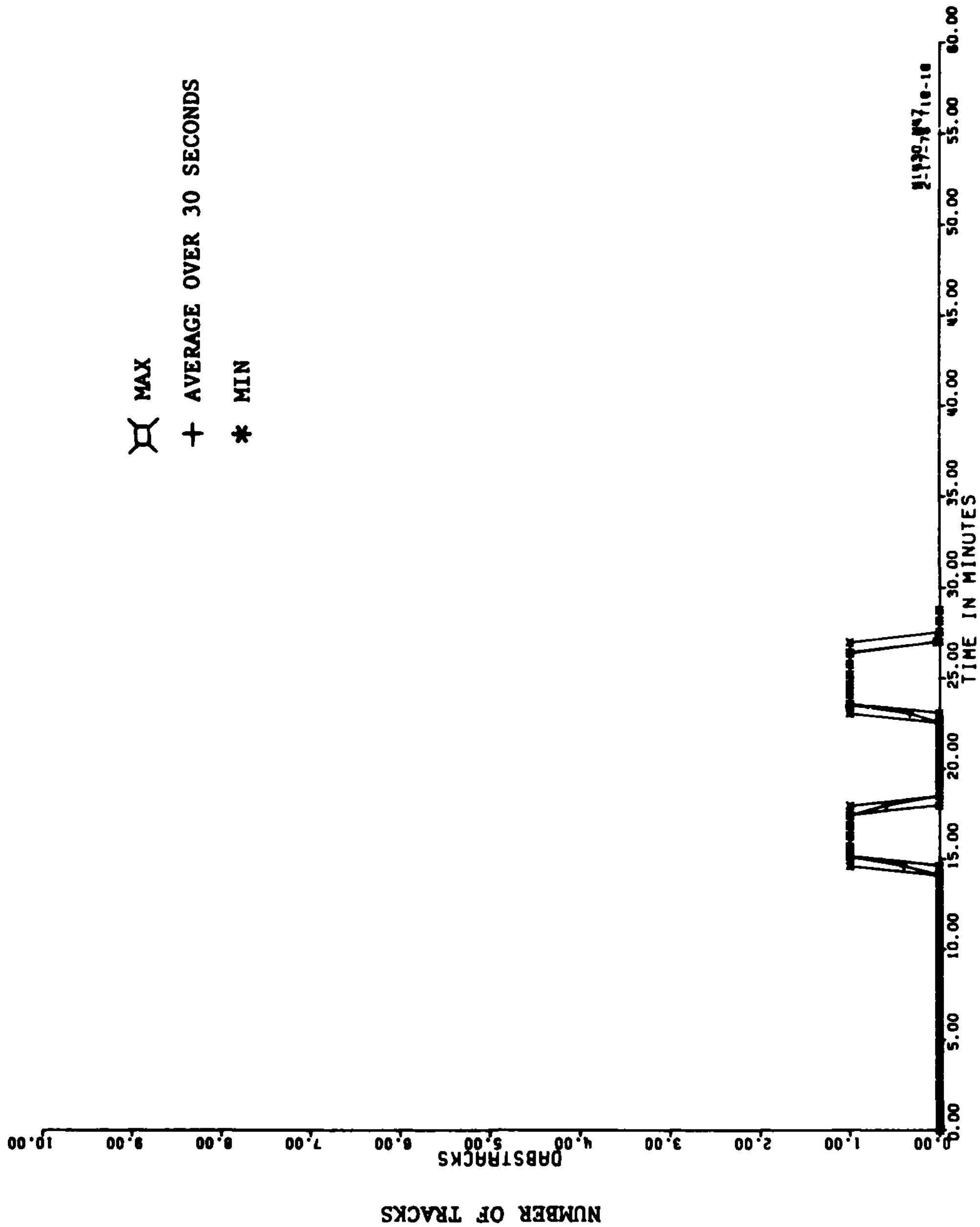


FIGURE 2-2
EXAMPLE OF NUMBER OF DABS TRACKS (FEBRUARY 17)

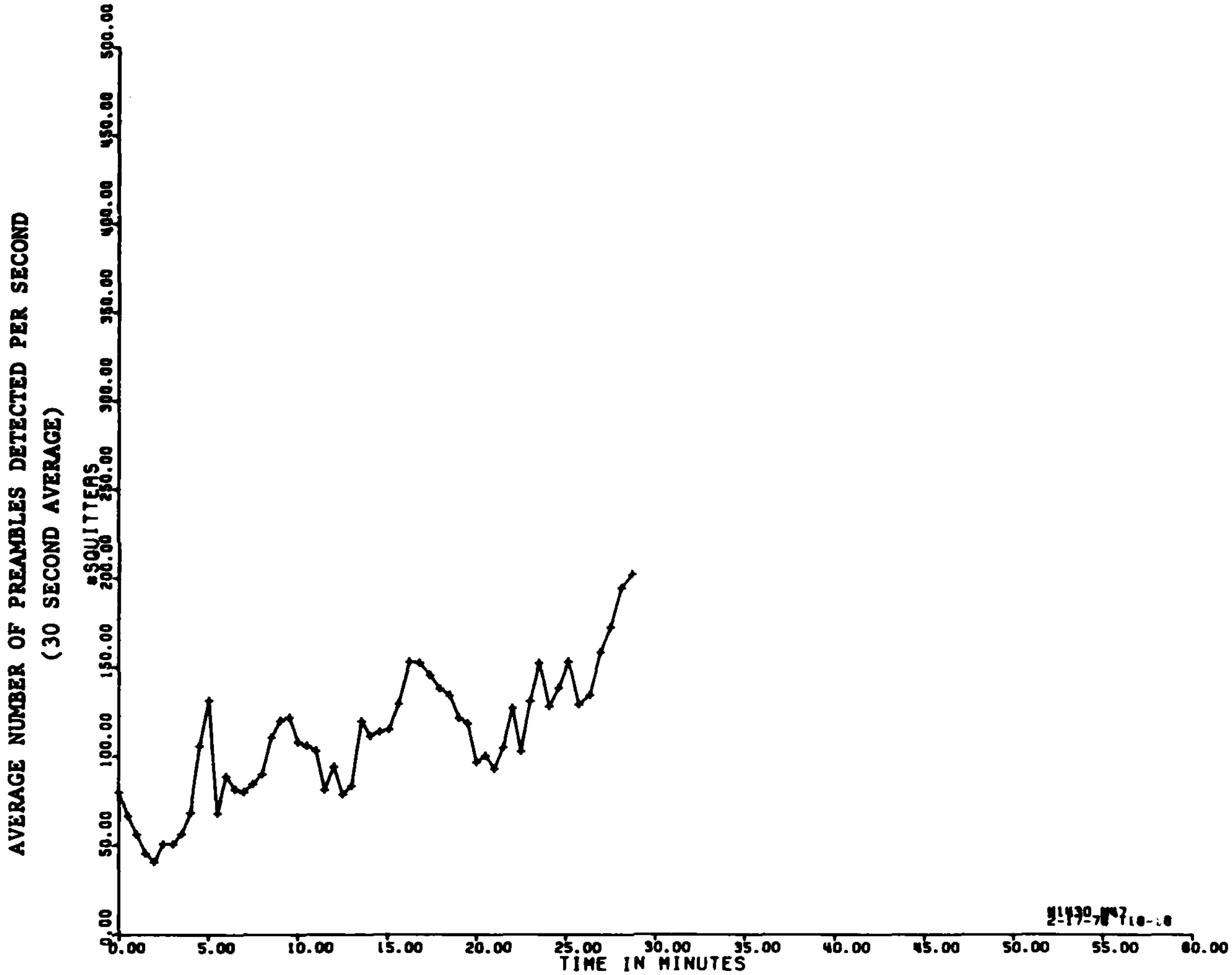


**FIGURE 2-3**
**RATE OF PREAMBLE DETECTIONS IN TYPICAL FLIGHT (FEBRUARY 17)**

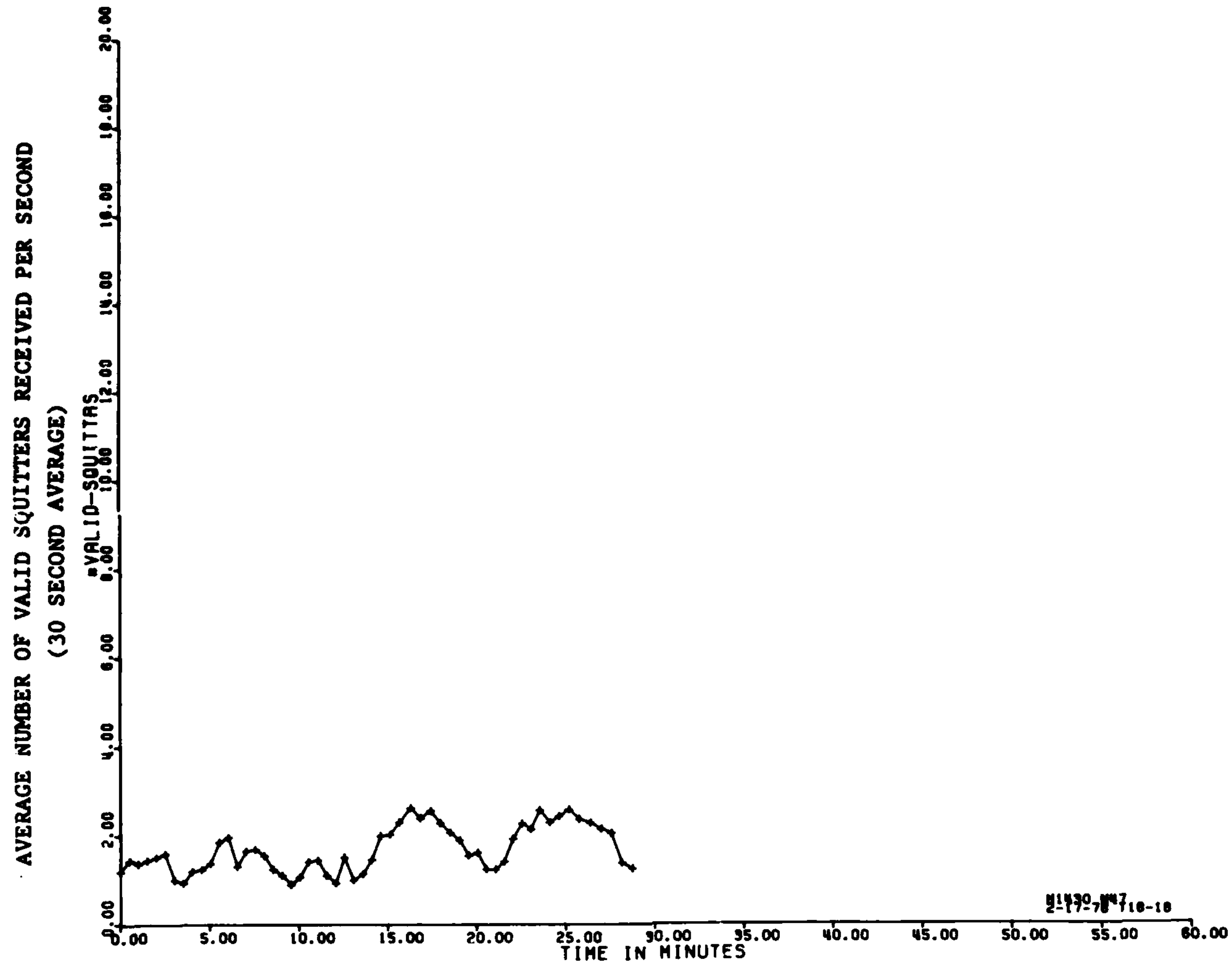


**FIGURE 2-4**
**VALID SQUITTER RATE IN TYPICAL FLIGHT (FEBRUARY 17)**

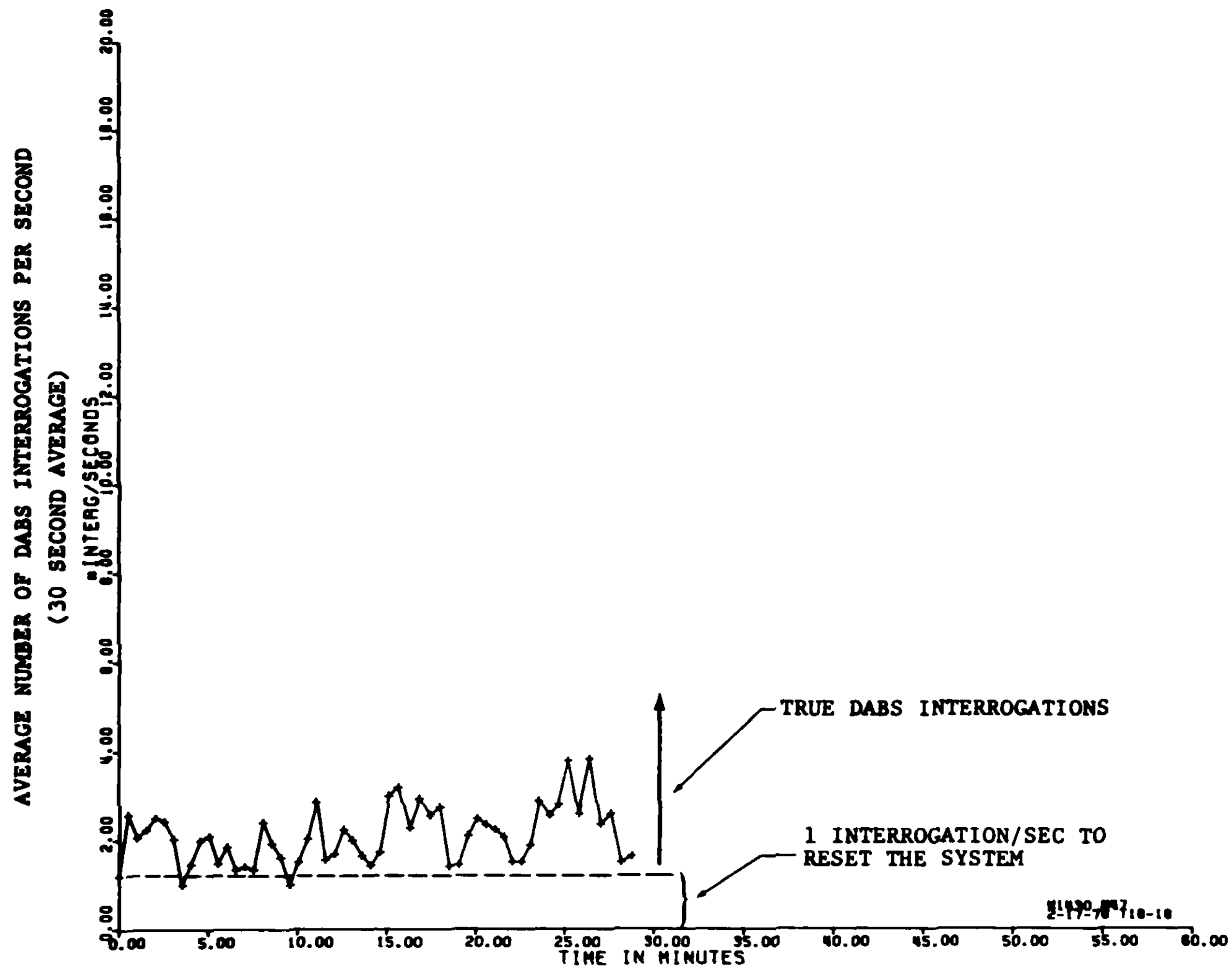


**FIGURE 2-5**
**DABS INTERROGATION RATE IN TYPICAL FLIGHT (FEBRUARY 17)**

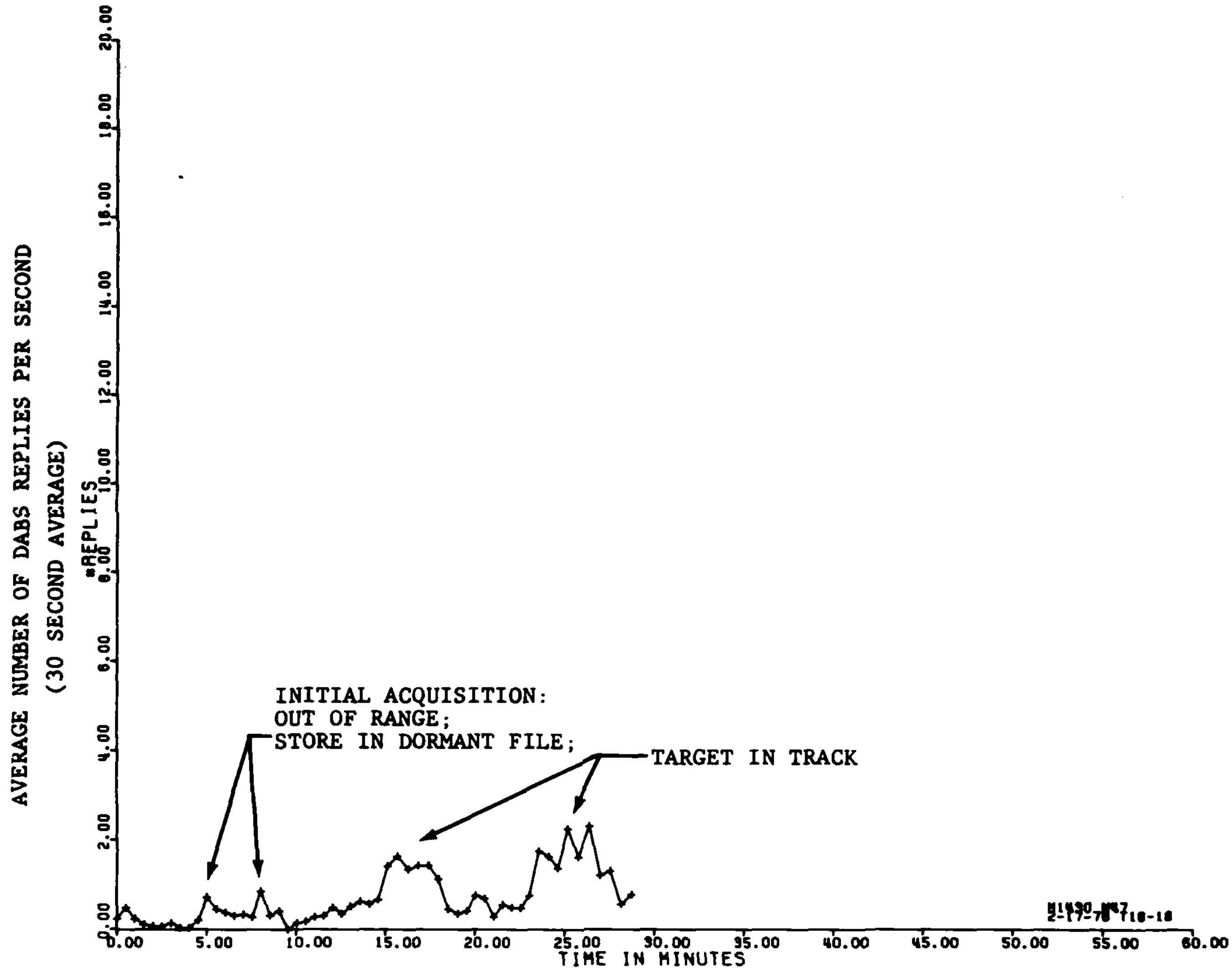


**FIGURE 2-6**
**DABS REPLY RATE IN TYPICAL DABS FLIGHT (FEBRUARY 17)**

but when they were near to each other, the number of squitters doubled.

The operation of the DABS link can be seen in Figures 2-5 and 2-6. Figure 2-5 shows the number of DABS interrogations per second. As an expedient in the test equipment, one zero address DABS interrogation was transmitted per second to clear the system, and therefore the number of interrogations to the target is one less than the curve. Whenever a target in track does not answer DABS reinterrogates, thus the number of interrogations can exceed two. Figure 2-6 shows the number of detected replies per second. This shows small peaks where the target is acquired and discovered to be out of range. Then, when it comes within range, the curve goes above one and stays there until the track is dropped at 12 nmi outbound. During this time the BCAS will reinterrogate if the error correcting code cannot correct the received errors, or if the reply is outside the predicted range window. The track is also reacquired every six seconds, which results in more than one reply per second on the average. All the points on the curves represent the per-second data averaged over a 30 second interval.

## 2.2 ATCRBS Performance

There are two primary measures of BCAS performance, the probability of missing an encounter, and the rate of false alarms. A false alarm is any alarm that is generated when in fact no aircraft is within the stated threat volume. We first discuss the probability of missing an encounter, or more specifically, the probability of not having a track on an intruder.

### 2.2.1 ATCRBS Effectiveness

For 16 intentional near-collision encounters in the Washington area and 84 in the vicinity of NAFEC, BCAS was found to be able to track the test aircraft and to give a 25 second warning every time; and, for targets of opportunity, it was able to track about 73% of all ARTS-identified aircraft within 10 nmi and at all altitudes. In Los Angeles an essentially identical test of near-collision encounters was conducted. The same power (greater than 2 kW) was used, but a significantly higher density of interfering aircraft was present. Figure 2-7 shows that about 80% of these one-on-one encounters were tracked within 6 nmi, but there was a rapid decrease in effectiveness beyond 8 nmi, which was not observed in Washington. The data in Figure 2-7 is for basic BCAS (no Whisper/Shout). However, while the data in Figure 2-7 is for a real time operation system (tracking while flying) which includes any problems due to computer overload, the DABS portion had been shut down because of the previously noted DABS transponder failure. When the DABS portion was sharing the computer with ATCRBS, meaning that ATCRBS was only allotted 50 active tracks and about 1/2 of the computer time, the ATCRBS performance was severely degraded, but the 80% performance still occurs, at close range. This is shown in Figure 2-8. The impact of the system overload is thus to reduce the effective range and, quite likely, to delay an alarm. Such gradual degradation, as contrasted to a "system crash," is an important characteristic of BCAS to enable it to recover its full capability quickly after passing through an excessively dense condition. More will be said about computer sizing in Section 2.4.4.

Next, we look at Figure 2-9. This shows the effectiveness of the ATCRBS mode in tracking targets of opportunity at all relative altitudes. For the Los Angeles data, this represents 4.23 hours with a maximum power setting of 630 Watts. This figure shows that, for the Basic mode within 5 nmi, the performance in Los Angeles is somewhat worse than in Washington.

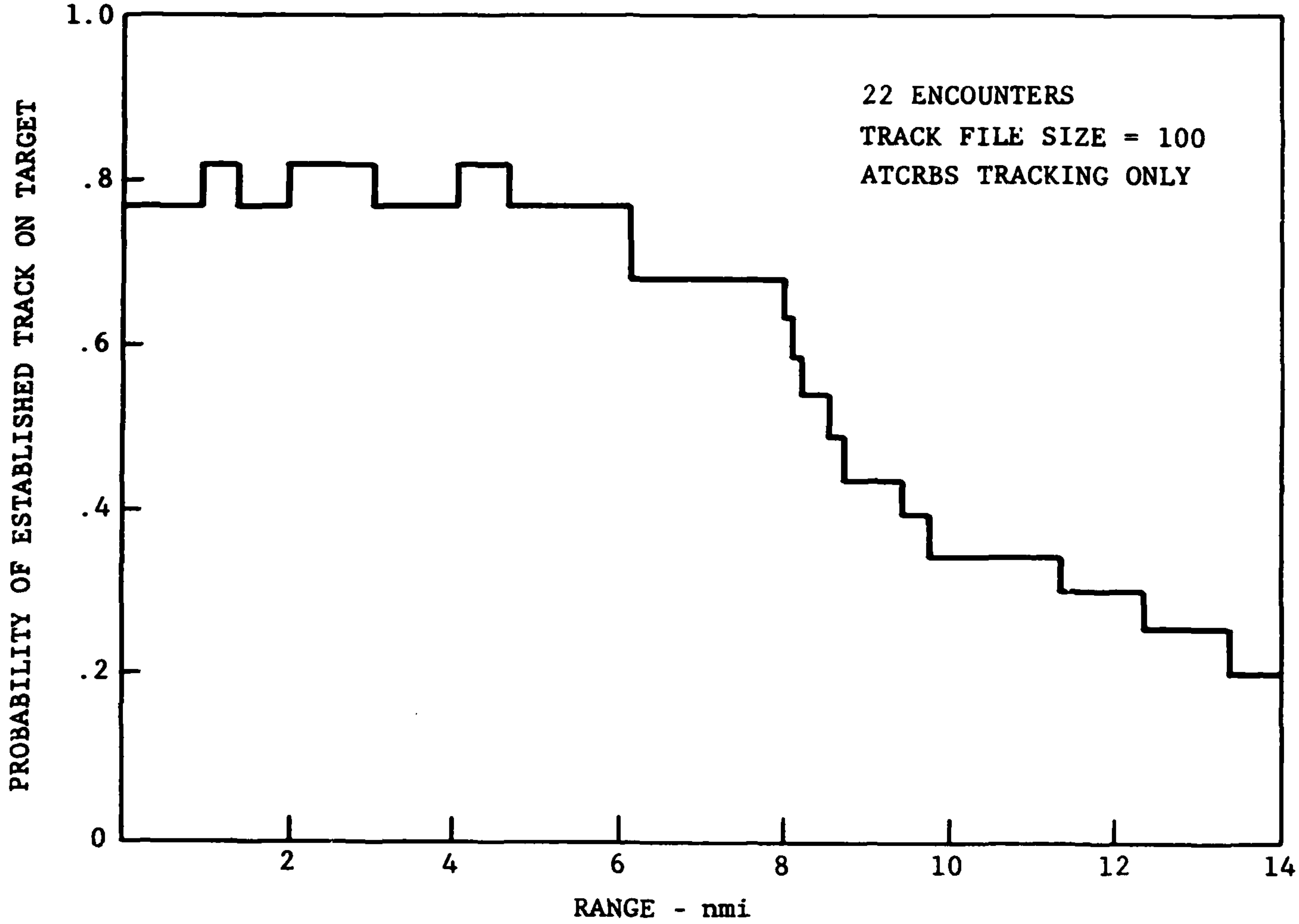


**FIGURE 2-7**
**ATCRBS PERFORMANCE FOR ONE-ON-ONE ENCOUNTERS IN THE LOS ANGELES BASIN**

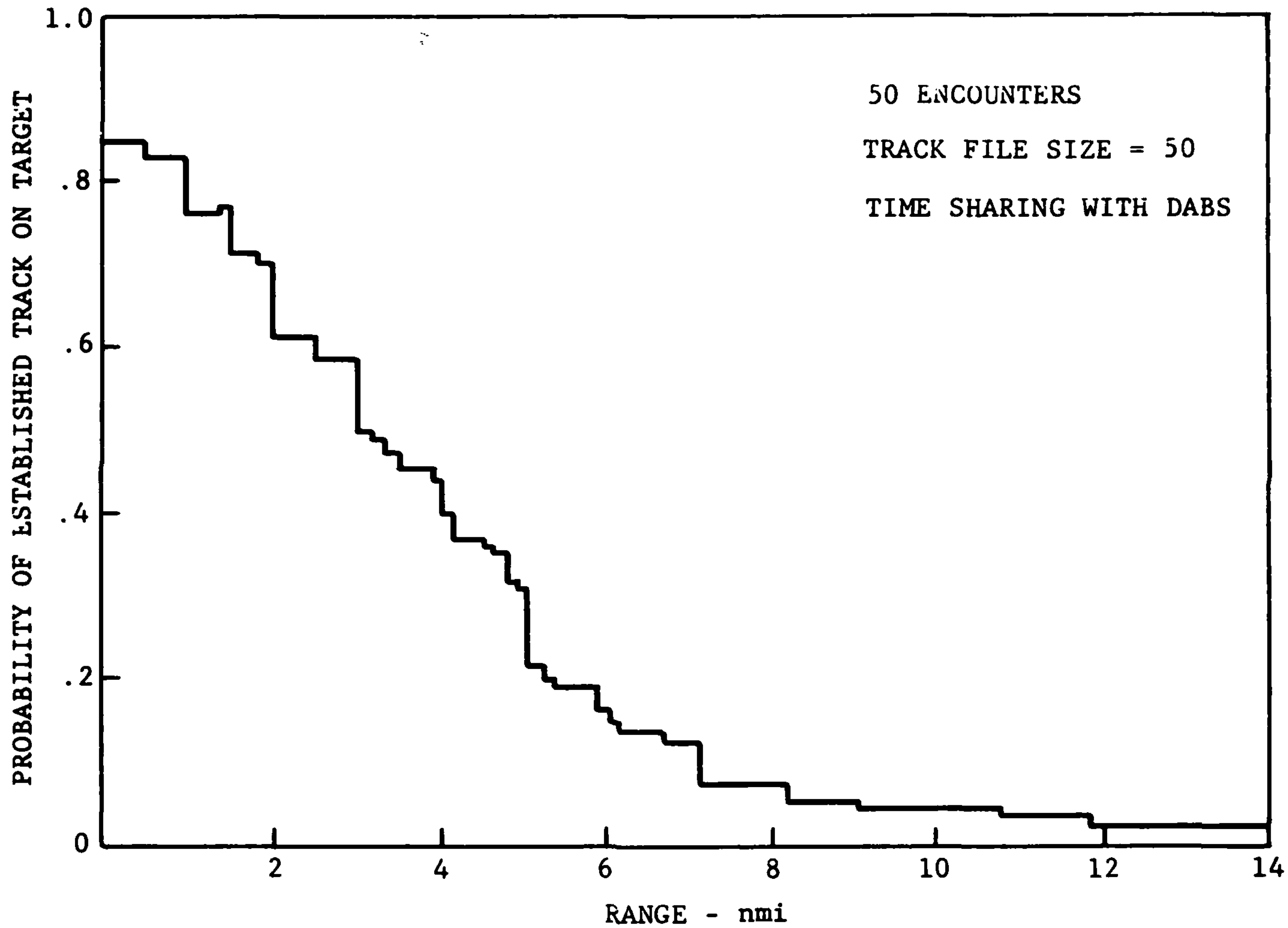


**FIGURE 2-8**
**ATCRBS PERFORMANCE FOR ONE-ON-ONE ENCOUNTERS WITH SEVERE OVERLOADING OF COMPUTER**

RANGE (nmi)

| RELATIVE ALTITUDE (k ft) | (a) WASHINGTON; BASIC 0-5 | (a) WASHINGTON; BASIC 6-10 | (b) LOS ANGELES; BASIC (MAY 7, 8, 9) 0-5 | (b) LOS ANGELES; BASIC (MAY 7, 8, 9) 6-10 | (c) LOS ANGELES; WHISPER/SHOUT (MAY 7, 8, 9) 0-5 | (c) LOS ANGELES; WHISPER/SHOUT (MAY 7, 8, 9) 6-10 |
|---|---|---|---|---|---|---|
| > 5 | .87 | .83 | .86 | .81 | .79 | .69 |
| 0 to 5 | .97 | .90 | .88 | .60 | .78 | .66 |
| 0 to -5 | .72 | .68 | .66 | .48 | .66 | .54 |
| < -5 | .65 | .71 | .48 | .49 | .56 | .59 |
| 0 to 1 | .98 | .90 | .89 | .46 | .86 | .51 |
| 0 to -1 | .90 | .75 | .89 | .51 | .87 | .57 |

(a) WASHINGTON; BASIC  (b) LOS ANGELES; BASIC (MAY 7, 8, 9)  (c) LOS ANGELES; WHISPER/SHOUT (MAY 7, 8, 9)

**FIGURE 2-9**
**ASSOCIATION DATA**

This is especially so in the region 0 to 5000 ft above the BCAS aircraft. There the performance dropped from 97% to 88%. At present, the cause of this reduction is not known.

Performance between 6 and 10 nmi is also worse, comparing Los Angeles to Washington. This is caused by a combination of more garble in Los Angeles and the reduction in overall power used in Los Angeles from 2 kW to 630 Watts. Some anomalies also appear in the Whisper/Shout data; this is discussed further in Section 2.4.1.

Further detailed data is shown for reference in Appendix A.

### 2.2.2. False Alarms

The tracker algorithm used in BCAS forms tentative tracks on any set of replies or fruit that looks anything like a track. Then, as time goes on, these tentative tracks are purged when they do not continue to behave as a reasonable aircraft track. Similarly, altitude "corrections" are made quite readily, and these corrections are purged after 10 seconds if they do not correlate better than the original track. The theory is that the "phantom" tracks will not live long enough to become established, which occurs after 25 to 30 seconds; or that phantom altitude corrections will not correlate better than the original altitude. Sometimes these expectations are not met and a phantom track is declared established and is sent on to the threat detector. Usually, the phantom is at the same range as a real track and is caused by difficulties in degarbling the altitude data. A phantom track is a BCAS track that had no corresponding ARTS track.

To obtain some assessment of the false alarm rate, we took each track that had a minimun TAU of less than 35 seconds and that was within an altitude of 5000 ft (at that time) of the BCAS aircraft and displayed the count, Figure 2-10. Since the actual alarm volume (Reference 7) is considerably smaller than this, we proceeded to count the numbers of false alarms that would be generated. The result was 8 false alarms in Los Angeles (4 positive and 4 negative). One of these positive alarms was found to be caused by a "stuck bit" in that aircraft's altitude encoder. Not counting the false alarm from this defective encoder gives a rate of 7 alarms in 4.23 hours, or 1.7 alarms/hour for the test-bed BCAS in Los Angeles. The tracks giving rise to false alarms are indicated by an asterisk in Figure 2-10.

Similar data for the less dense Washington area showed 1 false alarm in 1-1/4 hours of data*. This phantom lasted 4 seconds. In fact, the alarm started when the track was on the 5th consecutive coast and stopped after the track was purged. Since there was only one rather shaky false alarm, a more accurate estimate of the false alarm rate can be made by counting the total number of phantoms in Figure 2-10(a) and comparing it to the Los Angeles data. Thus in Figure 2-10(b) there were 45 phantoms and 7 false alarms (not counting the aircraft with the "stuck bit"), therefore the 5 phantoms in Washington would imply .8 false alarms in the 1-1/4 hours of the test, or about .6 false alarms/hour. This is not too different from the estimate obtained by just counting the false alarms directly.

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* This false alarm was discovered after going back through the Washington data; it had been missed when Reference 3 was written.

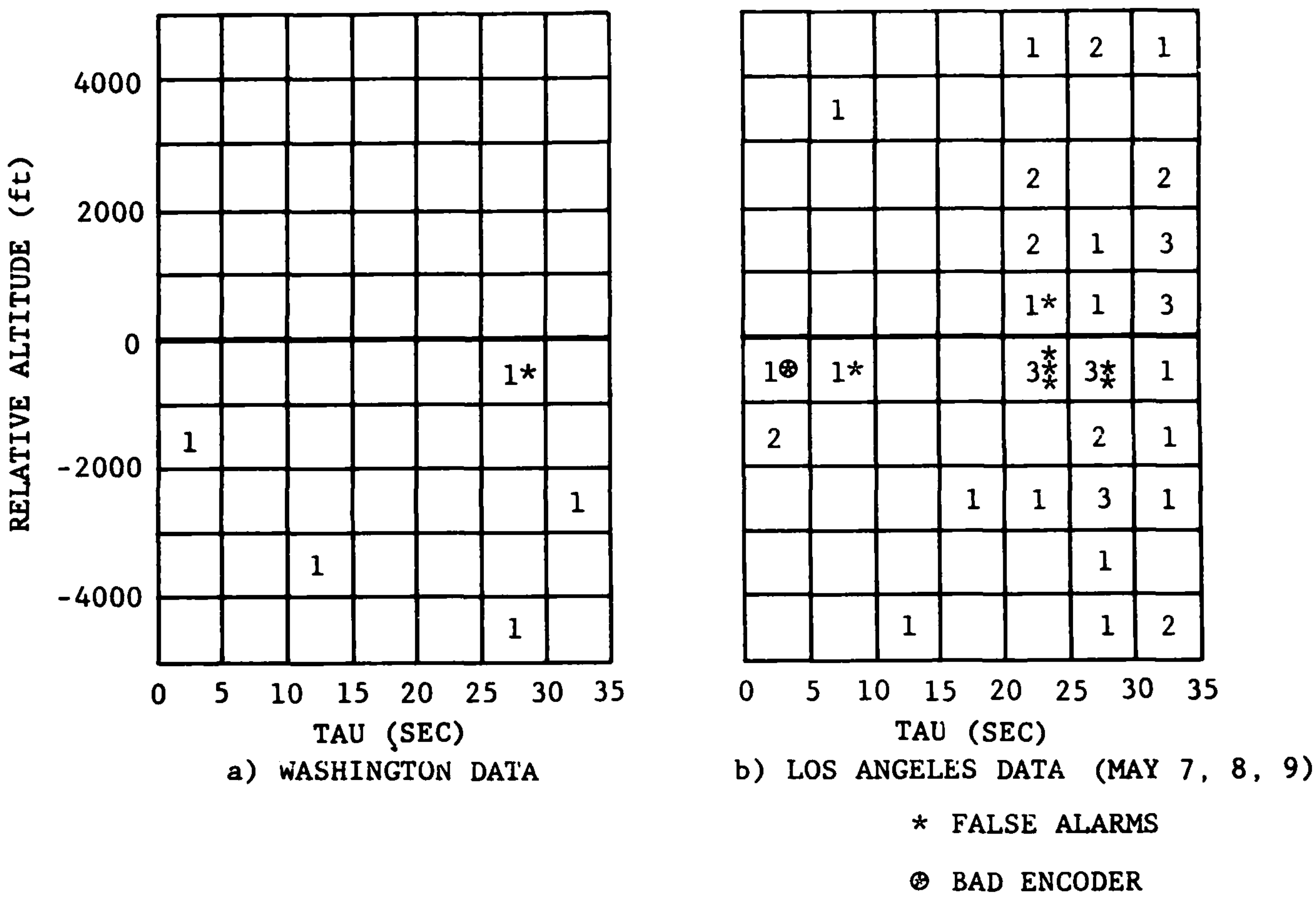



**FIGURE 2-10**
**ALTITUDE AT MINIMUM TAU FOR PHANTOM TRACKS**

In Figure 2-11 the false alarms are shown plotted against the average density of transponder equipped aircraft. The values of average density were developed from BCAS data, which provides the average density of aircraft having both transponders and encoders; this was modified by data produced by M.I.T. Lincoln Laboratory (Reference 10) to account for the fraction of transponders without altitude encoders. (These factors were as follows: in Los Angeles 48% of transponders had encoders; in Washington 72% of transponders had encoders.) Noting that the resultant curve has a large linear component may imply that multipath garble is the major cause of false alarms, rather than other forms of garble, which would be expected to cause a quadratic variation.

Looking more closely at the tracks that caused alarms, both real and false, a significant difference is apparent. At the onset of the alarm, the confidence level (the ratio of replies to interrogations) was found to be consistently higher for real tracks than for phantom tracks. Discounting the alarm caused by the faulty encoder in the Los Angeles data, all but one false alarm in Los Angeles and the only one in Washington were below 75% confidence. There were 4 real alarms in the Los Angeles data (an aircraft penetrated the threat volume); all of these had higher than 75% confidence. If the requirement of at least 75% confidence were imposed before a track would be used in the threat detector, then the curve of Figure 2-11 would more nearly resemble the dashed line, giving an estimated rate of about 1 alarm in 7 hours of flying in the Washington TCA environment, and about 1 alarm in 11 hours in a reference density of .02 aircraft per square nmi. As can be seen, the amount of data is quite small; more needs to be collected.

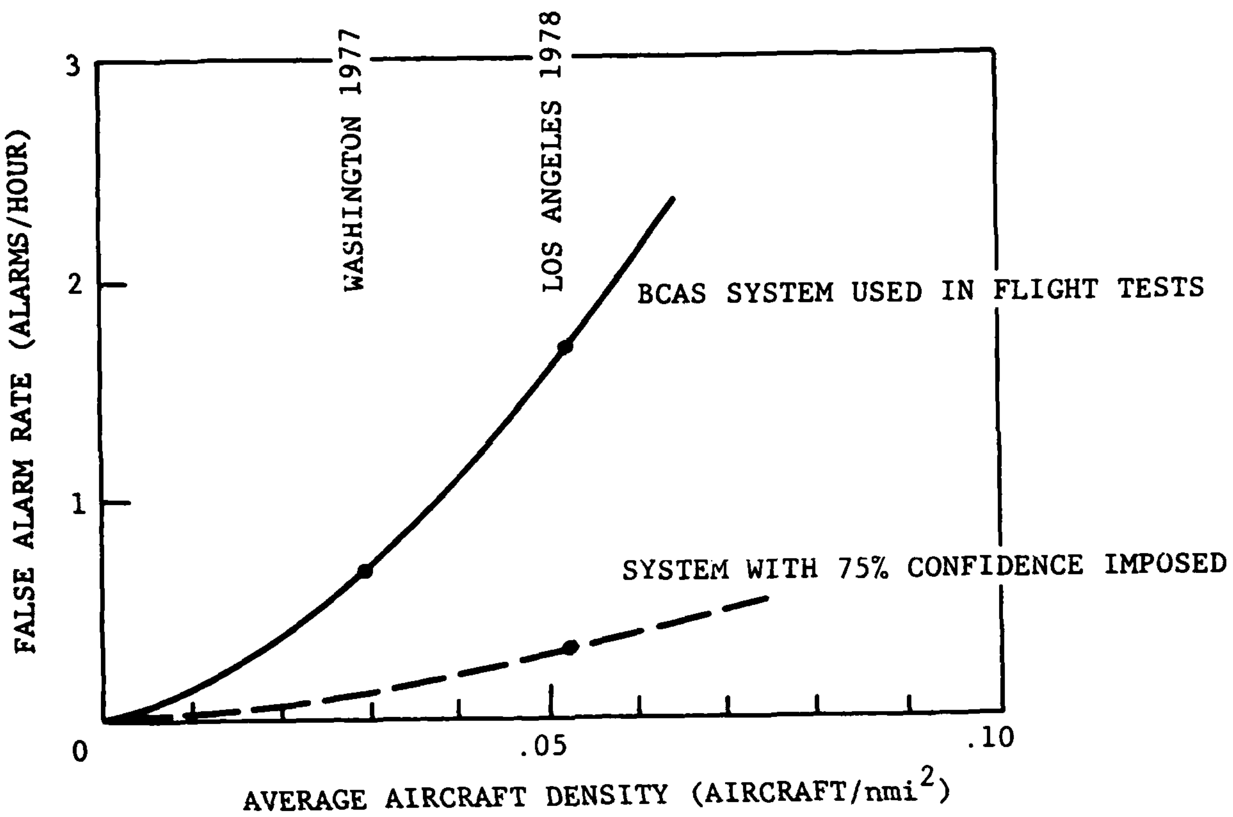



**FIGURE 2-11**
**FALSE ALARM RATE VS. AIRCRAFT DENSITY**

### 2.3 Factors Causing Degradation of BCAS Performance

There are a number of unavoidable factors which are detrimental to BCAS performance. These are the givens of the system design. In this section we try to give specific information on how detrimental each factor is.

#### 2.3.1 Garble

Garble is the primary enemy of the ATCRBS mode. A complicated tracking algorithm and the Whisper/Shout interrogation technique were developed just to fight garble. Therefore, a great deal of data was collected to see how well BCAS performs in various levels of garble. An accounting procedure was set up so that tracking with various levels of synchronous garble could be segregated. Figure 2-12 shows the fraction of aircraft seen by ARTS that were also tracked by BCAS, (called association) as a function of the number of overlapping tracks, as determined by the ARTS data. For the basic BCAS, the fraction starts at 71% for no overlaps (it is this low because it includes all aircraft as far out as 10 nmi and all altitudes), and rapidly falls off. The data for Whisper/Shout starts at 67% but degrades much less rapidly.

We also displayed the fraction of BCAS tracks which were correlated, as opposed to coasted, as a function of the number of overlaps, determined by ARTS data. These are shown in Figure 2-13, in this case we see that there is a negligible gain by Whisper/Shout, at most a few percentage points.

From these figures we see that garble does drive the performance down and that Whisper/Shout does help increase the percentage of aircraft tracked (but apparently not the correlation of individual tracks); however, garble is not the major problem in the region of interest. The same conclusion was drawn from the

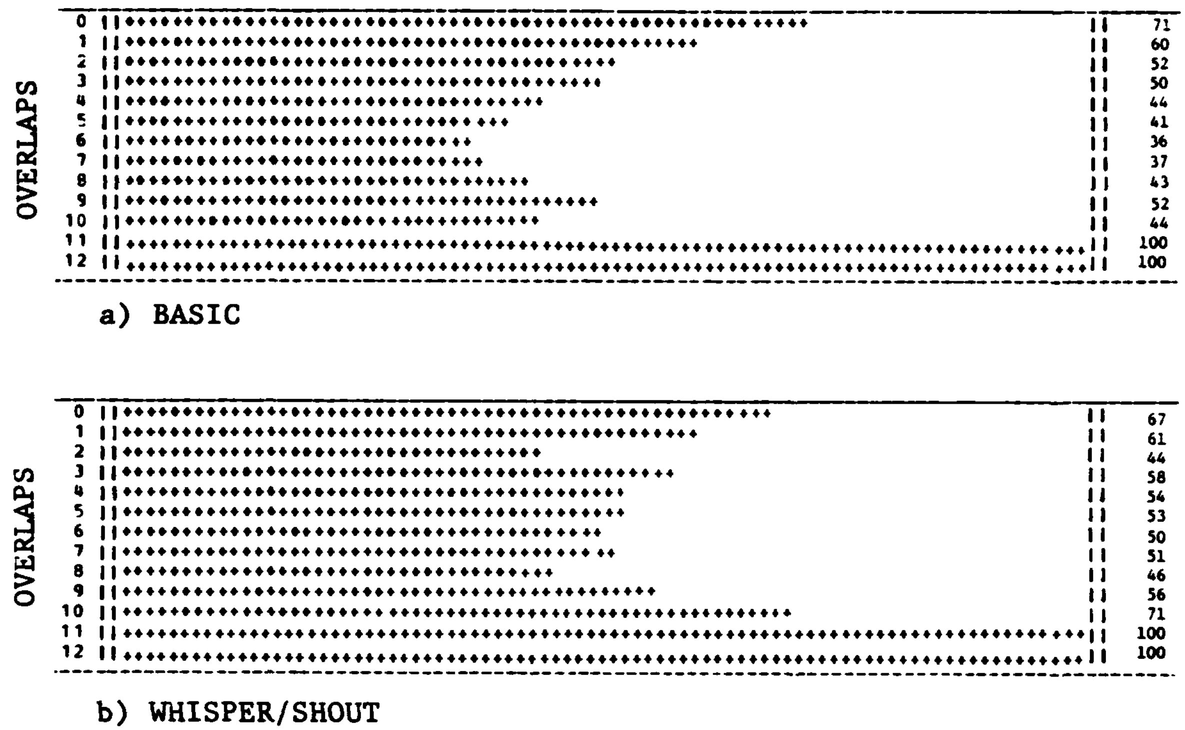
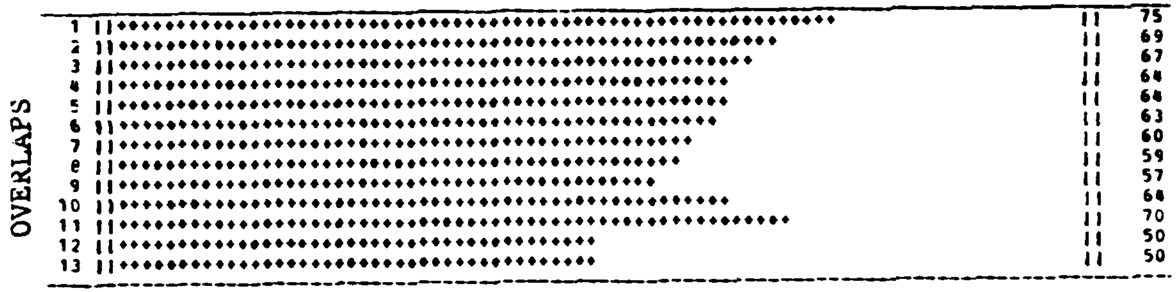
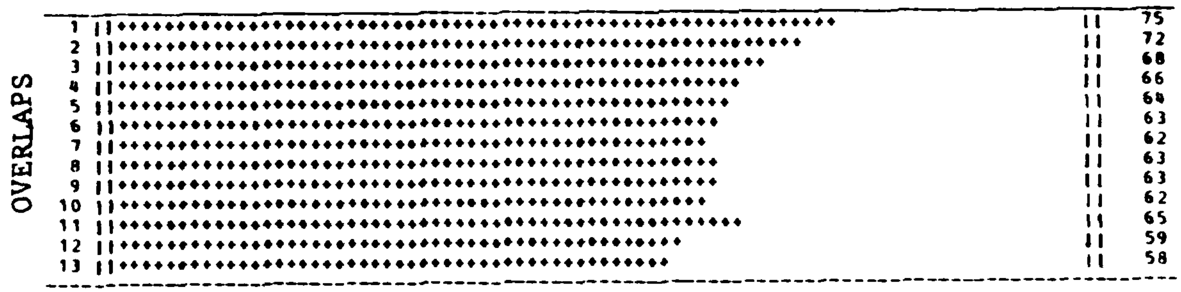



**FIGURE 2-12**
**RATIO OF SAMPLES OF ARTS TRACKS ASSOCIATED WITH BCAS TRACKS (MAY 7, 8, 9)**




a) BASIC




b)WHISPER/SHOUT

FIGURE 2-13
CORRELATION CHARACTERISTICS OF ASSOCIATED BCAS TRACKS (MAY 7, 8, 9)

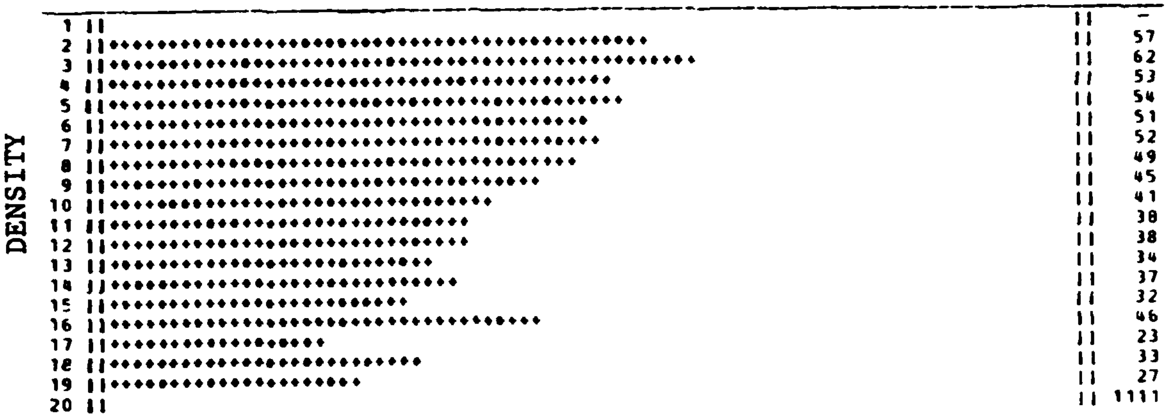
Washington data. This is apparent because the tracks with no overlaps do not correlate very well (75%), and when ARTS identifies such aircraft, BCAS tracks them only 71% of the time.

Reviewing the data in detail revealed two other factors. First, when a reply is in the clear this fact is known, and advantage could be taken of that fact. For example, the "stuck bit" phantom track was not garbled, yet all of the tentative tracks and start-up procedures were applied at each jump in apparent altitude. This obviously is an opportunity for improvement. A second observation is that utilizing the altitude rate data available when starting a new track would in many cases provide a quicker startup. The present algorithm assumes level flight until the tracker develops its own altitude rate estimate.

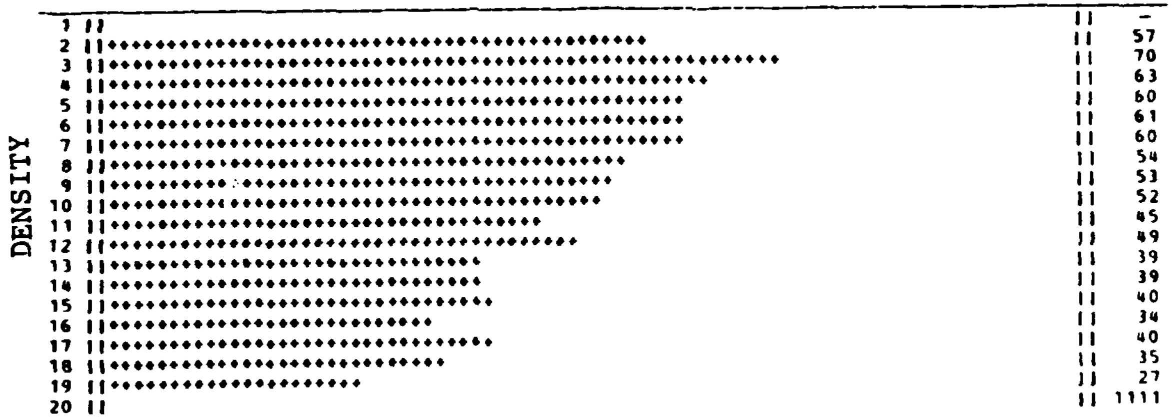
### 2.3.2 Density

As was true for overlaps, the data was segregated for various aircraft densities, where the density was defined to be the number of Mode C replying aircraft within 10 nmi of the BCAS aircraft (including BCAS aircraft), as determined by the ARTS data. Figure 2-14 shows percent association as a function of density. We see that the best performance was at a density of 3, but the data is very sparse for density of 2. As the density increases the performance decreases, but not as sharply as with overlaps. Thus the decrease could be caused by the accompanying increase in overlaps with increasing density, but definitely not by limited processing time, because this data was processed in non-real time with the computer allowed to take as long as it needed.

Figure 2-15 shows the percent correlation vs. density, and this performance is even less affected by density.




a) BASIC




b) WHISPER/SHOUT

DENSITY = THE NUMBER OF AIRCRAFT WITHIN 10 NMI, INCLUDING BCAS

**FIGURE 2-14**
**ARTS ASSOCIATION VS. AIRCRAFT DENSITY**
**(MAY 7, 8, 9)**

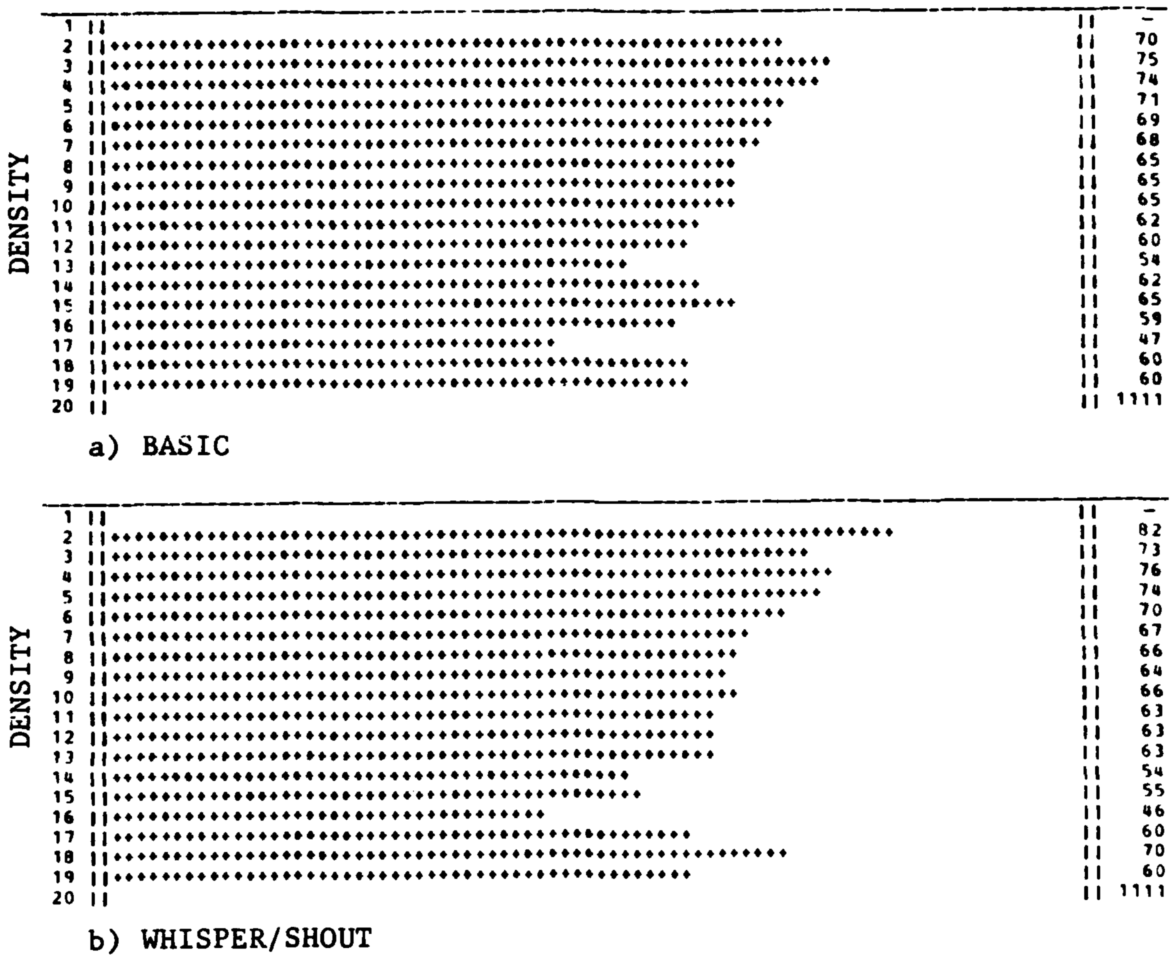



**FIGURE 2-15**
**BCAS TRACK CORRELATION VS. DENSITY (MAY 7, 8, 9)**

### 2.3.3 Shielding

During the flight tests at NAFEC and Washington it was recognized that there was a gap in coverage directly below the BCAS aircraft, caused by the use of bottom mounted transponder antennas on all ATCRBS equipped aircraft. The BCAS equipped aircraft used both top and bottom antennas for interrogations so that the shielding by the BCAS aircraft itself is minimized, but nothing can be done about the shielding by the target aircraft. This shielding is offset when both aircraft are BCAS equipped, because the DABS transponder (either as part of the BCAS or in conjunction with it) includes diversity reception from top and bottom antennas (Reference 8), thereby eliminating shielding when seen from above. Even without diversity at least one of the two BCAS aircraft would have a good, unshielded link.

Flight tests previously run at NAFEC (Reference 3) showed that when aircraft are within 2000 ft of each other, the effects of shielding are minimal. Thus, allowing 10 seconds for track acquisition, 25 seconds of warning would be given for aircraft closing at 3400 ft/min.

A brief assessment was made of the contribution of the bottom antenna. For May 7, the data was reduced (after the flight) first using replies from both antennas and then using replies from the top antenna only. The association characteristics are shown in Figure 2-16. The principal result is that removing the bottom antenna greatly decreases the association for aircraft below the BCAS aircraft--70% decreases to 52%. From this it appears that the lower antenna produces an effective contribution.

RANGE (nmi)

| RELATIVE ALTITUDE (k ft) | (a) 0-5 | (a) 6-10 | (b) 0-5 | (b) 6-10 |
|---|---|---|---|---|
| > 5 | - | .71 | - | .79 |
| 0 TO 5 | .83 | .59 | .86 | .63 |
| 0 TO -5 | .52 | .30 | .70 | .44 |
| < -5 | .19 | .28 | .49 | .47 |

| RELATIVE ALTITUDE (k ft) | (a) 0-5 | (a) 6-10 | (b) 0-5 | (b) 6-10 |
|---|---|---|---|---|
| 0 TO 1 | .86 | .37 | .96 | .49 |
| 0 TO -1 | .82 | .31 | .89 | .38 |

(a) TOP ANTENNA ONLY (b) TOP AND BOTTOM ANTENNAS

**FIGURE 2-16**
**EFFECT OF BCAS ANTENNAS ON ASSOCIATION**

Prior to going to Los Angeles a special set of flights were flown using the BCAS test bed in one aircraft and the Airborne Measurement Facility developed by M.I.T. Lincoln Laboratory in the other aircraft. This enabled reply-by-reply measurements to be made and the shielding/multipath question to be explored in depth. The results were presented in Reference 9 and gave a quantitative understanding to the phenomena of shielding and multipath.

### 2.3.4 Multipath

Multipath (reflections from the ground) affects BCAS in two ways. On the interrogation link, the BCAS Mode C interrogations may be converted to look like suppressions or like Mode A interrogations. In either of these cases the reply is not usable, although the tracker could have been modified to use the Mode A replies. On the reply path, multipath tends to generate extra garble. Both these problems are reduced by using the top antenna on the BCAS aircraft, which does not illuminate the ground as much as the lower, and (where possible) by using a top and bottom diversity on the target aircraft.

In its present configuration, the ATCRBS portion of BCAS was found to drop tracks momentarily at appropriate ranges over reflective ground due to mode conversion, as discussed in Reference 3. The additional garble on the return, when the reflection is specular, produces extra target tracks at a longer range; this impacts the performance when very near an airport, as will be discussed in Section 2.3.6. On the other hand, when the reflection is diffuse, yet strong, the multipath signal is greatly spread out in time and could cause many false 1's to appear in the reply. This characteristic, together with the effect of shielding, is a possible explanation for the poor correlation and association when aircraft are otherwise designated to be "in the clear."

### 2.3.5 FAA Transponders vs. Uncontrolled Transponders

All of the one-on-one data presented in this report was obtained by using FAA aircraft equipped with either DABS transponders, or calibrated ATCRBS transponders, while the target of opportunity data was taken with a sample of uncontrolled transponders. The difference is that the FAA transponders were tested regularly and therefore guaranteed to be in proper working order whenever data was collected.

In the case of the uncontrolled transponder population, there was no way to examine the transponders, and a certain number may not have met ATCRBS performance specifications even though they were tracked by ARTS III. As an example of this, in Section 2.2.2 we mentioned a particular false alarm that was determined, after carefully examining the ARTS data, to be the fault of a defective altitude encoder, which had one of the higher order bits "stuck" in one position.

The best direct comparison of performance of the controlled transponder vs. the uncontrolled transponders is a comparison of the basic ATCRBS performance against the target FAA aircraft and against all aircraft within 1000 ft altitude of the BCAS aircraft. For ranges less than 2 nmi or greater than 5 nmi, there was not much distinction between the two sets of aircraft. However between 2 and 5 nmi, tracking of the FAA aircraft was consistently better than for targets of opportunity. It is not clear why these differences exist and why they appear to be dependent on range.

### 2.3.6 Airports

Flying BCAS near airports tends to produce what is called a track bloom--a condition whereby many new phantom tracks are suddenly generated at nearly the same range. This occurs because stationary aircraft generate an unchanging garble pattern which allows the phantoms to become established. Several aircraft sitting on the ground can produce this effect, or a single aircraft and its reflection from a building can have the same effect. The phantom tracks caused by this garble do not die out as fast as those caused by moving aircraft because the only change in the garble pattern is that caused by the motion of the BCAS aircraft itself.

The ability of these track blooms to generate false alarms was discussed in Reference 3, and was found to be important only when the BCAS was within about one mile of the airport, such as when landing or when flying directly over it. An examination of the phantom tracks from the Los Angeles flight tests showed that track blooms existed about 10% of the time, were of short duration and did not destroy the other established tracks. The other aspect of track blooms that is of concern is the computer overloading that it may introduce. This was a factor in the design of the tracking algorithm. This algorithm provides the property of gradual degradation noted previously.

## 2.4 Parameters Affecting Performance

### 2.4.1 Whisper/Shout

Whisper/Shout was introduced to reduce the amount of garble by reducing the number of aircraft replying to each of the power levels. Table 2-1 shows how the replies were divided among the 8 levels over the 3 days of data, May 7, 8, 9. These numbers were fairly consistent throughout the three days. Only the

TABLE 2-1

PERCENT OF AIRCRAFT REPLYING TO WHISPER/SHOUT LEVELS

| | |
|---|---|
| Top Antenna Only | 100 |
| Bottom Antenna | 212.3 |
| Level 1 | 0.0 |
| Level 2 | 2.0 |
| Level 3 | 3.8 |
| Level 4 | 9.0 |
| Level 5 | 12.4 |
| Level 6 | 26.0 |
| Level 7 | 23.9 |
| Level 8 | 45.2 |
| Sum of 1-8 | 122.2 |

Notes: 1. Only replies between 5 nmi and 10 nmi were used.
2. Fruit was measured and subtracted by using Mode D interrogations on the top and bottom antennas.
3. Data represents totals from May 7, 8, 9 1978.

replies between 5 and 10 nmi were used in Table 2-1 because those were the aircraft that most needed garble improvement. It can be noted that some of the 8 levels are ineffective.

The objective of Whisper/Shout is to divide the population of responding aircraft into non-garbling sensitivity bands. The best that is possible is to have 1/8 of the aircraft reply in each band. Such a perfect splitting is not possible for two reasons. The sensitivity bands intentionally overlap by 1 dB to reduce the possibility that an aircraft falls in between bands and does not reply at all, and random variations in the target population sensitivity will cause the number of aircraft responding in each band to vary.

In the earlier tests in the Washington area we found that the best distribution that could be obtained by adjusting the 8 levels resulted in the most populous band containing 25% of the total population. Thus, some improvement could be obtained beyond that used in Los Angeles, but not a lot.

The overall changes brought about by the use of Whisper/Shout were shown in Figure 2-9 (page 2-12). It is seen that Whisper/Shout does nothing for performance within 5 nmi, in fact there is an unexplained loss, especially at higher altitudes. Beyond 5 nmi there is usually a small gain in Whisper/Shout performance as compared to the basic BCAS, but, again, there is an unexplained loss for the high altitudes.

A possible side benefit of Whisper/Shout is that it gives some targets more than one chance to reply, which could overcome low reply probability. Apparently this is not happening, because the percent correlation in the clear is no higher with Whisper/Shout, as was seen in Figure 2-13 (page 2-20).

The principal used in Whisper/Shout to break up garble has no effect on fruit received by BCAS, because fruit is the result of other interrogations. Consequently, the fruit rate in each of the sensitivity bands remains the same, and when the eight sets of replies are summed, the effective fruit rate is eight times that of Basic BCAS. This extra fruit for Whisper/Shout could have two effects; the performance in the presence of no garble may be worse for Whisper/Shout, and the phantom rate may be higher. From Figure 2-12 we saw that the performance in the absence of overlap is essentially unchanged. Therefore, the extra fruit has a negligible impact on the tracking capability. However, from Table 2-2, we see that the phantom track rate is increased by about 12% within 5 nmi.

The tradeoff on Whisper/Shout then is a questionable change in performance at the cost of a slight increase in phantom tracks. Thus, unless garble is a limiting factor (and it is not, for the Basic mode even in Los Angeles today) Whisper/Shout configured to reduced garble should be avoided.

There is a configuration of Whisper/Shout, however, which may reduce the effects of multipath--this format, proposed by M.I.T. Lincoln Laboratory, should be explored.

### 2.4.2 Power Level

On May 10 the data was collected for 4 runs with the normal power and 4 runs with the power decreased by 3 dB. One obvious result of the power decrease was a less even distribution of replies over the 8 Whisper/Shout interrogations. Figure 2-17 shows a summary of performance with a change of power of 3 dB.

TABLE 2-2

AVERAGE NUMBER OF PHANTOM TRACKS PER SCAN FOR
BASIC AND WHISPER/SHOUT (MAY 7, 8, 9)

| Range | Basic | Whisper/Shout |
|---|---|---|
| 0 - 5 nmi | .57 | .64 |
| 0 - 10 nmi | 2.21 | 2.78 |

Note: Only a small fraction of the phantom tracks become false alarms because most are outside the threat region.

RANGE (nmi)

| RELATIVE ALTITUDE (k ft) | (a) BASIC 0-5 | (a) BASIC 6-10 | (b) WHISPER/SHOUT 0-5 | (b) WHISPER/SHOUT 6-10 | (c) BASIC 0-5 | (c) BASIC 6-10 | (d) WHISPER/SHOUT 0-5 | (d) WHISPER/SHOUT 6-10 |
|---|---|---|---|---|---|---|---|---|
| > 5 | 100 | 90 | 100 | 91 | 100 | 96 | 100 | 96 |
| 0 TO 5 | 89 | 81 | 89 | 82 | 82 | 81 | 83 | 80 |
| 0 TO -5 | 69 | 56 | 69 | 57 | 52 | 60 | 52 | 59 |
| < -5 | 43 | 48 | 42 | 48 | 61 | 52 | 62 | 53 |
| 0 TO 1 | 96 | 73 | 96 | 78 | 83 | 74 | 83 | 74 |
| 0 TO -1 | 100 | 74 | 100 | 74 | 85 | 36 | 85 | 36 |

(a) BASIC, (b) WHISPER/SHOUT: 630 WATTS

(c) BASIC, (d) WHISPER/SHOUT: 315 WATTS

**FIGURE 2-17**
**ASSOCIATION DATA VS. POWER LEVEL FOR 10 MAY 1978**

We see that for both normal and Whisper/Shout there is usually an improvement in association within 5 nmi for the higher power. However, for moderate ranges (beyond 5 nmi), the increase in power actually appears to degrade the performance. It is difficult to blame this degradation on changes in the traffic between the two parts of the test, because the density and overlap distributions are comparable. One possible explanation is that the higher power elicits more replies at these moderate ranges, causing more synchronous garble, which in turn may overload the track file and degrade performance. The performance at close range, where the garble is much less and where an overloaded track file has less effect would improve somewhat because of the increased link reliability except possibly at low depression angles below the BCAS aircraft. It thus appears that a transmitter power of about 630 Watts, or in the range of 500 W to 1 kW is required.

It is interesting to note, also, that Whisper/Shout showed neither much benefit nor much degradation in this set of runs, confirming the conclusion of the preceding section.

### 2.4.3 Resuppression on Top Antenna

As shown in Reference 3, the suppression on the top antenna immediately before interrogation on the lower antenna may result in some targets not replying at all. For this reason, the suppression was removed for all Los Angeles flight tests except May 10 and 11. The effect of the suppression on performance was judged to be minimal. There was no improvement over the net of 75% of aircraft tracked in Washington even at very close ranges. Since the purpose of this suppression was to reduce the garble seen by the lower antenna, it should be retained.

### 2.4.4 Computer Loading

Up to this point we have seen the performance summary when the computer has sufficient time to complete its task. When it is forced to run in real time (one second to complete one second of tracking) the performance can degrade considerably in high density traffic. It was found on May 11 that a 15% to 20% loss in association occurred when run in real-time as compared to non-real-time. This is the result of trading off between computer resources and traffic load. Improvements are available, if needed, for increasing the efficiency of the operating code and for choosing the best memory size (next section).

The real time data obtained in the February flights, where only 1/2 of the computer was dedicated to ATCRBS would be expected to be even more degraded. Surprisingly it was better, even with approximately the same traffic density. This does not indicate that less computer is better, but that the 2 kW of power used in February more than made up for loss of computer resources. In comparing the February data with May 11 (not presented in this report) it was concluded that the 2 kW interrogations of February made some improvement in performance within 5 nmi, and beyond 10 nmi the additional computer power, plus Whisper/Shout, is more beneficial than large interrogator power (more than doubling the percentage of aircraft that were tracked).

### 2.4.5 Track File Size

Increasing the track file size for ATCRBS will generally improve the performance. On the other hand, an increased track file size will cause an increase in computer time required to make one update, and the possibility of an increase in the number of phantoms. The former effect is straight-forward and is not evaluated in this report. In fact, for the February flights, the relationship was used to make more computer time available for the DABS mode by reducing the ATCRBS track file from 100 down to 50. Generally, the computer time required for an update grows linearily with track file size, when there is enough traffic to fully load the system. The question considered here is: how big a track file is needed to get a given level of performance in the Los Angeles environment.

The May 7 data was run using different sizes of track files; Figures 2-18 to 2-20 show the total number of active tracks for a maximum track file size of 75, 100, and 200. During the busy periods the track file is 80% full no matter how large it is, implying that tracks are being discarded because of overflow, even with a track file size of 200. Figures 2-21 to 2-23, which show the established tracks only, indicate that there is practically no difference in performance between 100 and 200 track files. The 75 track file curve shows that somewhat fewer tracks are established during busy periods than for the other cases.

The summary performance of the three cases is shown in Figure 2-24. We see that the performance is essentially the same, with perhaps a slight advantage for the 100 track system. Table 2-3 shows that the 75 track system will produce the fewest phantoms. Therefore the 75 track system seems to be the best overall performer.

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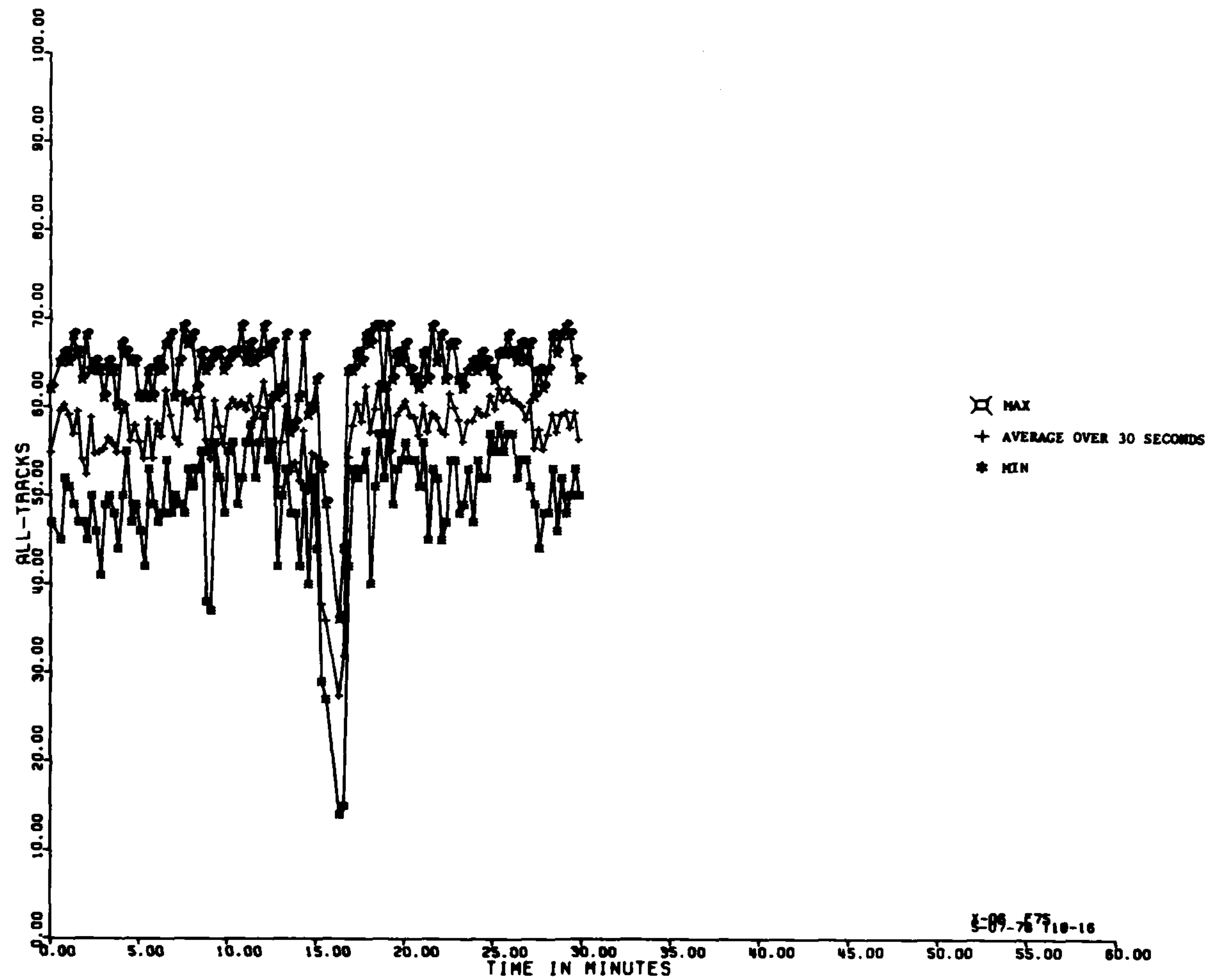



FIGURE 2-10
TRACK FILE VARIATIONS FOR A MAXIMUM TRACK
FILE SIZE OF 75 (MAY 7)

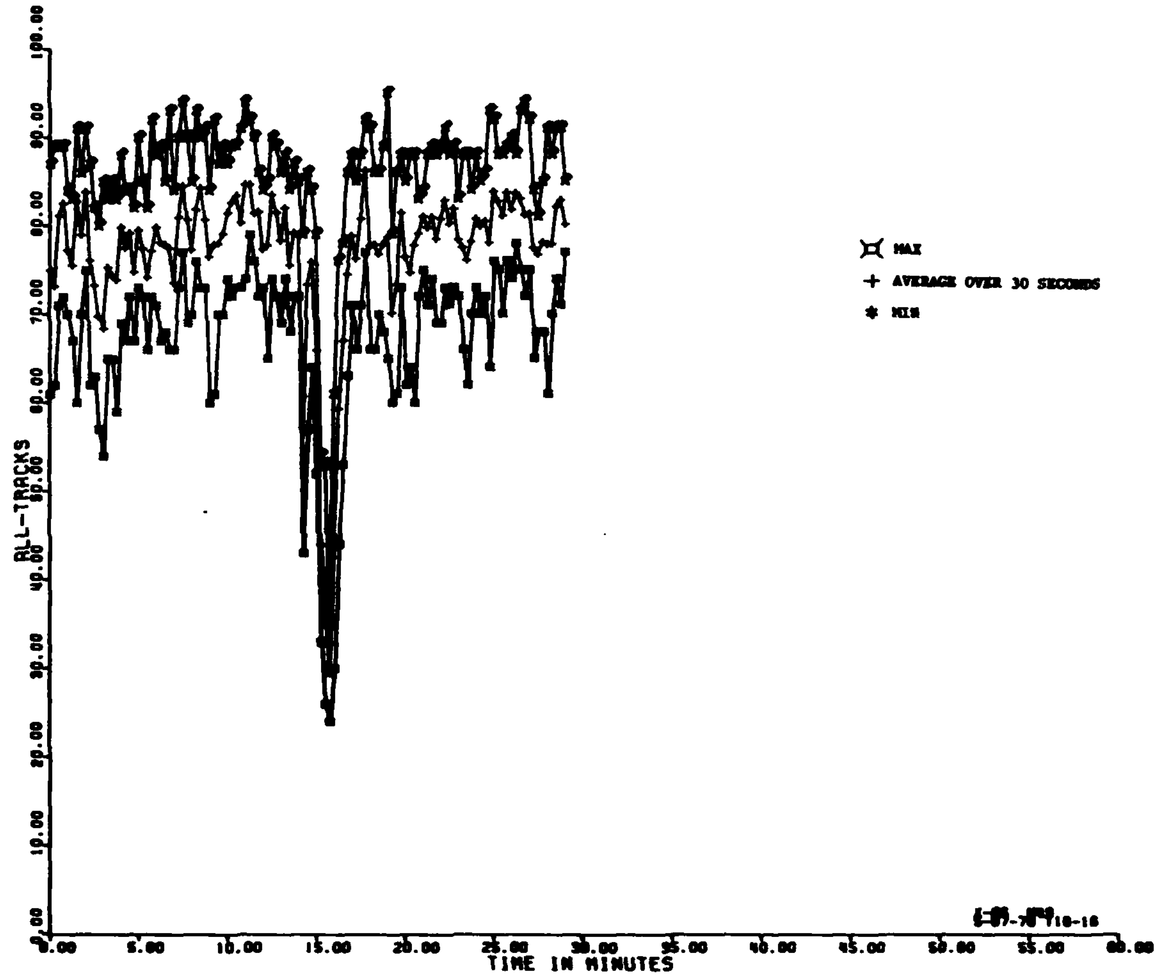



FIGURE 2-[illegible]
TRACK FILE [illegible] FOR A [illegible] TRACK
[illegible] OF [illegible])

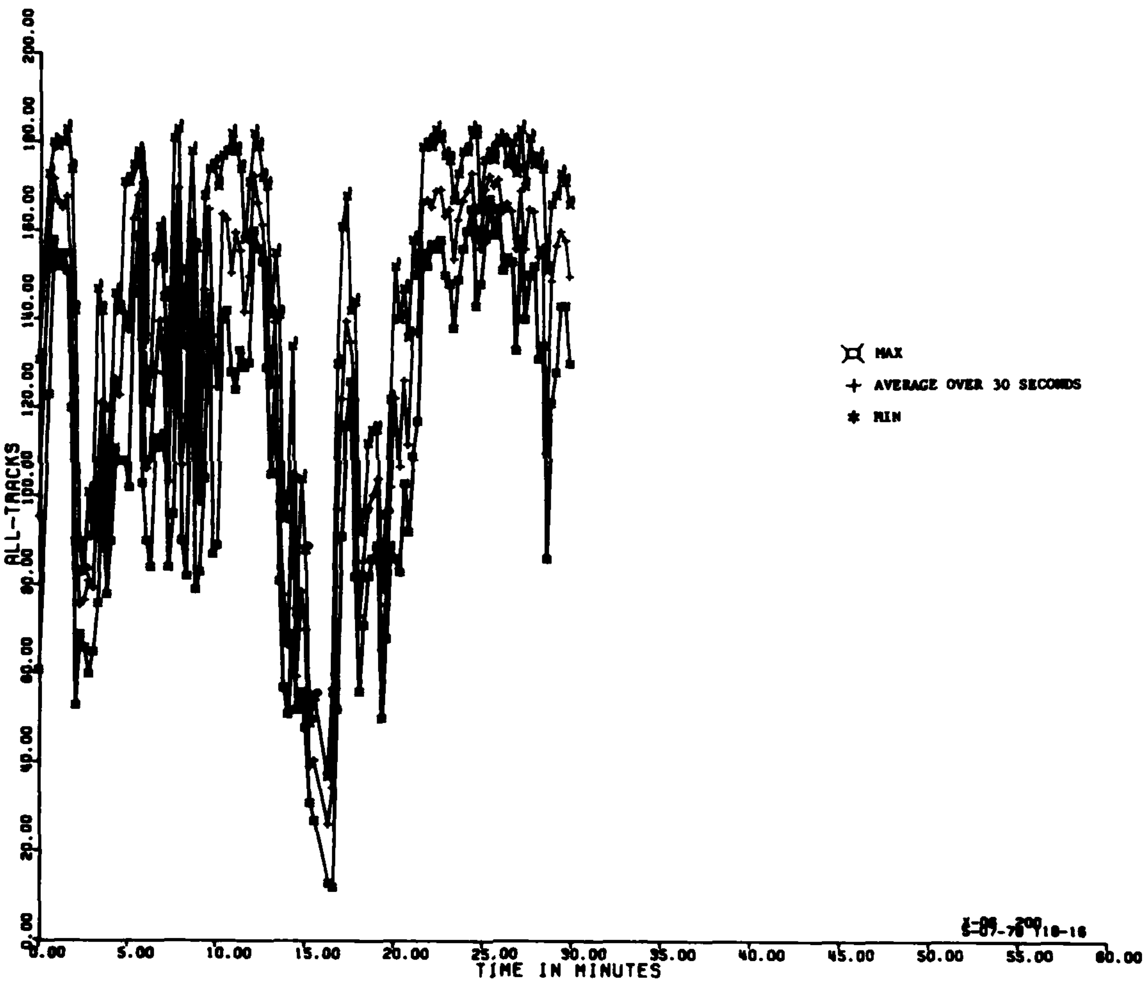



FIGURE 2-39
TRACK FILE VARIATIONS FOR A MAXIMUM TRACK
FILE SIZE OF 200 (MAY 7)

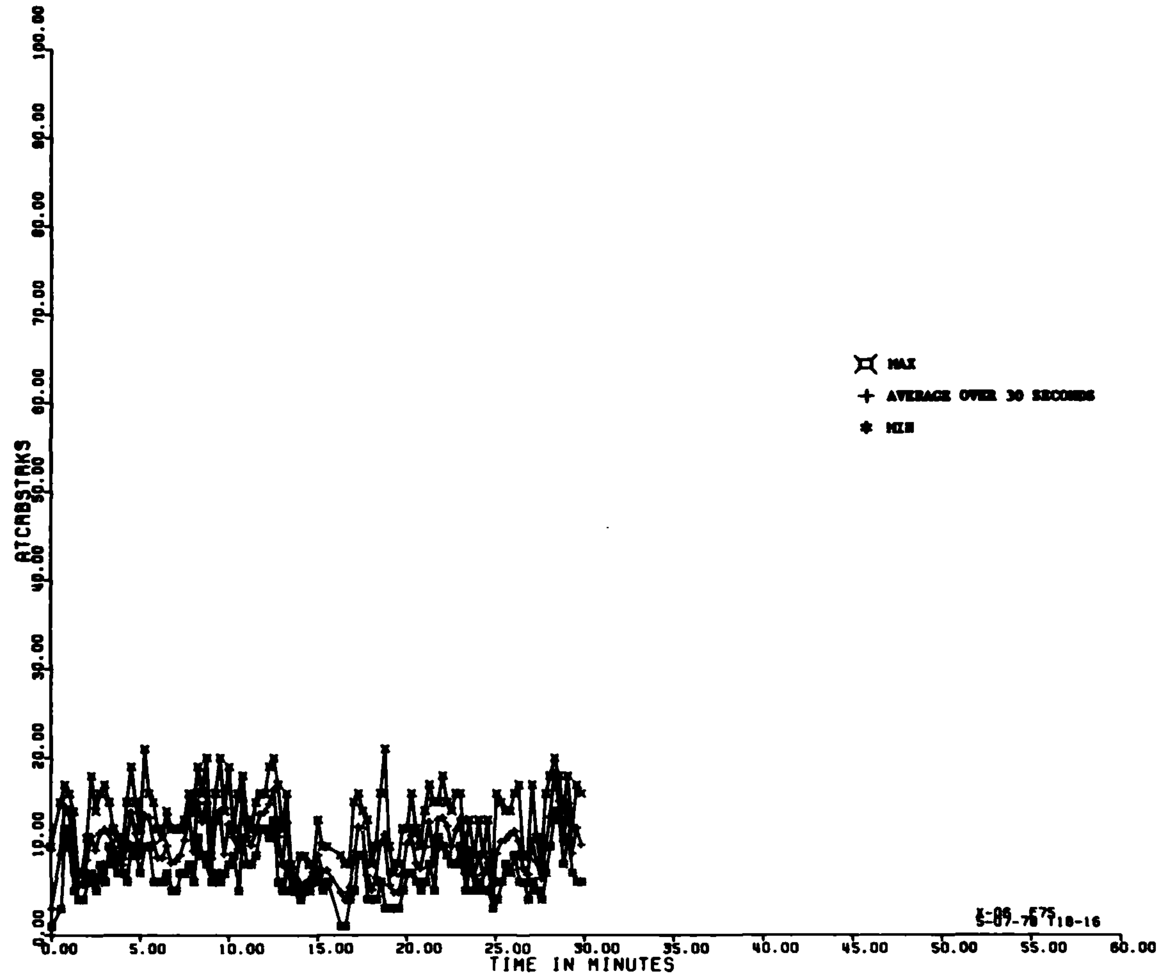



FIGURE 2-21
VARIATIONS IN NUMBER OF ESTABLISHED TRACKS
FOR A TRACK FILE SIZE OF 75

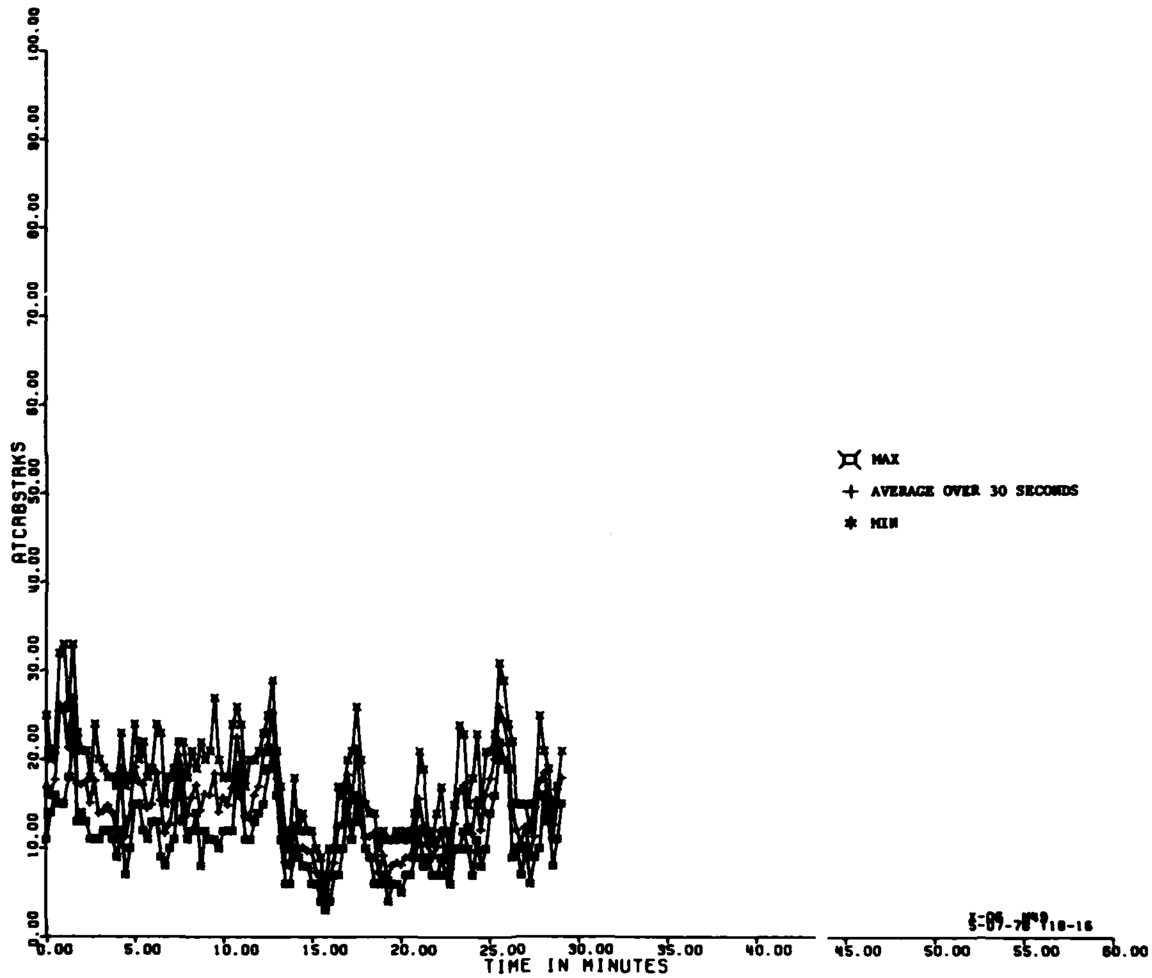



FIGURE 2-22
VARIATIONS IN NUMBER OF ESTABLISHED TRACKS
FOR A TRACK FILE SIZE OF 100

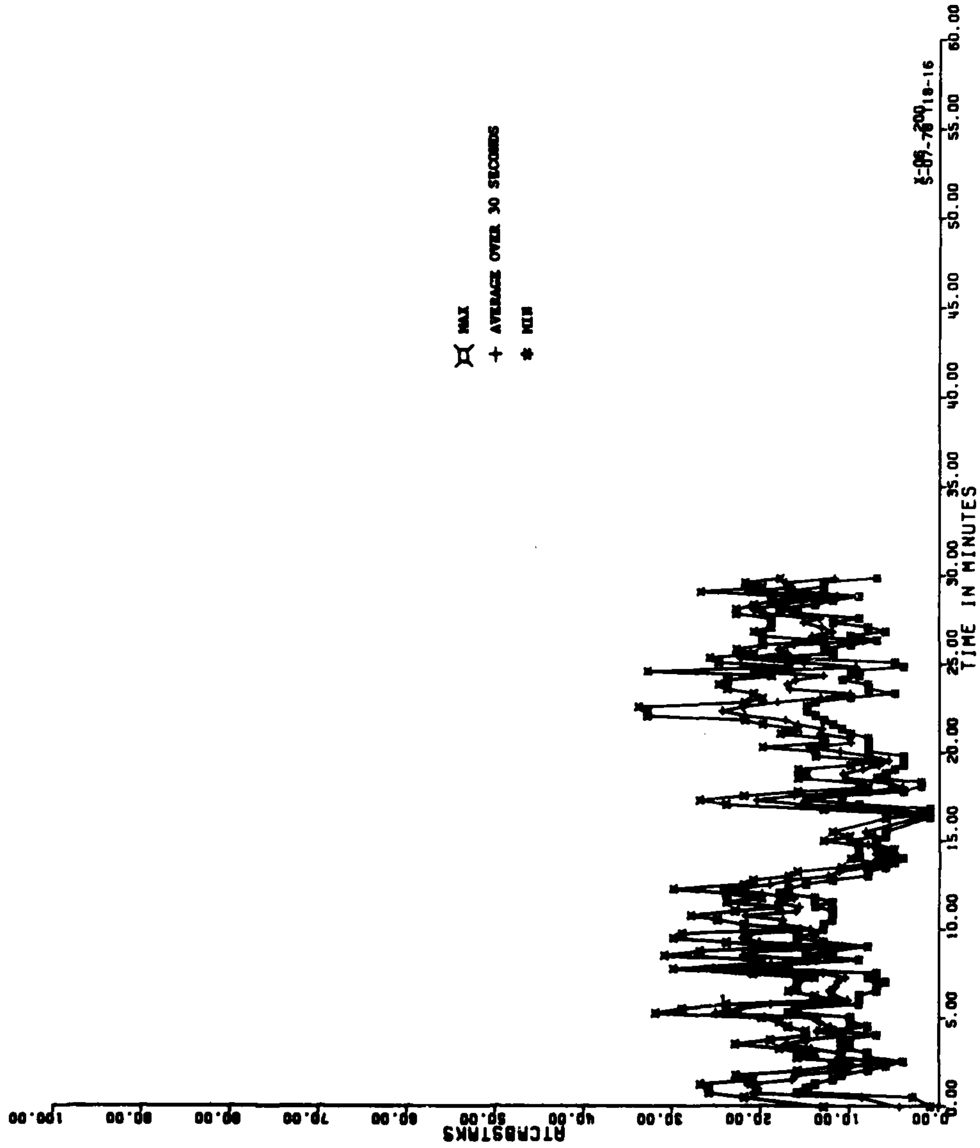



FIGURE 2-23
VARIATIONS IN NUMBER OF ESTABLISHED TRACKS
FOR A TRACK FILE SIZE OF 200

RANGE (nmi)

| RELATIVE ALTITUDE (k ft) | (a) 75 TRACKS 0-5 | (a) 75 TRACKS 6-10 | (b) 100 TRACKS 0-5 | (b) 100 TRACKS 6-10 | (c) 200 TRACKS 0-5 | (c) 200 TRACKS 6-10 |
|---|---|---|---|---|---|---|
| >5 | 100 | 75 | 100 | 79 | 100 | 75 |
| 0 TO 5 | 84 | 61 | 86 | 63 | 84 | 66 |
| 0 TO -5 | 69 | 40 | 70 | 44 | 66 | 46 |
| < -5 | 47 | 43 | 49 | 47 | 48 | 45 |
| 0 TO 1 | 92 | 40 | 96 | 49 | 93 | 50 |
| 0 TO -1 | 89 | 34 | 89 | 38 | 90 | 39 |

**FIGURE 2-24**
**ASSOCIATION DATA VS. TRACK FILE SIZE (MAY 7)**

TABLE 2-3

AVERAGE NUMBER OF PHANTOMS/SCAN
AS A FUNCTION OF TRACK FILE SIZE (MAY 7)

| | Phantom Rate | | |
|---|---|---|---|
| | Track File Size | | |
| Range | 75 | 100 | 200 |
| 0 - 5 nmi | .54 | .63 | .57 |
| 0 - 10 nmi | 1.87 | 2.25 | 2.48 |

# APPENDIX A

## DATA COLLECTED IN THE LOS ANGELES AREA FOR 1978 MAY 7, 8, 9

The following data is presented in substantially the same format as that for the earlier Washington tests, as reported in Reference 3. For convenience, that data and its accompanying explanation are presented as Appendix B of this report.

The differences between the Washington data and the Los Angeles data are as follows:

1. In Washington, the data base included targets as far as 20 miles from the BCAS aircraft. In Los Angeles, this maximum range was reduced to 12 nmi, and statistics were gathered on targets only as far as 10 nmi.

2. In Washington, BCAS tracks were declared to be established (and therefore usable for the CAS logic) if they had a minimum age of 10 seconds, which increased linearly with range to a maximum of 30 seconds at 20 nmi. In the present Los Angeles tests this was revised to be a flat minimum of 25 seconds.

It should be recalled (as noted in Reference 3) that while phantom tracks were removed from the association matrix data (Figures A-1 through A-10 of this Appendix), this is not so for the overlap and density histograms (Figures A-13 through A-17). Thus, there may appear to be some slight discrepencies if comparisons do not account for this factor.

### BASIC MODE

| RELATIVE ALTITUDE (FEET) | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ABOVE BCAS | 10000 | 0 | 0 | 0 | 2 | 7 | 3 | 1 | 4 | 0 | 3 | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 9500 | 0 | 5 | 19 | 23 | 10 | 12 | 5 | 12 | 19 | 29 | 6 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 9000 | 0 | 0 | 3 | 1 | 6 | 1 | 0 | 2 | 6 | 4 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 8500 | 0 | 0 | 3 | 0 | 0 | 4 | 4 | 7 | 5 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 8000 | 0 | 1 | 1 | 0 | 0 | 0 | 2 | 7 | 2 | 3 | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 7500 | 0 | 0 | 2 | 0 | 0 | 2 | 2 | 8 | 9 | 15 | 10 | 7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 7000 | 0 | 3 | 4 | 2 | 3 | 2 | 12 | 23 | 19 | 29 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 6500 | 0 | 1 | 3 | 5 | 2 | 6 | 18 | 20 | 19 | 18 | 1 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 6000 | 0 | 8 | 13 | 9 | 13 | 15 | 15 | 12 | 16 | 15 | 16 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 5500 | 0 | 1 | 1 | 2 | 16 | 27 | 13 | 6 | 17 | 20 | 9 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 5000 | 6 | 5 | 1 | 6 | 18 | 13 | 11 | 16 | 20 | 18 | 6 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 4500 | 4 | 3 | 8 | 12 | 8 | 13 | 20 | 30 | 28 | 20 | 5 | 15 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 4000 | 4 | 18 | 23 | 13 | 11 | 25 | 26 | 35 | 33 | 33 | 11 | 15 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 3500 | 3 | 16 | 25 | 18 | 19 | 21 | 27 | 43 | 41 | 37 | 30 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 3000 | 4 | 15 | 20 | 17 | 15 | 18 | 41 | 33 | 42 | 44 | 15 | 11 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 2500 | 2 | 6 | 17 | 17 | 13 | 17 | 68 | 29 | 43 | 28 | 6 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 2000 | 5 | 3 | 11 | 23 | 16 | 26 | 38 | 36 | 25 | 24 | 7 | 32 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 1500 | 0 | 4 | 11 | 32 | 23 | 22 | 17 | 21 | 26 | 37 | 12 | 13 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 1000 | 0 | 7 | 24 | 62 | 52 | 43 | 50 | 43 | 48 | 58 | 33 | 11 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 500 | 22 | 17 | 32 | 102 | 149 | 109 | 44 | 86 | 95 | 113 | 63 | 35 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| BCAS | | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | |
| BELOW BCAS | -500 | 6 | 9 | 22 | 28 | 53 | 33 | 58 | 47 | 81 | 49 | 26 | 26 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | -1000 | 9 | 18 | 12 | 12 | 35 | 21 | 54 | 29 | 53 | 63 | 24 | 21 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | -1500 | 8 | 14 | 24 | 20 | 26 | 55 | 56 | 43 | 85 | 54 | 36 | 17 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | -2000 | 1 | 7 | 21 | 41 | 38 | 71 | 68 | 53 | 59 | 72 | 24 | 27 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | -2500 | 4 | 27 | 26 | 38 | 68 | 97 | 138 | 139 | 140 | 162 | 23 | 22 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | -3000 | 9 | 40 | 73 | 125 | 85 | 92 | 152 | 170 | 191 | 246 | 123 | 124 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | -3500 | 17 | 23 | 54 | 87 | 100 | 106 | 152 | 235 | 261 | 304 | 136 | 132 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | -4000 | 10 | 44 | 90 | 159 | 170 | 213 | 244 | 251 | 297 | 268 | 89 | 89 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | -4500 | 1 | 14 | 55 | 149 | 191 | 225 | 207 | 207 | 237 | 209 | 72 | 77 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | -5000 | 9 | 42 | 81 | 108 | 190 | 233 | 241 | 281 | 232 | 271 | 99 | 80 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | -5500 | 7 | 37 | 80 | 98 | 178 | 227 | 214 | 237 | 215 | 188 | 75 | 82 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | -6000 | 0 | 62 | 145 | 204 | 236 | 215 | 294 | 283 | 299 | 373 | 82 | 102 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | -6500 | 0 | 56 | 114 | 168 | 204 | 226 | 288 | 350 | 345 | 397 | 119 | 88 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | -7000 | 0 | 122 | 202 | 187 | 185 | 253 | 237 | 267 | 241 | 327 | 132 | 168 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | -7500 | 0 | 1 | 0 | 0 | 6 | 5 | 9 | 10 | 17 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | -8000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | -8500 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | -9000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | -9500 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | -10000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | 131 | 629 | 1220 | 1770 | 2146 | 2451 | 2826 | 3075 | 3266 | 3535 | 1301 | 1236 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

RELATIVE RANGE (nmi)

**FIGURE A-1**
**TOTAL AIRCRAFT TRACK MATRIX (R VS. Z)**

BASIC MODE

| RANGE RATE (KNOTS) | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CLOSING -600 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| -570 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| -540 | 0 | 0 | 0 | 4 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| -510 | 0 | 0 | 2 | 2 | 0 | 0 | 2 | 1 | 5 | 3 | 2 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| -480 | 0 | 6 | 1 | 3 | 2 | 1 | 2 | 0 | 1 | 8 | 5 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| -450 | 0 | 2 | 6 | 7 | 3 | 3 | 3 | 6 | 9 | 22 | 8 | 9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| -420 | 0 | 6 | 10 | 10 | 17 | 21 | 8 | 22 | 35 | 24 | 2 | 8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| -390 | 1 | 3 | 12 | 15 | 34 | 41 | 57 | 66 | 66 | 73 | 20 | 36 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| -360 | 3 | 6 | 17 | 37 | 56 | 94 | 97 | 124 | 141 | 111 | 51 | 36 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| -330 | 1 | 9 | 30 | 58 | 121 | 127 | 134 | 120 | 90 | 98 | 38 | 31 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| -300 | 3 | 16 | 31 | 89 | 76 | 77 | 106 | 103 | 89 | 103 | 29 | 28 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| -270 | 3 | 24 | 61 | 65 | 84 | 79 | 76 | 94 | 92 | 105 | 25 | 24 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| -240 | 3 | 25 | 59 | 76 | 65 | 118 | 112 | 101 | 142 | 144 | 31 | 22 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| -210 | 4 | 39 | 56 | 79 | 104 | 95 | 93 | 131 | 111 | 148 | 27 | 26 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| -180 | 3 | 35 | 86 | 60 | 66 | 91 | 122 | 164 | 162 | 155 | 62 | 32 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| -150 | 6 | 56 | 70 | 61 | 101 | 110 | 151 | 107 | 147 | 203 | 62 | 64 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| -120 | 9 | 42 | 68 | 84 | 85 | 107 | 118 | 131 | 148 | 150 | 78 | 70 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| -90 | 15 | 34 | 68 | 100 | 124 | 130 | 148 | 121 | 190 | 188 | 90 | 60 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| -60 | 16 | 43 | 58 | 121 | 149 | 126 | 130 | 145 | 156 | 147 | 65 | 99 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| -30 | 25 | 43 | 57 | 123 | 106 | 118 | 91 | 144 | 130 | 170 | 82 | 101 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| BCAS | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | |
| SEPARATING 30 | 13 | 41 | 58 | 136 | 125 | 118 | 132 | 148 | 140 | 217 | 91 | 88 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 60 | 8 | 48 | 100 | 100 | 104 | 140 | 134 | 170 | 173 | 212 | 57 | 89 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 90 | 5 | 32 | 77 | 93 | 127 | 139 | 180 | 153 | 155 | 158 | 65 | 71 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 120 | 3 | 28 | 64 | 65 | 99 | 95 | 152 | 145 | 145 | 163 | 55 | 40 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 150 | 6 | 26 | 48 | 73 | 70 | 133 | 107 | 129 | 140 | 129 | 85 | 59 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 180 | 1 | 22 | 47 | 79 | 89 | 78 | 120 | 127 | 157 | 135 | 38 | 41 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 210 | 0 | 17 | 29 | 52 | 67 | 94 | 151 | 140 | 114 | 145 | 47 | 36 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 240 | 1 | 14 | 32 | 55 | 80 | 83 | 104 | 137 | 130 | 128 | 47 | 31 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 270 | 1 | 4 | 25 | 45 | 56 | 72 | 97 | 117 | 159 | 126 | 36 | 27 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 300 | 0 | 3 | 18 | 30 | 59 | 56 | 66 | 66 | 61 | 87 | 37 | 33 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 330 | 0 | 1 | 7 | 15 | 9 | 36 | 43 | 52 | 53 | 65 | 23 | 26 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 360 | 0 | 1 | 11 | 11 | 23 | 19 | 38 | 42 | 49 | 39 | 14 | 14 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 390 | 1 | 1 | 5 | 6 | 13 | 19 | 20 | 25 | 36 | 37 | 17 | 9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 420 | 0 | 1 | 2 | 9 | 11 | 12 | 13 | 17 | 15 | 17 | 3 | 7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 450 | 0 | 1 | 1 | 3 | 5 | 12 | 10 | 16 | 9 | 13 | 3 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 480 | 0 | 0 | 2 | 2 | 2 | 5 | 3 | 1 | 5 | 3 | 3 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 510 | 0 | 0 | 0 | 1 | 1 | 0 | 3 | 4 | 4 | 6 | 3 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 540 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 570 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 600 | 0 | 0 | 2 | 1 | 2 | 1 | 3 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | ===== | ===== | ===== | ===== | ===== | ===== | ===== | ===== | ===== | ===== | ===== | ===== | ===== | ===== | ===== | ===== | ===== | ===== | ===== | ===== |
| | 131 | 629 | 1220 | 1770 | 2146 | 2451 | 2826 | 3075 | 3266 | 3535 | 1301 | 1236 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

RELATIVE RANGE (nmi)

**FIGURE A-2**
**TOTAL AIRCRAFT TRACK MATRIX (R VS. R)**

BASIC MODE

| | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ABOVE BCAS | 10000 | 0 | 0 | 0 | 0 | 4 | 1 | 1 | 4 | 0 | 1 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 9500 | 0 | 5 | 19 | 21 | 10 | 12 | 5 | 10 | 15 | 17 | 6 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 9000 | 0 | 0 | 3 | 1 | 4 | 1 | 0 | 1 | 3 | 4 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 8500 | 0 | 0 | 3 | 0 | 0 | 2 | 3 | 4 | 3 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 8000 | 0 | 1 | 1 | 0 | 0 | 0 | 2 | 5 | 0 | 3 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 7500 | 0 | 0 | 2 | 0 | 0 | 2 | 1 | 7 | 6 | 9 | 4 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 7000 | 0 | 2 | 3 | 0 | 2 | 2 | 11 | 22 | 19 | 27 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 6500 | 0 | 1 | 2 | 3 | 0 | 5 | 17 | 16 | 19 | 16 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 6000 | 0 | 8 | 13 | 9 | 11 | 14 | 11 | 10 | 10 | 12 | 10 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 5500 | 0 | 1 | 1 | 2 | 15 | 25 | 10 | 4 | 11 | 18 | 5 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 5000 | 6 | 5 | 1 | 6 | 15 | 13 | 6 | 8 | 10 | 10 | 3 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 4500 | 4 | 3 | 7 | 10 | 7 | 11 | 17 | 26 | 18 | 5 | 3 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 4000 | 4 | 16 | 17 | 8 | 9 | 23 | 21 | 23 | 24 | 24 | 5 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 3500 | 3 | 11 | 22 | 15 | 15 | 21 | 21 | 21 | 17 | 8 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 3000 | 4 | 14 | 18 | 14 | 13 | 16 | 38 | 29 | 28 | 11 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 2500 | 2 | 6 | 16 | 14 | 10 | 8 | 52 | 18 | 23 | 14 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 2000 | 4 | 3 | 11 | 21 | 15 | 17 | 16 | 17 | 19 | 11 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 1500 | 0 | 4 | 10 | 26 | 18 | 10 | 8 | 15 | 14 | 15 | 0 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 1000 | 0 | 7 | 21 | 60 | 46 | 34 | 23 | 17 | 18 | 14 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 500 | 22 | 16 | 29 | 97 | 122 | 84 | 38 | 26 | 24 | 38 | 7 | 7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| BCAS | | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | | | |
| BELOW BCAS | -500 | 6 | 8 | 19 | 23 | 50 | 20 | 39 | 26 | 48 | 23 | 10 | 14 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | -1000 | 9 | 17 | 12 | 11 | 28 | 15 | 28 | 16 | 25 | 27 | 7 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | -1500 | 8 | 13 | 23 | 17 | 23 | 42 | 39 | 23 | 41 | 19 | 12 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | -2000 | 1 | 7 | 18 | 41 | 29 | 59 | 48 | 29 | 24 | 40 | 9 | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | -2500 | 3 | 20 | 17 | 29 | 57 | 66 | 76 | 68 | 47 | 65 | 3 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | -3000 | 5 | 23 | 54 | 87 | 48 | 44 | 80 | 72 | 76 | 98 | 28 | 29 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | -3500 | 6 | 8 | 34 | 65 | 56 | 62 | 95 | 126 | 124 | 95 | 32 | 19 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | -4000 | 2 | 28 | 50 | 95 | 70 | 111 | 114 | 101 | 125 | 118 | 33 | 11 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | -4500 | 0 | 4 | 30 | 57 | 103 | 138 | 100 | 80 | 92 | 72 | 31 | 14 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | -5000 | 0 | 3 | 26 | 57 | 122 | 135 | 135 | 136 | 104 | 109 | 38 | 17 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | -5500 | 0 | 5 | 28 | 71 | 104 | 133 | 126 | 118 | 96 | 88 | 25 | 33 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | -6000 | 0 | 4 | 64 | 90 | 113 | 96 | 125 | 112 | 133 | 139 | 31 | 33 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | -6500 | 0 | 10 | 45 | 66 | 93 | 127 | 147 | 182 | 161 | 181 | 44 | 20 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | -7000 | 0 | 72 | 111 | 99 | 114 | 163 | 135 | 109 | 133 | 169 | 55 | 54 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | -7500 | 0 | 1 | 0 | 0 | 3 | 5 | 6 | 4 | 9 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | -8000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | -8500 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | -9000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | -9500 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | -10000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | ===== | ===== | ===== | ===== | ===== | ===== | ===== | ===== | ===== | ===== | ===== | ===== | ===== | ===== | ===== | ===== | ===== | ===== | ===== | ===== |
| | | 89 | 326 | 730 | 1115 | 1329 | 1517 | 1594 | 1485 | 1519 | 1501 | 418 | 295 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |

RELATIVE RANGE (nmi)

FIGURE A-3
TOTAL BCAS ASSOCIATED AIRCRAFT TRACK MATRIX (R VS. Z)

BASIC MODE

| RANGE RATE (KNOTS) | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CLOSING | -600 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | -570 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | -540 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | -510 | 0 | 0 | 2 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | -480 | 0 | 6 | 1 | 2 | 2 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | -450 | 0 | 2 | 5 | 5 | 2 | 1 | 2 | 3 | 2 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | -420 | 0 | 5 | 8 | 6 | 11 | 11 | 1 | 7 | 14 | 6 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | -390 | 1 | 3 | 7 | 12 | 22 | 23 | 33 | 28 | 20 | 18 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | -360 | 2 | 4 | 10 | 21 | 33 | 40 | 49 | 48 | 48 | 24 | 5 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | -330 | 1 | 7 | 13 | 38 | 58 | 59 | 47 | 43 | 30 | 27 | 9 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | -300 | 3 | 6 | 18 | 47 | 34 | 36 | 41 | 37 | 46 | 38 | 6 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | -270 | 3 | 11 | 34 | 41 | 53 | 46 | 42 | 36 | 40 | 29 | 4 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | -240 | 2 | 13 | 38 | 43 | 46 | 71 | 55 | 35 | 54 | 62 | 12 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | -210 | 4 | 20 | 30 | 62 | 72 | 55 | 54 | 73 | 57 | 58 | 7 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | -180 | 2 | 18 | 55 | 40 | 43 | 55 | 81 | 93 | 78 | 61 | 23 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | -150 | 5 | 30 | 54 | 44 | 56 | 69 | 100 | 43 | 69 | 74 | 24 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | -120 | 6 | 22 | 40 | 53 | 47 | 69 | 63 | 66 | 81 | 71 | 31 | 9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | -90 | 9 | 20 | 42 | 59 | 77 | 87 | 84 | 64 | 73 | 65 | 13 | 8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | -60 | 11 | 23 | 37 | 90 | 104 | 98 | 73 | 74 | 89 | 59 | 11 | 27 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | -30 | 9 | 18 | 35 | 93 | 68 | 82 | 57 | 67 | 54 | 87 | 16 | 25 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| BCAS | | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | |
| SEPARATING | 30 | 10 | 18 | 38 | 101 | 93 | 79 | 77 | 69 | 78 | 113 | 29 | 27 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 60 | 7 | 32 | 67 | 61 | 67 | 103 | 85 | 72 | 87 | 102 | 35 | 39 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 90 | 5 | 18 | 41 | 57 | 77 | 95 | 106 | 78 | 61 | 79 | 26 | 24 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 120 | 2 | 12 | 39 | 34 | 73 | 54 | 94 | 80 | 69 | 72 | 33 | 20 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 150 | 5 | 12 | 32 | 40 | 41 | 82 | 62 | 73 | 77 | 61 | 32 | 25 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 180 | 1 | 9 | 31 | 48 | 55 | 57 | 84 | 76 | 93 | 79 | 17 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 210 | 0 | 8 | 17 | 33 | 41 | 62 | 99 | 82 | 60 | 80 | 11 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 240 | 0 | 4 | 10 | 31 | 58 | 60 | 60 | 70 | 57 | 60 | 15 | 9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 270 | 1 | 1 | 8 | 19 | 29 | 41 | 54 | 64 | 65 | 56 | 18 | 12 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 300 | 0 | 2 | 3 | 15 | 31 | 21 | 21 | 34 | 28 | 44 | 12 | 8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 330 | 0 | 0 | 4 | 3 | 3 | 18 | 22 | 17 | 25 | 24 | 9 | 7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 360 | 0 | 1 | 7 | 6 | 10 | 10 | 15 | 13 | 19 | 10 | 2 | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 390 | 0 | 1 | 2 | 4 | 11 | 8 | 14 | 17 | 21 | 15 | 7 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 420 | 0 | 0 | 1 | 3 | 7 | 9 | 5 | 9 | 5 | 6 | 3 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 450 | 0 | 0 | 1 | 0 | 2 | 9 | 7 | 9 | 6 | 8 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 480 | 0 | 0 | 0 | 0 | 2 | 5 | 3 | 1 | 5 | 2 | 3 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 510 | 0 | 0 | 0 | 1 | 1 | 0 | 2 | 3 | 4 | 5 | 3 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 540 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 570 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 600 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | ===== | ===== | ===== | ===== | ===== | ===== | ===== | ===== | ===== | ===== | ===== | ===== | ===== | ===== | ===== | ===== | ===== | ===== | ===== | ===== |
| | | 89 | 326 | 730 | 1115 | 1329 | 1517 | 1594 | 1485 | 1519 | 1501 | 418 | 295 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

RELATIVE RANGE (nmi)

FIGURE A-4
TOTAL BCAS ASSOCIATED AIRCRAFT TRACK MATRIX (R VS. $\dot{R}$)

BASIC MODE

| RELATIVE ALTITUDE (FEET) | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ABOVE BCAS | 10000 | 1111 | 1111 | 1111 | 1111 | 57 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 |
| | 9500 | 1111 | 99 | 99 | 91 | 99 | 99 | 99 | 83 | 78 | 58 | 99 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 |
| | 9000 | 1111 | 1111 | 1111 | 1111 | 66 | 1111 | 1111 | 1111 | 49 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 |
| | 8500 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 57 | 59 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 |
| | 8000 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 71 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 |
| | 7500 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 87 | 66 | 59 | 39 | 42 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 |
| | 7000 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 91 | 95 | 99 | 93 | 39 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 |
| | 6500 | 1111 | 1111 | 1111 | 59 | 1111 | 83 | 94 | 79 | 99 | 88 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 |
| | 6000 | 1111 | 99 | 99 | 99 | 84 | 93 | 73 | 83 | 62 | 79 | 62 | 49 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 |
| | 5500 | 1111 | 1111 | 1111 | 1111 | 93 | 92 | 76 | 66 | 64 | 89 | 55 | 9 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 |
| | 5000 | 99 | 99 | 1111 | 99 | 83 | 99 | 54 | 49 | 49 | 55 | 49 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 |
| | 4500 | 1111 | 1111 | 87 | 83 | 87 | 84 | 84 | 86 | 64 | 24 | 59 | 6 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 |
| | 4000 | 1111 | 88 | 73 | 61 | 81 | 91 | 80 | 65 | 72 | 72 | 45 | 26 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 |
| | 3500 | 1111 | 68 | 87 | 83 | 78 | 99 | 77 | 48 | 41 | 21 | 16 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 |
| | 3000 | 1111 | 93 | 89 | 82 | 86 | 88 | 92 | 87 | 66 | 24 | 13 | 0 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 |
| | 2500 | 1111 | 99 | 94 | 82 | 76 | 47 | 76 | 62 | 53 | 49 | 0 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 |
| | 2000 | 79 | 1111 | 99 | 91 | 93 | 65 | 42 | 47 | 75 | 45 | 0 | 9 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 |
| | 1500 | 1111 | 1111 | 90 | 81 | 78 | 45 | 47 | 71 | 53 | 40 | 0 | 38 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 |
| | 1000 | 1111 | 99 | 87 | 96 | 88 | 79 | 45 | 39 | 37 | 24 | 12 | 0 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 |
| | 500 | 99 | 94 | 90 | 95 | 81 | 77 | 86 | 30 | 25 | 33 | 11 | 19 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 |
| BCAS | | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | | | |
| BELOW BCAS | -500 | 99 | 88 | 86 | 82 | 94 | 60 | 67 | 55 | 59 | 46 | 38 | 53 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 |
| | -1000 | 99 | 94 | 99 | 91 | 79 | 71 | 51 | 55 | 47 | 42 | 29 | 19 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 |
| | -1500 | 99 | 92 | 95 | 84 | 88 | 76 | 69 | 53 | 48 | 35 | 33 | 17 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 |
| | -2000 | 1111 | 99 | 85 | 99 | 76 | 83 | 70 | 54 | 40 | 55 | 37 | 22 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 |
| | -2500 | 1111 | 74 | 65 | 76 | 83 | 68 | 55 | 48 | 33 | 40 | 13 | 4 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 |
| | -3000 | 55 | 57 | 73 | 69 | 56 | 47 | 52 | 42 | 39 | 39 | 22 | 23 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 |
| | -3500 | 35 | 34 | 62 | 74 | 55 | 58 | 62 | 53 | 47 | 31 | 23 | 14 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 |
| | -4000 | 19 | 63 | 55 | 59 | 41 | 52 | 46 | 40 | 42 | 44 | 37 | 12 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 |
| | -4500 | 1111 | 28 | 54 | 38 | 53 | 61 | 48 | 38 | 38 | 34 | 43 | 18 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 |
| | -5000 | 0 | 7 | 32 | 52 | 64 | 57 | 56 | 48 | 44 | 40 | 38 | 21 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 |
| | -5500 | 0 | 13 | 34 | 72 | 58 | 58 | 58 | 49 | 44 | 46 | 33 | 40 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 |
| | -6000 | 1111 | 6 | 44 | 44 | 47 | 44 | 42 | 39 | 44 | 37 | 37 | 32 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 |
| | -6500 | 1111 | 17 | 39 | 39 | 45 | 56 | 51 | 51 | 46 | 45 | 36 | 22 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 |
| | -7000 | 1111 | 59 | 54 | 52 | 61 | 64 | 56 | 40 | 55 | 51 | 41 | 32 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 |
| | -7500 | 1111 | 1111 | 1111 | 1111 | 49 | 99 | 66 | 39 | 52 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 |
| | -8000 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 |
| | -8500 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 |
| | -9000 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 |
| | -9500 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 |
| | -10000 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 |
| | | ===== | ===== | ===== | ===== | ===== | ===== | ===== | ===== | ===== | ===== | ===== | ===== | ===== | ===== | ===== | ===== | ===== | ===== | ===== | ===== |
| | | 67 | 51 | 59 | 62 | 61 | 61 | 56 | 48 | 46 | 42 | 32 | 23 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

RELATIVE RANGE (nmi)

**FIGURE A-5**
**RATIO OF BCAS ASSOCIATED AIRCRAFT TRACKS TO TOTAL AIRCRAFT TRACKS (R VS. Z)**

BASIC MODE

RANGE RATE (KNOTS)

| | Range rate | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CLOSING | -600 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 |
| | -570 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 |
| | -540 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 |
| | -510 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 19 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 |
| | -480 | 1111 | 99 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 0 | 0 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 |
| | -450 | 1111 | 1111 | 83 | 71 | 1111 | 1111 | 1111 | 49 | 22 | 18 | 0 | 0 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 |
| | -420 | 1111 | 83 | 79 | 59 | 64 | 52 | 12 | 31 | 39 | 24 | 1111 | 12 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 |
| | -390 | 1111 | 1111 | 58 | 79 | 64 | 56 | 57 | 42 | 30 | 24 | 0 | 0 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 |
| | -360 | 1111 | 66 | 58 | 56 | 58 | 42 | 50 | 38 | 34 | 21 | 9 | 2 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 |
| | -330 | 1111 | 77 | 43 | 65 | 47 | 46 | 35 | 35 | 33 | 27 | 23 | 6 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 |
| | -300 | 1111 | 37 | 58 | 52 | 44 | 46 | 38 | 35 | 51 | 36 | 20 | 3 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 |
| | -270 | 1111 | 45 | 55 | 63 | 63 | 58 | 55 | 38 | 43 | 27 | 15 | 4 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 |
| | -240 | 1111 | 51 | 64 | 56 | 70 | 60 | 49 | 34 | 38 | 43 | 38 | 13 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 |
| | -210 | 1111 | 51 | 53 | 78 | 69 | 57 | 58 | 55 | 51 | 39 | 25 | 7 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 |
| | -180 | 1111 | 51 | 63 | 66 | 65 | 60 | 66 | 56 | 48 | 39 | 37 | 12 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 |
| | -150 | 83 | 53 | 77 | 72 | 55 | 62 | 66 | 40 | 46 | 36 | 38 | 6 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 |
| | -120 | 66 | 52 | 58 | 63 | 55 | 64 | 53 | 50 | 54 | 47 | 39 | 12 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 |
| | -90 | 59 | 58 | 61 | 58 | 62 | 66 | 56 | 52 | 38 | 34 | 14 | 13 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 |
| | -60 | 68 | 53 | 63 | 74 | 69 | 77 | 56 | 51 | 57 | 40 | 16 | 27 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 |
| | -30 | 35 | 41 | 61 | 75 | 64 | 69 | 62 | 46 | 41 | 51 | 19 | 24 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 |
| BCAS | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | | | |
| SEPARATING | 30 | 76 | 43 | 65 | 74 | 74 | 66 | 58 | 46 | 55 | 52 | 31 | 30 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 |
| | 60 | 87 | 66 | 66 | 60 | 64 | 73 | 63 | 42 | 50 | 48 | 61 | 43 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 |
| | 90 | 99 | 56 | 53 | 61 | 60 | 68 | 58 | 50 | 39 | 49 | 39 | 33 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 |
| | 120 | 1111 | 42 | 60 | 52 | 73 | 56 | 61 | 55 | 47 | 44 | 59 | 49 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 |
| | 150 | 83 | 46 | 66 | 54 | 58 | 61 | 57 | 56 | 54 | 47 | 37 | 42 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 |
| | 180 | 1111 | 40 | 65 | 60 | 61 | 73 | 69 | 59 | 59 | 58 | 44 | 24 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 |
| | 210 | 1111 | 47 | 58 | 63 | 61 | 65 | 65 | 58 | 52 | 55 | 23 | 27 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 |
| | 240 | 1111 | 28 | 31 | 56 | 72 | 72 | 57 | 51 | 43 | 46 | 31 | 29 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 |
| | 270 | 1111 | 1111 | 31 | 42 | 51 | 56 | 55 | 54 | 40 | 44 | 49 | 44 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 |
| | 300 | 1111 | 1111 | 16 | 49 | 52 | 37 | 31 | 51 | 45 | 50 | 32 | 24 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 |
| | 330 | 1111 | 1111 | 57 | 19 | 15 | 49 | 51 | 32 | 47 | 36 | 39 | 26 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 |
| | 360 | 1111 | 1111 | 63 | 54 | 43 | 52 | 39 | 30 | 38 | 25 | 14 | 42 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 |
| | 390 | 1111 | 1111 | 39 | 66 | 84 | 42 | 69 | 67 | 58 | 40 | 41 | 11 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 |
| | 420 | 1111 | 1111 | 1111 | 33 | 63 | 74 | 38 | 52 | 33 | 35 | 1111 | 14 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 |
| | 450 | 1111 | 1111 | 1111 | 1111 | 39 | 74 | 69 | 56 | 66 | 61 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 |
| | 480 | 1111 | 1111 | 1111 | 1111 | 1111 | 99 | 1111 | 1111 | 99 | 1111 | 1111 | 79 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 |
| | 510 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 83 | 1111 | 79 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 |
| | 540 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 |
| | 570 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 |
| | 600 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 |
| | | ===== | ===== | ===== | ===== | ===== | ===== | ===== | ===== | ===== | ===== | ===== | ===== | ===== | ===== | ===== | ===== | ===== | ===== | ===== | ===== |
| | | 67 | 51 | 59 | 62 | 61 | 61 | 56 | 48 | 46 | 42 | 32 | 23 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

RELATIVE RANGE (nmi)

**FIGURE A-6**
**RATIO OF BCAS ASSOCIATED AIRCRAFT TRACKS TO TOTAL AIRCRAFT TRACKS (R VS. $\dot{R}$)**

| RANGE | TOTAL | ASSOC. | % A |
|---|---|---|---|
| 1 | 131 | 89 | 67 |
| 2 | 629 | 326 | 51 |
| 3 | 1220 | 730 | 59 |
| 4 | 1770 | 1115 | 62 |
| 5 | 2146 | 1329 | 61 |
| 6 | 2451 | 1517 | 61 |
| 7 | 2826 | 1594 | 56 |
| 8 | 3075 | 1485 | 48 |
| 9 | 3266 | 1519 | 46 |
| 10 | 3535 | 1501 | 42 |
| 11 | 1301 | 418 | 32 |
| 12 | 1236 | 295 | 23 |

(a) BASIC

| RANGE | TOTAL | ASSOC. | % A |
|---|---|---|---|
| 1 | 106 | 57 | 53 |
| 2 | 626 | 313 | 50 |
| 3 | 1224 | 727 | 59 |
| 4 | 1730 | 1119 | 64 |
| 5 | 2154 | 1436 | 66 |
| 6 | 2517 | 1739 | 69 |
| 7 | 2971 | 1930 | 64 |
| 8 | 3216 | 1822 | 56 |
| 9 | 3298 | 1734 | 52 |
| 10 | 3553 | 1719 | 48 |
| 11 | 1107 | 519 | 46 |
| 12 | 1140 | 461 | 40 |

(b) WHISPER/SHOUT

**FIGURE A-7**
**AIRCRAFT ASSOCIATION, FOR EACH MILE, FOR ALL ALTITUDES**

| > 5 k ft | R | (0-5) | (6-10) |
|---|---|---|---|
| | T | 149 | 410 |
| | A | 128 | 333 |
| | % | 85.9 | 81.2 |

| 0 TO 5 k ft ABOVE | R | (0-5) | (6-10) |
|---|---|---|---|
| | T | 640 | 1470 |
| | A | 560 | 880 |
| | % | 87.5 | 59.9 |

| 0 TO 5 k ft BELOW | R | (0-5) | (6-10) |
|---|---|---|---|
| | T | 2488 | 6737 |
| | A | 1642 | 3201 |
| | % | 66.0 | 47.5 |

| < 5 k ft | R | (0-5) | (6-10) |
|---|---|---|---|
| | T | 2617 | 6536 |
| | A | 1257 | 3202 |
| | % | 48.0 | 49.0 |

| 0 TO 1 k ft ABOVE | R | (0-5) | (6-10) |
|---|---|---|---|
| | T | 215 | 365 |
| | A | 192 | 168 |
| | % | 89.3 | 46.0 |

| 0 TO 1 k ft BELOW | R | (0-5) | (6-10) |
|---|---|---|---|
| | T | 456 | 753 |
| | A | 405 | 386 |
| | % | 88.8 | 51.3 |

**FIGURE A-8**
**BCAS PERFORMANCE FOR VARIOUS ALTITUDE AND RANGE ZONES**
**(BASIC)**

>5 k ft

| | | |
|---|---|---|
| R | (0-5) | (6-10) |
| T | 123 | 382 |
| A | 97 | 263 |
| % | 78.9 | 68.8 |

0 TO 5 k ft ABOVE

| | | |
|---|---|---|
| R | (0-5) | (6-10) |
| T | 590 | 1448 |
| A | 459 | 949 |
| % | 77.8 | 65.5 |

0 to 5 k ft BELOW

| | | |
|---|---|---|
| R | (0-5) | (6-10) |
| T | 2460 | 6776 |
| A | 1615 | 3632 |
| % | 65.7 | 53.6 |

<5 k ft

| | | |
|---|---|---|
| R | (0-5) | (6-10) |
| T | 2667 | 6949 |
| A | 1481 | 4100 |
| % | 55.5 | 59.0 |

0 TO 1 k ft ABOVE

| | | |
|---|---|---|
| R | (0-5) | (6-10) |
| T | 192 | 364 |
| A | 165 | 185 |
| % | 85.9 | 50.8 |

0 TO 1 k ft BELOW

| | | |
|---|---|---|
| R | (0-5) | (6-10) |
| T | 459 | 729 |
| A | 398 | 414 |
| % | 86.7 | 56.8 |

**FIGURE A-9**
**BCAS PERFORMANCE FOR VAROIUS ALTITUDE AND RANGE ZONES**
**(WHISPER/SHOUT)**

| RANGE | TOTAL | ASSOC. | % A |
|---|---|---|---|
| 1 | 131 | 89 | 67.9 |
| 2 | 760 | 415 | 54.6 |
| 3 | 1980 | 1145 | 57.8 |
| 4 | 3750 | 2260 | 60.3 |
| 5 | 5896 | 3589 | 60.9 |
| 6 | 8347 | 5106 | 61.2 |
| 7 | 11173 | 6700 | 60.0 |
| 8 | 14248 | 8185 | 57.4 |
| 9 | 17514 | 9704 | 55.4 |
| 10 | 21049 | 11205 | 53.2 |
| 11 | 22350 | 11623 | 52.0 |
| 12 | 23586 | 11918 | 50.5 |

(a) BASIC

| RANGE | TOTAL | ASSOC. | % A |
|---|---|---|---|
| 1 | 106 | 57 | 53.8 |
| 2 | 732 | 370 | 50.5 |
| 3 | 1956 | 1097 | 56.1 |
| 4 | 3686 | 2216 | 60.1 |
| 5 | 5840 | 3652 | 62.5 |
| 6 | 8357 | 5391 | 64.5 |
| 7 | 11328 | 7321 | 64.6 |
| 8 | 14544 | 9143 | 62.9 |
| 9 | 17842 | 10877 | 61.0 |
| 10 | 21395 | 12596 | 58.9 |
| 11 | 22502 | 13115 | 58.3 |
| 12 | 23642 | 13576 | 57.4 |

(b) WHISPER/SHOUT

**FIGURE A-10**
**CUMULATIVE PERCENT OF AIRCRAFT ASSOCIATION**

PROBABILITY OF PHANTOM TRACKS ALT VS RANGE

| | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 10000 | 0003 | 0000 | 0000 | 0022 | 0009 | 0022 | 0031 | 0050 | 0056 | 0019 | 0003 | 0019 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 |
| 9500 | 0000 | 0009 | 0007 | 0006 | 0009 | 0009 | 0012 | 0012 | 0016 | 0019 | 0000 | 0013 | 0000 | 0000 | 0000 | 0000 | 0000 | 0003 | 0000 | 0000 |
| 9000 | 0000 | 0000 | 0000 | 0000 | 0014 | 0006 | 0006 | 0006 | 0022 | 0031 | 0003 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 |
| 8500 | 0000 | 0000 | 0009 | 0019 | 0040 | 0037 | 0050 | 0044 | 0072 | 0084 | 0006 | 0019 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 |
| 8000 | 0000 | 0000 | 0016 | 0034 | 0036 | 0093 | 0059 | 0106 | 0131 | 0065 | 0031 | 0034 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 |
| 7500 | 0000 | 0000 | 0009 | 0031 | 0044 | 0075 | 0062 | 0044 | 0106 | 0075 | 0028 | 0037 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 |
| 7000 | 0000 | 0000 | 0000 | 0012 | 0034 | 0037 | 0059 | 0023 | 0059 | 0109 | 0016 | 0031 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 |
| 6500 | 0000 | 0000 | 0000 | 0019 | 0024 | 0059 | 0072 | 0044 | 0050 | 0075 | 0009 | 0025 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 |
| 6000 | 0000 | 0009 | 0012 | 0037 | 0031 | 0047 | 0062 | 0040 | 0062 | 0028 | 0006 | 0003 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 |
| 5500 | 0000 | 0006 | 0009 | 0031 | 0031 | 0047 | 0081 | 0044 | 0037 | 0031 | 0009 | 0012 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 |
| 5000 | 0000 | 0006 | 0009 | 0053 | 0053 | 0081 | 0081 | 0075 | 0090 | 0037 | 0016 | 0031 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 |
| 4500 | 0000 | 0000 | 0019 | 0084 | 0034 | 0053 | 0066 | 0037 | 0031 | 0025 | 0022 | 0019 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 |
| 4000 | 0000 | 0012 | 0012 | 0037 | 0040 | 0075 | 0087 | 0084 | 0056 | 0075 | 0019 | 0044 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 |
| 3500 | 0000 | 0006 | 0031 | 0025 | 0050 | 0034 | 0050 | 0047 | 0034 | 0025 | 0019 | 0033 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 |
| 3000 | 0000 | 0000 | 0028 | 0016 | 0025 | 0053 | 0087 | 0059 | 0025 | 0031 | 0012 | 0036 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 |
| 2500 | 0000 | 0003 | 0025 | 0090 | 0053 | 0068 | 0106 | 0025 | 0040 | 0062 | 0000 | 0003 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 |
| 2000 | 0000 | 0016 | 0016 | 0028 | 0065 | 0053 | 0068 | 0037 | 0031 | 0026 | 0006 | 0006 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 |
| 1500 | 0000 | 0000 | 0016 | 0028 | 0074 | 0069 | 0084 | 0037 | 0044 | 0044 | 0012 | 0028 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 |
| 1000 | 0000 | 0019 | 0016 | 0093 | 0143 | 0154 | 0103 | 0047 | 0047 | 0103 | 0019 | 0009 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 |
| 500 | 0019 | 0025 | 0016 | 0053 | 0134 | 0168 | 0218 | 0126 | 0090 | 0137 | 0022 | 0031 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 |
| -500 | 0000 | 0029 | 0044 | 0065 | 0165 | 0174 | 0218 | 0212 | 0162 | 0146 | 0059 | 0036 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 |
| -1000 | 0003 | 0003 | 0012 | 0096 | 0106 | 0162 | 0143 | 0187 | 0165 | 0134 | 0047 | 0028 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 |
| -1500 | 0016 | 0016 | 0053 | 0059 | 0036 | 0090 | 0140 | 0106 | 0118 | 0180 | 0044 | 0040 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 |
| -2000 | 0006 | 0012 | 0016 | 0065 | 0059 | 0109 | 0109 | 0140 | 0121 | 0078 | 0034 | 0076 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 |
| -2500 | 0006 | 0031 | 0037 | 0040 | 0081 | 0115 | 0096 | 0128 | 0115 | 0090 | 0025 | 0022 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 |
| -3000 | 0000 | 0006 | 0006 | 0059 | 0096 | 0081 | 0115 | 0106 | 0090 | 0134 | 0047 | 0012 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 |
| -3500 | 0000 | 0009 | 0025 | 0053 | 0100 | 0143 | 0174 | 0162 | 0137 | 0103 | 0037 | 0036 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 |
| -4000 | 0000 | 0009 | 0037 | 0100 | 0121 | 0096 | 0140 | 0124 | 0174 | 0230 | 0068 | 0037 | 0003 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 |
| -4500 | 0000 | 0006 | 0037 | 0050 | 0193 | 0255 | 0215 | 0202 | 0134 | 0258 | 0037 | 0037 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 |
| -5000 | 0003 | 0009 | 0072 | 0084 | 0134 | 0140 | 0187 | 0152 | 0165 | 0236 | 0037 | 0053 | 0600 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 |
| -5500 | 0003 | 0012 | 0081 | 0115 | 0159 | 0190 | 0177 | 0187 | 0096 | 0143 | 0050 | 0106 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 |
| -6000 | 0000 | 0006 | 0093 | 0124 | 0137 | 0267 | 0184 | 0199 | 0162 | 0199 | 0084 | 0075 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 |
| -6500 | 0000 | 0019 | 0075 | 0208 | 0234 | 0243 | 0239 | 0283 | 0255 | 0233 | 0056 | 0068 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 |
| -7000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0030 | 0000 | 0000 | 0000 | 0000 | 0000 | 0360 | 0000 | 0000 |
| -7500 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 |
| -8000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 |
| -8500 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 |
| -9000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 |
| -9500 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 |
| 10000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 |
| | 0056 | 0277 | 0834 | 1792 | 2694 | 3344 | 3639 | 3179 | 2992 | 3266 | 0880 | 0567 | 0003 | 0000 | 0000 | 0000 | 0000 | 0000 | 0003 | 0000 |
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |

FIGURE A-11
PROBABILITY OF PHANTOM OCCURRENCES (R VS. Z)

PROBABILITY OF PHANTOM TRACKS KNOTS VERSUS RANGE

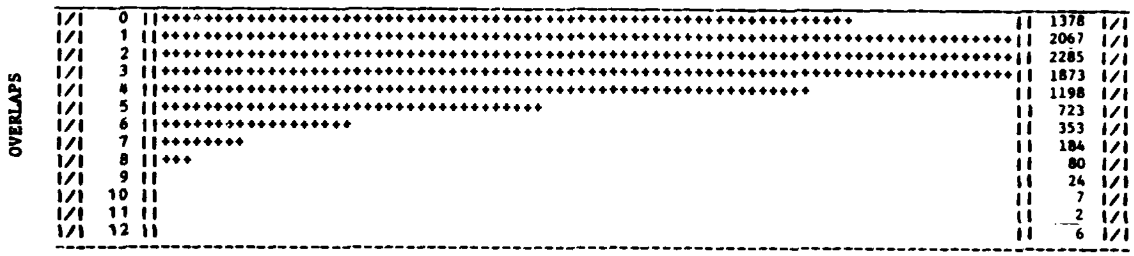
| | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| -600 | 0000 | 0000 | 0003 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 |
| -570 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 |
| -540 | 0000 | 0000 | 0000 | 0000 | 0000 | 0006 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 |
| -510 | 0000 | 0000 | 0000 | 0003 | 0009 | 0003 | 0003 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 |
| -480 | 0006 | 0009 | 0003 | 0000 | 0009 | 0006 | 0006 | 0009 | 0000 | 0006 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 |
| -450 | 0000 | 0000 | 0000 | 0037 | 0022 | 0028 | 0034 | 0009 | 0003 | 0003 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 |
| -420 | 0016 | 0009 | 0019 | 0044 | 0028 | 0025 | 0037 | 0031 | 0006 | 0009 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 |
| -390 | 0000 | 0006 | 0053 | 0059 | 0078 | 0050 | 0050 | 0047 | 0053 | 0022 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 |
| -360 | 0000 | 0006 | 0019 | 0072 | 0112 | 0056 | 0059 | 0072 | 0059 | 0068 | 0003 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 |
| -330 | 0000 | 0012 | 0025 | 0072 | 0090 | 0106 | 0072 | 0056 | 0034 | 0031 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 |
| -300 | 0000 | 0016 | 0053 | 0093 | 0078 | 0124 | 0090 | 0121 | 0087 | 0075 | 0009 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 |
| -270 | 0003 | 0016 | 0056 | 0084 | 0109 | 0124 | 0103 | 0053 | 0056 | 0081 | 0016 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 |
| -240 | 0000 | 0009 | 0031 | 0090 | 0118 | 0115 | 0115 | 0075 | 0100 | 0093 | 0000 | 0003 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 |
| -210 | 0003 | 0012 | 0034 | 0065 | 0112 | 0134 | 0168 | 0109 | 0121 | 0096 | 0037 | 0003 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 |
| -180 | 0003 | 0022 | 0050 | 0087 | 0072 | 0128 | 0159 | 0149 | 0065 | 0121 | 0025 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 |
| -150 | 0006 | 0012 | 0065 | 0096 | 0140 | 0156 | 0124 | 0112 | 0121 | 0137 | 0009 | 0022 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 |
| -120 | 0000 | 0028 | 0040 | 0100 | 0106 | 0168 | 0184 | 0202 | 0128 | 0171 | 0050 | 0019 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 |
| -90 | 0000 | 0016 | 0044 | 0106 | 0171 | 0162 | 0202 | 0162 | 0177 | 0146 | 0050 | 0050 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 |
| -60 | 0000 | 0006 | 0037 | 0121 | 0208 | 0208 | 0224 | 0184 | 0134 | 0131 | 0037 | 0056 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 |
| -30 | 0003 | 0016 | 0037 | 0084 | 0190 | 0196 | 0171 | 0109 | 0152 | 0199 | 0056 | 0084 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 |
| 30 | 0003 | 0016 | 0093 | 0096 | 0152 | 0162 | 0149 | 0115 | 0131 | 0190 | 0075 | 0050 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 |
| 60 | 0006 | 0000 | 0047 | 0103 | 0184 | 0221 | 0212 | 0140 | 0156 | 0193 | 0090 | 0152 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 |
| 90 | 0000 | 0019 | 0028 | 0096 | 0115 | 0196 | 0205 | 0128 | 0128 | 0159 | 0062 | 0087 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 |
| 120 | 0003 | 0022 | 0034 | 0068 | 0134 | 0149 | 0258 | 0193 | 0131 | 0240 | 0081 | 0050 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 |
| 150 | 0003 | 0006 | 0012 | 0050 | 0112 | 0152 | 0221 | 0205 | 0146 | 0149 | 0053 | 0053 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 |
| 180 | 0000 | 0009 | 0009 | 0050 | 0084 | 0093 | 0124 | 0180 | 0184 | 0096 | 0019 | 0044 | 0003 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 |
| 210 | 0000 | 0000 | 0016 | 0025 | 0068 | 0140 | 0165 | 0140 | 0131 | 0118 | 0012 | 0068 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 |
| 240 | 0000 | 0009 | 0019 | 0034 | 0044 | 0128 | 0121 | 0087 | 0184 | 0137 | 0028 | 0050 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 |
| 270 | 0000 | 0000 | 0003 | 0019 | 0053 | 0078 | 0078 | 0140 | 0149 | 0118 | 0047 | 0031 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 |
| 300 | 0000 | 0000 | 0000 | 0019 | 0047 | 0031 | 0053 | 0078 | 0087 | 0156 | 0022 | 0040 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 |
| 330 | 0000 | 0000 | 0003 | 0006 | 0019 | 0075 | 0050 | 0065 | 0062 | 0100 | 0047 | 0065 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 |
| 360 | 0000 | 0000 | 0000 | 0000 | 0006 | 0034 | 0093 | 0065 | 0065 | 0068 | 0025 | 0006 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 |
| 390 | 0000 | 0000 | 0000 | 0003 | 0006 | 0034 | 0022 | 0062 | 0065 | 0050 | 0009 | 0006 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 |
| 420 | 0000 | 0000 | 0000 | 0000 | 0003 | 0025 | 0037 | 0034 | 0037 | 0034 | 0006 | 0019 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 |
| 450 | 0000 | 0000 | 0000 | 0006 | 0016 | 0028 | 0034 | 0025 | 0022 | 0040 | 0003 | 0006 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 |
| 480 | 0000 | 0000 | 0000 | 0003 | 0000 | 0003 | 0003 | 0009 | 0016 | 0012 | 0006 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 |
| 510 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0012 | 0009 | 0003 | 0003 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 |
| 540 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0003 | 0003 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 |
| 570 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0003 | 0000 | 0006 | 0000 | 0003 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 |
| 600 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0003 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 |
| | 0056 | 0277 | 0834 | 1792 | 2694 | 3344 | 3639 | 3179 | 2992 | 3266 | 0880 | 0967 | 0003 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 | 0000 |
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |

FIGURE A-12
PROBABILITY OF PHANTOM OCCURRENCES (R VS. Ṙ)

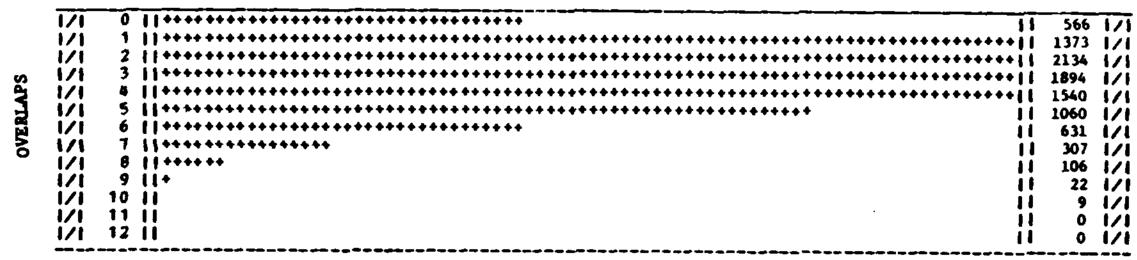
## TABLE A-1

### AVERAGE NUMBER OF PHANTOM TRACKS PER SCAN AT ANY ALTITUDE

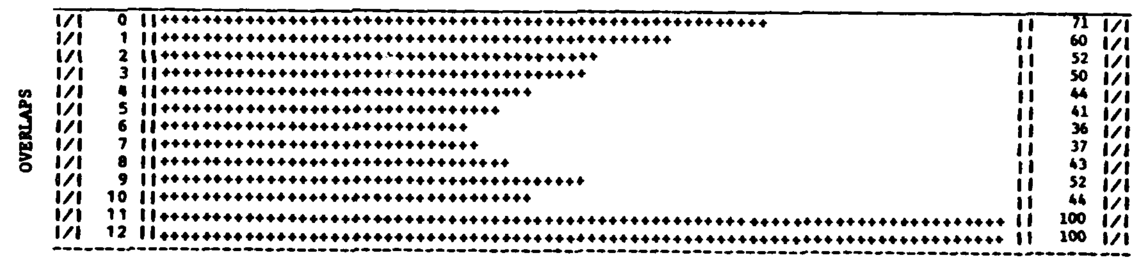
| | BASIC | WHISPER/SHOUT |
|---|---|---|
| 0 - 5 nmi | .57 | .64 |
| 0 - 10 nmi | 2.21 | 2.78 |
| 0 - 12 nmi | 2.39 | 3.08 |




a) NUMBER OF SUCCESSFUL ASSOCIATIONS

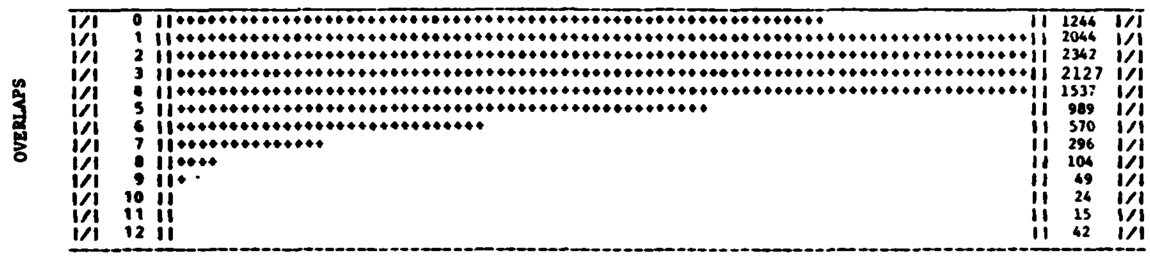



b) NUMBER OF MISSED ASSOCIATIONS

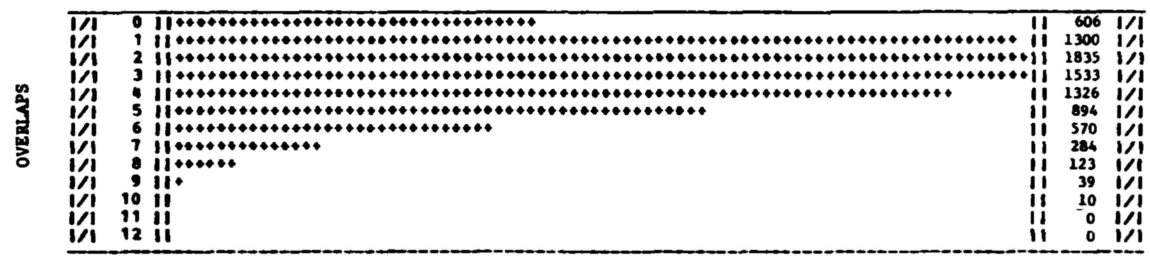



c) PERCENT ASSOCIATION

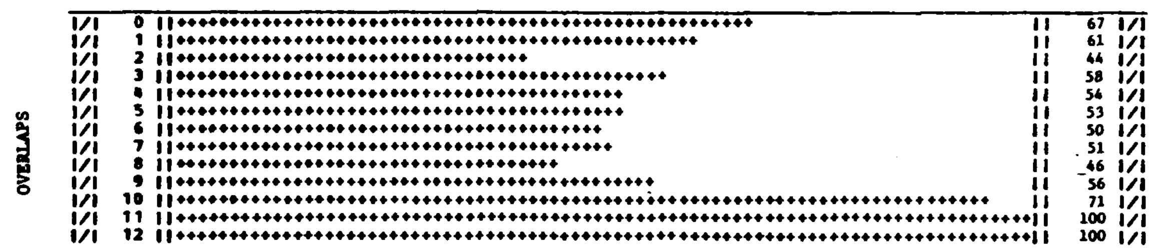
FIGURE A-13
ARTS ASSOCIATION VS. OVERLAPS (BASIC)




a) NUMBER OF SUCCESSFUL ASSOCIATIONS




b) NUMBER OF MISSED ASSOCIATIONS




c) PERCENT ASSOCIATION

**FIGURE A-14**
**ARTS ASSOCIATION VS. OVERLAPS (WHISPER/SHOUT)**

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 55 | 157 | 216 | 180 | 212 | 164 | 154 | 102 | 69 | 69 | 24 | 24 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | =1426 |
| 1 | 16 | 87 | 257 | 331 | 295 | 276 | 235 | 231 | 173 | 166 | 74 | 76 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | =2217 |
| 2 | 6 | 37 | 127 | 274 | 294 | 331 | 311 | 339 | 304 | 262 | 72 | 71 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | =2428 |
| 3 | 1111 | 9 | 60 | 155 | 217 | 242 | 303 | 265 | 314 | 308 | 72 | 67 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | =2012 |
| 4 | 1111 | 1111 | 14 | 46 | 99 | 198 | 214 | 201 | 213 | 213 | 73 | 32 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | =1303 |
| 5 | 1111 | 1 | 4 | 16 | 54 | 93 | 115 | 124 | 154 | 164 | 47 | 20 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | = 790 |
| 6 | 1111 | 1111 | 2 | 13 | 28 | 41 | 44 | 57 | 77 | 91 | 38 | 9 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | = 400 |
| 7 | 1111 | 1 | 1 | 3 | 6 | 11 | 45 | 31 | 45 | 41 | 14 | 2 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | = 200 |
| 8 | 1111 | 1111 | 1111 | 1111 | 3 | 6 | 16 | 10 | 21 | 24 | 3 | 1 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | = 84 |
| 9 | 1111 | 1111 | 1111 | 1 | 1111 | 3 | 8 | 4 | 5 | 3 | 1 | 2 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | = 27 |
| 10 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 5 | 1 | 1 | 3 | 1 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | = 11 |
| 11 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1 | 1111 | 1111 | 1 | 2 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | = 4 |
| 12 | 1111 | 1111 | 1111 | 1111 | 1 | 1111 | 1 | 1111 | 1 | 3 | 5 | 1 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | = 12 |
| | 77 | 292 | 681 | 1019 | 1207 | 1365 | 1487 | 1369 | 1377 | 1346 | 428 | 306 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | |

RANGE

a) SUCCESSFUL ASSOCIATIONS (BASIC)

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 33 | 89 | 97 | 72 | 53 | 41 | 61 | 36 | 43 | 41 | 36 | 86 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | = 688 |
| 1 | 2 | 81 | 133 | 166 | 184 | 162 | 156 | 177 | 153 | 199 | 143 | 246 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | =1762 |
| 2 | 7 | 101 | 132 | 163 | 228 | 209 | 272 | 307 | 338 | 377 | 184 | 245 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | =2563 |
| 3 | 1111 | 23 | 75 | 108 | 177 | 177 | 222 | 307 | 353 | 452 | 171 | 180 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | =2245 |
| 4 | 1111 | 5 | 32 | 71 | 88 | 160 | 207 | 291 | 325 | 361 | 140 | 87 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | =1767 |
| 5 | 1111 | 1 | 8 | 26 | 49 | 96 | 138 | 228 | 267 | 247 | 104 | 70 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | =1234 |
| 6 | 1111 | 1111 | 5 | 27 | 40 | 47 | 83 | 122 | 141 | 166 | 56 | 10 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | = 697 |
| 7 | 1111 | 1111 | 1111 | 7 | 7 | 15 | 53 | 62 | 63 | 100 | 18 | 6 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | = 331 |
| 8 | 1111 | 1111 | 1111 | 1111 | 1111 | 3 | 15 | 16 | 25 | 47 | 14 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | = 120 |
| 9 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 2 | 6 | 4 | 10 | 6 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | = 28 |
| 10 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 4 | 5 | 1111 | 1 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | = 10 |
| 11 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | = 0 |
| 12 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | = 0 |
| | 42 | 300 | 482 | 640 | 786 | 910 | 1209 | 1556 | 1717 | 2080 | 873 | 930 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | |

RANGE

b) MISSED ASSOCIATIONS (BASIC)

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 62 | 63 | 69 | 71 | 80 | 80 | 71 | 73 | 61 | 62 | 40 | 21 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 |
| 2 | 88 | 51 | 65 | 66 | 67 | 63 | 60 | 56 | 53 | 45 | 34 | 23 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 |
| 3 | 46 | 26 | 49 | 62 | 56 | 61 | 53 | 52 | 47 | 41 | 28 | 22 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 |
| 4 | 1111 | 28 | 44 | 58 | 55 | 57 | 57 | 46 | 47 | 40 | 29 | 27 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 |
| 5 | 1111 | 0 | 30 | 39 | 52 | 55 | 50 | 40 | 39 | 37 | 34 | 26 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 |
| 6 | 1111 | 50 | 33 | 28 | 51 | 49 | 45 | 35 | 36 | 39 | 31 | 22 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 |
| 7 | 1111 | 1111 | 28 | 32 | 41 | 46 | 34 | 31 | 35 | 35 | 40 | 47 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 |
| 8 | 1111 | 100 | 100 | 30 | 46 | 42 | 45 | 33 | 41 | 29 | 43 | 25 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 |
| 9 | 1111 | 1111 | 1111 | 1111 | 100 | 66 | 51 | 38 | 45 | 33 | 17 | 100 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 |
| 10 | 1111 | 1111 | 1111 | 100 | 1111 | 100 | 80 | 40 | 55 | 23 | 14 | 100 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 |
| 11 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 55 | 16 | 100 | 75 | 100 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 |
| 12 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 100 | 1111 | 1111 | 100 | 100 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 |
| 13 | 1111 | 1111 | 1111 | 1111 | 100 | 1111 | 100 | 1111 | 100 | 100 | 100 | 100 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 |
| | | | | 61 | 60 | 60 | 54 | 46 | 44 | 40 | 32 | 24 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 |
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |

c) RATIO OF SUCCESSFUL ASSOCIATIONS TO SUCCESSFUL PLUS MISSED ASSOCIATIONS

FIGURE A-16
ASSOCIATION PERFORMANCE AS A FUNCTION OF RANGE AND OVERLAPS

| DENSITY | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | OVERLAPS | | | | | | | | |
| 1 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | = | 12 |
| 2 | 53 | 29 | 2 | 3 | 2 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | = | 69 |
| 3 | 200 | 119 | 32 | 27 | 16 | 5 | 3 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | = | 404 |
| 4 | 194 | 235 | 140 | 53 | 22 | 20 | 12 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | = | 676 |
| 5 | 216 | 244 | 249 | 120 | 48 | 29 | 17 | 1 | 1111 | 1111 | 1111 | 1111 | 1111 | = | 924 |
| 6 | 180 | 301 | 317 | 211 | 81 | 40 | 11 | 7 | 1111 | 1111 | 1111 | 1111 | 1111 | = | 1148 |
| 7 | 175 | 402 | 432 | 291 | 148 | 55 | 15 | 4 | 1111 | 1111 | 1111 | 1111 | 1111 | = | 1522 |
| 8 | 132 | 287 | 373 | 329 | 189 | 84 | 23 | 9 | 3 | 1111 | 1111 | 1111 | 1111 | = | 1429 |
| 9 | 79 | 195 | 271 | 279 | 210 | 113 | 51 | 8 | 5 | 1111 | 1111 | 1111 | 1111 | = | 1211 |
| 10 | 48 | 147 | 223 | 248 | 196 | 114 | 60 | 37 | 4 | 1111 | 1111 | 1111 | 1111 | = | 1079 |
| 11 | 21 | 78 | 144 | 174 | 147 | 109 | 53 | 18 | 9 | 1111 | 1111 | 1111 | 1111 | = | 753 |
| 12 | 10 | 30 | 48 | 80 | 94 | 70 | 25 | 24 | 11 | 1111 | 1111 | 1111 | 1111 | = | 394 |
| 13 | 2 | 10 | 12 | 26 | 24 | 26 | 28 | 17 | 6 | 1111 | 1111 | 1111 | 1111 | = | 151 |
| 14 | 1 | 11 | 23 | 36 | 27 | 28 | 22 | 24 | 9 | 2 | 1111 | 1111 | 1111 | = | 183 |
| 15 | 1 | 8 | 19 | 11 | 14 | 16 | 21 | 8 | 4 | 1 | 1111 | 1111 | 1111 | = | 101 |
| 16 | 1111 | 8 | 12 | 5 | 3 | 10 | 5 | 11 | 7 | 4 | 2 | 1111 | 1111 | = | 67 |
| 17 | 1111 | 1 | 1 | 1 | 4 | 6 | 3 | 2 | 1 | 1 | 1111 | 1111 | 1111 | = | 19 |
| 18 | 1111 | 2 | 5 | 2 | 3 | 2 | 10 | 4 | 7 | 3 | 2 | 1111 | 1111 | = | 40 |
| 19 | 1111 | 1111 | 1111 | 1111 | 1 | 3 | 1111 | 1111 | 1111 | 1 | 1111 | 1111 | 1111 | = | 5 |
| 20 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | = | 0 |
| 21 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | = | 0 |
| | ==== | ==== | ==== | ==== | ==== | ==== | ==== | ==== | ==== | ==== | ==== | ==== | ==== | | ==== |
| | 1315 | 2109 | 2307 | 1899 | 1228 | 730 | 363 | 174 | 66 | 12 | 4 | 0 | 0 | \| | 10195 |

a) SUCCESSFUL ASSOCIATION (BASIC)

| DENSITY | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | = | 13 |
| 2 | 24 | 27 | 10 | 1 | 3 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | = | 65 |
| 3 | 44 | 60 | 41 | 44 | 32 | 19 | 4 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | = | 244 |
| 4 | 97 | 165 | 133 | 78 | 46 | 47 | 19 | 6 | 1111 | 1111 | 1111 | 1111 | 1111 | = | 591 |
| 5 | 64 | 232 | 199 | 151 | 75 | 38 | 12 | 1 | 1111 | 1111 | 1111 | 1111 | 1111 | = | 772 |
| 6 | 106 | 241 | 266 | 237 | 133 | 58 | 14 | 6 | 1111 | 1111 | 1111 | 1111 | 1111 | = | 1061 |
| 7 | 96 | 306 | 396 | 256 | 199 | 97 | 15 | 4 | 1 | 1111 | 1111 | 1111 | 1111 | = | 1370 |
| 8 | 74 | 213 | 427 | 352 | 223 | 121 | 43 | 16 | 4 | 1 | 1111 | 1111 | 1111 | = | 1474 |
| 9 | 85 | 174 | 316 | 316 | 275 | 184 | 85 | 24 | 8 | 1111 | 1111 | 1111 | 1111 | = | 1467 |
| 10 | 51 | 170 | 355 | 331 | 260 | 185 | 100 | 53 | 20 | 6 | 1111 | 1111 | 1111 | = | 1531 |
| 11 | 27 | 87 | 196 | 232 | 231 | 197 | 147 | 61 | 20 | 7 | 1111 | 1111 | 1111 | = | 1205 |
| 12 | 9 | 29 | 95 | 108 | 125 | 89 | 90 | 50 | 21 | 2 | 1 | 1111 | 1111 | = | 623 |
| 13 | 7 | 25 | 42 | 34 | 41 | 52 | 44 | 37 | 8 | 1 | 1111 | 1111 | 1111 | = | 291 |
| 14 | 3 | 11 | 29 | 56 | 55 | 62 | 55 | 21 | 10 | 1111 | 1111 | 1111 | 1111 | = | 302 |
| 15 | 1111 | 5 | 33 | 27 | 35 | 36 | 41 | 18 | 10 | 2 | 1111 | 1111 | 1111 | = | 207 |
| 16 | 1111 | 1 | 10 | 4 | 5 | 11 | 5 | 17 | 8 | 7 | 5 | 1111 | 1111 | = | 77 |
| 17 | 1111 | 2 | 5 | 8 | 9 | 20 | 7 | 4 | 3 | 2 | 1 | 1111 | 1111 | = | 61 |
| 18 | 1111 | 4 | 7 | 7 | 9 | 14 | 15 | 12 | 7 | 1111 | 3 | 1111 | 1111 | = | 78 |
| 19 | 1111 | 1111 | 1 | 3 | 3 | 4 | 1 | 1 | 1111 | 1111 | 1111 | 1111 | 1111 | = | 13 |
| 20 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | = | 0 |
| 21 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | = | 0 |
| | ==== | ==== | ==== | ==== | ==== | ==== | ==== | ==== | ==== | ==== | ==== | ==== | ==== | | ==== |
| | 688 | 1762 | 2563 | 2245 | 1767 | 1234 | 697 | 331 | 120 | 28 | 10 | 0 | 0 | \| | 11432 |

b) MISSED ASSOCIATION (BASIC)

| DENSITY | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 |
| 2 | 68 | 51 | 16 | [illegible] | [illegible] | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 |
| 3 | 81 | 66 | 43 | 38 | 36 | 25 | 42 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 |
| 4 | 66 | 56 | 51 | 40 | 22 | 29 | 36 | 0 | 1111 | 1111 | 1111 | 1111 | 1111 |
| 5 | 77 | 51 | 55 | 44 | 34 | 43 | 35 | 50 | 1111 | 1111 | 1111 | 1111 | 1111 |
| 6 | 62 | 55 | 54 | 47 | 37 | 40 | 44 | 53 | 1111 | 1111 | 1111 | 1111 | 1111 |
| 7 | 64 | 56 | 52 | 53 | 42 | 36 | 50 | 50 | 0 | 1111 | 1111 | 1111 | 1111 |
| 8 | 68 | 57 | 46 | 48 | 45 | 40 | 34 | 36 | 42 | 0 | 1111 | 1111 | 1111 |
| 9 | 48 | 52 | 46 | 46 | 43 | 38 | 37 | 25 | 38 | 1111 | 1111 | 1111 | 1111 |
| 10 | 48 | 46 | 38 | 42 | 43 | 36 | 37 | 41 | 16 | 0 | 1111 | 1111 | 1111 |
| 11 | 43 | 47 | 42 | 42 | 32 | 35 | 26 | 22 | 31 | 0 | 1111 | 1111 | 1111 |
| 12 | 52 | 50 | 33 | 42 | 41 | 44 | 24 | 32 | 34 | 0 | 0 | 1111 | 1111 |
| 13 | 22 | 28 | 22 | 43 | 36 | 33 | 38 | 31 | 42 | 0 | 1111 | 1111 | 1111 |
| 14 | 25 | 50 | 44 | 35 | 32 | 31 | 28 | 53 | 47 | 100 | 1111 | 1111 | 1111 |
| 15 | 100 | 61 | 36 | 28 | 25 | 30 | 33 | 30 | 26 | 33 | 1111 | 1111 | 1111 |
| 16 | 1111 | 89 | 54 | 55 | 25 | 47 | 50 | 39 | 46 | 36 | 28 | 1111 | 1111 |
| 17 | 1111 | 33 | 16 | 11 | 25 | 23 | 30 | 33 | 25 | 33 | 0 | 1111 | 1111 |
| 18 | 1111 | 33 | 41 | 22 | 25 | 12 | 40 | 25 | 50 | 100 | 40 | 1111 | 1111 |
| 19 | 1111 | 1111 | 0 | 0 | 25 | 42 | 0 | 0 | 1111 | 100 | 1111 | 1111 | 1111 |
| 20 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 |
| 21 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 |

(c) PERCENT ASSOCIATION (BASIC)

FIGURE A-16
ASSOCIATION PERFORMANCE AS A FUNCTION OF DENSITY AND OVERLAPS

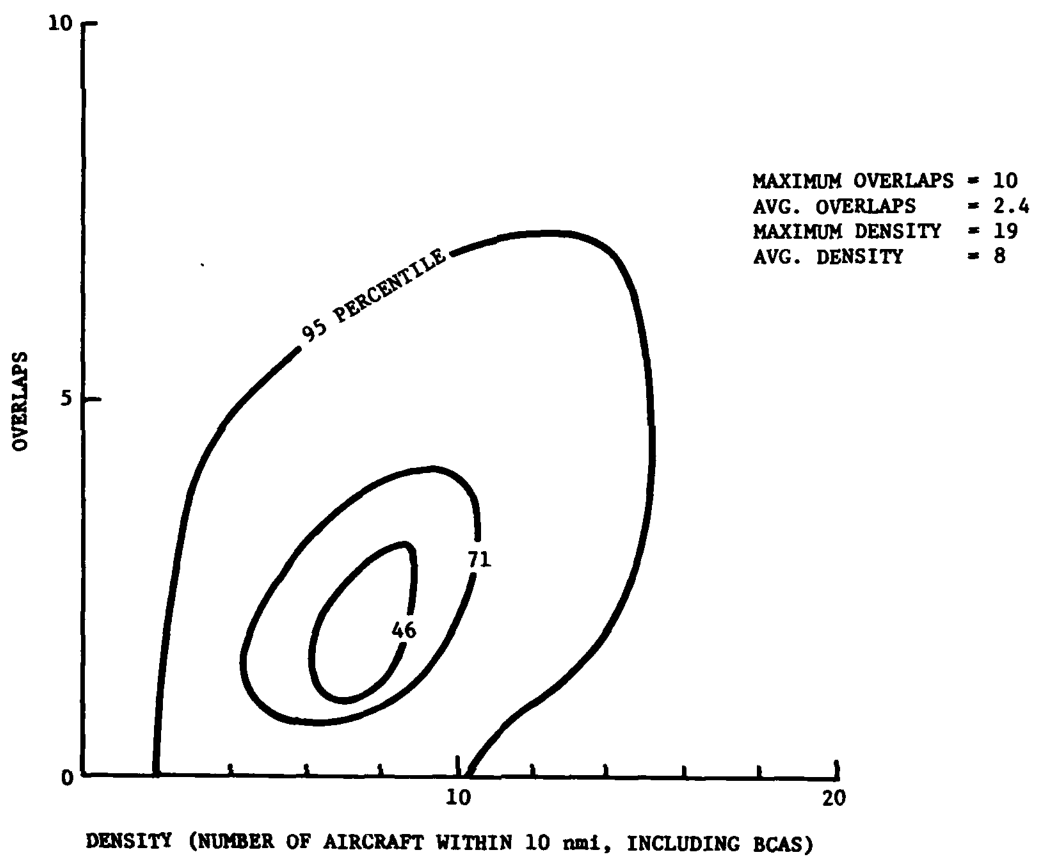



**FIGURE A-17**
**OVERLAPS VS DENSITY FOR LOS ANGELES DATA**

## APPENDIX B

### DATA COLLECTED IN THE WASHINGTON AREA

The following Appendix from Reference 3 is repeated for convenience. To maintain consistency, section and figure numbers will remain as they were in Reference 3.

In the following Figures A-15, A-16, A-19, and A-20, which refer to density, the entry for a density of "1" has been omitted, since it refers to be BCAS aircraft itself and has no significance.

## DATA COLLECTED IN WASHINGTON, D.C. AREA

### A.1 Introduction

The data presented in this Appendix comes from the data reduction package mentioned in Section 2. It is principally a comparison of BCAS tracks with the tracks obtained by using the target reports from ARTS III data tapes in the Washington flights.

First, an overall view of the system is shown by a series of matrices for "real" BCAS tracks and for "phantom" BCAS tracks. This is followed by detailed tables and histograms of performance with such parameters as the number of overlapping replies and the density of aircraft in the airspace. The figures for this section will be found grouped together at the end of the section.

### A.2 Overall Performance Characteristics

The Total Aircraft Track Matrix lists, for each scan and in each range-altitude bin, the number of tracked aircraft events obtained during the comparison interval. An aircraft track is determined principally by the presence of an ARTS track; however, if the ARTS track is lost and the corresponding BCAS track continues, the aircraft track is also continued. Thus an "aircraft track" implies a continuous process; whereas, an ARTS track is often a segmented process.

<u>Total Aircraft Tracks</u> are described by two matrices:

1. Range versus Altitude Matrix, denoted A (r,z) (Figure A-1)

where $\bar{r}$ - is the integerized range of an ARTS* track:

$\bar{r}$ = INTEGER(r) + 1; this implies that the range of a track is, at most, r nautical miles from BCAS aircraft.

$\bar{z}$ - is the relative altitude quantized into 500 foot bins.

$\bar{z}$ = (BCASALT MINUS THREAT ALT PLUS 10,000)/500;

e.g., suppose an aircraft is 5.597 nautical miles away from our BCAS equipped aircraft and has an altitude of 12,000 feet. Let BCAS altitude = 7,300 feet.

Then $\bar{r}$ = 5.597 + 1 = 6

$\bar{z}$ = (7,300 - 12,500 + 10,000)/500 = 4800/500 = 9.9 ≐ 9

So $(\bar{r},\bar{z})$ is put in the $\bar{r},\bar{z}$ slot of A(r,z).

Any aircraft having relative altitude, greater than 10,000 feet is counted as relative 10,000 feet.

2. Range versus Range Rate Matrix, denoted as JKR(r,k) (Figure A-2)

where $\bar{r}$ - is the integerized range of an ARTS track;

$\bar{k}$ - is the range rate in knots of an ARTS track quantized into 30 knot bins.

$\bar{k}$ = (Range rate of threat aircraft * 3,600 + 600)/30;

---

* As previously noted, the BCAS range is used in certain instances, when an ARTS track is lost.

e.g., let 3.79 be the relative range of a threat aircraft and -0.056 be its range rate (nmi/sec).

Then $\bar{r}$ = INTEGER (3.79) + 1 = 4

$\bar{k}$ = (-0.056 * 3,600 + 600)/30 = 13.28 = 13

So $(\bar{r},\bar{k})$ is put in the $\bar{r},\bar{k}$ slot of JKR(r,k).

Criteria for Track Association of a BCAS track with an ARTS track are as follows:

1. ABS $(\rho_B - \rho_A) < R_{WIN}$ & ABS $(Z_B - Z_A) < H_{WIN}$ where $\rho_B$ is relative range of aircraft being tracked by BCAS and $\rho_A$ is relative range of ARTS aircraft; $R_{WIN}$ is range window. $H_{WIN}$ is altitude window. $Z_B$ is altitude of aircraft being tracked by BCAS and $Z_A$ is the altitude of an aircraft being tracked by the ARTS site (i.e., Washington National). $R_{WIN}$ is set initially to 0.99 nmi and $H_{WIN}$ is set initially to 299 feet.

2. Both ARTS tracks and BCAS tracks must be established. An ARTS track is considered to be established when it reaches an age of 30 seconds, unless an established BCAS track associates with it, in which case two successive ARTS reports are required in order for the track to become established. BCAS tracks are established at an age of 10 seconds, increasing linearly with range to a maximum of 30 seconds at 20 nmi.

Total BCAS Associated Aircraft Track Matrices represent the total number of BCAS tracks* that were successfully associated with corresponding aircraft tracks during the course of the comparison interval. There are two associated BCAS track matrices. They are as follows:

1. Range vs. ALT matrix (Figure A-3) - denoted ASC(r,z) where r,z represents the range and altitude of an ARTS track with which a BCAS track successfully associates. However, if the ARTS track is temporarily lost, the r and z of the associated BCAS track is used.

$$ASC(r,z) \subseteq A(r,z)$$

2. Range vs. Range Rate matrix (Figure A-4) - denoted RATE (r,k where r,k represents the range and speed of an ARTS track with which a BCAS track successfully associates.

$$RATE(r,k) \subseteq JKR(r,k)$$

Ratio of BCAS Associated Aircraft Tracks to Total Aircraft Tracks gives the ratios of the preceding matrices and indicate the overall capability of BCAS to track aircraft within a radius of 20 nmi. These appear as Figures A-5 and A-6.

ARTS - BCAS Track Association Summary Tables (on a per mile basis) can be defined in the following way:

$$R_n = \sum_{n=1}^{20} B_n/A_n$$

* Here, BCAS tracks are those which remain after removing phantom tracks (see Section 6).

where $B_n$ is the number of times a BCAS track associated with an aircraft track whose range was n nmi, and $A_n$ is the total number of aircraft tracks at n nmi (Figures A-7 through A-9).

Cumulative Summary Table of BCAS associated aircraft tracks to total aircraft tracks (Figure A-10) is defined as follows:

$$\text{Cumulative ratio} = \sum_{S=1}^{20} (B_S + B_K)/(A_S + A_K)$$

where $B_S$, number of times a BCAS track associated with an aircraft track whose range was S nmi.

$B_K = \sum_{J=1}^{S-1} B_J$, total number of times a BCAS track associated with an aircraft track from 1 to (S-1) nmi.

$A_S$, total number of aircraft tracks at S nmi.

$A_K = \sum_{J=1}^{S-1} A_J$, total number of aircraft tracks from 1 to (S-1) nmi.

Note: If $S-1 = 0$, then $B_K$, $A_K = 0$.

Phantom Probability Matrix (Figures A-11 and A-12) contains those BCAS tracks that have been defined as being phantoms.

1. Any BCAS track with no association history at all is considered to be a phantom.

2. Any BCAS track not having either three consecutive associations, or at least 50 percent association, is also labeled as being a phantom.

Each entry consists of the number of scans that phantom tracks were found to exist divided by the total number of scans. If a BCAS track is found to be a phantom track, its entire track history is put into the phantom matrix. In addition, the association matrix is also modified, thus removing phantoms from it.

## A.3 Detailed Tables and Histograms

The preceding paragraphs provide the overall performance of BCAS. In order to understand some of the underlying relationships various other analyses were made. The following paragraphs examine the variation of performance with two major parameters, the number of overlapping replies and the number of aircraft in the airspace. These tables were compiled directly from ARTS and BCAS track data. No attempt was made here to distinguish between real and phantom tracks. In general, the results with the Basic system are presented first, followed by those for the Whisper-shout system.

The Track density table of ARTS peak traffic conditions (table A-1) provides the following for established ARTS tracks:

1. The range within which the indicated maximum number of overlaps occurs, and the time at which it occurs.

2. The range within which the indicated maximum number of aircraft (ARTS tracks only) occurs, and the time at which it occurs.

TABLE A-1

PEAK TRAFFIC CONDITIONS

| RANGE | MAX OVERLAPS | TIME | MAX AIRCRAFT | TIME |
|---|---|---|---|---|
| 2.50 | 3 | 53463 | 4 | 54602 |
| 5.00 | 5 | 52512 | 5 | 52512 |
| 7.50 | 7 | 53877 | 10 | 52071 |
| 10.00 | 9 | 52559 | 14 | 52569 |
| 15.00 | 9 | 52559 | 21 | 52602 |
| 20.00 | 9 | 52559 | 23 | 53750 |

Overlaps within a given range interval, J, are computed as follows:

Given: $A_k$, where k denotes the number of tracks, A, in an ARTS environment,

$$O_i = \left\{ \left( R(A_i) - 1.65 \right) \leq N \leq \left( R(A_i) + 1.65 \right) \right\} \;;\quad i = 2,k;\; R(A_i) \leq J$$

where N represents number of aircraft whose range falls within the overlap interval i.

$O_i$ = N-1 since the aircraft for which the overlaps are computed is not counted.

$R(A_i)$ stands for Range of track $A_i$.

Therefore, maximum overlaps within given interval J (denoted MAXJ) is defined as follows:

$$MAXJ = MAX(O_1, O_2, \ldots, O_h)$$

For example, suppose $A_2$, $A_3$, $A_4$, $A_5$ are BCAS tracks with range of 1.67, 2.47, 3.43, 5.19 nmi away from BCAS Equipped Aircraft ($A_1$).

Then to compute the Maximum Number of Overlaps within a given range interval (5 nmi) do as follows:

1. First count number of aircraft within overlap interval of $A_2$. Clearly, $R(A_2)$ and $R(A_3)$ falls within overlap interval of $A_2$ since:

$\{1.67 - 1.65 \leq R(A_2) \leq 1.67 + 1.65\}$ and
$\{1.67 - 1.65 \leq R(A_3) \leq 1.67 + 1.65\}$ and $R(A_2) \leq 5$ nmi

So there are two aircraft within overlap interval of $A_2$.

$\therefore$ N = 2

$0_2$ = N-1 = 1 since the aircraft $A_2$ for which the overlaps are computed is not counted.

2. Now count the number of aircraft within overlap interval of $A_3$.

Clearly, $R(A_2)$, $R(A_3)$, $R(A_4)$ falls within overlap interval of $A_3$ and $R(A_3) \leq 5$ nmi.

$\therefore$ N = 3

$0_3$ = N-1 = 2 OVERLAPS since the aircraft $A_3$ for which the overlaps are computed is not counted.

3. Count number of aircraft within overlap interval of $A_4$.

Clearly, $R(A_2)$, $R(A_3)$, $R(A_4)$ falls within overlap interval of $A_4$ and $R(A_4) \leq 5$ nmi.

$\therefore$ N = 3 aircraft

$0_4$ = N-1 = 2 OVERLAPS since the aircraft $A_4$ for which overlaps are computed is not counted.

4. Since $R(A_5) > 5$ nmi, its overlaps are not considered.

Therefore, $MAX(O_2,O_3,O_4) = MAX(1,2,2) = 2$ Overlaps.

So the maximum number of overlaps within 5 nmi is 2.

ARTS Association vs. the Number of Overlapping Replies is shown in Figure A-13 for the Basic mode; Figure A-14 is for Whisper-shout. ARTS tracks are listed as being associated with BCAS tracks or unassociated, as the case may be. The resulting histograms are shown.

Overlaps of ARTS traffic versus percent associations can be defined as follows:

$$R_{OVP} = \sum_{O_{VP}=0}^{12} A_{OVP}/(A_{OVP} + M_{OVP} + 0.01) * 100$$

where $A_{OVP}$ is the total number of associated ARTS tracks with OVP overlaps and

$M_{OVP}$ is the total number of unassociated ARTS tracks with OVP overlaps. $(A_{OVP} + M_{OVP})$ represents total ARTS tracks with OVP overlaps.

This data has been truncated so as to include only those tracks within 10 nmi and above 15 degrees depression angle.

ARTS association vs. density of aircraft is given in the next set of data, Figures A-15 and A-16. The data truncation beyond 10 nmi and below 15 degrees depression angle applies here. We define density here as the number of established ARTS tracks within 10 nmi of the BCAS aircraft. Therefore a "density" of 31 aircraft corresponds to 0.1 aircraft per $nmi^2$. The percent association is determined by evaluating the fraction

$$A_K = NA_K/(NA_K + M_K)$$

where $NA_K$ = number of associations in a density of K aircraft.
$M_K$ = number of missed association in a density of K aircraft.

BCAS track correlation vs. overlaps is shown, for associated BCAS tracks, in Figures A-17 and A-18. Correlation describes the status of the BCAS track at every scan interval (about 4.7 seconds). If the BCAS track does not correlate with a BCAS report at that time, the track is tagged with a coast status flag. Correlation is therefore the fraction of time that a track is not in coast status. ARTS data is used to determine how many overlapping replies exist for each BCAS track sample. The data is truncated at 10 nmi and 15 degrees.

BCAS track correlation vs. density relates BCAS coasting to the density of aircraft within 10 nmi. Figures A-19 and A-20 shows this data, for the Basic and the Whisper-shout systems, respectively.

BCAS Consecutive cost characteristics for associated tracks are shown in Figure A-21.

This consecutive coast status is obtained directly from the BCAS data tapes with the 1-second interrogation rate.

Association performance as a function of the range and overlaps is presented in Figure A-22. The data is truncated at 10 nmi and 15 degrees depression angle.

AD-A096 285 MITRE CORP MCLEAN VA METREK DIV F/G 1/2
RESULTS OF AN ACTIVE BEACON COLLISION AVOIDANCE EXPERIMENT COND--ETC(U)
MAY 79 P M EBERT, L T MOSES, N A SPENCER
UNCLASSIFIED MTR-79W00158 FAA-RD-80-7 NL

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Association performance as a function of the density and overlaps is presented in Figure A-23. Here, too, the data is truncated as noted.

BASIC MODE

| RELATIVE ALTITUDE (FEET) | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ABOVE BCAS 10000 | 0 | 0 | 0 | 0 | 4 | 3 | 10 | 8 | 26 | 43 | 32 | 31 | 45 | 68 | 70 | 74 | 66 | 65 | 60 | 30 |
| 9500 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 4 | 0 | 0 | 0 | 0 | 5 | 1 | 0 | 3 | 0 | 2 |
| 9000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 0 | 0 | 0 | 0 | 4 | 6 | 10 | 15 | 13 | 5 | 2 |
| 8500 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 0 | 0 | 0 | 4 | 4 | 0 | 0 | 1 | 5 | 13 | 2 |
| 8000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 0 | 0 | 2 | 3 | 1 | 0 | 0 | 0 | 6 | 3 | 3 |
| 7500 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 5 | 1 | 0 | 7 | 1 | 0 | 0 | 4 | 7 | 7 | 4 | 3 |
| 7000 | 0 | 0 | 8 | 15 | 8 | 22 | 9 | 4 | 9 | 6 | 7 | 3 | 0 | 1 | 6 | 6 | 16 | 7 | 0 | 0 |
| 6500 | 0 | 0 | 0 | 5 | 10 | 19 | 17 | 10 | 15 | 9 | 10 | 13 | 10 | 10 | 16 | 11 | 6 | 10 | 0 | 7 |
| 6000 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 2 | 5 | 0 | 0 | 9 | 5 | 4 | 0 | 0 | 6 | 12 |
| 5500 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 3 | 0 | 8 | 1 | 0 | 0 | 2 | 3 | 7 | 10 |
| 5000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 4 | 1 | 1 | 2 | 4 | 5 | 15 | 2 |
| 4500 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 4 | 6 | 6 | 1 | 4 | 4 | 13 | 13 | 6 | 12 |
| 4000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 5 | 7 | 8 | 5 | 13 | 2 | 6 | 4 | 8 | 7 | 6 | 8 |
| 3500 | 0 | 3 | 5 | 4 | 3 | 6 | 24 | 14 | 17 | 21 | 16 | 16 | 29 | 22 | 27 | 16 | 19 | 28 | 4 | 2 |
| 3000 | 2 | 1 | 0 | 2 | 6 | 20 | 15 | 18 | 12 | 17 | 14 | 11 | 8 | 21 | 11 | 22 | 16 | 7 | 2 | 11 |
| 2500 | 0 | 0 | 0 | 1 | 7 | 2 | 5 | 2 | 8 | 8 | 1 | 5 | 6 | 1 | 5 | 4 | 6 | 4 | 2 | 16 |
| 2000 | 1 | 0 | 0 | 0 | 3 | 7 | 6 | 1 | 6 | 17 | 3 | 9 | 3 | 7 | 8 | 11 | 10 | 6 | 1 | 0 |
| 1500 | 3 | 0 | 0 | 0 | 7 | 5 | 7 | 12 | 11 | 10 | 17 | 23 | 8 | 11 | 10 | 7 | 9 | 9 | 7 | 4 |
| 1000 | 29 | 47 | 52 | 49 | 45 | 54 | 56 | 53 | 58 | 60 | 88 | 79 | 106 | 109 | 70 | 53 | 51 | 16 | 25 | 5 |
| 500 | 7 | 0 | 2 | 5 | 1 | 5 | 1 | 5 | 11 | 12 | 13 | 6 | 12 | 14 | 4 | 16 | 28 | 36 | 7 | 10 |
| BCAS +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | |
| BELOW BCAS -500 | 4 | 5 | 3 | 4 | 4 | 7 | 12 | 11 | 5 | 5 | 11 | 21 | 20 | 11 | 7 | 19 | 25 | 16 | 8 | 14 |
| -1000 | 0 | 1 | 5 | 6 | 8 | 26 | 29 | 14 | 11 | 11 | 16 | 28 | 19 | 7 | 16 | 17 | 20 | 22 | 30 | 70 |
| -1500 | 0 | 1 | 3 | 3 | 10 | 16 | 2 | 13 | 4 | 9 | 27 | 17 | 9 | 23 | 25 | 24 | 22 | 6 | 16 | 22 |
| -2000 | 1 | 6 | 0 | 2 | 0 | 12 | 6 | 13 | 21 | 17 | 37 | 22 | 39 | 36 | 35 | 20 | 47 | 11 | 16 | 25 |
| -2500 | 2 | 16 | 9 | 17 | 13 | 16 | 10 | 15 | 22 | 30 | 55 | 39 | 22 | 23 | 23 | 75 | 21 | 16 | 10 | 26 |
| -3000 | 6 | 18 | 6 | 10 | 12 | 11 | 16 | 33 | 22 | 44 | 32 | 53 | 40 | 30 | 47 | 60 | 16 | 11 | 34 | 24 |
| -3500 | 2 | 21 | 33 | 22 | 15 | 26 | 32 | 28 | 22 | 22 | 7 | 39 | 34 | 27 | 35 | 27 | 39 | 33 | 30 | 14 |
| -4000 | 2 | 15 | 53 | 47 | 36 | 29 | 61 | 51 | 47 | 52 | 49 | 60 | 50 | 30 | 32 | 71 | 73 | 79 | 29 | 29 |
| -4500 | 4 | 5 | 20 | 48 | 89 | 96 | 95 | 80 | 62 | 74 | 85 | 63 | 96 | 159 | 178 | 153 | 96 | 126 | 55 | 35 |
| -5000 | 2 | 9 | 39 | 47 | 74 | 66 | 63 | 56 | 50 | 60 | 78 | 120 | 72 | 112 | 113 | 127 | 179 | 145 | 101 | 63 |
| -5500 | 1 | 22 | 42 | 55 | 56 | 52 | 65 | 39 | 104 | 114 | 146 | 153 | 163 | 106 | 81 | 89 | 83 | 75 | 47 | 63 |
| -6000 | 0 | 23 | 65 | 27 | 52 | 79 | 91 | 60 | 84 | 44 | 90 | 97 | 73 | 49 | 64 | 79 | 94 | 80 | 75 | 42 |
| -6500 | 0 | 36 | 42 | 35 | 48 | 56 | 51 | 54 | 89 | 60 | 82 | 67 | 38 | 48 | 32 | 35 | 57 | 11 | 11 | 3 |
| -7000 | 0 | 9 | 13 | 14 | 16 | 50 | 52 | 57 | 52 | 37 | 52 | 23 | 21 | 19 | 27 | 22 | 54 | 27 | 11 | 1 |
| -7500 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| -8000 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 1 | 1 | 0 | 0 | 0 |
| -8500 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| -9000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 |
| -9500 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| -10000 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 2 | 0 | 1 | 0 | 0 | 1 | 0 | 0 |
| | 66 | 240 | 400 | 422 | 528 | 686 | 740 | 663 | 792 | 796 | 992 | 1019 | 964 | 569 | 974 | 1075 | 1088 | 913 | 646 | 566 |
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |

RELATIVE RANGE (NMI)

FIGURE A-1
TOTAL AIRCRAFT TRACK MATRIX (R VS Z)

BASIC MODE

| RANGE RATE | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CLOSING | -600 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 4 | 4 | 1 | 2 | 4 | 1 | 5 | 3 | 2 | 1 | 1 | 1 | 0 |
| | -570 | 0 | 0 | 0 | 0 | 2 | 2 | 2 | 0 | 1 | 0 | 1 | 0 | 0 | 3 | 8 | 3 | 2 | 0 | 0 | 0 |
| | -540 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 2 | 7 | 4 | 1 | 1 | 0 | 0 | 0 |
| | -510 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 3 | 4 | 1 | 7 | 2 | 0 | 0 | 0 | 0 |
| | -480 | 1 | 0 | 0 | 0 | 0 | 1 | 6 | 3 | 5 | 7 | 10 | 6 | 11 | 6 | 3 | 1 | 1 | 0 | 0 | 0 |
| | -450 | 0 | 2 | 0 | 1 | 2 | 3 | 1 | 3 | 4 | 4 | 6 | 4 | 5 | 6 | 2 | 4 | 2 | 0 | 0 | 0 |
| | -420 | 1 | 0 | 4 | 5 | 6 | 5 | 10 | 11 | 12 | 6 | 10 | 7 | 14 | 7 | 8 | 4 | 2 | 0 | 0 | 0 |
| | -390 | 1 | 1 | 5 | 8 | 9 | 17 | 9 | 11 | 9 | 13 | 10 | 18 | 11 | 11 | 16 | 5 | 6 | 0 | 0 | 0 |
| | -360 | 0 | 5 | 10 | 10 | 4 | 11 | 17 | 8 | 8 | 17 | 26 | 23 | 23 | 18 | 21 | 27 | 7 | 2 | 0 | 0 |
| | -330 | 4 | 4 | 13 | 12 | 18 | 13 | 24 | 22 | 26 | 35 | 17 | 13 | 5 | 6 | 8 | 13 | 19 | 4 | 2 | 1 |
| | -300 | 3 | 4 | 13 | 19 | 16 | 18 | 27 | 24 | 23 | 25 | 19 | 23 | 13 | 27 | 18 | 17 | 16 | 9 | 1 | 0 |
| | -270 | 6 | 9 | 12 | 10 | 10 | 20 | 15 | 24 | 25 | 19 | 20 | 16 | 30 | 21 | 17 | 21 | 33 | 22 | 0 | 0 |
| | -240 | 2 | 18 | 19 | 30 | 17 | 22 | 31 | 34 | 20 | 23 | 22 | 27 | 31 | 26 | 27 | 37 | 40 | 26 | 2 | 0 |
| | -210 | 1 | 8 | 16 | 13 | 22 | 17 | 20 | 28 | 32 | 28 | 23 | 33 | 38 | 40 | 49 | 39 | 42 | 40 | 12 | 2 |
| | -180 | 2 | 10 | 13 | 24 | 30 | 32 | 55 | 34 | 25 | 24 | 38 | 32 | 16 | 30 | 32 | 48 | 46 | 24 | 20 | [illegible] |
| | -150 | 1 | 8 | 20 | 15 | 29 | 37 | 37 | 37 | 39 | 48 | 57 | 40 | 35 | 41 | 54 | 56 | 46 | 43 | 36 | 4 |
| | -120 | 4 | 23 | 24 | 40 | 55 | 54 | 40 | 55 | 61 | 52 | 65 | 53 | 58 | 49 | 50 | 49 | 72 | 56 | 37 | 13 |
| | -90 | 6 | 28 | 28 | 22 | 33 | 62 | 17 | 24 | 44 | 39 | 67 | 53 | 41 | 67 | 59 | 78 | 99 | 57 | 40 | 27 |
| | -60 | 3 | 25 | 31 | 11 | 33 | 49 | 52 | 19 | 53 | 43 | 86 | 112 | 83 | 74 | 46 | 93 | 79 | 67 | 54 | 77 |
| | -30 | 14 | 15 | 49 | 27 | 36 | 51 | 58 | 21 | 52 | 55 | 104 | 100 | 90 | 58 | 79 | 126 | 69 | 67 | 43 | 53 |
| | BCAS | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ |
| SEPARATING | 30 | 2 | 9 | 36 | 26 | 26 | 21 | 45 | 12 | 49 | 41 | 61 | 60 | 77 | 46 | 51 | 67 | 66 | 74 | 50 | 29 |
| | 60 | 1 | 10 | 20 | 33 | 25 | 44 | 73 | 37 | 42 | 65 | 59 | 72 | 49 | 68 | 55 | 69 | 72 | 73 | 40 | 35 |
| | 90 | 2 | 7 | 8 | 21 | 27 | 35 | 21 | 33 | 35 | 21 | 57 | 58 | 50 | 72 | 70 | 40 | 54 | 58 | 46 | 71 |
| | 120 | 2 | 14 | 11 | 21 | 18 | 27 | 36 | 56 | 44 | 38 | 38 | 49 | 55 | 49 | 44 | 43 | 70 | 53 | 42 | 46 |
| | 150 | 4 | 12 | 11 | 10 | 18 | 36 | 34 | 35 | 49 | 44 | 37 | 42 | 40 | 48 | 52 | 47 | 30 | 33 | 51 | 51 |
| | 180 | 4 | 12 | 22 | 23 | 40 | 24 | 30 | 30 | 39 | 49 | 31 | 36 | 57 | 52 | 37 | 30 | 45 | 56 | 45 | 40 |
| | 210 | 1 | 3 | 13 | 12 | 18 | 29 | 21 | 31 | 22 | 26 | 36 | 31 | 32 | 42 | 34 | 26 | 31 | 27 | 31 | 25 |
| | 240 | 0 | 6 | 4 | 13 | 8 | 17 | 16 | 19 | 22 | 31 | 39 | 37 | 42 | 31 | 34 | 32 | 32 | 32 | 35 | 36 |
| | 270 | 0 | 4 | 4 | 8 | 9 | 11 | 17 | 16 | 15 | 15 | 4 | 29 | 11 | 18 | 27 | 31 | 26 | 11 | 11 | 21 |
| | 300 | 1 | 4 | 8 | 2 | 7 | 9 | 9 | 15 | 15 | 5 | 19 | 14 | 7 | 9 | 17 | 13 | 14 | 13 | 5 | 11 |
| | 330 | 0 | 0 | 4 | 4 | 4 | 6 | 7 | 7 | 5 | 6 | 5 | 6 | 10 | 7 | 15 | 9 | 14 | 14 | 10 | [illegible] |
| | 360 | 0 | 1 | 2 | 1 | 2 | 3 | 4 | 3 | 3 | 4 | 8 | 6 | 9 | 7 | 7 | 5 | 8 | 3 | 6 | 6 |
| | 390 | 0 | 0 | 0 | 1 | 2 | 7 | 1 | 0 | 1 | 4 | 3 | 1 | 2 | 3 | 4 | 4 | 5 | 2 | 6 | 7 |
| | 420 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 3 | 3 | 0 | 1 | 2 | 5 | 5 | 7 | 7 | 2 | 6 | 2 | 4 |
| | 450 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 1 | 5 | 7 | 1 | 2 | 1 | 1 | 1 | 4 | 1 | 0 |
| | 480 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 3 | 2 | 3 | 3 | 2 | 3 | 2 | 2 | 3 | 5 |
| | 510 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 2 | 2 | 1 | 2 | 6 | 5 | 6 |
| | 540 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 1 | 2 | 1 | 0 | 0 |
| | 570 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 |
| | 600 | 0 | 0 | 0 | 0 | 0 | 2 | 3 | 1 | 1 | 2 | 0 | 0 | 1 | 2 | 1 | 0 | 2 | 3 | 3 | 2 |
| | | 66 | 240 | 400 | 422 | 528 | 686 | 740 | 663 | 792 | 796 | 992 | 1019 | 904 | 969 | 974 | 1075 | 1086 | 913 | 646 | 566 |
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |

RELATIVE RANGE (NMI)

FIGURE A-2
TOTAL AIRCRAFT TRACK MATRIX (R VS $\dot{R}$)

BASIC MODE

| RELATIVE ALTITUDE (FEET) \ RELATIVE RANGE (NMI) | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ABOVE BCAS 10000 | 0 | 0 | 0 | 0 | 4 | 3 | 7 | 8 | 26 | 41 | 25 | 29 | 42 | 58 | 57 | 65 | 36 | 39 | 39 | 26 |
| 9500 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 3 | 1 | 0 | 2 | 0 | 2 |
| 9000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 3 | 6 | 10 | 7 | 9 | 3 | 1 |
| 8500 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 0 | 0 | 0 | 4 | 4 | 0 | 0 | 1 | 4 | 12 | 2 |
| 8000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 0 | 0 | 2 | 3 | 1 | 0 | 0 | 0 | 6 | 3 | 2 |
| 7500 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 3 | 1 | 0 | 7 | 3 | 0 | 0 | 4 | 7 | 7 | 4 | 5 |
| 7000 | 0 | 0 | 8 | 13 | 5 | 18 | 9 | 4 | 9 | 4 | 0 | 2 | 0 | 1 | 8 | 6 | 9 | 2 | 3 | 0 |
| 6500 | 0 | 0 | 0 | 4 | 9 | 17 | 10 | 5 | 13 | 3 | 5 | 11 | 9 | 10 | 12 | 9 | 3 | 0 | 0 | 7 |
| 6000 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 2 | 5 | 0 | 0 | 6 | 5 | 1 | 0 | 0 | 6 | 5 |
| 5500 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 3 | 0 | 8 | 1 | 0 | 0 | 2 | 3 | 7 | 11 |
| 5000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 4 | 1 | 0 | 2 | 4 | 5 | 4 | 2 |
| 4500 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 4 | 4 | 6 | 1 | 2 | 4 | 10 | 5 | 5 | 11 |
| 4000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 5 | 7 | 5 | 5 | 11 | 2 | 6 | 4 | 5 | 2 | 4 | 7 |
| 3500 | 0 | 3 | 5 | 4 | 2 | 5 | 19 | 11 | 15 | 19 | 14 | 15 | 29 | 21 | 22 | 15 | 10 | 20 | 4 | 1 |
| 3000 | 0 | 0 | 0 | 2 | 5 | 20 | 15 | 16 | 6 | 14 | 7 | 1 | 5 | 16 | 5 | 1 | 5 | 6 | 0 | 3 |
| 2500 | 0 | 0 | 0 | 0 | 3 | 2 | 5 | 2 | 7 | 8 | 1 | 5 | 6 | 1 | 0 | 2 | 5 | 1 | 0 | 3 |
| 2000 | 1 | 0 | 0 | 0 | 3 | 5 | 6 | 1 | 6 | 15 | 3 | 9 | 3 | 1 | 5 | 5 | 2 | 0 | 1 | 0 |
| 1500 | 3 | 0 | 0 | 0 | 7 | 5 | 7 | 12 | 11 | 4 | 11 | 21 | 4 | 7 | 6 | 3 | 0 | 1 | 2 | 0 |
| 1000 | 29 | 46 | 52 | 49 | 45 | 53 | 52 | 49 | 55 | 49 | 71 | 52 | 51 | 51 | 30 | 13 | 3 | 0 | 0 | 0 |
| 500 | 0 | 0 | 2 | 5 | 1 | 5 | 1 | 1 | 7 | 12 | 13 | 6 | 6 | 2 | 1 | 11 | 11 | 7 | 0 | 3 |
| BCAS +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | | | |
| BELOW BCAS -500 | 4 | 4 | 3 | 4 | 4 | 6 | 8 | 8 | 5 | 4 | 9 | 13 | 6 | 5 | 3 | 10 | 10 | 6 | 0 | 0 |
| -1000 | 0 | 1 | 4 | 6 | 6 | 25 | 15 | 5 | 11 | 11 | 12 | 20 | 11 | 4 | 14 | 16 | 11 | 5 | 22 | 53 |
| -1500 | 0 | 1 | 3 | 2 | 9 | 16 | 1 | 6 | 1 | 6 | 20 | 10 | 3 | 13 | 16 | 3 | 8 | 1 | 11 | 10 |
| -2000 | 1 | 6 | 0 | 1 | 0 | 10 | 6 | 9 | 20 | 14 | 27 | 19 | 20 | 17 | 19 | 9 | 7 | 6 | 8 | 1 |
| -2500 | 2 | 9 | 3 | 16 | 10 | 16 | 10 | 13 | 21 | 25 | 39 | 24 | 5 | 12 | 7 | 51 | 7 | 10 | 5 | 9 |
| -3000 | 4 | 12 | 5 | 5 | 8 | 11 | 16 | 28 | 18 | 31 | 25 | 26 | 21 | 11 | 16 | 21 | 8 | 7 | 17 | 15 |
| -3500 | 2 | 19 | 26 | 17 | 6 | 24 | 18 | 21 | 12 | 15 | 2 | 11 | 21 | 12 | 10 | 8 | 13 | 6 | 14 | [illegible] |
| -4000 | 2 | 13 | 41 | 40 | 18 | 23 | 38 | 29 | 30 | 22 | 24 | 20 | 26 | 14 | 16 | 26 | 27 | 24 | 8 | 9 |
| -4500 | 0 | 1 | 13 | 36 | 55 | 67 | 55 | 43 | 36 | 39 | 47 | 39 | 36 | 66 | 74 | 88 | 56 | 55 | 32 | 16 |
| -5000 | 2 | 8 | 17 | 30 | 49 | 54 | 40 | 28 | 30 | 44 | 56 | 75 | 60 | 61 | 57 | 57 | 100 | 77 | 26 | 35 |
| -5500 | 1 | 9 | 25 | 32 | 33 | 36 | 40 | 19 | 84 | 84 | 113 | 114 | 110 | 86 | 49 | 40 | 51 | 34 | 12 | 29 |
| -6000 | 0 | 12 | 40 | 21 | 38 | 40 | 41 | 26 | 52 | 32 | 59 | 59 | 40 | 29 | 20 | 42 | 49 | 57 | 26 | 23 |
| -6500 | 0 | 18 | 30 | 29 | 33 | 37 | 45 | 36 | 61 | 44 | 60 | 38 | 19 | 23 | 21 | 30 | 33 | 10 | 11 | 3 |
| -7000 | 0 | 6 | 13 | 14 | 12 | 50 | 52 | 57 | 51 | 34 | 46 | 22 | 21 | 19 | 23 | 18 | 52 | 27 | 11 | 1 |
| -7500 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| -8000 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 |
| -8500 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| -9000 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 |
| -9500 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| -10000 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 0 |
| | 51 | 169 | 290 | 334 | 366 | 548 | 519 | 449 | 606 | 586 | 712 | 660 | 594 | 579 | 516 | 586 | 553 | 445 | 307 | 314 |

FIGURE A-3
TOTAL BCAS ASSOCIATED AIRCRAFT TRACK MATRIX (R VS Z)

BASIC MODE

| RANGE RATE | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CLOSING -600 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 2 | 3 | 1 | 5 | 2 | 2 | 1 | 0 | 0 | 0 |
| -570 | 0 | 0 | 0 | 0 | 2 | 0 | 2 | 0 | 1 | 0 | 1 | 0 | 0 | 3 | 7 | 3 | 0 | 0 | 0 | 0 |
| -540 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 2 | 7 | 3 | 0 | 0 | 0 | 0 | 0 |
| -510 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 1 | 3 | 4 | 1 | 3 | 2 | 0 | 0 | 0 | 0 |
| -480 | 1 | 0 | 0 | 0 | 0 | 0 | 3 | 2 | 4 | 6 | 8 | 4 | 11 | 5 | 1 | 1 | 1 | 0 | 0 | 0 |
| -450 | 0 | 2 | 0 | 1 | 1 | 3 | 1 | 2 | 4 | 4 | 6 | 4 | 5 | 3 | 2 | 3 | 2 | 0 | 0 | 0 |
| -420 | 1 | 0 | 3 | 5 | 6 | 5 | 5 | 8 | 9 | 6 | 8 | 5 | 9 | 5 | 4 | 1 | 1 | 0 | 0 | 0 |
| -390 | 1 | 1 | 4 | 6 | 7 | 13 | 6 | 7 | 7 | 10 | 9 | 15 | 9 | 6 | 6 | 4 | 4 | 0 | 0 | 0 |
| -360 | 0 | 5 | 9 | 8 | 3 | 9 | 12 | 6 | 3 | 9 | 14 | 13 | 14 | 12 | 13 | 7 | 1 | 0 | 0 | 0 |
| -330 | 4 | 4 | 11 | 10 | 15 | 13 | 21 | 15 | 17 | 22 | 7 | 7 | 2 | 5 | 6 | 7 | 4 | 1 | 2 | 1 |
| -300 | 3 | 4 | 12 | 17 | 13 | 11 | 13 | 15 | 15 | 16 | 10 | 8 | 6 | 17 | 9 | 9 | 6 | 1 | 1 | 0 |
| -270 | 6 | 8 | 10 | 8 | 5 | 11 | 6 | 12 | 17 | 13 | 5 | 9 | 21 | 10 | 4 | 11 | 11 | 11 | 0 | 0 |
| -240 | 2 | 15 | 16 | 26 | 14 | 19 | 27 | 28 | 14 | 18 | 12 | 20 | 20 | 15 | 14 | 20 | 16 | 13 | 0 | 0 |
| -210 | 1 | 6 | 13 | 13 | 17 | 16 | 14 | 22 | 30 | 19 | 20 | 26 | 25 | 28 | 30 | 24 | 22 | 13 | 4 | 2 |
| -180 | 2 | 10 | 10 | 21 | 21 | 25 | 30 | 19 | 16 | 20 | 35 | 28 | 7 | 23 | 15 | 25 | 20 | 9 | 2 | 1 |
| -150 | 1 | 7 | 11 | 12 | 16 | 28 | 25 | 16 | 34 | 41 | 42 | 26 | 19 | 22 | 24 | 41 | 15 | 7 | 11 | 0 |
| -120 | 3 | 17 | 17 | 34 | 35 | 42 | 25 | 34 | 38 | 32 | 43 | 30 | 39 | 20 | 27 | 25 | 14 | 15 | 28 | 4 |
| -90 | 0 | 16 | 24 | 20 | 22 | 54 | 13 | 18 | 34 | 29 | 47 | 23 | 24 | 39 | 26 | 30 | 35 | 24 | 17 | 8 |
| -60 | 2 | 13 | 15 | 7 | 29 | 44 | 47 | 14 | 42 | 33 | 76 | 70 | 28 | 22 | 21 | 30 | 37 | 37 | 21 | 44 |
| -30 | 9 | 7 | 37 | 20 | 27 | 44 | 47 | 16 | 40 | 38 | 73 | 64 | 47 | 34 | 23 | 61 | 62 | 36 | 14 | 30 |
| BCAS +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ |
| SEPARATING 30 | 2 | 5 | 23 | 20 | 19 | 14 | 32 | 9 | 35 | 30 | 38 | 30 | 42 | 24 | 22 | 60 | 45 | 39 | 29 | 17 |
| 60 | 0 | 6 | 13 | 25 | 16 | 36 | 48 | 22 | 37 | 49 | 41 | 45 | 26 | 43 | 32 | 36 | 31 | 49 | 24 | 21 |
| 90 | 1 | 3 | 6 | 16 | 12 | 27 | 16 | 25 | 28 | 17 | 39 | 36 | 37 | 47 | 40 | 22 | 39 | 40 | 25 | 35 |
| 120 | 2 | 11 | 5 | 8 | 7 | 24 | 27 | 40 | 40 | 26 | 24 | 30 | 42 | 32 | 25 | 29 | 50 | 31 | 25 | 24 |
| 150 | 4 | 4 | 8 | 8 | 9 | 28 | 22 | 27 | 38 | 51 | 26 | 29 | 33 | 29 | 29 | 29 | [illegible] | 16 | 26 | 23 |
| 180 | 4 | 10 | 15 | 15 | 33 | 15 | 19 | 23 | 29 | 38 | 20 | 27 | 33 | 30 | 22 | 13 | 16 | 28 | 19 | 25 |
| 210 | 1 | 3 | 11 | 11 | 16 | 18 | 18 | 24 | 17 | 18 | 33 | 19 | 17 | 28 | 15 | 15 | 20 | 17 | 11 | 16 |
| 240 | 0 | 5 | 4 | 10 | 8 | 16 | 8 | 13 | 18 | 24 | 32 | 30 | 28 | 21 | 26 | 20 | 18 | 13 | 10 | 13 |
| 270 | 0 | 3 | 2 | 7 | 5 | 9 | 15 | 9 | 13 | 15 | 4 | 24 | 10 | 13 | 19 | 23 | 16 | 6 | 6 | 10 |
| 300 | 1 | 3 | 5 | 2 | 1 | 8 | 7 | 13 | 13 | 5 | 16 | 13 | 5 | 6 | 13 | 8 | 14 | 13 | 3 | 7 |
| 330 | 0 | 0 | 4 | 3 | 2 | 5 | 6 | 6 | 3 | 5 | 4 | 4 | 9 | 5 | 13 | 7 | 5 | 7 | 5 | 5 |
| 360 | 0 | 1 | 2 | 0 | 2 | 2 | 1 | 1 | 3 | 3 | 6 | 5 | 7 | 4 | 2 | 2 | 7 | 3 | 5 | 4 |
| 390 | 0 | 0 | 0 | 1 | 1 | 7 | 0 | 0 | 1 | 4 | 2 | 0 | 2 | 2 | 3 | 3 | 4 | 2 | 6 | 6 |
| 420 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 2 | 3 | 0 | 1 | 2 | 5 | 4 | 7 | 7 | 2 | 2 | 2 | 4 |
| 450 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 4 | 7 | 1 | 2 | 1 | 1 | 1 | 2 | 0 | 0 |
| 480 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 3 | 1 | 3 | 3 | 2 | 3 | 2 | 2 | 1 | 3 |
| 510 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 2 | 2 | 1 | 2 | 4 | 3 | 6 |
| 540 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 1 | 2 | 1 | 0 | 0 |
| 570 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 |
| 600 | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 1 | 1 | 1 | 0 | 0 | 1 | 2 | 0 | 0 | 1 | 3 | 3 | 2 |
| | 51 | 169 | 290 | 334 | 366 | 548 | 519 | 449 | 606 | 586 | 712 | 660 | 594 | 579 | 518 | 586 | 553 | 445 | 307 | 314 |

RELATIVE RANGE (NMI)

**FIGURE A-4**
**TOTAL BCAS ASSOCIATED AIRCRAFT TRACK MATRIX (R VS Ṙ)**

BASIC MODE

| RELATIVE ALTITUDE (FEET) | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ABOVE BCAS 10000 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 69 | 95 | 99 | 95 | 78 | 93 | 93 | 65 | 81 | 93 | 54 | 59 | 54 | 73 |
| 9500 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 |
| 9000 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 99 | 99 | 46 | 69 | 59 | 1111 |
| 8500 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 79 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 73 | 92 | 1111 |
| 8000 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 99 | 1111 | 1111 |
| 7500 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 59 | 1111 | 1111 | 99 | 1111 | 1111 | 1111 | 1111 | 95 | 99 | 1111 | 99 |
| 7000 | 1111 | 1111 | 99 | 86 | 62 | 81 | 95 | 1111 | 99 | 66 | 0 | 1111 | 1111 | 1111 | 99 | 99 | 56 | 28 | 1111 | 1111 |
| 6500 | 1111 | 1111 | 1111 | 79 | 89 | 89 | 58 | 49 | 86 | 32 | 49 | 84 | 85 | 99 | 66 | 81 | 49 | 0 | 1111 | 59 |
| 6000 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 99 | 1111 | 1111 | 66 | 99 | 1111 | 1111 | 1111 | 99 | 74 |
| 5500 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 59 | 1111 | 1111 | 1111 | 1111 | 1111 | 95 | 68 |
| 5000 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 99 | 93 | 1111 |
| 4500 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 66 | 99 | 1111 | 1111 | 1111 | 76 | 38 | 63 | 91 |
| 4000 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 95 | 99 | 95 | 62 | 99 | 84 | 1111 | 59 | 1111 | 62 | 28 | 66 | 67 |
| 3500 | 1111 | 1111 | 95 | 1111 | 1111 | 83 | 79 | 78 | 88 | 90 | 87 | 93 | 99 | 95 | 81 | 83 | 52 | 71 | 1111 | 1111 |
| 3000 | 1111 | 1111 | 1111 | 1111 | 83 | 95 | 99 | 88 | 49 | 82 | 49 | 9 | 62 | 76 | 45 | 4 | 31 | 85 | 1111 | 27 |
| 2500 | 1111 | 1111 | 1111 | 1111 | 42 | 1111 | 99 | 1111 | 87 | 99 | 1111 | 59 | 95 | 1111 | 0 | 1111 | 62 | 1111 | 1111 | 16 |
| 2000 | 1111 | 1111 | 1111 | 1111 | 1111 | 71 | 99 | 1111 | 99 | 86 | 1111 | 99 | 1111 | 14 | 62 | 81 | 19 | 0 | 1111 | 1111 |
| 1500 | 1111 | 1111 | 1111 | 1111 | 99 | 99 | 99 | 94 | 99 | 39 | 64 | 91 | 49 | 63 | 59 | 42 | 0 | 11 | 26 | 1111 |
| 1000 | 99 | 97 | 99 | 99 | 99 | 98 | 92 | 92 | 94 | 81 | 80 | 65 | 46 | 46 | 42 | 24 | 5 | 0 | 0 | 0 |
| 500 | 0 | 1111 | 1111 | 99 | 1111 | 99 | 1111 | 19 | 63 | 99 | 95 | 99 | 49 | 14 | 1111 | 61 | 39 | 18 | 0 | 18 |
| BCAS | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | | |
| BELOW BCAS -500 | 1111 | 79 | 1111 | 1111 | 1111 | 85 | 66 | 72 | 99 | 79 | 81 | 61 | 25 | 45 | 42 | 52 | 39 | 33 | 0 | 0 |
| -1000 | 1111 | 1111 | 79 | 99 | 74 | 96 | 51 | 35 | 99 | 99 | 74 | 71 | 57 | 57 | 87 | 94 | 54 | 22 | 73 | 75 |
| -1500 | 1111 | 1111 | 1111 | 1111 | 65 | 99 | 1111 | 46 | 1111 | 66 | 74 | 58 | 33 | 56 | 63 | 12 | 36 | 16 | 66 | 45 |
| -2000 | 1111 | 99 | 1111 | 1111 | 1111 | 83 | 99 | 69 | 95 | 82 | 72 | 86 | 51 | 47 | 54 | 44 | 14 | 54 | 49 | 3 |
| -2500 | 1111 | 56 | 33 | 94 | 76 | 99 | 99 | 86 | 95 | 83 | 70 | 61 | 22 | 52 | 30 | 67 | 55 | 62 | 49 | 34 |
| -3000 | 66 | 66 | 83 | 49 | 66 | 99 | 99 | 84 | 81 | 70 | 76 | 49 | 52 | 36 | 34 | 34 | 49 | 63 | 49 | 62 |
| -3500 | 1111 | 90 | 78 | 77 | 39 | 92 | 56 | 74 | 54 | 68 | 28 | 28 | 61 | 44 | 28 | 29 | 35 | 18 | 46 | 92 |
| -4000 | 1111 | 86 | 77 | 85 | 49 | 79 | 62 | 56 | 63 | 42 | 48 | 33 | 51 | 46 | 56 | 36 | 36 | 30 | 27 | 31 |
| -4500 | 1111 | 19 | 64 | 74 | 61 | 69 | 57 | 53 | 58 | 52 | 55 | 61 | 39 | 54 | 41 | 57 | 58 | 43 | 58 | 45 |
| -5000 | 1111 | 88 | 43 | 63 | 66 | 81 | 63 | 49 | 59 | 73 | 71 | 62 | 83 | 54 | 50 | 44 | 55 | 53 | 25 | 55 |
| -5500 | 1111 | 40 | 59 | 58 | 58 | 69 | 61 | 48 | 80 | 73 | 77 | 74 | 67 | 81 | 60 | 44 | 61 | 45 | 25 | 46 |
| -6000 | 1111 | 52 | 61 | 77 | 73 | 50 | 45 | 43 | 61 | 72 | 65 | 60 | 54 | 59 | 31 | 53 | 52 | 71 | 34 | 54 |
| -6500 | 1111 | 49 | 71 | 82 | 68 | 66 | 88 | 66 | 68 | 73 | 73 | 56 | 49 | 47 | 65 | 85 | 89 | 90 | 99 | 1111 |
| -7000 | 1111 | 66 | 99 | 99 | 74 | 99 | 99 | 99 | 98 | 91 | 92 | 97 | 99 | 99 | 85 | 81 | 96 | 99 | 99 | 1111 |
| -7500 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 |
| -8000 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 |
| -8500 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 |
| -9000 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 |
| -9500 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 |
| -10000 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 |
| | 77 | 70 | 72 | 79 | 69 | 79 | 70 | 67 | 76 | 73 | 71 | 64 | 61 | 59 | 53 | 54 | 50 | 46 | 47 | 53 |

RELATIVE RANGE (NMI)

FIGURE A-6
RATIO OF BCAS ASSOCIATED AIRCRAFT TRACKS
TO TOTAL AIRCRAFT TRACKS (R VS Z)

BASIC MODE

| RELATIVE ALTITUDE (FEET) | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CLOSING | -600 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 0 | 24 | 1111 | 99 | 74 | 1111 | 99 | 66 | 99 | 1111 | 1111 | 1111 | 1111 |
| | -570 | 1111 | 1111 | 1111 | 1111 | 99 | 0 | 99 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 99 | 67 | 99 | 0 | 1111 | 1111 | 1111 |
| | -540 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 99 | 99 | 74 | 1111 | 1111 | 1111 | 1111 | 1111 |
| | -510 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 99 | 99 | 1111 | 42 | 99 | 1111 | 1111 | 1111 | 1111 |
| | -480 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 49 | 66 | 79 | 85 | 79 | 66 | 99 | 83 | 33 | 1111 | 1111 | 1111 | 1111 | 1111 |
| | -450 | 1111 | 99 | 1111 | 1111 | 49 | 99 | 1111 | 66 | 99 | 99 | 99 | 99 | 99 | 49 | 99 | 74 | 99 | 1111 | 1111 | 1111 |
| | -420 | 1111 | 1111 | 74 | 99 | 99 | 99 | 49 | 72 | 74 | 99 | 79 | 71 | 64 | 71 | 49 | 24 | 49 | 1111 | 1111 | 1111 |
| | -390 | 1111 | 1111 | 79 | 74 | 77 | 76 | 66 | 63 | 77 | 76 | 89 | 83 | 81 | 54 | 37 | 79 | 66 | 1111 | 1111 | 1111 |
| | -360 | 1111 | 99 | 89 | 79 | 74 | 81 | 70 | 74 | 37 | 52 | 53 | 56 | 60 | 66 | 61 | 25 | 14 | 0 | 1111 | 1111 |
| | -330 | 99 | 99 | 84 | 83 | 83 | 99 | 87 | 68 | 65 | 62 | 41 | 53 | 39 | 83 | 74 | 53 | 21 | 24 | 99 | 1111 |
| | -300 | 99 | 99 | 92 | 89 | 81 | 61 | 48 | 62 | 65 | 63 | 52 | 34 | 46 | 62 | 49 | 52 | 49 | 11 | 1111 | 1111 |
| | -270 | 99 | 88 | 83 | 79 | 49 | 54 | 39 | 49 | 67 | 68 | 24 | 56 | 69 | 47 | 23 | 52 | 35 | 49 | 1111 | 1111 |
| | -240 | 99 | 83 | 84 | 86 | 82 | 86 | 87 | 82 | 69 | 76 | 54 | 74 | 64 | 57 | 51 | 54 | 39 | 46 | 0 | 1111 |
| | -210 | 1111 | 74 | 81 | 99 | 77 | 94 | 69 | 76 | 93 | 67 | 86 | 78 | 65 | 69 | 61 | 61 | 52 | 32 | 33 | 99 |
| | -180 | 99 | 99 | 76 | 87 | 69 | 78 | 54 | 55 | 63 | 83 | 92 | 87 | 38 | 76 | 46 | 52 | 41 | 37 | 9 | 1111 |
| | -150 | 1111 | 87 | 54 | 79 | 55 | 75 | 67 | 43 | 87 | 85 | 73 | 64 | 54 | 53 | 44 | 73 | 31 | 16 | 30 | 0 |
| | -120 | 74 | 73 | 70 | 84 | 63 | 77 | 62 | 61 | 62 | 61 | 66 | 56 | 67 | 40 | 53 | 51 | 19 | 25 | 75 | 30 |
| | -90 | 0 | 57 | 85 | 90 | 66 | 87 | 76 | 74 | 77 | 74 | 70 | 43 | 56 | 58 | 47 | 36 | 35 | 42 | 42 | 29 |
| | -60 | 66 | 56 | 48 | 63 | 87 | 89 | 90 | 73 | 79 | 76 | 86 | 62 | 33 | 29 | 45 | 32 | 46 | 42 | 36 | 57 |
| | -30 | 64 | 46 | 75 | 74 | 74 | 86 | 81 | 76 | 76 | 69 | 70 | 63 | 52 | 56 | 29 | 48 | 69 | 53 | 32 | 56 |
| BCAS | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | | | |
| SEPARATING | 30 | 99 | 55 | 63 | 76 | 73 | 66 | 71 | 74 | 71 | 73 | 62 | 49 | 54 | 52 | 43 | 66 | 68 | 52 | 57 | 56 |
| | 60 | 1111 | 59 | 64 | 75 | 63 | 81 | 65 | 59 | 88 | 75 | 69 | 62 | 53 | 63 | 58 | 52 | 43 | 67 | 52 | 59 |
| | 90 | 49 | 42 | 74 | 76 | 44 | 77 | 76 | 75 | 79 | 80 | 68 | 62 | 73 | 65 | 57 | 54 | 72 | 66 | 63 | 53 |
| | 120 | 99 | 78 | 45 | 38 | 36 | 88 | 74 | 71 | 90 | 68 | 63 | 61 | 76 | 65 | 56 | 67 | 71 | 58 | 59 | 52 |
| | 150 | 99 | 33 | 72 | 79 | 49 | 77 | 64 | 77 | 77 | 70 | 70 | 69 | 82 | 60 | 55 | 61 | 69 | 46 | 50 | 45 |
| | 180 | 99 | 83 | 68 | 65 | 82 | 62 | 63 | 76 | 74 | 77 | 64 | 74 | 57 | 57 | 59 | 43 | 35 | 49 | 42 | 62 |
| | 210 | 1111 | 99 | 84 | 91 | 88 | 62 | 85 | 77 | 77 | 69 | 91 | 61 | 53 | 66 | 44 | 57 | 64 | 62 | 25 | 63 |
| | 240 | 1111 | 83 | 99 | 76 | 99 | 94 | 49 | 68 | 81 | 77 | 82 | 81 | 66 | 67 | 76 | 62 | 56 | 40 | 28 | 34 |
| | 270 | 1111 | 74 | 49 | 87 | 55 | 81 | 88 | 56 | 86 | 99 | 99 | 82 | 90 | 72 | 70 | 74 | 69 | 54 | 54 | 47 |
| | 300 | 1111 | 74 | 62 | 99 | 14 | 88 | 77 | 86 | 86 | 99 | 84 | 92 | 71 | 66 | 76 | 61 | 99 | 99 | 59 | 62 |
| | 330 | 1111 | 1111 | 99 | 74 | 49 | 83 | 85 | 85 | 59 | 83 | 79 | 66 | 89 | 71 | 86 | 77 | 35 | 49 | 49 | 45 |
| | 360 | 1111 | 1111 | 99 | 1111 | 99 | 66 | 24 | 33 | 99 | 74 | 74 | 83 | 77 | 57 | 28 | 39 | 87 | 99 | 83 | 66 |
| | 390 | 1111 | 1111 | 1111 | 1111 | 49 | 99 | 1111 | 1111 | 1111 | 99 | 66 | 1111 | 99 | 66 | 74 | 74 | 79 | 99 | 99 | 85 |
| | 420 | 1111 | 1111 | 1111 | 1111 | 99 | 1111 | 1111 | 66 | 99 | 1111 | 1111 | 99 | 99 | 79 | 99 | 99 | 99 | 33 | 99 | 99 |
| | 450 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 0 | 1111 | 79 | 99 | 1111 | 99 | 1111 | 1111 | 1111 | 49 | 1111 | 1111 |
| | 480 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 99 | 49 | 99 | 99 | 99 | 99 | 99 | 99 | 33 | 59 |
| | 510 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 99 | 99 | 1111 | 99 | 66 | 59 | 99 |
| | 540 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 99 | 1111 | 99 | 1111 | 1111 | 1111 |
| | 570 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 0 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 |
| | 600 | 1111 | 1111 | 1111 | 1111 | 1111 | 49 | 66 | 1111 | 1111 | 49 | 1111 | 1111 | 1111 | 99 | 1111 | 1111 | 49 | 99 | 99 | 99 |
| | | 77 | 70 | 72 | 79 | 69 | 79 | 70 | 67 | 76 | 73 | 71 | 64 | 61 | 59 | 53 | 54 | 50 | 48 | 47 | 53 |

RELATIVE RANGE (NMI)

FIGURE A-8
RATIO OF BCAS ASSOCIATED AIRCRAFT TRACKS TO TOTAL AIRCRAFT TRACKS (R VS R)

| RANGE | TOTAL | ASSOC. | %A |
|---|---|---|---|
| 1 | 66 | 51 | 77 |
| 2 | 240 | 169 | 70 |
| 3 | 400 | 290 | 72 |
| 4 | 422 | 334 | 79 |
| 5 | 528 | 366 | 69 |
| 6 | 686 | 548 | 79 |
| 7 | 740 | 519 | 70 |
| 8 | 663 | 449 | 67 |
| 9 | 792 | 606 | 76 |
| 10 | 796 | 586 | 73 |
| 11 | 992 | 712 | 71 |
| 12 | 1019 | 660 | 64 |
| 13 | 964 | 594 | 61 |
| 14 | 969 | 579 | 59 |
| 15 | 974 | 518 | 53 |
| 16 | 1075 | 586 | 54 |
| 17 | 1086 | 553 | 50 |
| 18 | 913 | 445 | 48 |
| 19 | 646 | 307 | 47 |
| 20 | 586 | 314 | 53 |

FIGURE A-7
AIRCRAFT ASSOCIATION, FOR EACH MILE, FOR ALL ALTITUDES

a) RELATIVE ALT GREATER THAN 5K FT

| RANGE | TOTAL | ASSOC. | %A |
|---|---|---|---|
| 1 | 0 | 0 | 0. |
| 2 | 0 | 0 | 0. |
| 3 | 8 | 8 | 100. |
| 4 | 22 | 19 | 86. |
| 5 | 22 | 18 | 82. |
| 6 | 44 | 38 | 86. |
| 7 | 37 | 27 | 73. |
| 8 | 23 | 18 | 78. |
| 9 | 69 | 62 | 90. |
| 10 | 65 | 53 | 82. |
| 11 | 54 | 35 | 65. |
| 12 | 56 | 51 | 91. |
| 13 | 63 | 59 | 94. |
| 14 | 97 | 83 | 86. |
| 15 | 112 | 93 | 83. |
| 16 | 110 | 100 | 91. |
| 17 | 111 | 63 | 57. |
| 18 | 116 | 69 | 59. |
| 19 | 91 | 67 | 74. |
| 20 | 63 | 55 | 87. |

b) RELATIVE ALT LESS THAN 5K FT

| RANGE | TOTAL | ASSOC. | %A |
|---|---|---|---|
| 1 | 35 | 34 | 97. |
| 2 | 51 | 49 | 96. |
| 3 | 57 | 57 | 100. |
| 4 | 56 | 56 | 100. |
| 5 | 71 | 65 | 92. |
| 6 | 94 | 90 | 96. |
| 7 | 115 | 106 | 92. |
| 8 | 111 | 102 | 92. |
| 9 | 117 | 105 | 90. |
| 10 | 140 | 114 | 81. |
| 11 | 157 | 121 | 77. |
| 12 | 154 | 113 | 73. |
| 13 | 191 | 126 | 66. |
| 14 | 176 | 102 | 58. |
| 15 | 142 | 76 | 54. |
| 16 | 125 | 52 | 42. |
| 17 | 140 | 48 | 34. |
| 18 | 98 | 41 | 42. |
| 19 | 75 | 37 | 49. |
| 20 | 76 | 42 | 55. |

FIGURE A-8
AIRCRAFT ASSOCIATION, EACH MILE, FOR VARIOUS ALTITUDE ZONES

c) RELATIVE ALT GREATER THAN -5K FT

| RANGE | TOTAL | ASSOC. | %A |
|---|---|---|---|
| 1 | 28 | 15 | 54. |
| 2 | 89 | 66 | 74. |
| 3 | 139 | 102 | 73. |
| 4 | 173 | 140 | 81. |
| 5 | 203 | 129 | 64. |
| 6 | 257 | 214 | 83. |
| 7 | 279 | 177 | 63. |
| 8 | 276 | 168 | 61. |
| 9 | 236 | 165 | 70. |
| 10 | 281 | 182 | 65. |
| 11 | 339 | 221 | 65. |
| 12 | 363 | 196 | 54. |
| 13 | 345 | 157 | 46. |
| 14 | 376 | 181 | 48. |
| 15 | 427 | 191 | 45. |
| 16 | 507 | 256 | 50. |
| 17 | 409 | 164 | 40. |
| 18 | 386 | 137 | 35. |
| 19 | 249 | 122 | 49. |
| 20 | 280 | 129 | 46. |

d) RELATIVE ALT LESS THAN -5K FT

| RANGE | TOTAL | ASSOC. | %A |
|---|---|---|---|
| 1 | 3 | 3 | 100. |
| 2 | 100 | 54 | 54. |
| 3 | 196 | 123 | 63. |
| 4 | 171 | 120 | 70. |
| 5 | 232 | 154 | 66. |
| 6 | 291 | 206 | 71. |
| 7 | 309 | 209 | 68. |
| 8 | 253 | 161 | 64. |
| 9 | 370 | 274 | 74. |
| 10 | 310 | 235 | 76. |
| 11 | 442 | 334 | 76. |
| 12 | 446 | 301 | 67. |
| 13 | 365 | 251 | 69. |
| 14 | 320 | 213 | 67. |
| 15 | 293 | 158 | 54. |
| 16 | 333 | 177 | 53. |
| 17 | 426 | 280 | 66. |
| 18 | 313 | 196 | 63. |
| 19 | 231 | 81 | 35. |
| 20 | 167 | 91 | 54. |

FIGURE A-8
AIRCRAFT ASSOCIATION, EACH MILE, FOR VARIOUS ALTITUDE ZONES (CONTINUED)

| Altitude Zone | | (0-5) | (6-10) | (11-15) | (16-20) |
|---|---|---|---|---|---|
| > 5K FT ABOVE | R | (0-5) | (6-10) | (11-15) | (16-20) |
| | T | 52 | 238 | 362 | 491 |
| | A | 45 | 196 | 321 | 354 |
| | % | 86.5 | 85.2 | 84.0 | 72.1 |
| 0 TO 5K FT ABOVE | R | (0-5) | (6-10) | (11-15) | (16-20) |
| | T | 270 | 577 | 820 | 514 |
| | A | 261 | 517 | 538 | 220 |
| | % | 96.7 | 89.6 | 65.6 | 42.8 |
| 0 TO 5K FT BELOW | R | (0-5) | (6-10) | (11-15) | (16-20) |
| | T | 632 | 1329 | 1850 | 1831 |
| | A | 452 | 906 | 946 | 808 |
| | % | 71.5 | 66.2 | 51.1 | 44.1 |
| > 5K FT BELOW | R | (0-5) | (6-10) | (11-15) | (16-20) |
| | T | 702 | 1533 | 1666 | 1470 |
| | A | 454 | 1085 | 1257 | 825 |
| | % | 64.7 | 70.8 | 67.4 | 56.1 |

FIGURE A-9
BCAS PERFORMANCE FOR VARIOUS ALTITUDE AND RANGE ZONES

| RANGE | TOTAL | ASSOC. | %A |
|---|---|---|---|
| 1 | 66 | 51 | 77.3 |
| 2 | 306 | 220 | 71.9 |
| 3 | 706 | 510 | 72.2 |
| 4 | 1128 | 844 | 74.8 |
| 5 | 1656 | 1210 | 73.1 |
| 6 | 2342 | 1758 | 75.1 |
| 7 | 3082 | 2277 | 73.9 |
| 8 | 3745 | 2726 | 72.8 |
| 9 | 4537 | 3332 | 73.4 |
| 10 | 5333 | 3918 | 73.5 |
| 11 | 6325 | 4630 | 73.2 |
| 12 | 7344 | 5290 | 72.0 |
| 13 | 8308 | 5884 | 70.8 |
| 14 | 9277 | 6463 | 69.7 |
| 15 | 10251 | 6981 | 68.1 |
| 16 | 11326 | 7567 | 66.8 |
| 17 | 12412 | 8120 | 65.4 |
| 18 | 13325 | 8565 | 64.3 |
| 19 | 13971 | 8872 | 63.5 |
| 20 | 14557 | 9186 | 63.1 |

**FIGURE A-10**
**CUMULATIVE PERCENT OF AIRCRAFT ASSOCIATION**

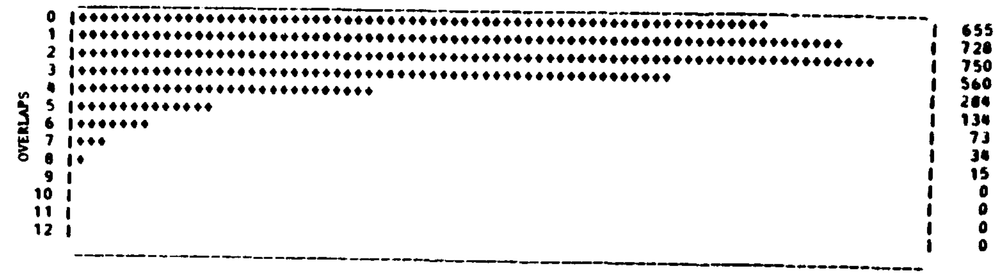
| | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 10000 | .0041 | .0072 | .0196 | .0186 | .0320 | .0299 | .0186 | .0247 | .0258 | .0216 | .0113 | .0041 | .0021 | .0072 | .0165 | .0144 | .0134 | .0196 | .0268 | [illegible] |
| 9500 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0021 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0010 | .0000 | .0000 |
| 9000 | .0000 | .0000 | .0000 | .0000 | .0031 | .0021 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0010 |
| 8500 | .0000 | .0000 | .0000 | .0010 | .0010 | .0000 | .0052 | .0072 | .0000 | .0052 | .0031 | .0000 | .0021 | .0010 | .0010 | .0000 | .0021 | .0010 | .0000 | .0010 |
| 8000 | .0010 | .0000 | .0000 | .0000 | .0000 | .0010 | .0000 | .0000 | .0000 | .0000 | .0000 | .0041 | .0000 | .0000 | .0041 | .0010 | .0010 | .0031 | .0000 | .0000 |
| 7500 | .0000 | .0000 | .0072 | .0010 | .0000 | .0021 | .0072 | .0103 | .0010 | .0041 | .0010 | .0010 | .0000 | .0010 | .0031 | .0000 | .0010 | .0021 | .0000 | .0010 |
| 7000 | .0000 | .0000 | .0021 | .0010 | .0000 | .0010 | .0072 | .0041 | .0010 | .0031 | .0062 | .0000 | .0052 | .0093 | .0072 | .0031 | .0010 | .0010 | .0010 | .0000 |
| 6500 | .0000 | .0000 | .0021 | .0010 | .0010 | .0000 | .0000 | .0000 | .0010 | .0000 | .0000 | .0010 | .0031 | .0000 | .0021 | .0021 | .0031 | .0010 | .0000 | .0010 |
| 6000 | .0000 | .0010 | .0021 | .0000 | .0000 | .0000 | .0000 | .0000 | .0031 | .0000 | .0010 | .0010 | .0021 | .0010 | .0021 | .0041 | .0031 | .0062 | .0000 | .0000 |
| 5500 | .0000 | .0000 | .0010 | .0000 | .0000 | .0010 | .0000 | .0010 | .0052 | .0000 | .0010 | .0031 | .0031 | .0021 | .0010 | .0021 | .0000 | .0000 | .0000 | .0021 |
| 5000 | .0000 | .0010 | .0010 | .0010 | .0010 | .0000 | .0010 | .0000 | .0000 | .0010 | .0010 | .0010 | .0000 | .0010 | .0021 | .0010 | .0000 | .0010 | .0021 | .0000 |
| 4500 | .0000 | .0000 | .0000 | .0000 | .0021 | .0021 | .0021 | .0000 | .0000 | .0000 | .0000 | .0031 | .0021 | .0010 | .0021 | .0041 | .0010 | .0000 | .0000 | .0021 |
| 4000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0010 | .0010 | .0021 | .0000 | .0000 | .0062 | .0000 | .0010 | .0000 | .0000 | .0010 | .0031 | .0062 | .0031 |
| 3500 | .0010 | .0010 | .0031 | .0000 | .0021 | .0010 | .0000 | .0010 | .0021 | .0072 | .0041 | .0010 | .0021 | .0031 | .0041 | .0010 | .0010 | .0010 | .0010 | .0010 |
| 3000 | .0010 | .0010 | .0010 | .0000 | .0021 | .0000 | .0000 | .0000 | .0031 | .0021 | .0000 | .0000 | .0000 | .0000 | .0021 | .0031 | .0062 | .0031 | .0021 | .0000 |
| 2500 | .0010 | .0021 | .0010 | .0010 | .0000 | .0000 | .0000 | .0021 | .0000 | .0021 | .0010 | .0010 | .0000 | .0052 | .0010 | .0052 | .0052 | .0000 | .0010 | .0000 |
| 2000 | .0000 | .0000 | .0010 | .0041 | .0021 | .0000 | .0000 | .0010 | .0000 | .0010 | .0031 | .0000 | .0000 | .0010 | .0062 | .0072 | .0000 | .0021 | .0000 | .0000 |
| 1500 | .0010 | .0010 | .0041 | .0000 | .0010 | .0010 | .0041 | .0000 | .0010 | .0021 | .0000 | .0000 | .0000 | .0031 | .0031 | .0000 | .0021 | .0000 | .0010 | .0000 |
| 1000 | .0000 | .0000 | .0000 | .0000 | .0041 | .0031 | .0041 | .0021 | .0021 | .0041 | .0010 | .0021 | .0000 | .0010 | .0010 | .0052 | .0021 | .0021 | .0021 | .0103 |
| 500 | .0010 | .0000 | .0021 | .0010 | .0031 | .0052 | .0021 | .0031 | .0052 | .0031 | .0010 | .0052 | .0031 | .0021 | .0041 | .0021 | .0052 | .0010 | .0052 | .0000 |
| +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | +++++ | |
| -500 | .0010 | .0010 | .0010 | .0041 | .0021 | .0010 | .0041 | .0010 | .0031 | .0021 | .0052 | .0031 | .0052 | .0062 | .0103 | .0041 | .0000 | .0010 | .0031 | .0000 |
| -1000 | .0000 | .0000 | .0052 | .0072 | .0021 | .0010 | .0082 | .0041 | .0113 | .0052 | .0052 | .0082 | .0010 | .0052 | .0124 | .0021 | .0010 | .0000 | .0010 | .0010 |
| -1500 | .0000 | .0021 | .0010 | .0031 | .0031 | .0052 | .0062 | .0041 | .0041 | .0041 | .0082 | .0031 | .0072 | .0103 | .0072 | .0021 | .0000 | .0000 | .0000 | .0000 |
| -2000 | .0000 | .0010 | .0021 | .0041 | .0021 | .0000 | .0031 | .0000 | .0052 | .0031 | .0052 | .0062 | .0000 | .0021 | .0000 | .0021 | .0010 | .0000 | .0000 | .0000 |
| -2500 | .0010 | .0000 | .0031 | .0010 | .0010 | .0010 | .0010 | .0010 | .0000 | .0031 | .0021 | .0062 | .0000 | .0000 | .0010 | .0010 | .0010 | .0000 | .0000 | .0000 |
| -3000 | .0010 | .0031 | .0041 | .0021 | .0103 | .0000 | .0010 | .0062 | .0082 | .0041 | .0010 | .0041 | .0010 | .0000 | .0000 | .0052 | .0000 | .0000 | .0000 | .0000 |
| -3500 | .0000 | .0041 | .0021 | .0010 | .0062 | .0021 | .0021 | .0031 | .0041 | .0021 | .0000 | .0000 | .0010 | .0000 | .0000 | .0021 | .0000 | .0010 | .0031 | .0000 |
| -4000 | .0000 | .0000 | .0000 | .0041 | .0021 | .0021 | .0021 | .0021 | .0000 | .0021 | .0031 | .0041 | .0010 | .0000 | .0010 | .0031 | .0031 | .0031 | .0000 | .0021 |
| -4500 | .0000 | .0000 | .0021 | .0062 | .0062 | .0052 | .0031 | .0082 | .0021 | .0031 | .0041 | .0113 | .0000 | .0052 | .0062 | .0062 | .0052 | .0000 | .0000 | .0021 |
| -5000 | .0010 | .0052 | .0021 | .0134 | .0103 | .0072 | .0010 | .0021 | .0021 | .0062 | .0021 | .0021 | .0021 | .0010 | .0072 | .0041 | .0041 | .0041 | .0010 | .0021 |
| -5500 | .0000 | .0000 | .0072 | .0082 | .0041 | .0082 | .0082 | .0103 | .0072 | .0041 | .0103 | .0000 | .0041 | .0062 | .0041 | .0041 | .0021 | .0010 | .0021 | .0052 |
| -6000 | .0000 | .0021 | .0062 | .0165 | .0113 | .0031 | .0062 | .0113 | .0093 | .0072 | .0000 | .0041 | .0093 | .0062 | .0041 | .0062 | .0052 | .0010 | .0000 | .0031 |
| -6500 | .0000 | .0021 | .0062 | .0031 | .0165 | .0165 | [illegible] | .0299 | .0165 | .0216 | .0165 | .0134 | .0165 | .0144 | .0021 | .0134 | .0258 | .0227 | .0124 | .0052 |
| -7000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 |
| -7500 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 |
| -8000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 |
| -8500 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 |
| -9000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 |
| -9500 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 |
| -10000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 |
| | ===== | ===== | ===== | ===== | ===== | ===== | ===== | ===== | ===== | ===== | ===== | ===== | ===== | ===== | ===== | ===== | ===== | ===== | ===== | ===== |
| | .0144 | .0351 | .0897 | .1341 | .1340 | .1321 | .1093 | .1412 | .1278 | .1247 | .0979 | .1000 | .0732 | .0969 | .1206 | .1113 | .0969 | .0835 | .0741 | .0546 |

PHANTOM RATE WITHIN 5 NM= 0.37732
PHANTOM RATE WITHIN 10 NM= 0.98247
PHANTOM RATE WITHIN 15 NM= 1.47113
PHANTOM RATE WITHIN 20 NM= 1.88865

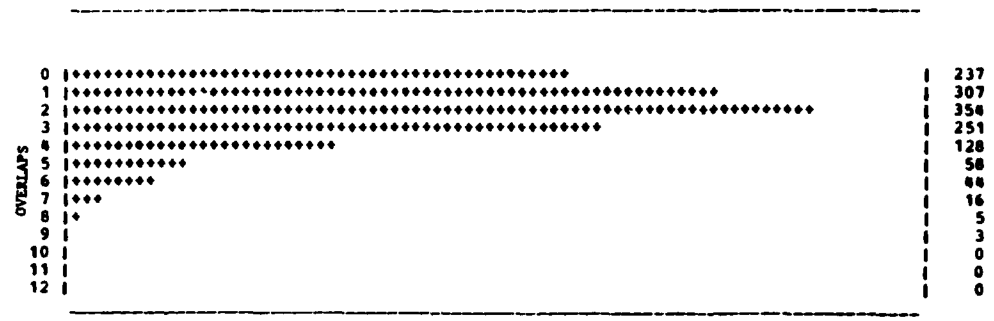
FIGURE A-11
PROBABILITY OF PHANTOM OCCURRENCES (R VS Z)

| | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| -600 | .0010 | .0041 | .0021 | .0021 | .0010 | .0021 | .0000 | .0000 | .0010 | .0000 | .0000 | .0000 | .0000 | .0000 | .0021 | .0000 | .0000 | .0000 | .0000 | .0000 |
| -570 | .0000 | .0021 | .0010 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0010 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 |
| -540 | .0000 | .0010 | .0021 | .0000 | .0000 | .0010 | .0000 | .0000 | .0000 | .0010 | .0000 | .0000 | .0000 | .0000 | .0021 | .0010 | .0010 | .0000 | .0000 | .0000 |
| -510 | .0000 | .0000 | .0010 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0010 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 |
| -480 | .0010 | .0010 | .0021 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0010 | .0021 | .0021 | .0000 | .0010 | .0000 | .0000 | .0000 |
| -450 | .0000 | .0000 | .0000 | .0021 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0041 | .0031 | .0010 | .0010 | .0021 | .0021 | .0010 | .0000 | .0000 | .0000 |
| -420 | .0000 | .0010 | .0041 | .0000 | .0021 | .0021 | .0021 | .0010 | .0010 | .0010 | .0000 | .0000 | .0000 | .0000 | .0000 | .0010 | .0000 | .0000 | .0000 | .0000 |
| -390 | .0021 | .0000 | .0021 | .0021 | .0031 | .0021 | .0021 | .0010 | .0010 | .0010 | .0000 | .0000 | .0000 | .0010 | .0000 | .0031 | .0000 | .0000 | .0000 | .0000 |
| -360 | .0000 | .0031 | .0021 | .0072 | .0041 | .0052 | .0021 | .0021 | .0010 | .0000 | .0010 | .0000 | .0000 | .0010 | .0010 | .0000 | .0000 | .0000 | .0000 | .0000 |
| -330 | .0000 | .0021 | .0031 | .0031 | .0041 | .0052 | .0021 | .0041 | .0000 | .0000 | .0000 | .0010 | .0000 | .0000 | .0021 | .0000 | .0000 | .0000 | .0000 | .0000 |
| -300 | .0000 | .0010 | .0062 | .0052 | .0021 | .0031 | .0021 | .0010 | .0000 | .0000 | .0000 | .0000 | .0000 | .0010 | .0021 | .0031 | .0010 | .0010 | .0000 | .0000 |
| -270 | .0041 | .0031 | .0031 | .0041 | .0052 | .0021 | .0000 | .0031 | .0000 | .0000 | .0000 | .0021 | .0000 | .0010 | .0031 | .0010 | .0041 | .0000 | .0000 | .0000 |
| -240 | .0000 | .0000 | .0052 | .0103 | .0041 | .0010 | .0041 | .0041 | .0010 | .0031 | .0031 | .0000 | .0000 | .0010 | .0031 | .0052 | .0041 | .0000 | .0000 | .0000 |
| -210 | .0000 | .0031 | .0062 | .0103 | .0041 | .0031 | .0072 | .0000 | .0021 | .0021 | .0052 | .0062 | .0041 | .0052 | .0021 | .0021 | .0021 | .0010 | .0010 | .0000 |
| -180 | .0000 | .0031 | .0072 | .0021 | .0021 | .0041 | .0082 | .0113 | .0031 | .0031 | .0082 | .0021 | .0010 | .0031 | .0000 | .0010 | .0000 | .0000 | .0031 | .0000 |
| -150 | .0000 | .0021 | .0021 | .0010 | .0031 | .0052 | .0021 | .0041 | .0031 | .0010 | .0010 | .0062 | .0010 | .0010 | .0000 | .0021 | .0000 | .0041 | .0021 | .0000 |
| -120 | .0000 | .0000 | .0103 | .0124 | .0124 | .0113 | .0031 | .0010 | .0134 | .0031 | .0041 | .0021 | .0041 | .0041 | .0052 | .0010 | .0031 | .0031 | .0072 | .0000 |
| -90 | .0010 | .0010 | .0072 | .0000 | .0155 | .0052 | .0010 | .0041 | .0062 | .0072 | .0021 | .0031 | .0021 | .0021 | .0021 | .0031 | .0010 | .0021 | .0062 | .0000 |
| -60 | .0000 | .0000 | .0010 | .0072 | .0082 | .0041 | .0041 | .0072 | .0113 | .0062 | .0041 | .0093 | .0010 | .0021 | .0062 | .0031 | .0000 | .0052 | .0000 | .0021 |
| -30 | .0000 | .0021 | .0031 | .0031 | .0052 | .0062 | .0052 | .0072 | .0082 | .0186 | .0062 | .0144 | .0031 | .0031 | .0062 | .0052 | .0000 | .0052 | .0021 | .0041 |
| | ***** | ***** | ***** | ***** | ***** | ***** | ***** | ***** | ***** | ***** | ***** | ***** | ***** | ***** | ***** | ***** | ***** | ***** | ***** | ***** |
| 30 | .0010 | .0000 | .0010 | .0010 | .0021 | .0062 | .0062 | .0052 | .0113 | .0062 | .0062 | .0052 | .0010 | .0041 | .0103 | .0031 | .0021 | .0031 | .0010 | .0031 |
| 60 | .0010 | .0000 | .0072 | .0021 | .0041 | .0041 | .0124 | .0124 | .0113 | .0041 | .0031 | .0041 | .0062 | .0062 | .0103 | .0062 | .0021 | .0052 | .0010 | .0041 |
| 90 | .0000 | .0000 | .0010 | .0041 | .0093 | .0041 | .0041 | .0103 | .0082 | .0062 | .0041 | .0031 | .0021 | .0093 | .0041 | .0052 | .0103 | .0031 | .0052 | .0000 |
| 120 | .0000 | .0021 | .0021 | .0062 | .0031 | .0010 | .0052 | .0113 | .0062 | .0082 | .0062 | .0021 | .0082 | .0072 | .0021 | .0113 | .0155 | .0113 | .0052 | .0010 |
| 150 | .0000 | .0010 | .0021 | .0041 | .0134 | .0062 | .0052 | .0175 | .0082 | .0134 | .0144 | .0072 | .0052 | .0103 | .0103 | .0062 | .0062 | .0041 | .0021 | .0062 |
| 180 | .0000 | .0000 | .0000 | .0052 | .0062 | .0021 | .0093 | .0093 | .0082 | .0103 | .0082 | .0052 | .0052 | .0072 | .0021 | .0052 | .0031 | .0041 | .0041 | .0041 |
| 210 | .0010 | .0021 | .0010 | .0031 | .0021 | .0021 | .0052 | .0052 | .0052 | .0062 | .0031 | .0031 | .0072 | .0031 | .0062 | .0093 | .0041 | .0010 | .0041 | .0010 |
| 240 | .0000 | .0000 | .0021 | .0021 | .0041 | .0031 | .0021 | .0041 | .0021 | .0082 | .0031 | .0103 | .0093 | .0000 | .0103 | .0052 | .0041 | .0062 | .0031 | .0021 |
| 270 | .0000 | .0000 | .0000 | .0000 | .0041 | .0031 | .0021 | .0010 | .0021 | .0031 | .0031 | .0031 | .0052 | .0093 | .0082 | .0082 | .0062 | .0041 | .0062 | .0021 |
| 300 | .0010 | .0000 | .0000 | .0010 | .0021 | .0021 | .0021 | .0072 | .0031 | .0052 | .0041 | .0021 | .0031 | .0031 | .0041 | .0093 | .0072 | .0041 | .0062 | .0062 |
| 330 | .0000 | .0000 | .0010 | .0010 | .0021 | .0021 | .0021 | .0010 | .0031 | .0000 | .0000 | .0031 | .0000 | .0010 | .0031 | .0010 | .0031 | .0010 | .0021 | .0031 |
| 360 | .0000 | .0000 | .0000 | .0000 | .0010 | .0000 | .0031 | .0021 | .0031 | .0010 | .0000 | .0000 | .0000 | .0021 | .0021 | .0041 | .0093 | .0031 | .0031 | .0072 |
| 390 | .0000 | .0000 | .0000 | .0000 | .0010 | .0010 | .0021 | .0000 | .0000 | .0010 | .0000 | .0000 | .0000 | .0000 | .0000 | .0010 | .0010 | .0041 | .0031 | .0010 |
| 420 | .0010 | .0000 | .0000 | .0000 | .0000 | .0000 | .0021 | .0000 | .0000 | .0010 | .0000 | .0010 | .0000 | .0010 | .0031 | .0000 | .0000 | .0021 | .0000 | .0031 |
| 450 | .0000 | .0000 | .0000 | .0000 | .0021 | .0000 | .0000 | .0010 | .0000 | .0010 | .0000 | .0000 | .0021 | .0000 | .0000 | .0000 | .0000 | .0000 | .0010 | .0010 |
| 480 | .0000 | .0000 | .0010 | .0021 | .0010 | .0010 | .0000 | .0010 | .0010 | .0010 | .0021 | .0000 | .0000 | .0021 | .0010 | .0021 | .0000 | .0021 | .0021 | .0010 |
| 510 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0010 | .0000 | .0021 | .0010 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0021 | .0010 | .0000 | .0000 |
| 540 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0010 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 |
| 570 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 |
| 600 | .0000 | .0000 | .0000 | .0000 | .0000 | .0010 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 | .0000 |
| | ===== | ===== | ===== | ===== | ===== | ===== | ===== | ===== | ===== | ===== | ===== | ===== | ===== | ===== | ===== | ===== | ===== | ===== | ===== | ===== |
| | .0144 | .0351 | .0897 | .1041 | .1340 | .1021 | .1093 | .1412 | .1278 | .1247 | .0979 | .1000 | .0732 | .0969 | .1206 | .1119 | .0909 | .0835 | .0711 | .0546 |

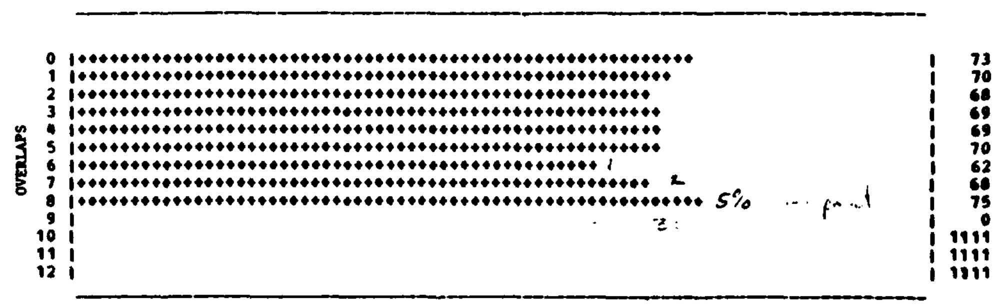
FIGURE A-12
PROBABILITY OF PHANTOM OCCURRENCES (R VS Ṙ)




a) NUMBER OF SUCCESSFUL ASSOCIATIONS



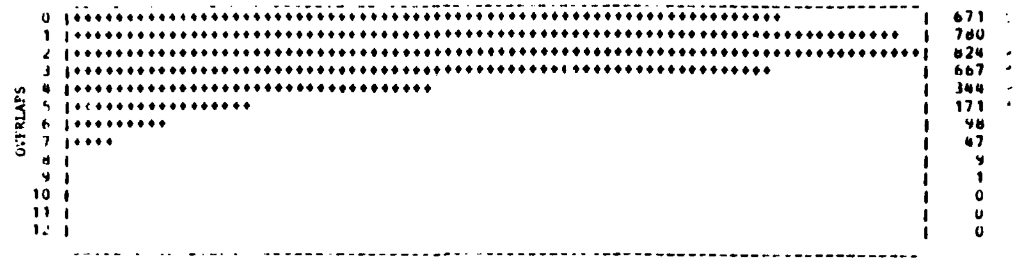

b) NUMBER OF MISSED ASSOCIATIONS



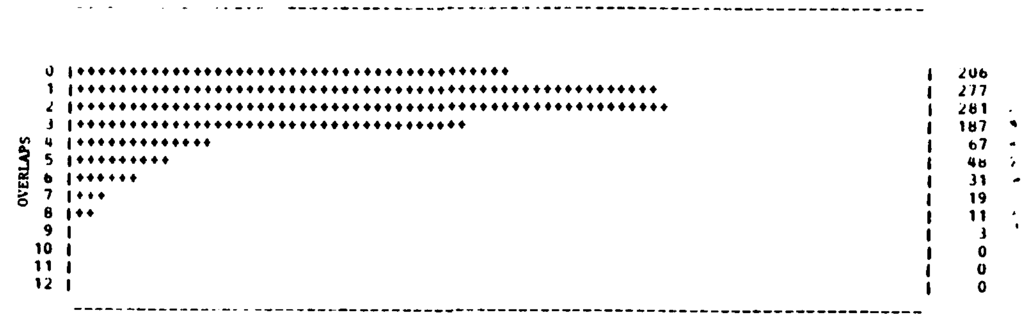

c) PERCENT ASSOCIATION

NOTE: DATA TRUNCATED AT 10 NMI AND 15° DEPRESSION ANGLE

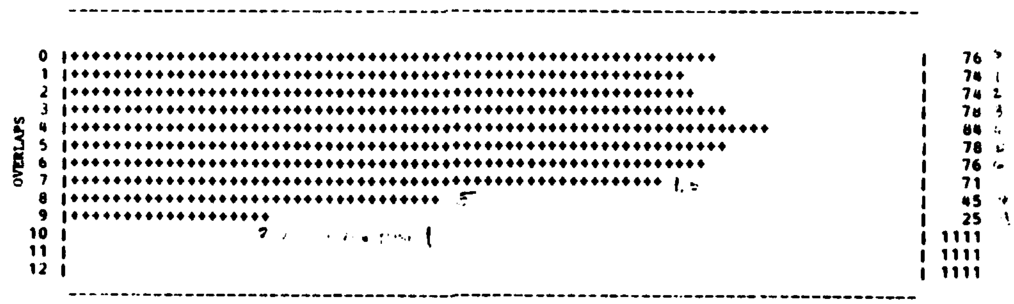
**FIGURE A-13**
**ARTS ASSOCIATION VS. OVERLAPS (BASIC)**




a) NUMBER OF SUCCESSFUL ASSOCIATIONS



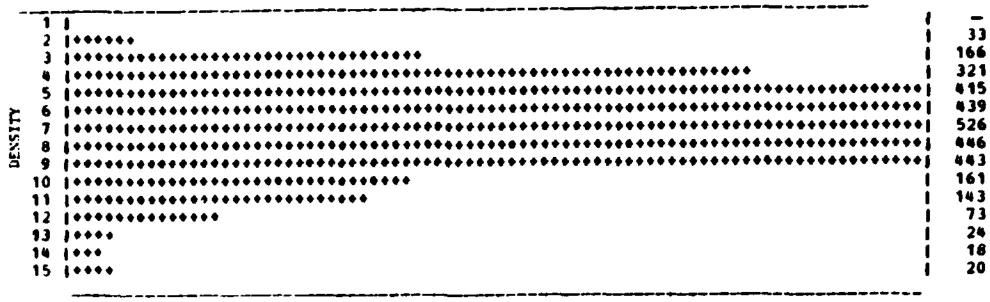

b) NUMBER OF MISSED ASSOCIATIONS



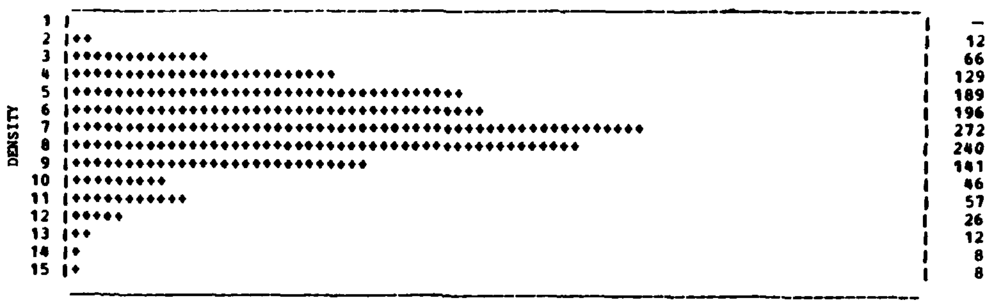

c) PERCENT ASSOCIATION

NOTE: DATA TRUNCATED AT 10 NMI AND 15° DEPRESSION ANGLE

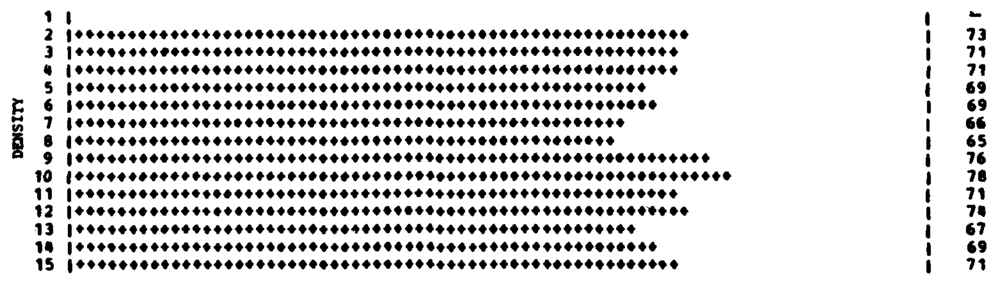
FIGURE A-14
ARTS ASSOCIATION VS. OVERLAPS (WHISPER-SHOUT)




a) NUMBER OF SUCCESSFUL ASSOCIATIONS




b) NUMBER OF MISSED ASSOCIATIONS

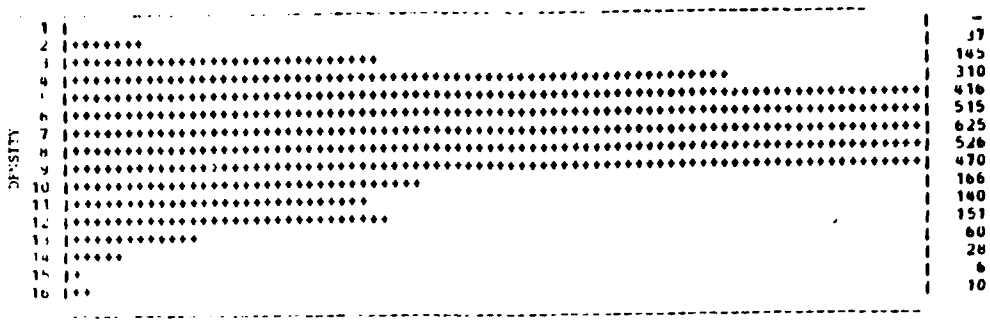



c) PERCENT ASSOCIATION

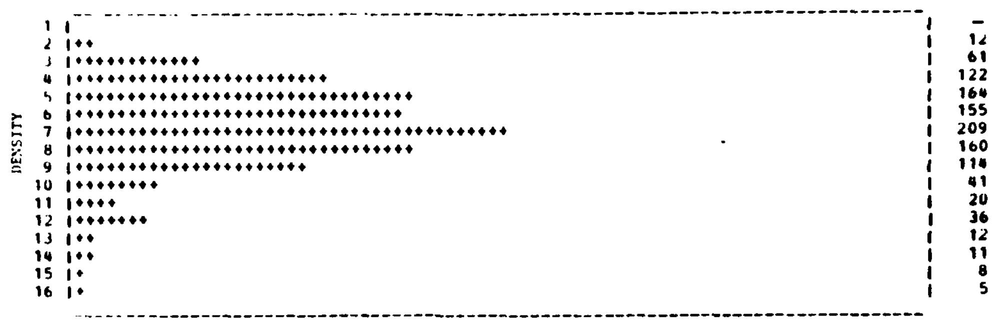
NOTE: 1. DATA TRUNCATED AT 10 NMI AND 15° DEPRESSION ANGLE

2. DENSITY = THE NUMBER OF AIRCRAFT WITHIN 10 NMI

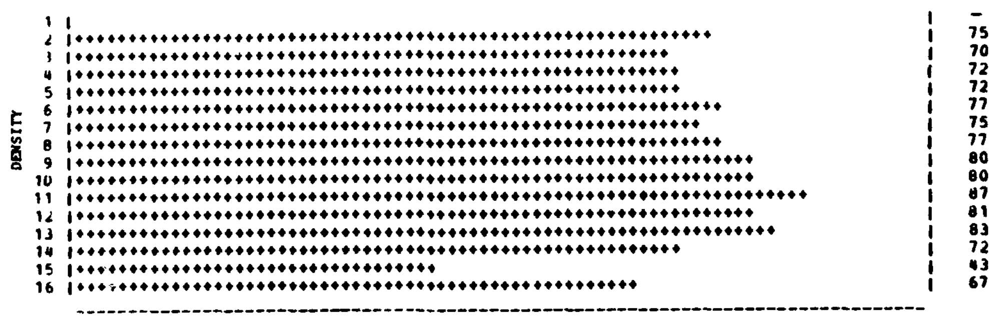
**FIGURE A-15**
**ARTS ASSOCIATION VS. AIRCRAFT DENSITY (BASIC)**




a) NUMBER OF SUCCESSFUL ASSOCIATIONS




b) NUMBER OF MISSED ASSOCIATIONS

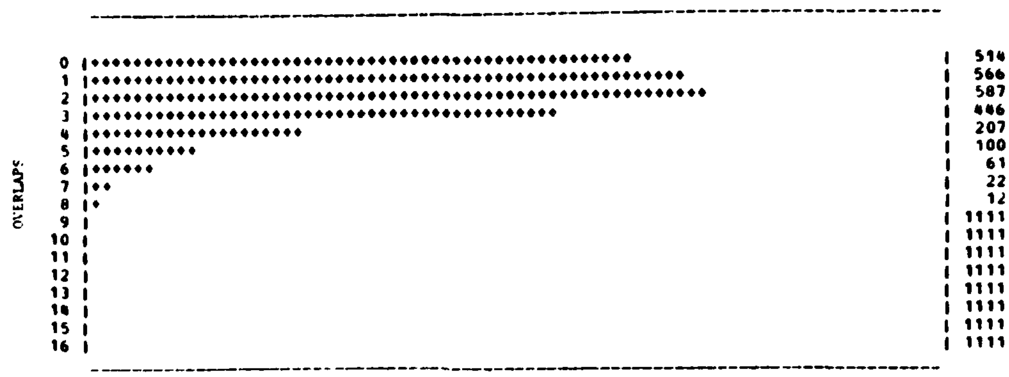



c) PERCENT ASSOCIATION

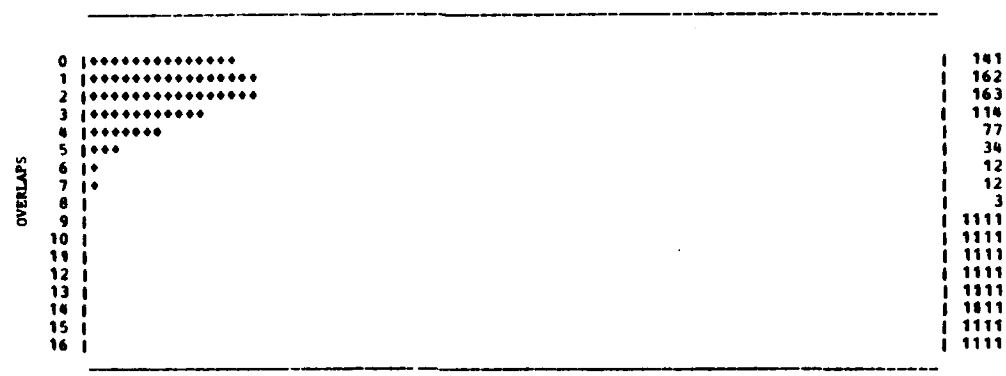
NOTE: 1. DATA TRUNCATED AT 10 NMI AND 15° DEPRESSION ANGLE

2. DENSITY = THE NUMBER OF AIRCRAFT WITHIN 10 NMI

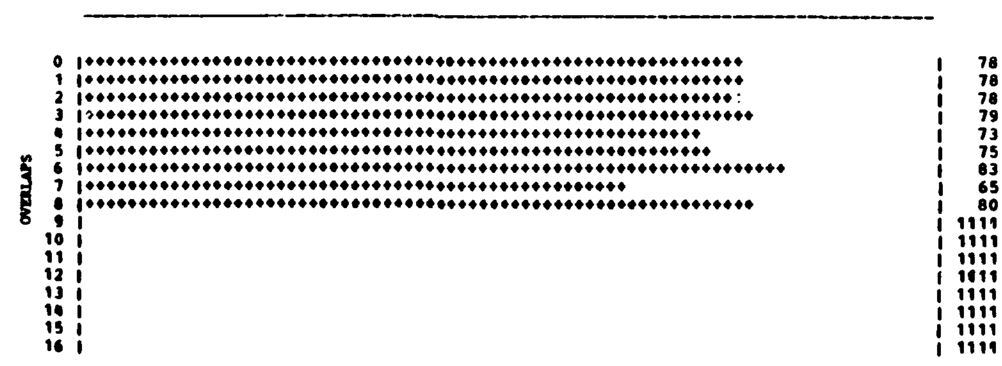
**FIGURE A-16**
**ARTS ASSOCIATION VS. AIRCRAFT DENSITY (WHISPER-SHOUT)**




a) NUMBER OF SUCCESSFUL CORRELATIONS



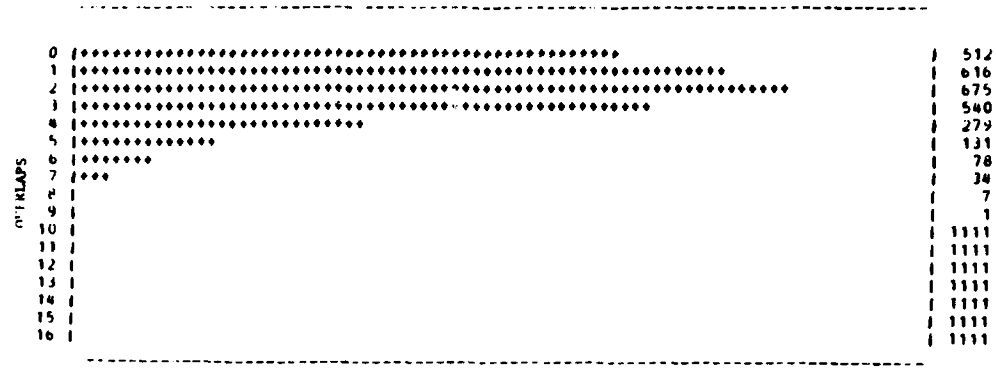

b) NUMBER OF COASTS



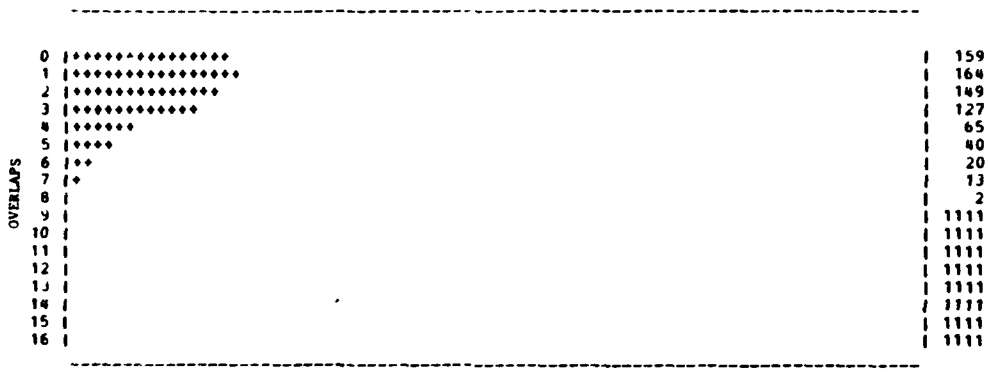

c) PERCENT CORRELATION

NOTE: DATA TRUNCATED AT 10 NMI AND 15° DEPRESSION ANGLE

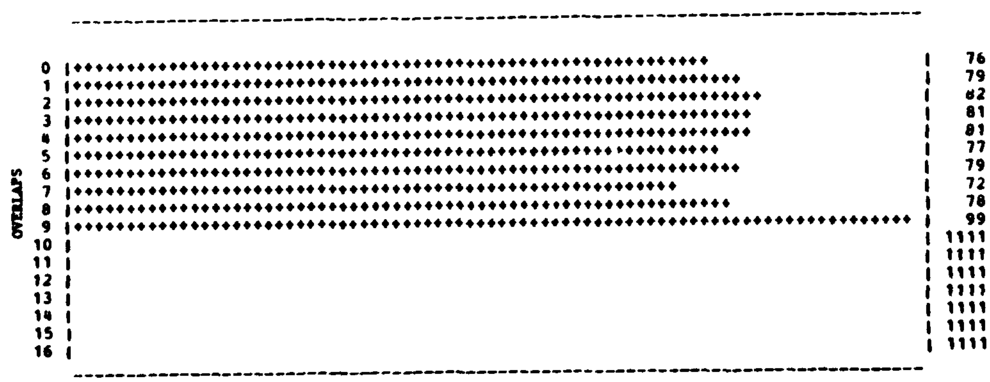
**FIGURE A-17**
**BCAS TRACK CORRELATION VS. OVERLAPS (BASIC)**




a) NUMBER OF SUCCESSFUL CORRELATIONS




b) NUMBER OF COASTS




c) PERCENT CORRELATION

NOTE: DATA TRUNCATED AT 10 NMI AND 15° DEPRESSION ANGLE

**FIGURE A-18**
**BCAS TRACK CORRELATION VS. OVERLAPS (WHISPER-SHOUT)**

| DENSITY | |
|---|---|
| 1 | – |
| 2 | 28 |
| 3 | 137 |
| 4 | 253 |
| 5 | 324 |
| 6 | 337 |
| 7 | 399 |
| 8 | 351 |
| 9 | 346 |
| 10 | 125 |
| 11 | 113 |
| 12 | 51 |
| 13 | 19 |
| 14 | 14 |
| 15 | 13 |

a) NUMBER OF SUCCESSFUL CORRELATIONS

| DENSITY | |
|---|---|
| 1 | – |
| 2 | 5 |
| 3 | 29 |
| 4 | 68 |
| 5 | 91 |
| 6 | 102 |
| 7 | 127 |
| 8 | 95 |
| 9 | 97 |
| 10 | 36 |
| 11 | 30 |
| 12 | 22 |
| 13 | 5 |
| 14 | 4 |
| 15 | 7 |

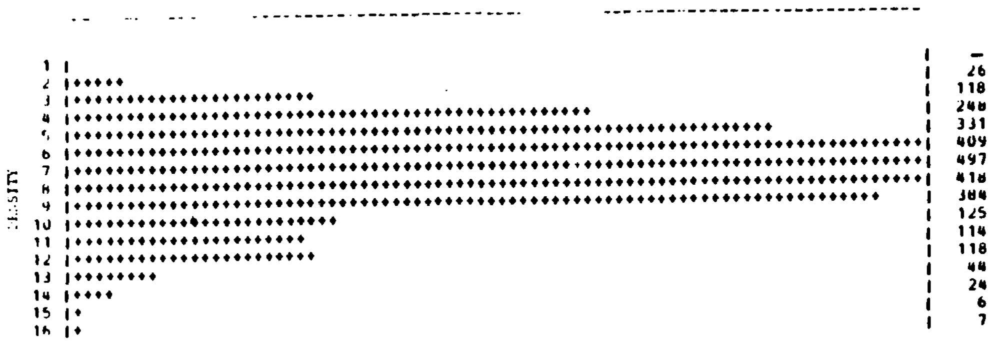
b) NUMBER OF COASTS

| DENSITY | |
|---|---|
| 1 | – |
| 2 | 85 |
| 3 | 82 |
| 4 | 79 |
| 5 | 78 |
| 6 | 77 |
| 7 | 76 |
| 8 | 79 |
| 9 | 78 |
| 10 | 78 |
| 11 | 79 |
| 12 | 70 |
| 13 | 79 |
| 14 | 78 |
| 15 | 65 |

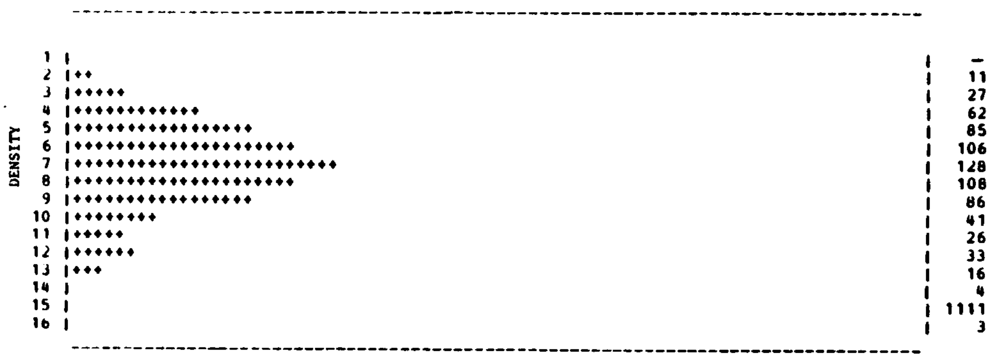
c) PERCENT CORRELATION

NOTE: DATA TRUNCATED AT 10 NMI AND 15° DEPRESSION ANGLE

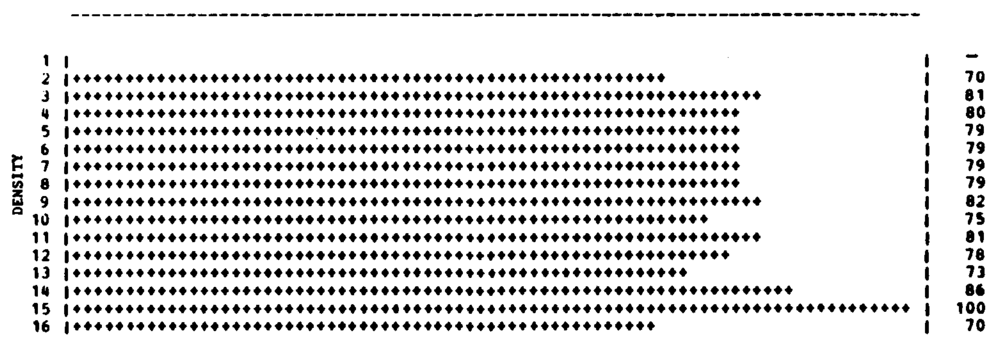
FIGURE A-19
BCAS TRACK CORRELATION VS. DENSITY (BASIC)




a) NUMBER OF SUCCESSFUL CORRELATIONS



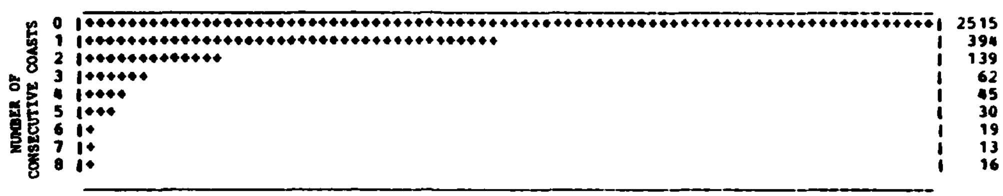

b) NUMBER OF COASTS



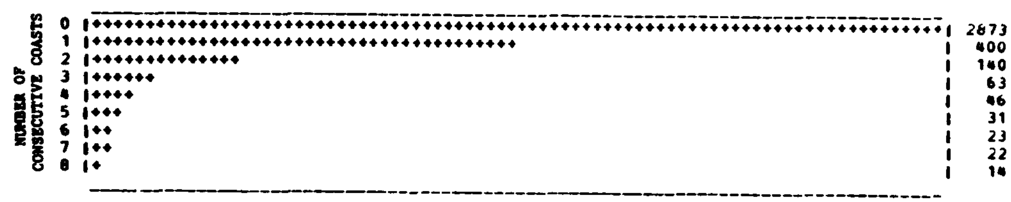

c) PERCENT CORRELATION

DATA TRUNCATED AT 10 NMI
AND 15° DEPRESSION ANGLE

FIGURE A-20
BCAS TRACK CORRELATION VS. DENSITY (WHISPER-SHOUT)




a) BASIC




b) WHISPER-SHOUT

FIGURE A-21
BCAS CONSECUTIVE COAST STATUS FOR ASSOCIATED TRACKS

| OVERLAPS \ RANGE | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 32 | 101 | 109 | 63 | 65 | 90 | 53 | 44 | 68 | 30 |
| 1 | 6 | 35 | 68 | 98 | 102 | 74 | 90 | 67 | 100 | 88 |
| 2 | 2 | 23 | 58 | 92 | 78 | 134 | 94 | 68 | 102 | 99 |
| 3 | 1111 | 5 | 99 | 36 | 50 | 91 | 116 | 96 | 64 | 83 |
| 4 | 1111 | 1111 | 1111 | 3 | 19 | 49 | 40 | 30 | 74 | 69 |
| 5 | 1111 | 1111 | 1111 | 1 | 4 | 16 | 12 | 17 | 24 | 60 |
| 6 | 1111 | 1111 | 1111 | 1111 | 1111 | 2 | 10 | 14 | 21 | 26 |
| 7 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1 | 5 | 15 | 13 |
| 8 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 8 | 7 |
| 9 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 |
| 10 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 |
| 11 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 |
| 12 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 |

a) SUCCESSFUL ASSOCIATIONS (BASIC)

| OVERLAPS \ RANGE | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 33 | 110 | 113 | 55 | 62 | 62 | 59 | [illegible] | [illegible] | 21 |
| 1 | 7 | 39 | 77 | 106 | 112 | 64 | 86 | 77 | 100 | 92 |
| 2 | 3 | 30 | 69 | 96 | 94 | 135 | 109 | 80 | 105 | 103 |
| 3 | 1111 | 3 | 27 | 47 | 79 | 106 | 140 | 107 | 71 | 65 |
| 4 | 1111 | 2 | 2 | 6 | 17 | 52 | 52 | 41 | 69 | [illegible] |
| 5 | 1111 | 1111 | 1111 | 1 | 1 | 15 | 16 | 26 | 32 | 76 |
| 6 | 1111 | 1111 | 1111 | 1111 | 4 | 4 | 15 | 26 | 21 | 30 |
| 7 | 1111 | 1111 | 1111 | 1111 | 1 | 3 | 5 | 12 | 13 | 13 |
| 8 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 6 | 3 |
| 9 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1 | 1111 |
| 10 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 |
| 11 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 |
| 12 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 |

c) SUCCESSFUL ASSOCIATIONS (WHISPER-SHOUT)

| OVERLAPS \ RANGE | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 12 | 28 | 29 | 21 | 29 | 21 | 22 | 36 | 21 | 18 |
| 1 | 2 | 47 | 48 | 32 | 47 | 42 | 31 | 30 | 26 | 39 |
| 2 | 1111 | 16 | 33 | 26 | 48 | 26 | 53 | 55 | 51 | 46 |
| 3 | 1111 | 5 | 7 | 6 | 30 | 30 | 69 | 43 | 29 | 32 |
| 4 | 1111 | 1111 | 1111 | 1111 | 7 | 16 | 30 | 22 | 24 | 29 |
| 5 | 1111 | 1111 | 1111 | 1111 | 1111 | 1 | 11 | 9 | 13 | 24 |
| 6 | 1111 | 1111 | 1111 | 1111 | 1111 | 4 | 7 | 10 | 11 | 12 |
| 7 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 2 | 3 | 4 | 7 |
| 8 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 5 |
| 9 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 3 |
| 10 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 |
| 11 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 |
| 12 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 |

b) MISSED ASSOCIATIONS (BASIC)

| OVERLAPS \ RANGE | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 11 | 19 | 25 | 19 | 22 | 26 | 18 | 26 | 18 | 20 |
| 1 | 2 | 14 | 32 | 30 | 44 | 34 | 32 | 25 | 29 | 35 |
| 2 | 1111 | 16 | 25 | 15 | 30 | 34 | 36 | 45 | 41 | 39 |
| 3 | 1111 | 5 | 3 | 6 | 16 | 16 | 58 | 32 | 21 | 26 |
| 4 | 1111 | 1111 | 1 | 1111 | 3 | 12 | 12 | 15 | 12 | 12 |
| 5 | 1111 | 1111 | 1111 | 1111 | 1 | 5 | 7 | 5 | 11 | 19 |
| 6 | 1111 | 1111 | 1111 | 1111 | 1111 | 2 | 5 | 3 | 11 | 10 |
| 7 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1 | 2 | 9 | 7 |
| 8 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 2 | 9 |
| 9 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 3 |
| 10 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 |
| 11 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 |
| 12 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 |

d) MISSED ASSOCIATIONS (WHISPER-SHOUT)

NOTE: DATA TRUNCATED AT 10 NMI AND 15° DEPRESSION ANGLE

FIGURE A-22
ASSOCIATION PERFORMANCE AS A FUNCTION OF RANGE AND OVERLAPS

| DENSITY | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 1111 | 3 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | = | 5 |
| 2 | 32 | 1 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | = | 33 |
| 3 | 116 | 45 | 3 | 1111 | 2 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | = | 166 |
| 4 | 162 | 110 | 34 | 8 | 4 | 3 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | = | 321 |
| 5 | 118 | 152 | 117 | 21 | 4 | 2 | 1 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | = | 415 |
| 6 | 59 | 149 | 148 | 69 | 11 | 3 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | = | 439 |
| 7 | 71 | 113 | 148 | 120 | 42 | 24 | 7 | 1 | 1111 | 1111 | 1111 | 1111 | 1111 | = | 526 |
| 8 | 44 | 67 | 105 | 120 | 69 | 30 | 7 | 4 | 1111 | 1111 | 1111 | 1111 | 1111 | = | 446 |
| 9 | 24 | 53 | 116 | 130 | 74 | 29 | 15 | 2 | 1111 | 1111 | 1111 | 1111 | 1111 | = | 443 |
| 10 | 6 | 13 | 32 | 44 | 35 | 25 | 5 | 1 | 1111 | 1111 | 1111 | 1111 | 1111 | = | 161 |
| 11 | 11 | 10 | 20 | 29 | 21 | 11 | 23 | 9 | 1 | 1111 | 1111 | 1111 | 1111 | = | 103 |
| 12 | 6 | 6 | 9 | 13 | 15 | 4 | 11 | 8 | 1 | 1111 | 1111 | 1111 | 1111 | = | 73 |
| 13 | 1 | 5 | 2 | 2 | 7 | 3 | 2 | 1 | 1 | 1111 | 1111 | 1111 | 1111 | = | 24 |
| 14 | 1111 | 4 | 3 | 1 | 1111 | 1111 | 2 | 5 | 3 | 1111 | 1111 | 1111 | 1111 | = | 18 |
| 15 | 3 | 1111 | 2 | 3 | 1111 | 1111 | 1111 | 3 | 9 | 1111 | 1111 | 1111 | 1111 | = | 20 |
| | 655 | 720 | 750 | 560 | 284 | 134 | 73 | 34 | 15 | 0 | 0 | 0 | 0 | \| | 3233 |

a) SUCCESSFUL CORRELATIONS (BASIC)

| DENSITY | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1111 | 1111 | 1 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | = | 1 |
| 2 | 12 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | = | 12 |
| 3 | 43 | 17 | 5 | 1 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | = | 66 |
| 4 | 61 | 45 | 16 | 2 | 3 | 2 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | = | 129 |
| 5 | 60 | 59 | 57 | 6 | 3 | 2 | 2 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | = | 189 |
| 6 | 25 | 75 | 51 | 41 | 3 | 1 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | = | 196 |
| 7 | 22 | 58 | 69 | 75 | 26 | 15 | 5 | 2 | 1111 | 1111 | 1111 | 1111 | 1111 | = | 272 |
| 8 | 11 | 29 | 72 | 55 | 47 | 15 | 4 | 7 | 1111 | 1111 | 1111 | 1111 | 1111 | = | 240 |
| 9 | 3 | 12 | 46 | 38 | 25 | 6 | 8 | 3 | 1111 | 1111 | 1111 | 1111 | 1111 | = | 141 |
| 10 | 1111 | 6 | 11 | 14 | 8 | 3 | 4 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | = | 46 |
| 11 | 1111 | 2 | 11 | 18 | 5 | 8 | 10 | 2 | 1111 | 1111 | 1111 | 1111 | 1111 | = | 57 |
| 12 | 1111 | 3 | 8 | 3 | 4 | 4 | 3 | 1 | 1111 | 1111 | 1111 | 1111 | 1111 | = | 26 |
| 13 | 1111 | 1 | 3 | 3 | 3 | 1 | 1111 | 1111 | 1 | 1111 | 1111 | 1111 | 1111 | = | 12 |
| 14 | 1111 | 1111 | 3 | 1 | 1111 | 1111 | 1111 | 1 | 2 | 1 | 1111 | 1111 | 1111 | = | 8 |
| 15 | 1111 | 1111 | 1 | 1 | 1 | 1 | 1111 | 1111 | 2 | 2 | 1111 | 1111 | 1111 | = | 8 |
| | 237 | 307 | 354 | 251 | 120 | 58 | 44 | 16 | 5 | 3 | 0 | 0 | 0 | \| | 1003 |

b) MISSED CORRELATIONS (BASIC)

| DENSITY | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 3 | 1111 | 4 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | = | 7 |
| 2 | 36 | 1 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | = | 37 |
| 3 | 107 | 34 | 3 | 1 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | = | 145 |
| 4 | 157 | 102 | 39 | 4 | 4 | 4 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | = | 310 |
| 5 | 115 | 160 | 115 | 14 | 7 | 3 | 2 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | = | 416 |
| 6 | 68 | 169 | 168 | 89 | 18 | 3 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | = | 515 |
| 7 | 86 | 141 | 177 | 141 | 37 | 33 | 8 | 2 | 1111 | 1111 | 1111 | 1111 | 1111 | = | 625 |
| 8 | 40 | 79 | 116 | 147 | 89 | 42 | 6 | 7 | 1111 | 1111 | 1111 | 1111 | 1111 | = | 526 |
| 9 | 29 | 54 | 115 | 133 | 84 | 33 | 18 | 4 | 1111 | 1111 | 1111 | 1111 | 1111 | = | 470 |
| 10 | 11 | 16 | 20 | 35 | 41 | 22 | 16 | 5 | 1111 | 1111 | 1111 | 1111 | 1111 | = | 166 |
| 11 | 7 | 3 | 37 | 35 | 24 | 8 | 22 | 6 | 1111 | 1111 | 1111 | 1111 | 1111 | = | 140 |
| 12 | 4 | 9 | 19 | 56 | 30 | 9 | 14 | 7 | 2 | 1 | 1111 | 1111 | 1111 | = | 151 |
| 13 | 4 | 7 | 6 | 7 | 8 | 10 | 8 | 9 | 1 | 1111 | 1111 | 1111 | 1111 | = | 60 |
| 14 | 1 | 5 | 4 | 3 | 1 | 4 | 4 | 5 | 1 | 1111 | 1111 | 1111 | 1111 | = | 28 |
| 15 | 1 | 1111 | 1 | 1 | 1111 | 1111 | 1111 | 1 | 2 | 1111 | 1111 | 1111 | 1111 | = | 6 |
| 16 | 2 | 1111 | 1111 | 1 | 3 | 1111 | 1111 | 1 | 3 | 1111 | 1111 | 1111 | 1111 | = | 10 |
| | 671 | 780 | 824 | 667 | 344 | 171 | 98 | 47 | 9 | 1 | 0 | 0 | 0 | \| | 3612 |

c) SUCCESSFUL CORRELATIONS (WHISPER-SHOUT)

| DENSITY | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | = | 0 |
| 2 | 12 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | = | 12 |
| 3 | 40 | 19 | 2 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | = | 61 |
| 4 | 63 | 32 | 19 | 4 | 3 | 1 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | = | 122 |
| 5 | 54 | 54 | 46 | 5 | 1 | 3 | 1 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | = | 164 |
| 6 | 17 | 62 | 48 | 24 | 3 | 1 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | = | 155 |
| 7 | 11 | 57 | 63 | 55 | 8 | 10 | 3 | 2 | 1111 | 1111 | 1111 | 1111 | 1111 | = | 209 |
| 8 | 5 | 23 | 48 | 44 | 24 | 10 | 2 | 4 | 1111 | 1111 | 1111 | 1111 | 1111 | = | 160 |
| 9 | 4 | 21 | 33 | 27 | 17 | 3 | 6 | 3 | 1111 | 1111 | 1111 | 1111 | 1111 | = | 114 |
| 10 | 1111 | 5 | 3 | 12 | 6 | 8 | 5 | 2 | 1111 | 1111 | 1111 | 1111 | 1111 | = | 41 |
| 11 | 1111 | 1111 | 5 | 5 | 1 | 2 | 7 | 1111 | 1111 | 1111 | 1111 | 1111 | 1111 | = | 20 |
| 12 | 1111 | 3 | 7 | 8 | 2 | 5 | 6 | 5 | 1111 | 1111 | 1111 | 1111 | 1111 | = | 36 |
| 13 | 1111 | 1 | 4 | 1111 | 1 | 3 | 1 | 1 | 1 | 1111 | 1111 | 1111 | 1111 | = | 12 |
| 14 | 1111 | 1111 | 3 | 1 | 1111 | 1 | 1111 | 1 | 4 | 1 | 1111 | 1111 | 1111 | = | 11 |
| 15 | 1111 | 1111 | 1111 | 1 | 1 | 1 | 1111 | 1111 | 4 | 1 | 1111 | 1111 | 1111 | = | 8 |
| 16 | 1111 | 1111 | 1111 | 1 | 1111 | 1111 | 1111 | 1 | 2 | 1 | 1111 | 1111 | 1111 | = | 5 |
| | 206 | 277 | 281 | 187 | 67 | 48 | 31 | 19 | 11 | 3 | 0 | 0 | 0 | \| | 1130 |

d) MISSED CORRELATIONS (WHISPER-SHOUT)

NOTE: DATA [illegible] AT 10 [illegible]
AND 15° [illegible] ANGLE

FIGURE A-23
ASSOCIATION PERFORMANCE AS A FUNCTION OF DENSITY AND OVERLAPS

## APPENDIX C

## REFERENCES

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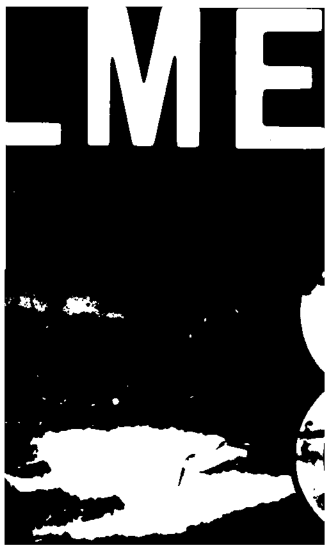
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