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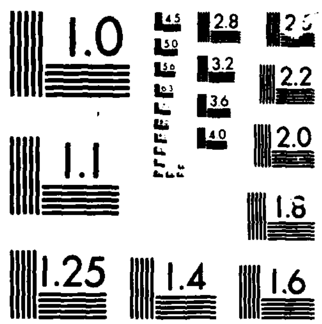

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The Impact of a Traffic Alert and Collision Avoidance System on the Air Traffic Control Radar Beacon System and Mode S System in the Los Angeles Basin

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Under Contract to
Department of Defense

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16. Abstract

An analysis was performed to predict the impact of the Traffic Alert and Collision Avoidance System (TCAS) on the performance of selected air traffic control and surveillance systems in the Los Angeles Basin. The predictions involved the impact of minimum TCAS II (TCAS II M) on both the Air Traffic Control Radar Beacon System (ATCRBS) interrogator at Long Beach, and a hypothetical Mode S sensor at Los Angeles (LAX-4), as well as the impact of the combined TCAS I and TCAS II M signal environment on the Long Beach ATCRBS interrogator. These predictions were made using a hypothetical peak Los Angeles Basin airborne deployment and subsets of that deployment.

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PREFACE

The Electromagnetic Compatibility Analysis Center (ECAC) is a Department of Defense facility, established to provide advice and assistance on electromagnetic compatibility matters to the Secretary of Defense, the Joint Chiefs of Staff, the military departments, and other DoD components. The Center, located at North Severn, Annapolis, Maryland 21402, is under policy control of the Assistant Secretary of Defense for Communication, Command, Control, and Intelligence and the Chairman, Joint Chiefs of Staff, or their designees, who jointly provide policy guidance, assign projects, and establish priorities. ECAC functions under the executive direction of the Secretary of the Air Force, and the management and technical direction of the Center are provided by military and civil service personnel. The technical support function is provided through an Air Force sponsored contract with the IIT Research Institute (IITRI).

This report was prepared for the Program Engineering and Maintenance Service of the Federal Aviation Administration in accordance with Interagency Agreement DOT-FA70WA1-175, as part of AF Project 649E under Contract F-19628-80-C-0042, by the staff of the IIT Research Institute at the Department of Defense Electromagnetic Compatibility Analysis Center.

To the extent possible, all abbreviations and symbols used in this report are taken from American Standards Y10.19 (1967) "Units Used in Electrical Science and Electrical Engineering" issued by the USA Standards Institute.

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EXECUTIVE SUMMARY

The Traffic Alert and Collision Avoidance System (TCAS) analyzed in this report was developed to provide a collision-avoidance function for TCAS-equipped aircraft in air traffic environments populated with both Air Traffic Control Radar Beacon System (ATCRBS) and Mode S (referred to previously as the Discrete Address Beacon System (DABS)) transponder-equipped aircraft. TCAS-equipped aircraft perform the Collision Avoidance System (CAS) tracking function by actively interrogating other aircraft operating in the local airspace. The Federal Aviation Administration (FAA) requested that the Electromagnetic Compatibility Analysis Center (ECAC) investigate the effect of these TCAS-related emissions on the performance of the ATCRBS Automated Radar Terminal System (ARTS) III processor and a hypothetical Mode S sensor.

Currently, two versions of TCAS are being developed to provide various levels of collision-avoidance protection. For this analysis, TCAS operations were modeled in accordance with a simple TCAS I and a minimum TCAS II (TCAS II M) design. TCAS II M, the more sophisticated of the two systems, maintains a safe separation from all other air traffic by tracking local intruders via the exchange of ATCRBS- and Mode S-formatted signals. The FAA is considering the TCAS II M design for use in commercial aircraft. TCAS I, a lower cost, less sophisticated version of the TCAS II M system, will locate nearby aircraft by periodically eliciting replies using an ATCRBS interrogation format. TCAS I emission powers of 20, 120, and 500 watts were used in this analysis. The FAA is considering the TCAS I system for use by general aviation aircraft.

A TCAS Signal Environment Model (SEM) was developed by ECAC to simulate both TCAS I and TCAS II M operations and to construct the resultant TCAS-related signal environment. This TCAS signal environment was merged with a simulated ground-based air traffic control (ATC) signal environment which was constructed using the DABS/ATCRBS/AIMS[a] Performance Prediction Model (PPM).

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[a]The name DABS is used only in referring to the computer model DABS/ATCRBS/AIMS. The model was developed prior to DABS being referred to as Mode S.

The DABS/ATCRBS/AIMS PPM was used to predict the performance of selected ground-based ATC systems in the composite TCAS and ATC signal environment.

Simulations were conducted to predict the impact of TCAS II M emissions on the performance of both the Long Beach ATCRBS interrogator with an ARTS III processor and a hypothetical Mode S sensor located, for the study, at Los Angeles (LAX-4). In addition, simulations to predict the impact of the combined TCAS I and TCAS II M signal environment at the Long Beach ATCRBS interrogator were conducted. Six air traffic deployments were constructed as subsets of a hypothesized peak Los Angeles Basin airborne deployment. ATCRBS ground system performance was predicted both with and without TCAS II M operating, as well as with and without the combined TCAS I and TCAS II M operating. Mode S ground system performance was predicted with and without TCAS II M operating. ATCRBS performance was predicted based on the ability of the ARTS III processor system to detect, code validate, and track aircraft. Mode S sensor performance prediction was based on the ability of the sensor to elicit decodable surveillance and data-link replies from Mode S-equipped aircraft with a minimum number of interrogations. Mode S performance was also measured in terms of the sensor's ability to detect ATCRBS aircraft and receive Modes A and C reply codes with high confidence.

For the Long Beach ATCRBS simulations, it was predicted that the operation of TCAS II M in any of the air traffic deployments analyzed will have the following effects:

On the transponders:

1. Will reduce average reply efficiency by a maximum of 1.9%.

On the interrogator:

1. Will not reduce target detection efficiency
2. Will reduce the Mode A validation efficiency by a maximum of 0.3%

3. Will reduce the Mode C validation efficiency by a maximum of 0.7%
4. Will not significantly reduce the ability to track aircraft.

For the Long Beach ATCRBS simulations, it was predicted that the operation of both TCAS I and TCAS II M, using any of the three TCAS I emission powers (20, 120, and 500 watts), will have the following effects:

On the transponders:

1. Will reduce average reply efficiency by a maximum of 2.5%.

On the interrogator:

1. Will not reduce target detection efficiency
2. Will reduce the Mode A validation efficiency by a maximum of 1.3%
3. Will reduce the Mode C validation efficiency by a maximum of 2.4%
4. Will not significantly reduce the ability to track aircraft.

For the simulations of the hypothetical Mode S sensor at Los Angeles, it was predicted that the operation of TCAS II M in any of the air traffic deployments analyzed will have the following effects:

On the transponders:

1. Will reduce average reply efficiency by a maximum of 1.5%.

On the interrogator:

1. Will not reduce the target detection efficiency
2. Will not reduce the high-confidence Mode A validation efficiency
3. Will not reduce the high-confidence Mode C validation efficiency
4. Will increase the roll-call interrogation rate by a maximum of 0.8%.

In addition to the analysis described above, the FAA requested that ECAC compare the environment of ATCRBS interrogators in the Los Angeles Basin area used in the analysis to the actual operational environment of such emitters. This request was made because the fruit rates generated by ECAC's computer simulation model were higher than those measured during a Lincoln Laboratory flight test. This was expected since the original interrogator environment was developed with the assumption that all interrogators in the environment were operational continuously. This is a worst-case assumption; however, it does not affect the results of analyses such as this TCAS study, where impact is presented in terms of comparative performance predictions, (i.e., the difference in ATCRBS and Mode S performance with and without TCAS). This request prompted ECAC to investigate the current location, status, and operational characteristics for each of the interrogator sites used in the current analysis. The results of the investigation were used to define an updated interrogator deployment. The fruit rates for the updated deployment were predicted by the computer simulation model and compared favorably (within 7.2%) with the Lincoln Laboratory measurements. This new updated Los Angeles Basin environment was used only for model validation purposes.

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SECTION 1

INTRODUCTION

BACKGROUND

Several airborne Collision Avoidance Systems (CAS) that are compatible with the existing FAA Air Traffic Control Radar Beacon System (ATCRBS) and the planned Mode S system (formerly denoted DABS, Discrete Address Beacon System) have been proposed.

During the past several years, the Federal Aviation Administration (FAA) has requested the Electromagnetic Compatibility Analysis Center (ECAC) to study the impact of various CAS systems on existing and proposed Air Traffic Control (ATC) systems.[1,2] In FY-81, the FAA requested that ECAC investigate the effects of an omnidirectional version of TCAS on ATCRBS and Mode S system performance in a hypothetical Los Angeles Basin air traffic deployment and in subsets of that deployment.[3,4] For those air traffic deployments, it was predicted that TCAS activity would not degrade ATCRBS or Mode S ATC system performance; however, interference-limiting constraints resulted in undesired reductions in the protection volume of TCAS-equipped aircraft that were operating in densely populated airspace.

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[1]Theberge, Norman, The Impact of a Proposed Active BCAS on ATCRBS Performance in the Washington, DC, 1981 Environment, FAA-RD-177-140, FAA, Washington, DC, September 1977, ADA 048589.

[2]Gettier, C., et al, Analysis of Elements of Three Airborne Beacon Based Collision Avoidance Systems, FAA-RD-79-123, FAA, Washington, DC, May 1979, ADA 082026.

[3]Hildenberger, Mark, User's Manual for the Los Angeles Basin Standard Traffic Model (Card Deck/Character Tape Version), FAA-RD-73-89, FAA, Washington, DC, May 1973, ADA 768846.

[4]Patrick, G., and Keech, T., Impact of an Omnidirectional Traffic Alert and Collision Avoidance System on the Air Traffic Control Radar Beacon System and the Discrete Address Beacon System, FAA/RD-81/106, FAA, Washington, DC, November 1981, ADA 116170.

To maximize the protection area for TCAS-equipped aircraft operating in future high-density environments, the FAA proposed a directional, scanning TCAS design which uses ATCRBS and Mode S emission characteristics, and associated revisions to interference-limiting procedures.[5] The design was chosen to reduce the extent of interference limiting and thus allow TCAS-equipped aircraft to successfully perform the collision avoidance function in even the most congested airspace and also to reduce the potential for interference with ground-based ATC systems. The FAA developed two types of TCAS units: TCAS I and minimum TCAS II (TCAS II M). TCAS II M, the more sophisticated of the two systems, is designed for omnidirectional Mode S surveillance capability and a limited directional ATCRBS surveillance capability. TCAS II M-equipped aircraft track nearby ATCRBS transponder-equipped aircraft by periodically eliciting replies using an ATCRBS-only interrogation format; nearby Mode S transponder-equipped aircraft are tracked by periodically eliciting replies using a Mode S interrogation format. The FAA is considering the TCAS II M design for use in commercial aircraft. TCAS I, a less expensive version of TCAS II M, locates nearby aircraft, both ATCRBS and Mode S, by periodically eliciting replies using an ATCRBS interrogation format. Three emission powers of 20, 120, and 500 watts were considered for use with the TCAS I system in the ECAC model. The FAA is considering the TCAS I design for use in general aviation aircraft.

In view of these and other system changes, and to further investigate the effects of TCAS II M and the combined TCAS I and TCAS II M operation on ATCRBS and Mode S performance, ECAC was requested to perform a simulation analysis, similar to the FY-81 Los Angeles Basin study, to predict the effects of TCAS on ATC system performance.

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[5] Radio Technical Commission for Aeronautics, Proposed Final Draft for Minimum Operational Performance Standards (MOPS) for Traffic Alert and Collision Avoidance System (TCAS) Airborne Equipment, RTCA/DO-185, Washington, DC, September 1983.

In addition, during FY-84 the FAA requested that ECAC compare the environment of ATCRBS interrogators in the Los Angeles Basin area used in the analysis to the current operational environment of such emitters. This request was made because the fruit rates predicted by ECAC's simulation model were higher than those measured during a Lincoln Laboratory flight test. This was expected since the original interrogator environment was developed with the assumption that all interrogators in the environment were operational all the time. This is a worst-case assumption; however, it does not affect the results of comparative (relative) performance analyses such as those ECAC has performed. Also it was suggested that changes had occured in the actual environment since the original environment files were developed. Because of this, ECAC was requested to investigate the current location, status, and operational characteristics for each of the interrogator sites used in the current analysis. The results of this investigation were used to define an updated interrogator deployment. The fruit rates using the updated interrogator deployment were predicted by the computer simulation model, and were then compared with the measured results of the Lincoln Laboratory flight test. This independent analysis is discussed in an appendix to this report.

Since this task was presented to ECAC late in FY-84, the updated interrogator deployment was not considered for the analysis described in the body of this report.

OBJECTIVES

The objectives of the analysis were 1) to predict the impact of the proposed TCAS II M on the performance of ATCRBS and Mode S air traffic control and surveillance systems in a hypothesized peak Los Angeles Basin air traffic deployment and in subsets of that deployment, and 2) to predict the effect of the combined TCAS I and TCAS II M operation on the performance of the Long Beach interrogator in a reduced air population deployment, with TCAS I operating at the three power levels of 20, 120, and 500 watts.

APPROACH

This analysis was conducted as a simulation using the DABS/ATCRBS/AIMS Performance Prediction Model (PPM)[6] supplemented with the TCAS Signal Environment Model (SEM).[7] The DABS/ATCRBS/AIMS PPM is a deterministic computer model designed to simulate the operations and interactions of ground-based ATC interrogators and airborne transponders in a selected deployment, and to predict the resultant ATC performance of a single interrogator-of-interest (I_o) in that deployment. The TCAS SEM is a statistical computer model designed to simulate the surveillance activity of TCAS II M-equipped aircraft and to predict the time-average TCAS I and TCAS II M signal rates received at each deployed aircraft. TCAS I is modeled as a constant emitter. These rates are then accessed during a DABS/ATCRBS/AIMS PPM simulation, and are used as the basis with which to merge (statistically) the TCAS-related signal environment with signals from ground-based ATC interrogators. The DABS/ATCRBS/AIMS PPM simulation is repeated, using identical starting conditions (interrogator transmit phase and antenna azimuth orientations), without accessing TCAS I and TCAS II M rates, to predict the I_o performance baseline (i.e., without TCAS I and TCAS II M operating). The results of the simulations both with and without TCAS I and TCAS II M are then compared in order to quantify the effects of TCAS on the performance of the I_o.

For this analysis, simulations were conducted using the standard, hypothesized, peak Los Angeles basin air traffic deployment consisting of 743 transponder-equipped A/C within 60 nmi of the Los Angeles terminal site (LAX-4) (see Reference 3). Two additional deployments were developed to simulate lower density environments by randomly deleting A/C from the standard deployment to produce air traffic populations of 474 and 328 aircraft.

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[6]Crawford, C. R., and Ehler, C. W., The DABS/ATCRBS/AIMS Performance Prediction Model, FAA-RD-79-88, FAA, Washington, DC, November 1979, ADA 089440.

[7]Gilchrist, C., The TCAS Signal Environment Model, FAA, Washington, DC, (to be published).

For each of the three air traffic deployments described above, simulations were performed both with and without TCAS II M using the Long Beach ATCRBS facility as the I_o. Simulations were also performed, using a modified version of the 474 aircraft deployment, to determine the effects of the combined TCAS I and TCAS II M signal environment on the ATCRBS interrogator at Long Beach. For the planned LAX-4 Mode S facility as the I_o, similar simulations were conducted for the air traffic deployments of 743 and 474 aircraft. The interrogator deployment for both the Long Beach ATCRBS and LAX-4 Mode S analysis was developed from the ATCRBS/IFF data base at ECAC. This deployment, as specified by the FAA, consisted of all interrogators within 500 nmi of LAX-4. The LAX-4 Mode S deployment differed from the ATCRBS deployment in that four specified FAA ATCRBS interrogators were modeled as Mode S interrogators.

The performance of the Long Beach ATCRBS ATC system is determined in terms of the ARTS III[a] target detection and tracking performance. Mode S ATC performance at LAX-4 is determined in terms of the Mode S roll-call transaction efficiency and the ATCRBS target detection and code processing performance. Secondary performance prediction parameters, such as transponder reply efficiency, interrogation rates, suppression rates, and fruit rates, are also determined for both sites since they are indicative of overall system performance trends.

In addition to the simulations described above, several simulations were conducted, using only the TCAS SEM and the air traffic population of 474 aircraft, to determine the effects of variations in the percentage of aircraft that are TCAS II M-equipped on interrogation and suppression rates.

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[a]ARTS III - reply processor associated with ATCRBS FAA terminal sites which correlates replies to determine aircraft range, altitude, and identification.

REPORT ORGANIZATION

The remainder of this report is divided into five sections and five appendixes, as described below.

Section 2 contains a discussion which includes operational characteristics of ATCRBS and Mode S interrogators, the interrogator deployments, and the interrogator operation. Transponder operational characteristics are outlined in Section 3, which provides details on the six different aircraft deployments. Section 4 presents information on the differences between the TCAS I and TCAS II M designs, their operational characteristics, and TCAS II M ATC compatibility design. The results of the analysis are given in Section 5, which include the impact of the TCAS operation on ATCRBS and Mode S performance. Section 6 summarizes the simulation results of ATCRBS performance at Long Beach and Mode S performance at Los Angeles.

The five appendixes give supplementary information such as charts, tables, and graphs. They are:

APPENDIX	CONTENT
A	Aircraft Deployments
B	Simulation Results
C	TCAS SEM Results
D	Updated Interrogator Analysis
E	ARTS III Tracker Performance

SECTION 2

ATCRBS AND MODE S INTERROGATOR OPERATION AND CHARACTERISTICS

INTRODUCTION

The DABS/ATCRBS/AIMS PPM is a detailed computer model that simulates the signal interactions and overall performance of ATC systems in modeled environments. Each ATC interrogator is modeled as having a directional antenna. The antenna rotation rate, gain, and beamwidth, as well as a number of interrogator characteristics such as transmitter power and receiver sensitivity, are all assigned in the model according to the characteristics of that particular interrogator.

This section begins with a description of the interrogator deployments used in the analysis. Next is a summary of the operational and technical characteristics, as modeled, for both the Long Beach ATCRBS systems and LAX-4 Mode S system. This is followed by a description of the Mode S surveillance operations.

INTERROGATOR DEPLOYMENTS

The interrogator deployment was modeled by selecting interrogators from ECAC's ATCRBS/IFF environment files. The deployment consisted of 61 ATCRBS interrogators within 500 nmi of Los Angeles and was derived from a total ATC system population of 140 interrogators (Figure 2-1).[a] This resulting deployment is illustrated in Figure 2-2 and was used to predict the impact of both TCAS I and TCAS II M operations on the Long Beach ATCRBS ground interrogator. A second deployment was generated, differing from the first in that four FAA terminal interrogators were converted to Mode S sensors. This deployment was used to predict the impact of TCAS II M on Mode S at LAX-4.

[a]Due to terrain shielding and power limitations, 79 interrogators were eliminated.

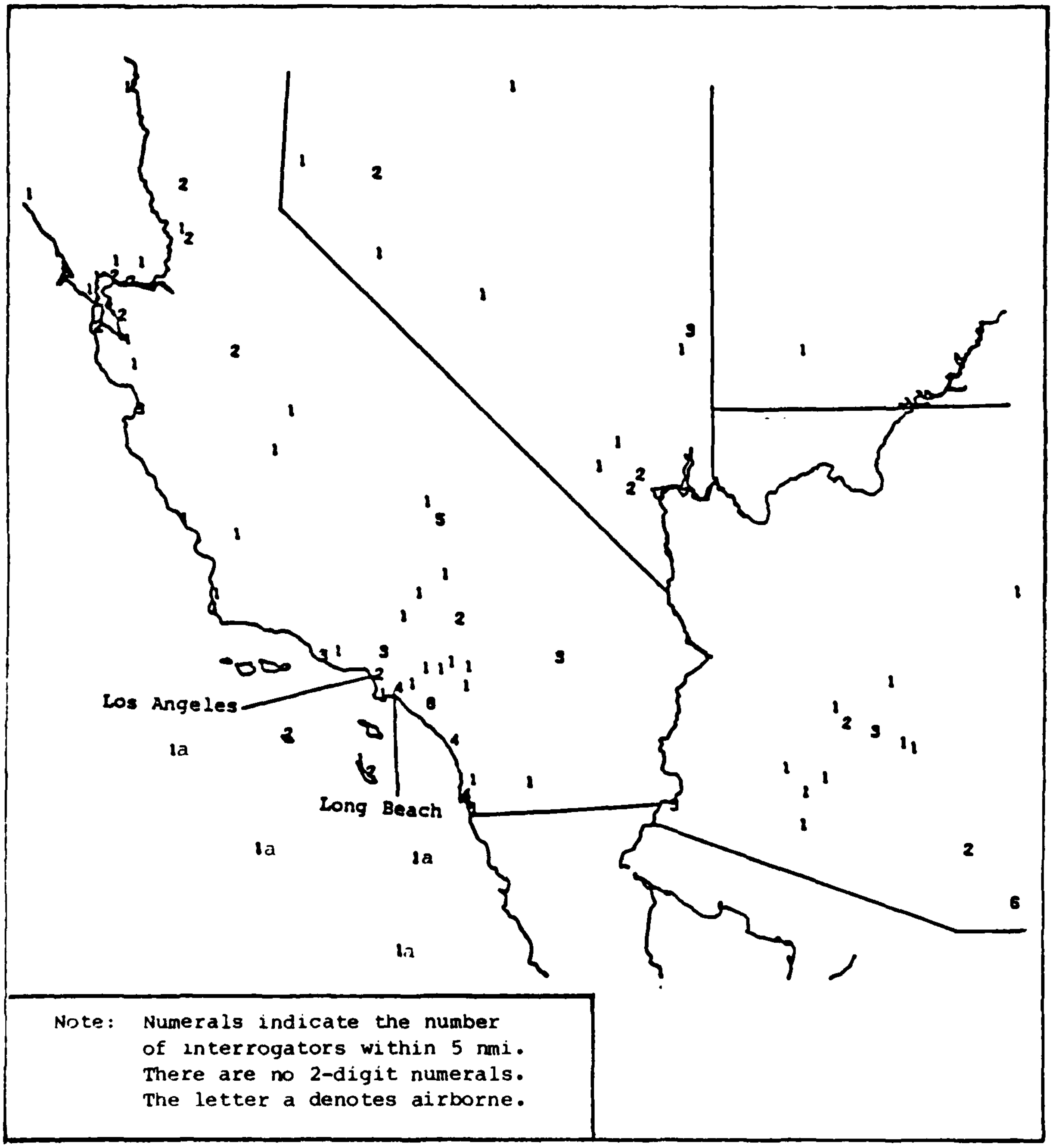
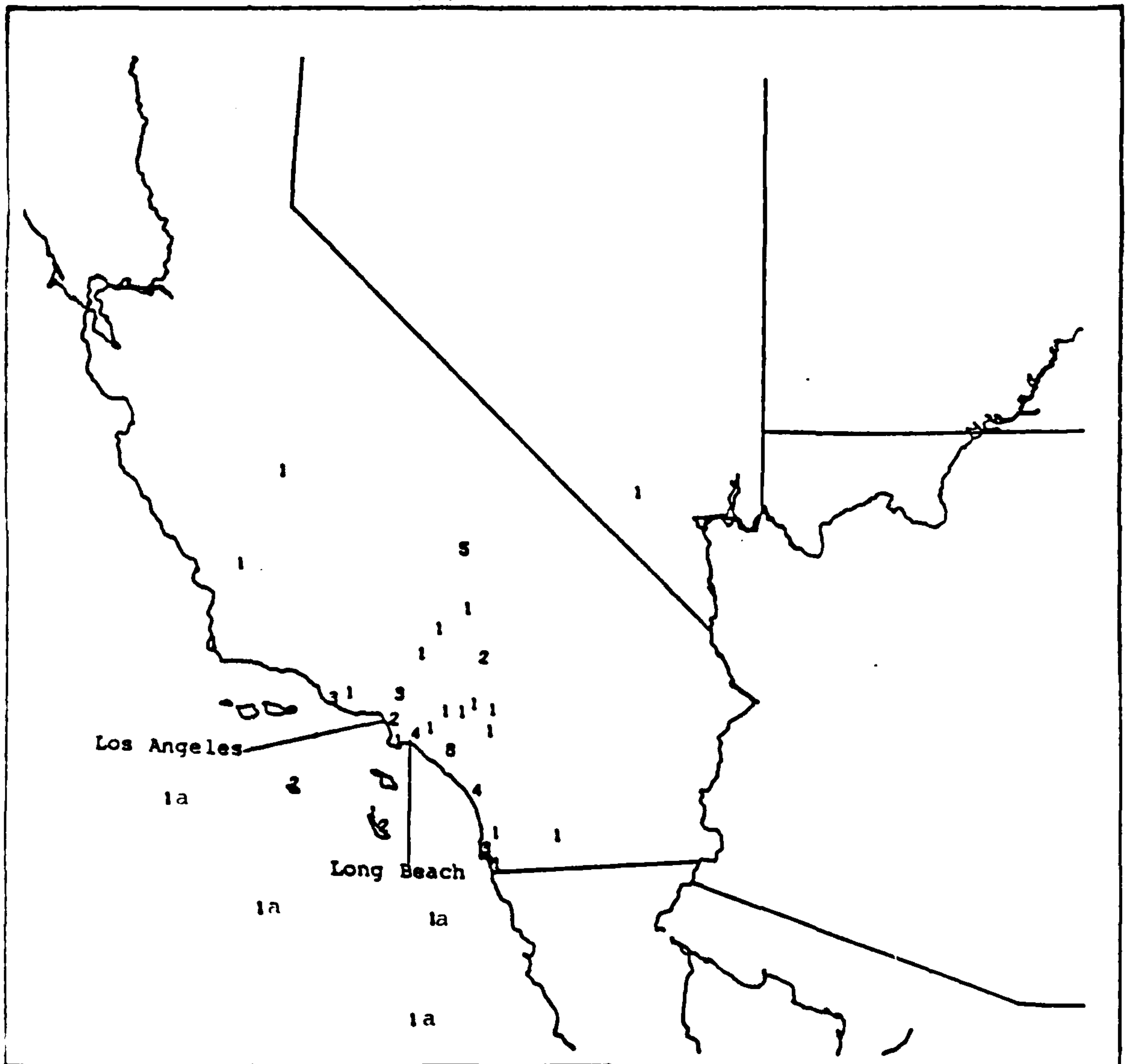


Figure 2-1. Interrogator deployment (not including terrain shielding; 136 ground interrogators and 4 airborne training interrogators).



Note: Numerals indicate the number of interrogators within 5 nmi. There are no 2-digit numerals. The letter a denotes airborne.

Figure 2-2. Interrogator deployment (including terrain shielding; 57 ground interrogators and 4 airborne training interrogators).

The four converted interrogators were LAX-4, Burbank, El Toro, and Ontario. Their surveillance and data-link coverage zones (described later) are given in TABLE 2-1 and illustrated in Figure 2-3. (Transponder deployment is also shown in Figure 2-3, but is described in Section 3.)

INTERROGATOR OPERATION

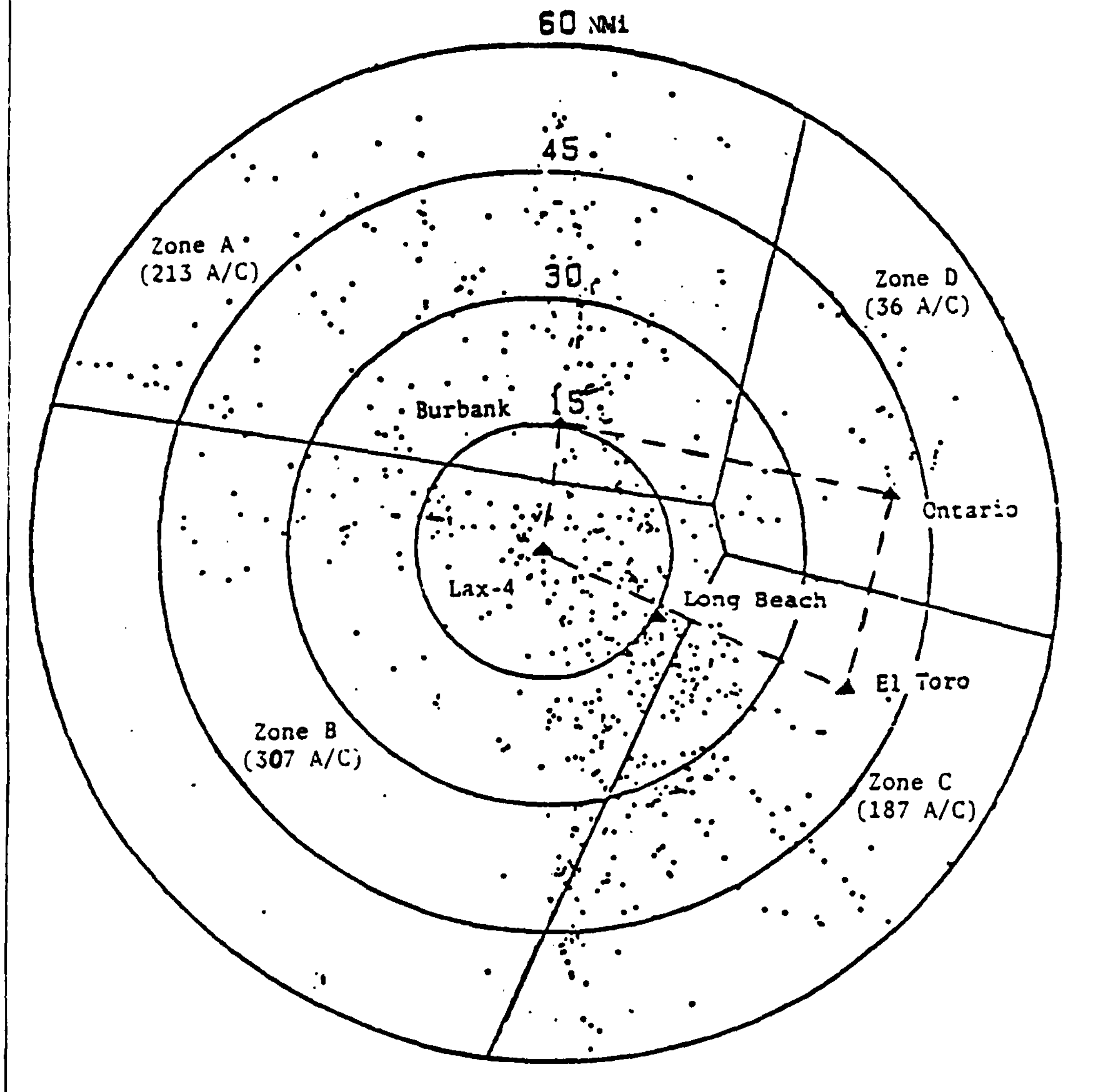
General

Simulations were conducted to predict the effects of TCAS I and TCAS II M operations on ATCRBS as well as TCAS II M operation on Mode S ATC systems. The Long Beach terminal system was modeled as the victim ATCRBS I_o; LAX-4 was modeled as the victim Mode S I_o. The location and characteristics of the Long Beach ATCRBS and the LAX-4 Mode S interrogators are given in TABLES 2-2 and 2-3, respectively.

TABLE 2-1

MODE S INTERROGATOR SURVEILLANCE AND DATA LINK ZONE ASSIGNMENTS
(See Figure 2-3)

Site	Surveillance Responsibility		Data Link Responsibility
	Primary Zone	Secondary Zone	
Burbank	A	B	A
Los Angeles	B	C	B
El Toro	C	D	C
Ontario	D	A	D



A, B, C, and D are the primary surveillance zones of the Mode S sensors at Burbank, Los Angeles, El Toro, and Ontario, respectively.

Figure 2-3. Airborne transponder deployment with surveillance zones A-D (origin is LAX-4, 33°57'12"N, 118°24'00"W).

TABLE 2-2

PARAMETER ASSIGNMENTS FOR THE LONG BEACH ATCRBS INTERROGATOR

Latitude	33°49'09"N
Longitude	118°08'16"W
Power	0.08 kW
Scan Rate	13 rpm
Interrogation Rate	415/s
Mode Interlace	A, A, C
Receiver Sensitivity (MTL)	-86 dBm
Receiver Range	60 nmi
Interrogator Type	ATCBI-0003D
Cabling Loss	4 dB
STC (Sensitivity Time Control)	40 dB @ 1 nmi
Antenna Gain and Beamwidth	21 dBi for 4°
SLS Type	Improved sidelobe suppression (ISLS)

TABLE 2-3

PARAMETER ASSIGNMENTS FOR THE LAX-4 MODE S SENSOR

Latitude	33°57'12"N
Longitude	118°24'00"W
Power	0.1 kW
Scan Rate	13 rpm
Interrogation Rate	128/s[a]
Mode Interlace	A, C
Receiver Sensitivity (MTL)	-88 dBm
Receiver Range	200 nmi
Cabling Loss	4 dB
STC (Sensitivity Time Control)	N/A
Antenna Gain and Beamwidth	21 dBi for 4°
SLS Type	Receiver SLS

[a]The reciprocal of the time interval between MODE S all-call interrogations.

The 61 interrogator population can be partitioned into 6 classes based on interrogator operational/technical characteristics. TABLE 2-4 gives the nominal value of the principal characteristics of each interrogator type, along with the number of systems of each type for the two interrogator deployments developed for this analysis.

TABLE 2-4

ENVIRONMENTAL INTERROGATOR CHARACTERISTICS

Parameter	Classes					
	ATCRBS Terminal 1	ATCRBS Terminal 2	ATCRBS Enroute 1	ATCRBS Enroute 2	ATCRBS Enroute 3	Mode S
Effective Radiated Power (dBw)	40	45	48	55	38	41
Scan Rate (RPM)	13	15	6	5	6	13
Interrogation Rate (/s)	300	300	275	250	300	125
Receiver Sensitivity (dBm)	-86	-81	-81	-88	-81	-86
Surveillance Range (nmi)	60	60	200	200	200	200
Number of Systems in ATCRBS Analysis Deployment	19	11	21	7	3	0
Number of Systems in Mode S Analysis Deployment	15	11	21	7	3	4

Long Beach ATCRBS

The Long Beach ATCRBS facility, as modeled, was equipped with the ARTS III Modular Automated ATC System. ARTS III performance was measured in terms of the ability of the system to detect targets and validate in terms of Mode A (identity) and Mode C (altitude) reply code validation and its ability to develop stable target tracks, as measured by "firmness" indicators. Target detection and mode validation are single-scan performance measures.[8] Detection requires the reception of 5 clear bracket reply pulse pairs (framing pulses) from the approximately 21 interrogations that each aircraft receives during the I_o mainbeam dwell period. Mode validation requires the reception of 2 consecutive clear replies to interrogations of the same mode (i.e., two Mode A interrogations or two Mode C interrogations).

Target tracking performance is a multiple-scan (long-term) performance indicator.[9] Each target is assigned a track firmness (an octal number ranging from 0 to 37) that is related to the stability of the scan-to-scan Mode A validations (TABLE 2-5). The higher the value of a track's firmness, the higher the stability of the target's track history. The track's firmness is adjusted each scan with the value of the adjustment dependent upon both the existing track firmness and whether or not the Mode A validation was successful. The sequential relationship of firmness values to existing values for successful and unsuccessful correlation are given in TABLE 2-5.

Target track development can be illustrated using a simple example. Suppose that an aircraft has entered the surveillance area of an ARTS III-equipped ATC system and remains within that area for a period of 10 scans. (This is a period of 50 seconds for a terminal site with an antenna rotation rate of 12 rpm.) Assume that the scan-by-scan Mode A validation decisions

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[8] ARTS III Beacon Message Processing, NAS-MD-606, Naval Air Station, Washington, DC, January 1981.

[9] ARTS III Tracked and Untracked Target Processing, NAS-MD-607, Washington, DC, January 1981.

TABLE 2-5

TRACK FIRMNESS TABLE

Previous Firmness (in octal)	Firmness Subsequent to Successful Correlation (in octal)	Firmness Subsequent to Unsuccessful Correlation (in octal)	Track Firmness State
0	3	0	Tabular Coast[a]
1	5	0	
2	6	1	
3	7	2	
4	15	0	Initial Track[a]
5	16	4	
6	17	5	
7	20	6	
10	13	10	
11	13	10	Turning Track[a]
12	13	11	
13	25	13	Turning Trial Track[a]
14	16	0	
15	17	14	
16	20	15	
17	21	16	
20	22	17	
21	23	20	
22	24	21	
23	25	22	
24	26	23	
25	27	24	
26	30	25	Normal, Parent and Parent Trial Tracks[a]
27	31	26	
30	32	27	
31	33	30	
32	34	31	
33	35	32	
34	36	33	
35	37	34	
36	37	35	
37	37	36	

[a]See Reference 9 for explanation of these terms.

were delivered to the ARTS III tracker as shown by columns 1 and 2 of TABLE 2-6. Using TABLE 2-5 in conjunction with the correlation decisions, the target track development during the 10-scan period is shown in the last two columns of TABLE 2-6.

TABLE 2-6

EXAMPLE OF THE ARTS III TARGET TRACK DEVELOPMENT

Scan	Target Identity Correlation Decision (Mode A Validation)	Firmness	
		Scan N-1	Scan N
1	Yes	0	3
2	Yes	3	7
3	Yes	7	20
4	Yes	20	22
5	No	22	21
6	Yes	21	23
7	Yes	23	25
8	Yes	25	27
9	No	27	26
10	Yes	26	30

For this hypothetical case, if the target remains within the ARTS III system surveillance area for several more scans, and correlation fails for each of these scans, then the application of the negative correlation decisions shown in TABLE 2-5 would lead to a firmness value of zero after the 12th consecutive unsuccessful scan. A zero firmness value results in a tabular coast state, which implies complete uncertainty in target position.

LAX-4 Mode S

The LAX-4 Mode S system, in accordance with the Mode S system design, was modeled to operate using both ATCRBS and Mode S surveillance techniques.

ATCRBS performance is based on the ability of the processor to detect aircraft and to declare high-confidence Mode A and Mode C reply codes. Detection required two clear framing pulse pairs in response to interrogations of either mode. Each aircraft receives approximately 7 interrogations during the mainbeam dwell period. Declaration of high-confidence mode requires receipt of a single composite clear reply constructed from the set of replies to that particular mode. Mode S surveillance and data-link performance is based on the ability of the system to elicit decodable roll-call replies from aircraft located within its surveillance and data-link volumes with a minimum number of interrogations. The surveillance and data-link interrogation rates are variables depending upon aircraft location and type. These rates are discussed next. (See Reference 6 for a more comprehensive discussion of Mode S data-link and surveillance formats as well as Mode S protocol.)

Mode S Surveillance

Mode S signal activity consisted of a combination of surveillance and Cockpit Display of Traffic Information (CDTI) services.[10,11] The service provided to each aircraft from each Mode S sensor was dependent upon aircraft type. Air-carrier and high-performance general-aviation aircraft (11% of the total aircraft population) were defined as high-option targets and received from their primary sensor high-option CDTI services (Extended Length Message (ELM)) which consisted of a series of Comm-C data segments addressed to a particular aircraft, containing information about other aircraft in the immediate vicinity (within the threat volume) of the addressed aircraft. The threat volume about each addressed aircraft was constructed as a cylinder (hockey puck) with the horizontal boundary at 3 nmi and the vertical

[10] Notice in the Federal Register, Vol. 43, No. 59, Monday, March 27, 1978, Part II, entitled, "Proposed U.S. National Aviation Standard for the Discrete Address Beacon System (DABS)".

[11] Keech, T., and Fleming, G., Impact of the Discrete Address Beacon System (DABS) on Air Traffic Control Radar Beacon System (ATCRBS) Performance in Selected Deployments, FAA/RD-80-93, FAA, Washington, DC, November 1979, ADA 089611.

boundaries at ±2500 feet. There were assumed to be [((T/2)+2.5) 'ru'] Comm-C segments transmitted per scan to each high-option target, where T was the number of targets within the threat volume (ru denotes "rounding upward" to the next larger integer). All but two of the Comm-C segments were contained within a precursor, and did not elicit replies.[a] The remaining two Comm-C segments, which serve to finalize the ELM transaction, each elicited an ELM Comm-D reply.

Fourteen percent of the aircraft population (Mode S-equipped) received mid-option CDTI or standard data link services that consisted of ((T/2) ru + P) Comm-A[b] interrogations per scan, where P is a random variable of Poisson distribution with a mean of 1.0. Each Comm-A transmission contained data for two targets. All but one of the Comm-A interrogations elicited surveillance (altitude or identity) replies. The remaining Comm-A interrogation elicited a mid-option CDTI finalizing Comm-B reply. If both T and P for a particular aircraft were zero, the aircraft received one surveillance interrogation per scan from its primary sensor.

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[a]Comm-C segments that do not elicit replies are transmitted at the beginning of the Mode S interrogation schedule and thus are referred to as the precursor (see Reference 6).

[b]Comm-A segments are used for ground-to-air transmission of short ATC messages.

SECTION 3

TRANSPONDER OPERATION AND CHARACTERISTICS

AIRCRAFT DEPLOYMENTS

For this analysis, simulations were conducted using the standard, hypothesized, peak Los Angeles basin air traffic deployment and two subsets of that deployment. The peak deployment consists of 743 transponder-equipped aircraft that are all within 60 nmi of Los Angeles (689 general aviation, 30 air-carrier, and 24 military). Each aircraft deployment was constructed while maintaining a nominal mix of 25% Mode S (11% TCAS II M)[a] and 75% ATCRBS transponder-equipped aircraft. For the peak deployment, deployment A, 53 of the general-aviation aircraft are designated high-performance (multiple-engine) aircraft. The 188 Mode S transponder-equipped aircraft in deployment A include the 30 air-carrier, the 53 high-performance general aviation, and 105 of the remaining general aviation aircraft. The 30 air-carrier and the 53 high-performance general aviation aircraft were assumed to be equipped with TCAS II M interrogators. The remainder of the air traffic population (555 aircraft) was modeled as equipped with ATCRBS transponders (TABLE 3-1).

The two reduced deployments, deployments B and C (TABLE 3-1), were developed by randomly deleting aircraft from deployment A to produce air traffic populations of 474 and 328 aircraft. These two deployments correspond to maximum aircraft densities of 0.3 and 0.2 aircraft per square nmi within 5 nmi of any TCAS II M-equipped aircraft; the maximum 5-nmi density in the peak deployment (deployment A) is 0.534 aircraft per square nmi.[b] Deployment B was developed to predict the effects of TCAS II M while operating in an air traffic environment for which it was designed. TCAS II M was designed to be

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[a]25% Mode S (11% TCAS II M) means that 25% of the aircraft deployment are Mode S-equipped and 11% of the aircraft deployment are TCAS II M-equipped. All TCAS II M-equipped aircraft are also Mode S-equipped.

[b]The maximum aircraft densities correspond to maximum numbers of aircraft within the 5 nmi radius of: 42 aircraft for deployment A, 24 aircraft for deployment B, and 16 aircraft for deployment C.

TABLE 3-1

AIRCRAFT DEPLOYMENTS USED IN THE ANALYSIS

Parameter	Deployment					
	A	B	C	B1	B2	B3
Total Number of Aircraft (within 60 nmi of LAX)	743	474	328	474	474	474
(within 60 nmi of Long Beach)	716	460	319	460	460	460
Approximate Density (within 30 nmi of LAX)	0.159	0.100	0.070	0.100	0.100	0.100
Number of Mode S-Equipped	188	112	72	112	112	289
(TCAS II M-Equipped)	(83)	(49)	(34)	(65)	(83)	(49)
(TCAS I-Equipped)						(240)
Number ATCRBS-Equipped	555	362	256	362	362	185
Maximum Aircraft Density Within 5 nmi of Any TCAS II M-Equipped Aircraft	0.534	0.305	0.203	0.305	0.382[a]	0.305
Maximum Aircraft Density Within 10 nmi of Any TCAS II M-Equipped Aircraft	0.394	0.248	0.159	0.248	0.248	0.248
Maximum Aircraft Density Within 30 nmi of Any TCAS II M-Equipped Aircraft	0.164	0.104	0.070	0.104	0.104	0.104

[a]This density is due to the increasing numbers of TCAS II (83) contained in deployment B2 compared to the number of TCAS II (49) contained in deployment B.

capable of successfully performing the collision-avoidance function in air traffic deployments where the maximum density of aircraft within 5 nmi of the TCAS II M-equipped aircraft does not exceed 0.3 A/C per square nmi. The 5-nmi maximum density deployment (deployment C) of 0.2 corresponds to the density observed in the LA Basin in 1983.[12] It should be emphasized that the density correspondence is the only known similarity of deployment C to 1983 observations.

As requested by the FAA, three additional deployment configurations (deployments B1, B2, and B3) were developed from deployment B by varying the percentage of transponders that are ATCRBS-, Mode S-, and TCAS equipped. Deployments B1 and B2 (TABLE 3-1) were developed by increasing the fraction of Mode S-equipped aircraft that are TCAS II M-equipped: for deployment B1, 58% of the Mode S population was TCAS II M-equipped; for deployment B2, 74% of the Mode S population was TCAS II M-equipped. Deployment B3 (TABLE 3-1) was constructed by modeling 61% of the air traffic population as Mode S-equipped with the remaining 39% modeled as ATCRBS-equipped. In this B3 deployment, 17% of the Mode S-equipped transponders were modeled as TCAS II M-equipped, and the remaining 83% were modeled as TCAS I-equipped.[a]

Range and altitude distribution for each deployment are given in TABLES A-1 and A-2 of APPENDIX A. Figure 2-3 shows the peak deployment (deployment A) as seen by the LAX-4 Mode S sensor. Figures A-1 through A-6 show each aircraft deployment along with the corresponding Mode S-equipped and TCAS I- and TCAS II M-equipped aircraft locations.

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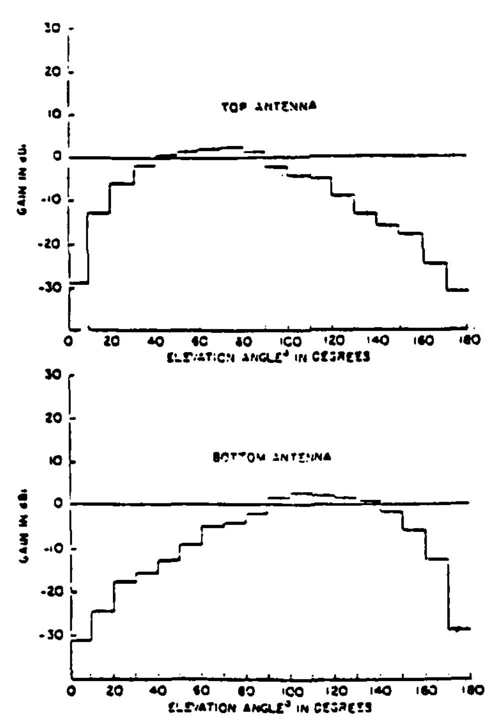
[a]Currently, there are three proposed TCAS I emission powers: 20, 120, and 500 watts.

[12]Traffic Alert and Collision Avoidance System (TCAS) Quarterly Technical Letter, TCAS 42 QTL-83-01, Lincoln Laboratory, MA, 25 April 1983.

TRANSPONDER CHARACTERISTICS

Each transponder-equipped aircraft is represented by an antenna (omni-directional in azimuth), antenna cable, receiver/processor, and a transmitter. The (quantized) vertical antenna gain patterns, as modeled, are illustrated in Figure 3-1. These patterns were derived from measured data for the Boeing 727 antenna/airframe configuration.[a] For this analysis, it was assumed that ATCRBS transponder-equipped aircraft were fitted with a single, bottom-mounted antenna, while Mode S transponder-equipped aircraft were fitted with both top- and bottom-mounted antennas. ATCRBS and Mode S transponders are assumed to utilize the same bottom antenna pattern. Polarization losses were neglected.



[a]Elevation angles: 0° - directly above aircraft,
180° - directly below aircraft.

Figure 3-1. Quantized vertical antenna patterns assumed for transponder deployed aircraft.

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[a]Patterns were supplied to ECAC by the FAA.

The cable loss from the antenna terminals to the receiver/transmitter terminals was assumed to be 3 dB for the entire transponder population.

The receiver sensitivity and transmitter power output of each type of transponder were assigned statistically, using Monte Carlo techniques, based on measured data[13] for the ATCRBS transponders and equipment specifications for the Mode S and TCAS transponders. As an example, the population distributions of ATCRBS receiver sensitivity and transmitter power distribution for the peak deployment (deployment A) are illustrated in Figures 3-2 and 3-3, respectively. The average value of receiver sensitivity is -74 dBm; the average value of transmitter power is 27 dBw.

Mode S transponder-equipped aircraft receiver/transmitter characteristics were assigned using the normal probability distribution function (see Reference 10).[14] The receiver sensitivity distribution for Mode S transponder-equipped aircraft that were not TCAS II M-equipped was developed using a mean value of -77 dBm with a standard deviation of 1.5 dB. The sensitivity distribution for Mode S transponder-equipped aircraft that were TCAS II M-equipped was constructed using a mean value of -77 dBm with a standard deviation of 0.5 dB. Reply power levels for the two populations of Mode S transponders were assigned in a similar way: an average reply power of 27 dBw for both populations with 1) a standard deviation of 1.5 dB for Mode S aircraft that are not TCAS II M-equipped, and 2) a standard deviation of 0.5 dB for Mode S aircraft that are TCAS II M-equipped.

Transponders are subjected to a variety of signal formats from ATCRBS interrogators, Mode S interrogators, and TCAS interrogators. The reaction of a transponder receiver/processor and transmitter to each type of signal is, in general, different for Mode S and ATCRBS transponders. TABLE 3-2 lists the

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[13] Colby, G. V., and Crocker, E. A., Final Report Transponder Test Program, FAA-RD-72-30, FAA, Washington, DC, April 1972, AD 740786.

[14] "U.S. National Standard for IFF Mark X (SIF)/Air Traffic Control Radar Beacon System Characteristics," Agency Order 1010.51, FAA, Washington, DC, March 1971.

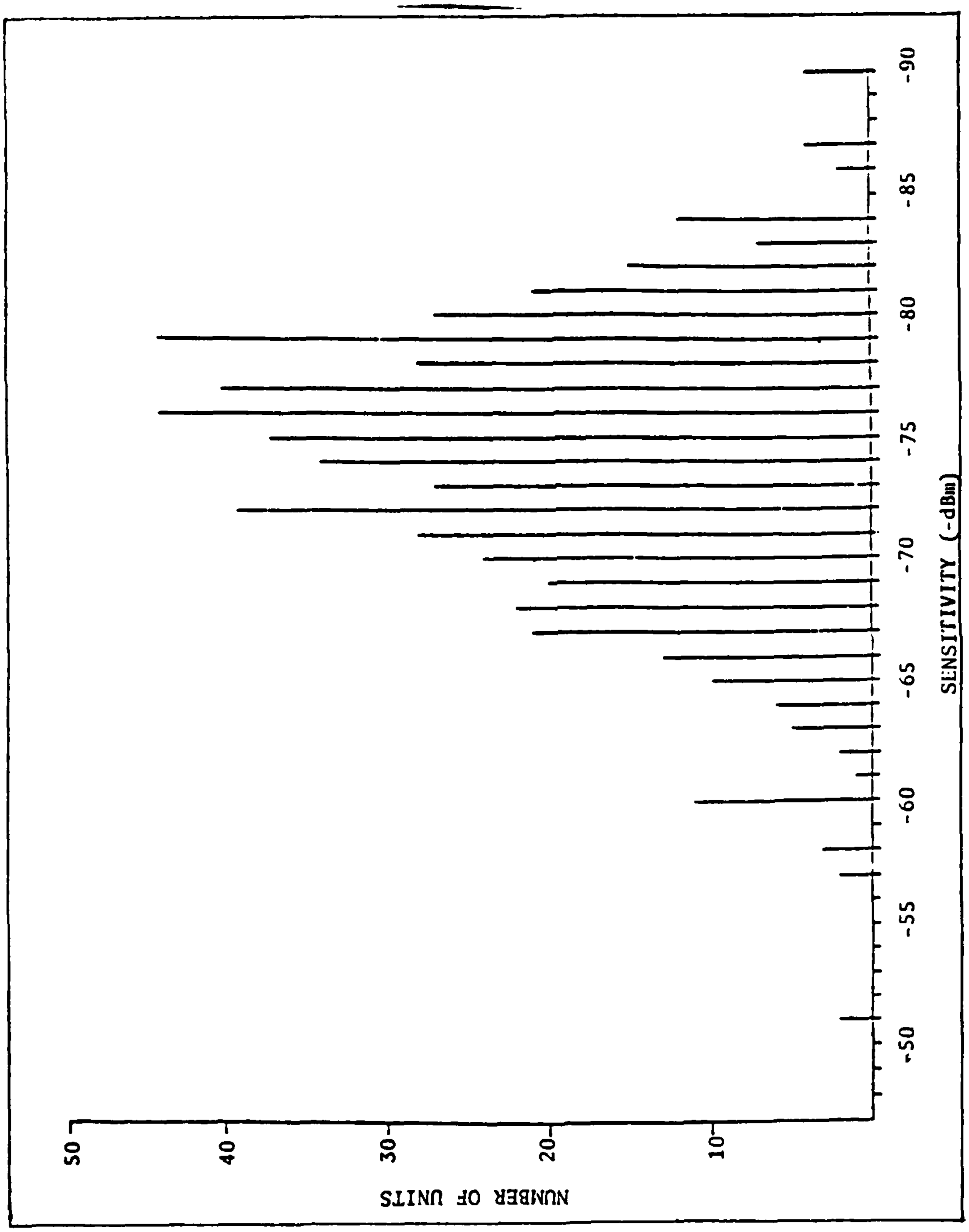

Figure 3-2. Distribution of receiver sensitivities assigned to the ATCRBS transponder population (deployment A).

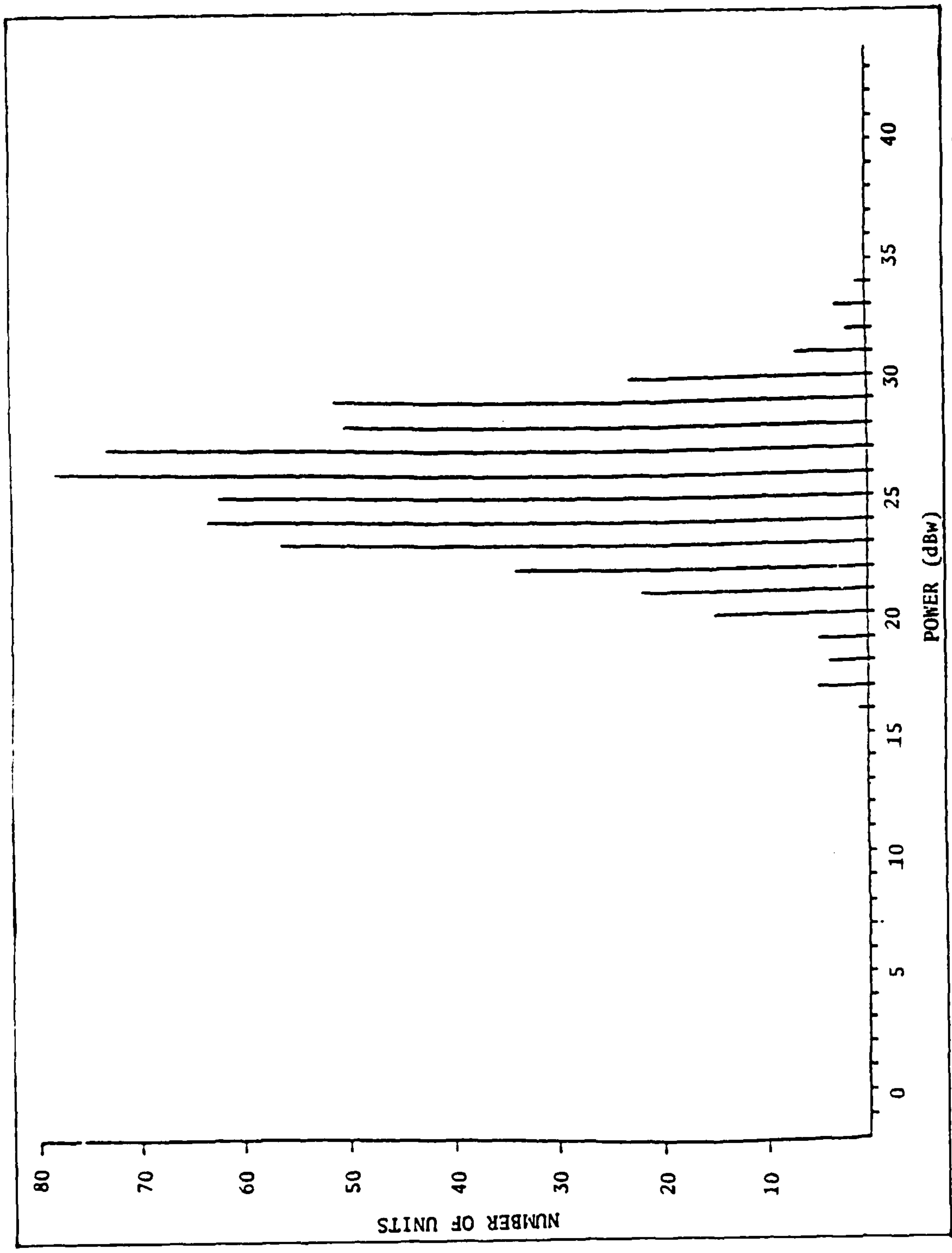

Figure 3-3. Distribution of transmitter power assigned to the ATCRBS transponder population (deployment A).

TABLE 3-2

TRANSPONDER INTERROGATION PROCESSING AND DEAD TIMES

Transmission Type	Transponder Type	Receiver Dead Time (μs)	Transmitter Action
ATCRBS Interrogation	ATCRBS	60	Reply
ATCRBS-Only Interrogation[a]	ATCRBS	60	Reply
ATCRBS-Suppression	ATCRBS	35	Suppression
Mode S Interrogation (All-Call and Roll-Call)	ATCRBS	35	Suppression
ATCRBS Interrogation	Mode S	60	Reply
ATCRBS-Only Interrogation	Mode S	24	Suppression
ATCRBS Suppression	Mode S	35	Suppression
Mode S Interrogation (at transponder address)	Mode S	192 (short reply) 248 (long reply)	Reply
Mode S Interrogation (not at transponder address)	Mode S	20 (short interrogation) 32 (long interrogation)	Suppression Suppression
Mode S All-Call Interrogation	Mode S	128	Reply

[a]ATCRBS-only interrogations are transmitted by Mode S sensors and TCAS II M interrogators.

different types of signals that may be received at transponders, and the attendant receiver/processor and transmitter action (see References 10 and 14).

SECTION 4

TCAS OPERATIONS AND CHARACTERISTICS

INTRODUCTION

This section contains a brief description of TCAS II M and TCAS I surveillance operations, as modeled in the TCAS Signal Environment Model (SEM), as well as a discussion of the TCAS interference-limiting constraints which are included in the TCAS II M design to ensure TCAS/ATC system compatibility (see Reference 5).[15,16] A detailed description of TCAS II M surveillance protocol is included in the TCAS SEM software documentation (see Reference 7).

TCAS II M

TCAS II M is an airborne system that is designed to use existing ATCRBS and Mode S signal formats to perform the collision-avoidance function. TCAS II M tracks ATCRBS-equipped aircraft in its vicinity via the whisper-shout power management technique (described later) and listens for Mode S replies (squitters) to determine if establishment of a track is required for Mode S aircraft. This tracking of both ATCRBS- and Mode S-equipped aircraft is performed once per second and is designated a search cycle. TABLE 4-1 gives TCAS II M interrogator characteristics.

The TCAS II M-equipped aircraft carries a Mode S air traffic control transponder. The Mode S transponder performs the functions of existing ATCRBS (Modes A & C) transponders and provides Mode S air-to-air communications for coordinating the resolution of encounters between TCAS II M-equipped aircraft. The Mode S transponder is also used for communications with the

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[15] Orlando, V.A., et al, Traffic Alert and Collision Avoidance System (TCAS I) Design Guidelines, FAA-RD-82-12, FAA, Washington, DC, April 1982, ADA 121300.

[16] Mann, Patricia, Simulation of Surveillance Processing Algorithms Proposed for the DABS Mode of BCAS, FAA-RD-77-138, FAA, Washington, DC, February 1978.

TABLE 4-1

TCAS II M CHARACTERISTICS

Power[a]	P_t (at transmitter)
Receiver Sensitivity (MTL) (1090-MHz channel)[b]	R_s
Cable Loss	3 dB
Peak Antenna Gain (omnidirectional in azimuth)[c]	3 dBi
Peak Antenna Gain (directional in azimuth)[d]	7 dBi

[a] P_t = (A X 0.79 N) kW, where A is the transmitter power depending on statistical assignment and N is the number of 1 dB power reductions required to satisfy the interference-limiting inequalities.

[b] R_S = (A + N) dBm, where A is the sensitivity depending on statistical assignment and N is the number of 1 dB sensitivity reductions required to satisfy the interference-limiting inequalities.

[c] Mode S transmissions.

[d] ATCRBS transmissions.

ground-based Mode S sensor for surveillance and air-to-ground data link purposes.

The Mode S transponder receives discretely addressed TCAS II M interrogations on 1030 MHz and replies (squitters) to these interrogations on 1090 MHz. The timing and altitude information from TCAS II M interrogations is used to establish the collision-threat potential of an intruder Mode S aircraft. This results in Mode S aircraft being interrogated less often when they are beyond a distance based on the protection volume.

As stated above, the TCAS II M unit performs the search cycle once per second. The first part of the cycle is used for ATCRBS tracking. The second, much larger part of the cycle, is used for Mode S tracking. When a Mode S-equipped aircraft transmission (squitter) is received and identified by the TCAS II M unit as a potential threat (i.e., within the potential collision altitude window), TCAS II M will discretely interrogate the aircraft to obtain range and altitude in order to determine the closure rate for that aircraft. If a collision is projected, a resolution advisory is sent to the indicator in the cockpit of the aircraft. Mode S surveillance protocol requires that a TCAS II M-equipped aircraft elicit a decodable Mode S reply once per second from all other Mode S aircraft within approximately 7 nmi, and at a rate which decreases monotonically with range for aircraft beyond 7 nmi.

The current TCAS II M design employs a four-beam directional antenna on top of the aircraft and a bottom-mounted omnidirectional antenna for ATCRBS surveillance. Each TCAS II M tracks ATCRBS aircraft via a whisper-shout power management technique.

This technique uses directional interrogations from each of the four beams of the top antenna, and starts with a lower power interrogation level and proceeds to higher power interrogation level in 1 dB increments. A total of 83 whisper-shout interrogations are transmitted each second. In the final step, the full power of the TCAS II M transmitter is used for the interrogation in the forward direction. The time between each interrogation is 1 ms. All the interrogations for each beam position, except the first, are preceded by a lower level suppression pulse pair 2 or 3 μs prior to the next interrogation message. This suppression is used to prevent the more sensitive transponders from replying again. This technique partitions the ATCRBS environment with respect to transponder sensitivity, to reduce the number of overlapping replies received from each interrogation. The whisper-shout is sequenced through the four beams of the TCAS II M top antenna and the bottom omnidirectional antenna once each second, using the number of levels as indicated in TABLE 4-2. The function of the transmission from the bottom antenna is to minimize false targets that are generated by multipath conditions.

TCAS I

As modeled herein, TCAS I is a simple ATCRBS Mode C interrogator which transmits at a rate of one interrogation per second and has an associated

TABEL 4-2

WHISPER-SHOUT SEQUENCE

Antenna	Beam	Number of Whisper-Shout Levels
Top	Forward	24
Top	Right	20
Top	Left	20
Top	Rear	15
Bottom	Omni	4

Mode S transponder (see Reference 15). As modeled, it is a constant source of interrogations at a fixed power and rate and employs no interference limiting. TABLE 4-3 gives TCAS I operational characteristics.

TABLE 4-3

TCAS I CHARACTERISTICS

Power[a]	P_t (at transmitter)
Receiver Sensitivity (MTL) (1030 MHz Channel)[b]	R_s
Cable Loss	3 dB
Peak Antenna Gain	3.0 dBi

[a]The three proposed TCAS I emission powers of 20, 120, and 500 watts at once per second.

[b]Sensitivity depends on statistical assignment.

TCAS/ATC COMPATIBILITY DESIGN

Each TCAS II M unit periodically computes interference estimates that are used to ensure that TCAS II M-related emissions will not cause excessive interference to ground-based ATC and surveillance systems (see Reference 2).

Interference-limiting is implemented by adjusting a TCAS II M unit's output power and minimum triggering level (MTL) and by eliminating selected ATCRBS interrogation steps from the "Whisper-Shout" sequence to satisfy three inequalities:

$$\sum_{i=1}^{I} \frac{P(i)}{250 \text{ watts}} < \frac{280}{1 + NTA} \tag{4-1}$$

$$\sum_{i=1}^{I} M(i) < 0.01 \text{ second} \tag{4-2}$$

$$\sum_{k=1}^{K} \frac{PA(k)}{250 \text{ watts}} < \frac{80}{1 + NTA} \tag{4-3}$$

The variables in these inequalities are defined as follows:

I = the total number of Mode S interrogations transmitted in a 1-second period.

i = the index number of the current Mode S interrogation; $i = 1,2,...,I$.

$P(i)$ = the total radiated Mode S power (in watts) from the antenna for i-th interrogation.

NTA = the number of squitter detected TCAS II M interrogators.

$M(i)$ = mutual suppression interval for the TCAS II M transponder associated with the i-th interrogation.

K = the total number of ATCRBS interrogations in a 1-second period.

k = the index number of ATCRBS interrogation; $k = 1,2,...,K$.

PA(k) = the total radiated power (in watts) from the antenna for the k-th ATCRBS interrogation.

Inequality 4-1 assures that the reply efficiency of local "victim" ATCRBS transponders is not reduced by more than 1% due to incident TCAS II M emissions; inequality 4-2 assures that the reply efficiency of the transponder aboard the TCAS II M aircraft is not reduced by more than 1% due to mutual suppression by TCAS II M interrogations; inequality 4-3 assures that a local "victim" ATCRBS transponder will not transmit more than 80 ATCRBS replies per second due to TCAS II M interrogations. These inequalities and the associated physical mechanisms are discussed in more detail in Reference 5.

SECTION 5
SIMULATION RESULTS

INTRODUCTION

ATCRBS system performance at Long Beach is presented in terms of the predicted ARTS III target detection and code procesing performance and predicted tracking performance. Mode S ATC performance at LAX-4 is presented in terms of the predicted Mode S roll-call transaction efficiency and the predicted ATCRBS target detection and code processing performance. Other performance prediction parameters such as transponder reply efficiency, interrogation rates, suppression rates, and fruit rates, are also given since they are indicative of overall system performance trends.

LONG BEACH ATCRBS

The Long Beach ATCRBS results are based on a 10-scan simulation of the ATCRBS interrogator. Simulation results[a] for transponder deployments (A, B, B3, and C), both with and without TCAS activity, are presented in terms of both uplink (1030 MHz) and downlink (1090 MHz) system performance. Also included are the effects of TCAS operations on the ability of the ARTS III processor to detect and code validate target replies and to track aircraft. The location, Mode S interrogation rate, and transmission power for each TCAS II M unit for each simulation are listed in APPENDIX C.

Transponder Performance

The average transponder reply efficiency is defined as the ratio of the total number of transponder replies to the total number of Long Beach interrogations received (above MTL) at transponders within 60 nmi of Long Beach. Each transponder-equipped aircraft received approximately 21 ATCRBS

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[a]Results for TCAS I at emission powers of 20, 120, and 500 watts are also included.

interrogations from the Long Beach interrogator during each of the 10 mainbeam dwell periods. The average ATCRBS interrogation rate, the average ATCRBS SLS rate, and the average Mode S suppression rate are defined as the average number of each of these types of signals received (above MTL) per second at all aircraft within 60 nmi of the Long Beach interrogator.

The average and standard deviation of the transponder reply efficiency for each of the simulations along with interrogation and suppression rate statistics are given with and without TCAS II M operating (see TABLE 5-1) and with and without the combined TCAS I and TCAS II M operating (see TABLE 5-2). It can be seen from TABLE 5-1 that with TCAS II M operating, the average transponder reply efficiency was reduced by a maximum of 1.9%[a] for each of the three air traffic deployments. With TCAS I and TCAS II M operating, as shown in TABLE 5-2, the average transponder reply efficiency was reduced by a maximum of 2.5% in the environment with TCAS I operating at 500 watts.

In addition, other transponder performance measures for the transponders operating at Long Beach are contained in APPENDIX B.

Interrogator Performance

The effects of TCAS II M and combined TCAS I and TCAS II M on the ATCRBS interrogator performance at Long Beach are summarized in TABLES 5-3 and 5-4, respectively.

Fruit Rates. The two types of fruit arriving at the Long Beach interrogator receiver are defined as follows:

- ATCRBS fruit. ATCRBS replies elicited by ATCRBS and TCAS I and TCAS II M interrogators other than the Long Beach interrogator.

[a]Note that these percentage differences are defined as the change in reply efficiency when TCAS is introduced into the environment divided by the reply efficiency when TCAS is not in the environment.

TABLE 5-1

SUMMARY OF EFFECTS OF TCAS II M ON ALL TRANSPONDERS RESPONDING TO LONG BEACH ATCRBS INTERROGATIONS (UPLINK)

Deployment	A		B		C	
Total # of A/C (within 60 nmi) % Mode S (% TCAS II M) % TCAS I % ATCRBS	716 25(11) - 75		460 25(11) - 75		319 25(11) - 75	
TCAS II M Operation	Without	With (% Diff.)	Without	With (% Diff.)	Without	With (% Diff.)
Average ATCRBS Interrogations Per Second	348	395 (+13.5)	344	370 (+ 7.6)	357	373 (+ 4.5)
(Standard Deviation)	(300)	(324)	(297)	(310)	(304)	(309)
Average ATCRBS Sidelobe Suppressions Per Second	673	812 (+20.7)	652	731 (+12.1)	647	694 (+7.3)
(Standard Deviation)	(602)	(743)	(579)	(648)	(570)	(613)
Average Mode S Suppressions Per Second Due to TCAS II M	--	287	--	172	--	66
(Standard Deviation)	--	(211)	--	(91)	--	(39)
Average ATCRBS Reply Efficiency	.957	.940 (-1.8)	.958	.948 (-1.0)	.956	.951 (-.5)
(Standard Deviation)	(.034)	(.045)	(.032)	(.037)	(.034)	(.038)
Average Mode S Reply Efficiency	.956	.947 (-.9)	.957	.950 (-.7)	.959	.956 (-.3)
(Standard Deviation)	(.025)	(.029)	(.025)	(.027)	(.025)	(.026)
Average TCAS II M Reply Efficiency	.957	.939 (-1.9)	.957	.944 (-1.4)	.959	.951 (-.8)
(Standard Deviation)	(.023)	(.030)	(.023)	(.025)	(.022)	(.023)

TABLE 5-2
SUMMARY OF EFFECTS OF TCAS I AND TCAS II M ON ALL TRANSPONDERS
RESPONDING TO LONG BEACH ATCRBS INTERROGATORS (UPLINK)

Deployment	B3		B3		B3		B3	
Total # of A/C (within 60 nmi) % Mode S (% TCAS II M) % TCAS I % ATCRBS	460 61(11) - 39		460 61(11) 50 39		460 61(11) 50 39		460 61(11) 50 39	
TCAS I OPERATION	Without	Without	Without	20 Watts	Without	120 Watts	Without	500 Watts
TCAS II M OPERATION	Without	With (% Diff.)	Without	With (% Diff.)	Without	With (% Diff.)	Without	(With (% Diff.)
Average ATCRBS Interrogations Per Second	345	357 (+3.5)	345	373 (+8.1)	345	417 (+20.9)	345	501 (+45.2)
(Standard Deviation)	(283)	(287)	(283)	(293)	(283)	(304)	(283)	(311)
Average ATCRBS Sidelobe Suppression Per Second	638	717 (+12.4)	638	717 (+12.4)	638	717 (+12.4)	638	717 (+12.4)
(Standard Deviation)	(526)	(575)	(526)	(575)	(526)	(575)	(526)	(575)
Average Mode S Suppressions Per Second Due to TCAS II M	-	306	-	306	-	306	-	306
(Standard Deviation)	-	(204)	-	(204)	-	(204)	-	(204)
Average ATCRBS Reply Efficiency	.960	.947 (-1.4)	.960	.945 (-1.6)	.960	.942 (-1.9)	.960	.939 (-2.2)
(Standard Deviation	(.133)	(.039)	(.133)	(.040)	(.133)	(.042)	(.133)	(.044)
Average Mode S Reply Efficiency	.956	.946 (-1.0)	.956	.946 (-1.0)	.956	.945 (-1.2)	.956	.939 (-1.8)
(Standard Deviation)	(.027)	(.030)	(.027)	(.031)	(.027)	(.032)	(.027)	(.031)
Average TCAS II M Reply Efficiency	.957	.941 (-1.7)	.957	.942 (-1.6)	.957	.938 (-2.0)	.957	.933 (-2.5)
(Standard Deviation)	.023)	(.029)	(.023)	(.024)	(.023)	(.028)	(.023)	(.029)

TABLE 5-3

SUMMARY OF EFFECTS OF TCAS II M ON ATCRBS INTERROGATOR PERFORMANCE AT LONG BEACH (DOWNLINK)

Deployment	A		B		C	
Total # of A/C (within 60 nmi) % Mode S (% TCAS II M) % TCAS I % ATCRBS	716 25(11) - 75		460 25(11) - 75		319 25(11) - 75	
TCAS II M Operation	Without	With (% Diff.)	Without	With (% Diff.)	Without	With (% Diff.)
ATCRBS Fruit Per Second	11181	12489 (+11.7)	6117	6508 (+6.4)	5111	5282 (+3.3)
Mode S Roll Call Fruit Per Second	-	47	-	20	-	7
Target Detection Efficiency[a]	.831	.831 (0)	.833	.833 (0)	.811	.811 (0)
Mode A Validation Efficiency	.653	.651 (-.3)	.725	.725 (0)	.745	.745 (0)
Mode C Validation	.586	.582 (-.7)	.671	.671 (0)	.703	.703 (0)

[a]In deployment A, 15.2% of the aircraft within 60 nmi could not be detected due to insufficient power from the Long Beach ATCRBS interrogator.
In deployment B, 15.5% of the aircraft within 60 nmi could not be detected due to insufficient power from the Long Beach ATCRBS interrogator.
In deployment C, 18.5% of the aircraft within 60 nmi could not be detected due to insufficient power from the Long Beach ATCRBS interrogator.

TABLE 5-4

SUMMARY OF EFFECTS OF TCAS I AND TCAS II M ON ATCRBS INTERROGATOR PERFORMANCE AT LONG BEACH (DOWNLINK)

DEPLOYMENT	B3		B3		B3		B3	
Total # of A/C (within 60 nmi) % Mode S (% TCAS II M) % TCAS I % ATCRBS	460 61(11) - 39		460 61(11) 50 39		460 61(11) 50 39		460 61(11) 50 39	
TCAS I OPERATION TCAS II M OPERATION	Without Without	Without With (% Diff.)	Without Without	20 Watts With (% Diff.)	Without Without	120 Watts With (% Diff.)	Without Without	500 Watts With (% Diff.)
Average Fruit Per Second	8217	8438 (+2.7)	8217	8812 (+7.2)	8217	9709 (+18.2)	8217	11069 (+34.7)
Mode S Roll Call Fruit Per Second	-	56	-	56	-	56	-	56
Target Detection Efficiency	.891	.891 (0)	.891	.891 (0)	.891	.891(0)	.891	.891 (0)
Mode A Validation Efficiency	.763	.762 (-.1)	.763	.761 (-.3)	.763	.759 (-.5)	.763	.753 (-1.3)
Mode C Validation Efficiency	.701	.697 (-.6)	.701	.694 (-1.0)	.701	.689 (-1.7)	.701	.684 (-2.4)

- Roll-Call fruit. Mode S replies elicited by TCAS II M roll-call interrogations.

ARTS III TRACKING PERFORMANCE

Simulation results for the ARTS III tracker (described in Section 2) for TCAS II M and combined TCAS I and TCAS II M are presented in TABLES 5-5 and 5-6, respectively. Since the ARTS III performance is a multiple-scan (long-term) performance indicator, the results presented in TABLES 5-5 and 5-6 are only for the 10th scan simulation. The 10th scan of simulation will determine the maximum target track firmness value that each aircraft can obtain for the analysis.

In general, it can be seen from TABLE 5-5 that the performance of the ARTS III tracker is not significantly reduced with TCAS II M operating over the case when TCAS II M is not operating. For example, in the peak deployment (deployment A) without TCAS II M operating, the number of aircraft that is tracked is 524.[a] With TCAS II M operating the number tracked is 523.

Similar results can be seen with both TCAS I and TCAS II M operating (TABLE 5-6). For example, the addition of TCAS II M and 500-watt TCAS I reduces the number of tracked aircraft from 382 to 380, a relatively benign reduction.

Untracked targets will fluctuate in and out of track over time, as aircraft move with respect to each other and synchronous garble is relieved. APPENDIX E contains the tracks for all 10 scans for all simulations.

The results in terms of the percentage of aircraft tracked via the ARTS III processor are summarized in TABLES 5-7 and 5-8. They indicate no significant reduction in percent of aircraft tracked with the addition of TCAS.

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[a] The number of aircraft considered tracked are those not given a track firmness value of zero.

TABLE 5-5

EFFECTS OF TCAS II M ON ARTS III TRACKER PERFORMANCE AT LONG BEACH

			TRACK FIRMNESS VALUE																													
			0	1	2	3	4	5	6	7	10	11	12	13	14	15	16	17	20	21	22	23	24	25	26	27	30	31	32	33	34	35	36
			NUMBER OF AIRCRAFT FOR EACH TRACK FIRMNESS VALUE (AT 10th SCAN)																													
Deployment A Total # of A/C (within 60 nmi)	716	Without TCAS II M	82	2	2	3	4	2	1	5	0	0	0	0	5	4	0	17	4	2	15	3	16	9	4	7	25	5	7	30	7	0	345
% Mode S (% TCAS II M) % TCAS I % ATCRBS	25(11) -- 75	With TCAS II M	83	0	2	2	4	2	2	5	0	0	0	0	4	5	2	19	4	5	11	4	14	11	9	6	20	4	5	34	10	0	333
Deployment B Total # of A/C (within 60 nmi)	460	Without TCAS II M	23	0	2	3	0	0	2	3	0	0	0	0	5	1	0	7	2	5	9	1	3	7	3	4	11	2	7	17	3	0	268
% Mode S (% TCAS II M) % TCAS I % ATCRBS	25(11) -- 75	With TCAS II M	22	0	2	3	1	0	2	3	0	0	0	0	5	1	0	7	2	4	9	2	4	7	3	3	13	1	7	18	3	0	266
Deployment C Total # of A/C (within 60 nmi)	319	Without TCAS II M	8	0	0	0	0	0	1	4	0	0	0	0	2	0	0	2	1	3	3	1	1	3	2	1	7	2	2	13	4	0	200
% Mode S (% TCAS II M) % TCAS I % ATCRBS	25(11) -- 75	With TCAS II M	8	0	0	0	0	0	1	4	0	0	0	0	2	1	0	2	0	3	3	1	1	5	2	0	7	2	2	12	4	0	200

TABLE 5-6

EFFECTS OF TCAS II M AND TCAS I ON ARTS III TRACKER PERFORMANCE AT LONG BEACH

			TRACK FIRMNESS VALUE																													
			0	1	2	3	4	5	6	7	10	11	12	13	14	15	16	17	20	21	22	23	24	25	26	27	30	31	32	33	34	35	36
			NUMBER OF AIRCRAFT FOR EACH TRACK FIRMNESS VALUE (AT 10th SCAN)																													
Deployment B3 Total # of A/C (within 60 nmi) • Mode S (• TCAS II) • TCAS I • ATCRBS	460 61(11) -- 39	WITHOUT TCAS II M AND TCAS I	33	0	1	3	2	1	3	5	0	0	0	0	6	1	0	4	2	1	8	3	6	7	2	2	9	3	6	19	6	0	283
		WITH TCAS II M WITHOUT TCAS I	32	0	1	3	1	1	3	4	0	0	0	0	8	1	0	6	2	2	7	3	4	7	3	3	12	1	6	20	6	0	279
Deployment B3 Total # of A/C (within 60 nmi) • Mode S (• TCAS II M) • TCAS I (@ 20 watts) • ATCRBS	460 61(11) 50 39	WITHOUT TCAS II M AND TCAS I	33	0	1	3	2	1	3	5	0	0	0	0	6	1	0	4	2	1	8	3	6	7	2	2	9	3	6	18	6	0	283
		WITH TCAS II M AND TCAS I	33	1	1	3	2	1	3	5	0	0	0	0	5	1	0	5	2	2	11	2	5	5	2	3	7	2	6	20	7	0	281
Deployment B3 Total # of A/C (within 60 nmi) • Mode S (• TCAS II M) • TCAS I (@ 120 watts) • ATCRBS	460 61(11) 50 39	WITHOUT TCAS II M AND TCAS I	33	0	1	3	2	1	3	5	0	0	0	0	6	1	0	4	2	1	8	3	6	7	2	2	9	3	6	18	6	0	283
		WITH TCAS II M AND TCAS I	33	1	1	3	2	1	2	5	0	0	0	0	7	1	0	5	4	2	7	3	4	7	3	2	7	2	7	21	5	0	280
Deployment B3 Total # of A/C (within 60 nmi) • Mode S (• TCAS II) • TCAS I (@ 500 watts) • ATCRBS	460 61(11) 50 39	WITHOUT TCAS II M AND TCAS I	33	0	1	3	2	1	3	5	0	0	0	0	6	1	0	4	2	1	8	3	6	7	2	2	9	3	6	[illegible]	6	[illegible]	[illegible]
		WITH TCAS II M AND TCAS I	35	1	1	3	1	1	1	5	0	0	0	0	7	1	0	4	4	1	8	2	6	9	1	4	9	1	8	23	7	0	272

TABLE 5-7

SUMMARY OF EFFECTS OF TCAS II M ON THE ARTS III TRACKER PERFORMANCE AT LONG BEACH (AT 10TH SCAN)

% Tracked	Deployment		
	A	B	C
Without TCAS II M	73.3	79.5	79.0
With TCAS II M	73.1	79.7	79.0

TABLE 5-8

SUMMARY OF EFFECTS OF TCAS II M AND TCAS I ON THE ARTS III TRACKER PERFORMANCE AT LONG BEACH (AT 10TH SCAN) FOR DEPLOYMENT B3

% Tracked	TCAS I Operation			
	Without	20 Watts	120 Watts	500 Watts
Without TCAS II M	83.2	83.2	83.2	83.2
With TCAS II M	83.4	83.2	83.2	82.7

LOS ANGELES MODE S

The Los Angeles Mode S results are based on a 1-scan simulation of the LAX-4 sensor. Simulation results for two transponder deployments (A and B), both with and without TCAS II M operating, are presented in terms of both uplink (1030 MHz) and downlink (1090 MHz) system performance. The location, interrogation rate, and transmission power of each TCAS II M unit for each simulation are listed in APPENDIX C.

Transponder Performance

The average transponder reply efficiency is defined as the ratio of the total number of LAX-4 elicited replies to the total number of LAX-4 interrogations per transponder. Each transponder-equipped aircraft received approximately 7 ATCRBS-only interrogations per scan from the LAX-4 Mode S interrogator. The average ATCRBS interrogation rate, the average ATCRBS SLS rate, and the average Mode S suppression rate are defined as the average number of each of these types of signals received (above MTL) per second at each aircraft within 60 nmi of Los Angeles. Other transponder performance measures for transponders operating at Los Angeles are contained in APPENDIX B.

TABLE 5-9 gives the performances of ATCRBS-equipped transponders within 60 nmi of the Los Angeles sensor, both with and without TCAS II M operating. It can be seen that with TCAS II M deployed the reduction in average transponder reply efficiency was a maximum of 1.5% for each of the air traffic deployments (deployment A and B).

TABLE 5-9

SUMMARY OF EFFECTS OF TCAS II M ON ATCRBS TRANSPONDERS RESPONDING TO ATCRBS INTERROGATIONS FROM LOS ANGELES MODE S SENSOR (UPLINK)

Deployment	A		B	
TCAS II M Operation	Without	With (% Diff.)	Without	With (% Diff.)
Average ATCRBS Interrogations Per Second	396	437 (+10.4)	416	438 (+5.2)
(Standard Deviation)	(441)	(448)	(450)	(452)
Average ATCRBS Sidelobe Suppressions Per Second	473	560 (+18.4)	444	495 (+11.5)
(Standard Deviation)	(491)	(514)	(468)	(481)
Average Mode S Suppressions Per Second Due to TCAS II M	--	271	--	155
(Standard Deviation)	--	(249)	--	(116)
Average ATCRBS Reply Efficiency	.965	.951 (-1.5)	.968	.960 (-.83)
(Standard Deviation)	(.080)	(.092)	(.069)	(.075)

TABLE 5-10

SUMMARY OF EFFECTS OF TCAS II M ON MODE S SENSOR PERFORMANCE AT LOS ANGELES (DOWNLINK)

Deployment	A		B	
TCAS II M Operation	Without	With (% Diff.)	Without	With (% Diff.)
ATCRBS Fruit Per Second	3155	3489 (+10.6)	2106	2221 (+5.5)
Mode S All-Call Fruit Per Second	2	2 (0)	1	1 (0)
Mode S Roll-Call Fruit Per Second	2	10	1	7
Target Detection Efficiency[a]	.939	.939 (0)	.936	.936 (0)
High-Confidence Mode A Detection Efficiency	.721	.721 (0)	.826	.826 (0)
High-Confidence Mode C Detection Efficiency	.742	.742 (0)	.831	.831 (0)
Roll-Call Interrogations Per Scan From Mode S Sensor	245	247 (+.8)	144	145 (+.7)

[a] In deployment A, 6.1% of the aircraft could not be detected due to insufficient interrogation power from the LAX-4 Mode S sensor.
In deployment B, 6.4% of the aircraft could not be detected due to insufficient interrogation power from the LAX-4 Mode S sensor.

ATCRBS Mode of Mode S Target Detection and Code Confidence

The same number of ATCRBS transponder-equipped aircraft were detected and processed with high Mode A and Mode C code confidence for all simulations both with and without TCAS II M operating.

Mode S Surveillance and Data-Link Performance

The same number of Mode S transponder-equipped aircraft were detected for all simulations, with and without TCAS II M operating.

SECTION 6

SUMMARY OF RESULTS

ATCRBS PERFORMANCE AT LONG BEACH

It was predicted that the operation of TCAS II M in any of the air traffic deployments analyzed will have the effects described below.

On the transponders:

1. Will reduce average reply efficiency by a maximum of 1.9%.

On the interrogator:

1. Will not reduce target detection efficiency
2. Will reduce the Mode A validation efficiency by a maximum of 0.3%
3. Will reduce the Mode C validation efficiency by a maximum of 0.7%
4. Will not significantly reduce the ability to track aircraft.

For the Long Beach ATCRBS simulations, it was predicted that the operation of both TCAS I and TCAS II M, using any of the three TCAS I emission powers (20, 120, and 500 watts) analyzed, will have the following effects:

On the transponders:

1. Will reduce average reply efficiency by a maximum of 2.5%.

On the interrogator:

1. Will not reduce target detection efficiency
2. Will reduce the Mode A validation efficiency by a maximum of 1.3%
3. Will reduce the Mode C validation efficiency by a maximum of 2.4%
4. Will not significantly reduce the ability to track aircraft.

MODE S PERFORMANCE AT LOS ANGELES

For the simulations of the hypothetical Mode S sensor at Los Angeles, it was predicted that the operation of TCAS II M in any of the air traffic deployments analyzed will have the effects described below.

On the transponders:

1. Will reduce average reply efficiency by a maximum of 1.5%.

On the interrogator:

1. Will not reduce the target detection efficiency
2. Will not reduce the high-confidence Mode A validation efficiency
3. Will not reduce high-confidence Mode C validation efficiency
4. Will increase the roll-call interrogation rate by a maximum of 0.8%.

APPENDIX A

AIRCRAFT DEPLOYMENTS

TABLES A-1 and A-2 give the aircraft altitude and range distributions about the Los Angeles Mode S sensor and about the Long Beach ATCRBS interrogator for the three aircraft populations used in this study. Figures A-1 through A-6 show the aircraft distribution as viewed from LAX-4 for each of the air traffic environments.

TABLE A-1

AIRCRAFT DISTRIBUTION ABOUT LOS ANGELES
(See Figures A-1, A-2, A-3)

Altitude				Range			
Increments (1000-Foot)	Number of Aircraft Deployments			Increments (nmi)	Number of Aircraft Deployments		
	A	B	C		A	B	C
0-1	69	41	26	0-5	35	23	15
1-2	139	91	67	5-10	45	29	21
2-3	129	89	63	10-15	93	56	39
3-4	111	76	50	15-20	89	58	43
4-5	89	61	42	20-25	104	63	38
5-6	51	23	14	25-30	86	56	42
6-7	41	24	18	30-35	81	51	35
7-8	31	22	13	35-40	57	35	27
8-9	39	23	17	40-45	66	50	32
9-10	15	9	5	45-50	47	30	21
10-11	8	5	5	50-55	24	16	11
11-12	1	1	0	55-60	14	5	3
12-13	1	1	1	60-65	2	2	1
13-14	1	0	0				
14-15	0	0	0				
15-16	0	0	0				
16-17	2	1	1				
17-18	1	0	0				
18-19	1	1	1				
19-20	1	0	0				
20-21	1	1	1				
21-22	2	1	1				
22-23	0	0	0				
23-24	4	1	0				
24-25	4	2	2				
25-26	0	0	0				
26-27	1	0	0				
27-28	0	0	0				
28-29	1	1	1				
29-30	0	0	0				

TABLE A-2
AIRCRAFT DISTRIBUTION ABOUT LONG BEACH

Altitude				Range			
Increments (1000-Foot)	Number of Aircraft Deployments			Increments (nmi)	Number of Aircraft Deployments		
	A	B	C		A	B	C
0-1	69	41	26	0-5	32	16	13
1-2	139	91	67	5-10	87	55	36
2-3	129	89	63	10-15	83	54	37
3-4	111	76	50	15-20	109	72	50
4-5	89	61	42	20-25	62	35	22
5-6	51	23	14	25-30	69	52	35
6-7	41	24	18	30-35	67	44	29
7-8	31	22	13	35-40	72	45	34
8-9	39	23	17	40-45	46	28	20
9-10	15	9	5	45-50	32	17	16
10-11	8	5	5	50-55	28	20	11
11-12	1	1	0	55-60	29	22	16
12-13	1	1	1	60-65	14	7	9
13-14	1	0	0	65-70	9	6	9
14-15	0	0	0	70-75	4	1	0
15-16	0	0	0				
16-17	2	1	1				
17-18	1	0	0				
18-19	1	1	1				
19-20	1	0	0				
20-21	1	1	1				
21-22	2	1	1				
22-23	0	0	0				
23-24	4	1	0				
24-25	4	2	2				
25-26	0	0	0				
26-27	1	0	0				
27-28	0	0	0				
28-29	1	1	1				
29-30	0	0	0				

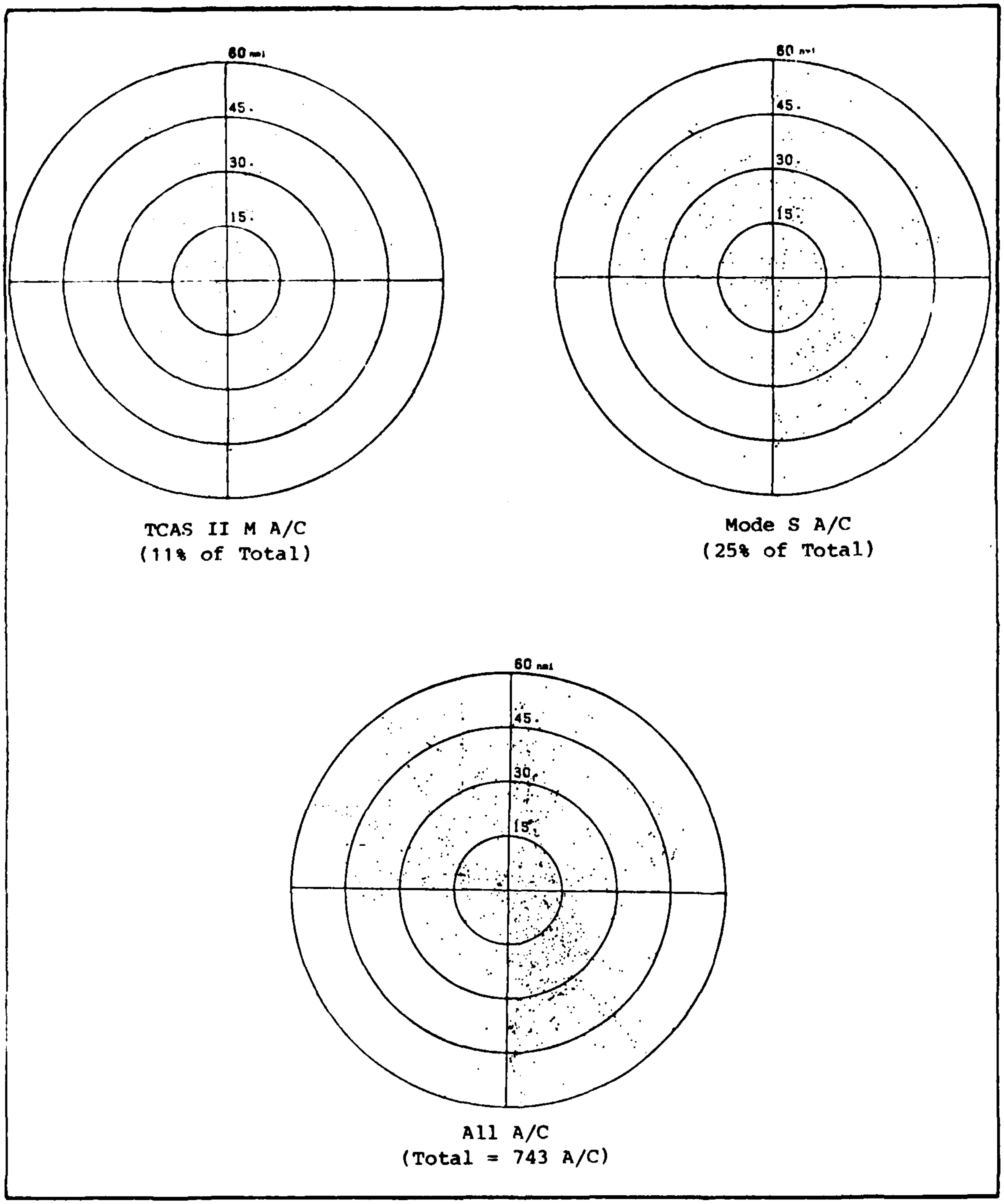

Figure A-1. Distribution of aircraft about Los Angeles - TABLE 3-1 Deployment A (.159 A/C per sq nmi to 30 nmi).

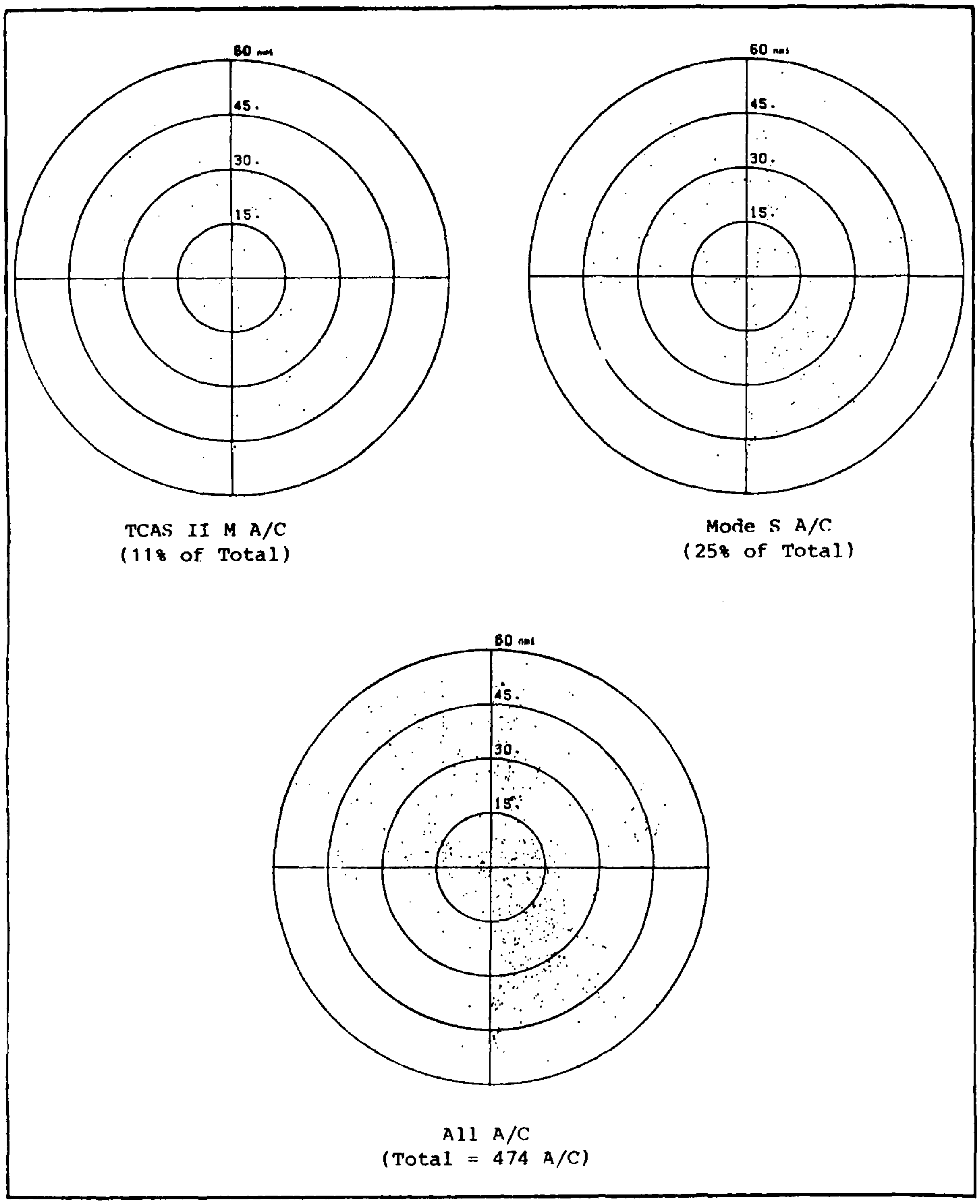

Figure A-2. Distribution of aircraft about Los Angeles - TABLE 3-1 Deployment B (.100 A/C per sq nmi to 30 nmi).

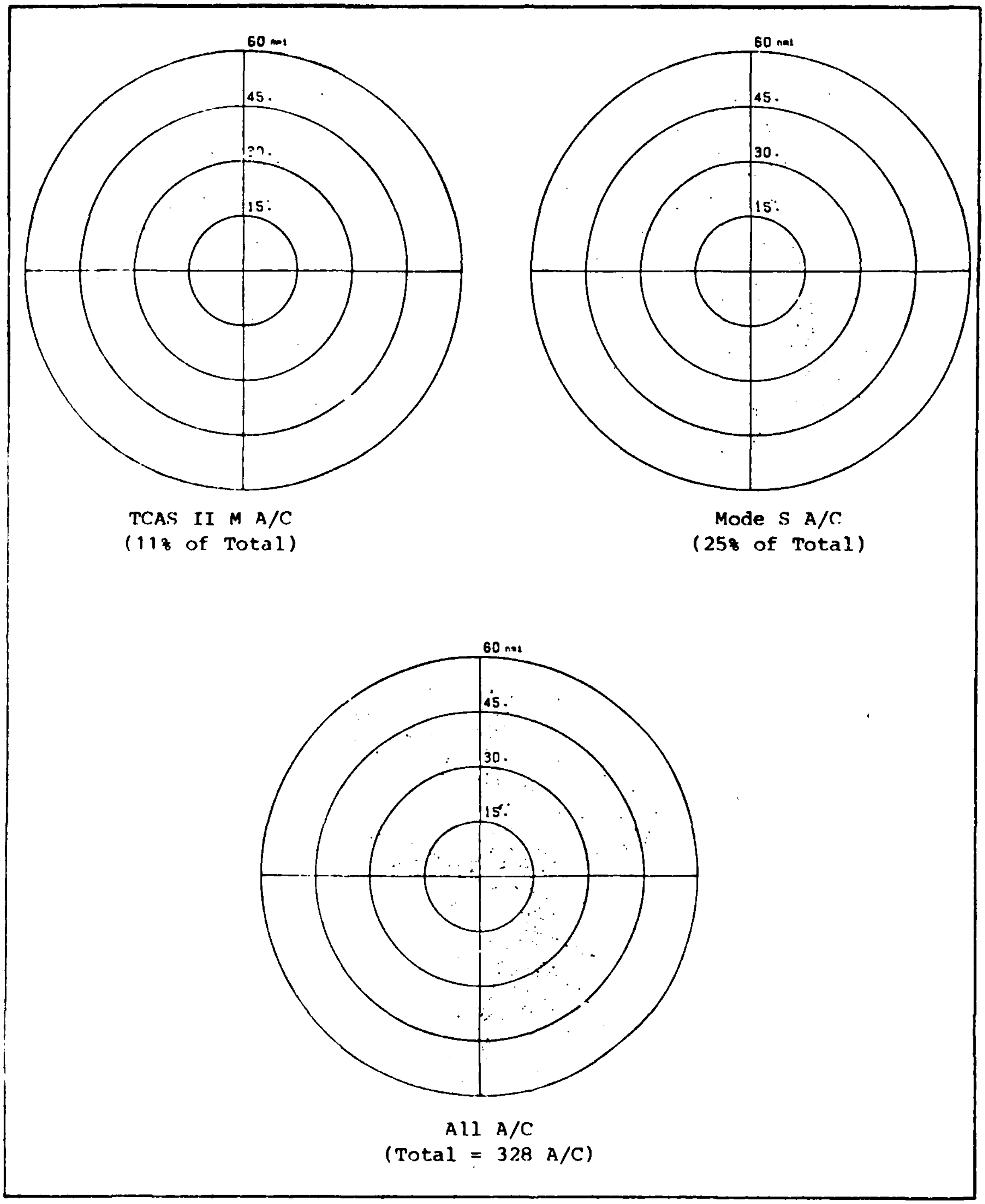

Figure A-3. Distribution of aircraft about Los Angeles - TABLE 3-1 Deployment C (.070 A/C per sq nmi to 30 nmi).

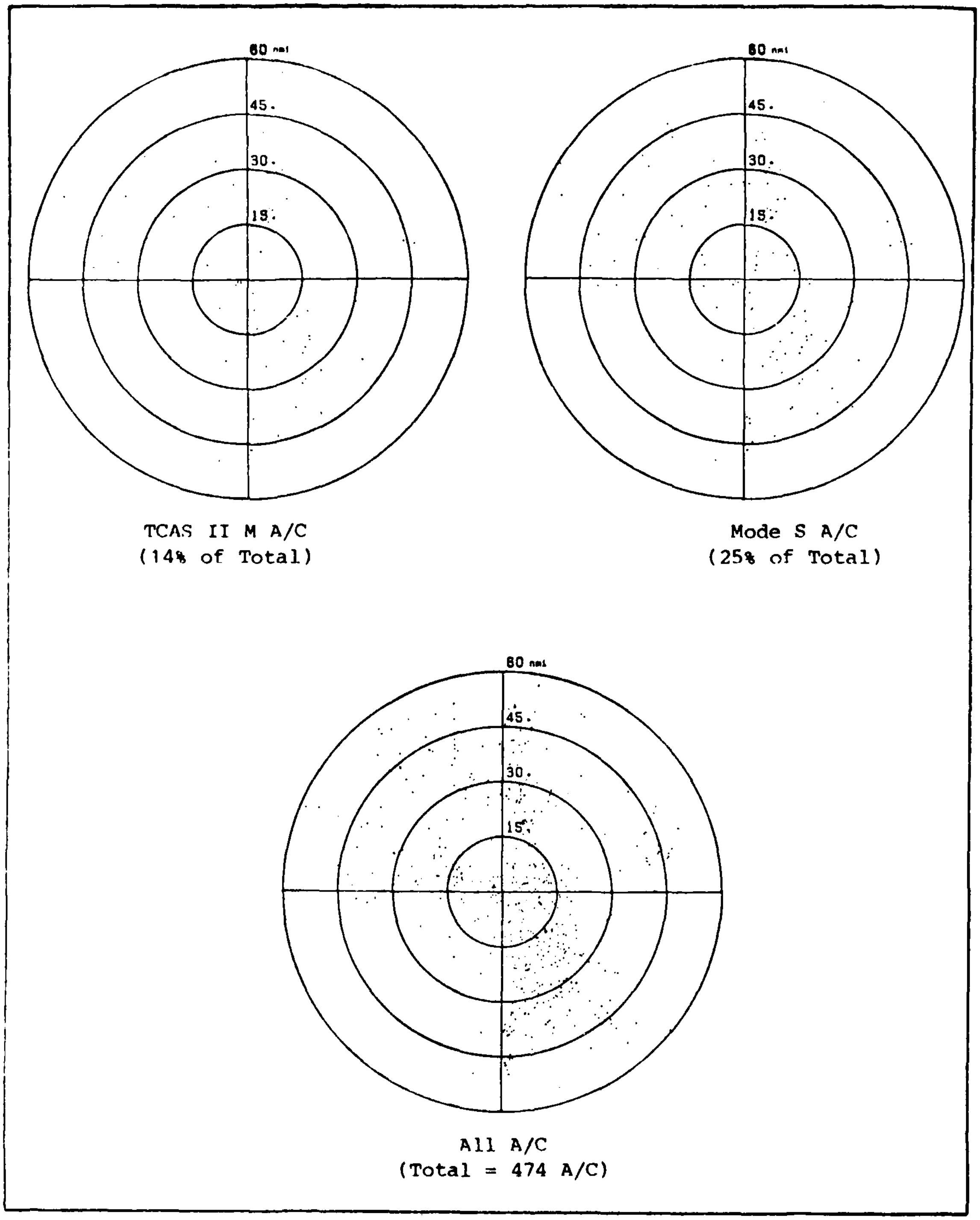

Figure A-4. Distribution of aircraft about Los Angeles - TABLE 3-1 Deployment B1 (.100 A/C per sq nmi to 30 nmi).

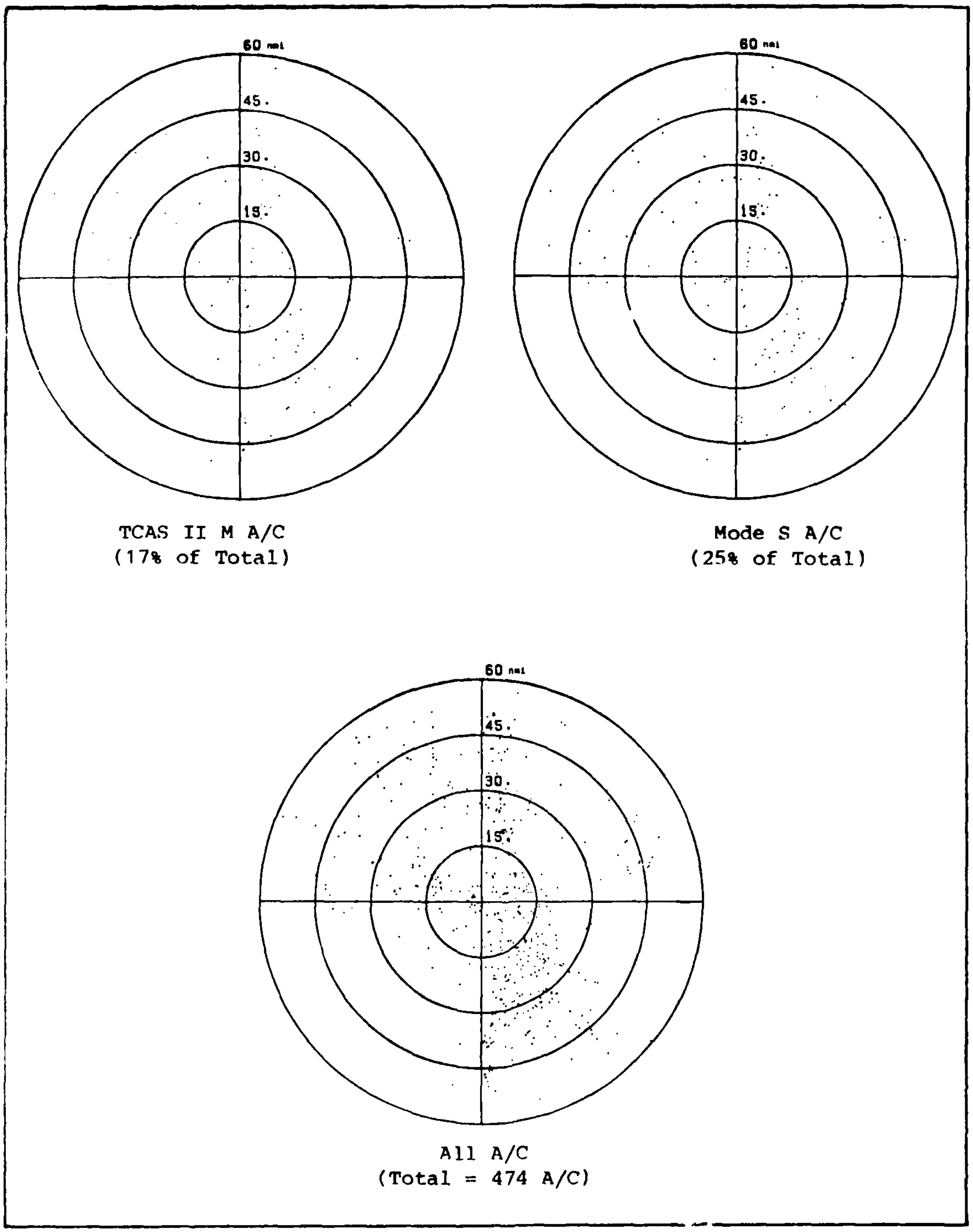

Figure A-5. Distribution of aircraft about Los Angeles - TABLE 3-1 Deployment B2 (.100 A/C per sq nmi to 30 nmi).

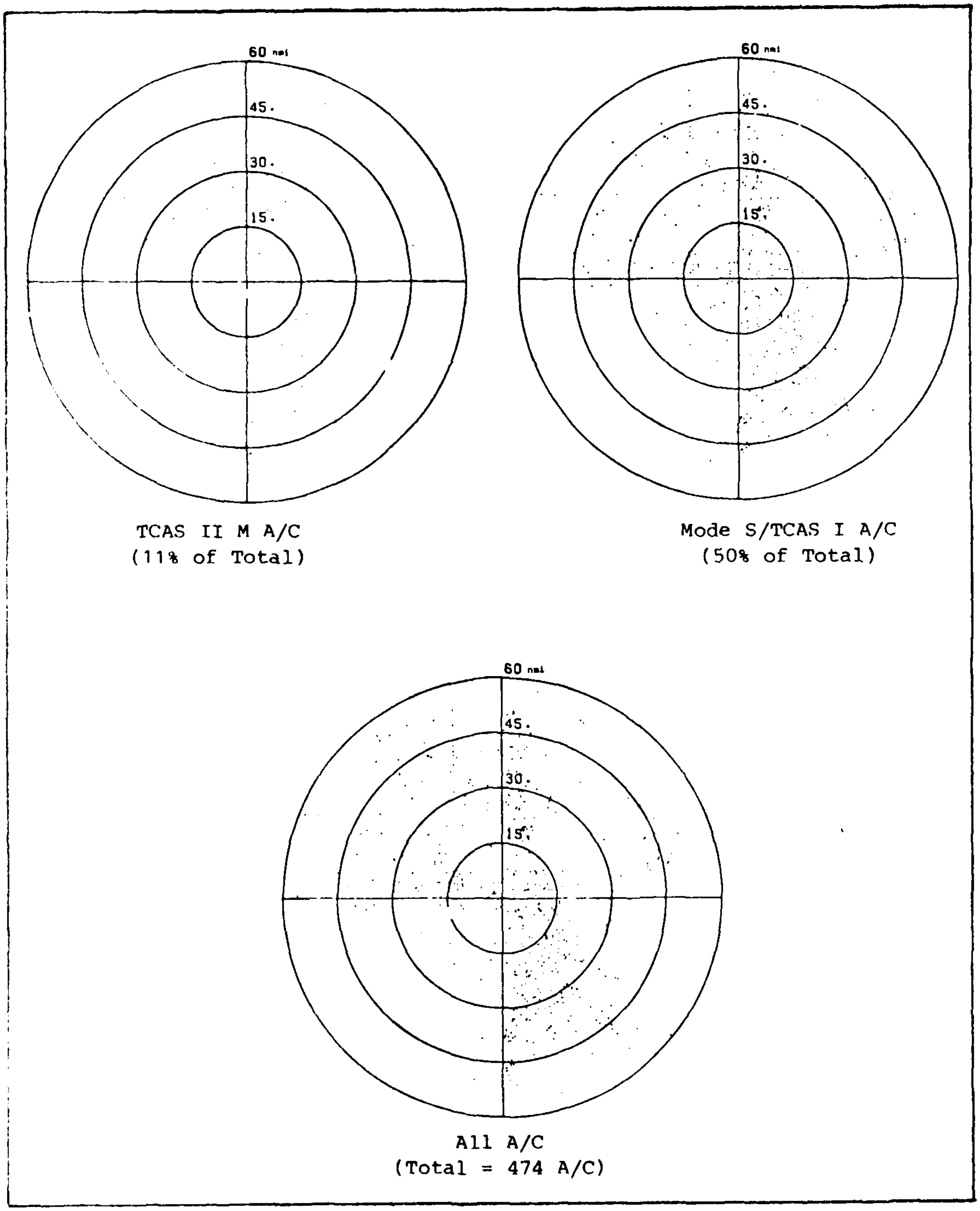

Figure A-6. Distribution of aircraft about Los Angeles - TABLE 3-1 Deployment B3 (.100 A/C per sq nmi to 30 nmi).

APPENDIX B
SIMULATION RESULTS

Figures B-1 through B-6 graphically present the reply performance of transponders corresponding to deployment B.[a] Included is the position of the aircraft with the lowest probability of reply for each simulation.[b] Note that the Long Beach ATCRBS interrogator transmits an average of 21.28 interrogations to each aircraft during the mainbeam dwell; some aircraft received 21 interrogations and some received 22. Similarly, the Los Angeles Mode S sensor transmits an average of 6.56 ATCRBS-only interrogations to each aircraft during the mainbeam dwell; some aircraft received 6 interrogations and some received 7. Note that these results give the cumulative distribution for the number of missed replies per scan averaged over ten scans.

Figures B-7 through B-18 give the cumulative distributions of both the ATCRBS interrogation and suppression rate for transponders in deployment B.

It should be noted that an Automatic Overload Control (AOC) algorithm is not included in the DABS/ATCRBS/AIMS PPM. As a result, interrogation rates given in the appendix are higher than if the AOC algorithm was implemented. Specifically, the AOC will adjust sensitivity such that a transponder will not reply to more than 1200 interrogations per second. It can been seen from the results presented in this appendix that interrogation rates do exceed 1200 per second for all simulations.

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[a]Deployment B was developed to predict the effects of TCAS in an air traffic environment for which it was designed.

[b]Aircraft positions are given in radians; multiply by 57.296 to find the position in degrees.

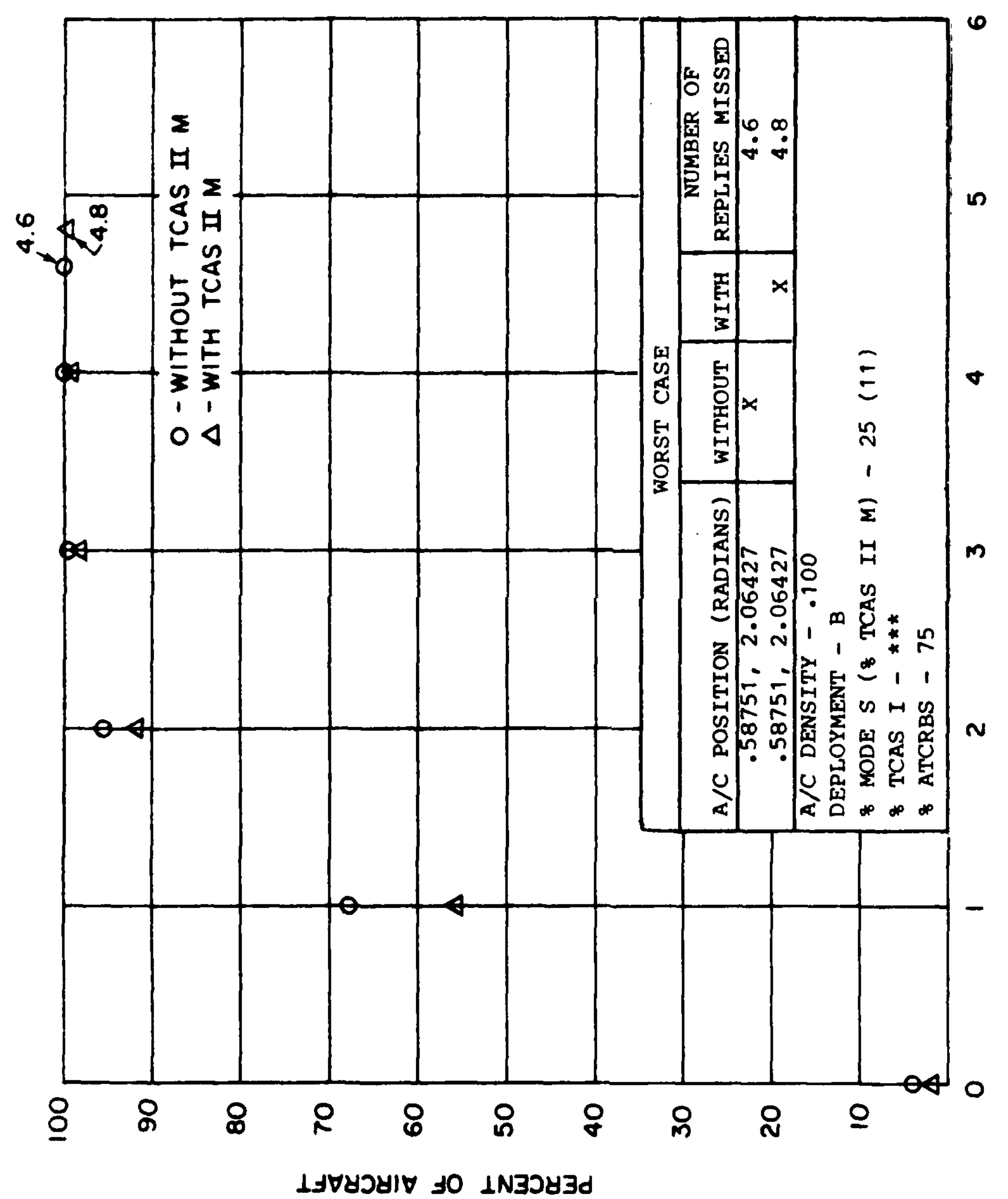


Figure B-1. Cumulative distribution for the number of missed interrogations (N) out of a possible 21 or 22 per mainbeam dwell for the Long Beach ATCRBS interrogator.

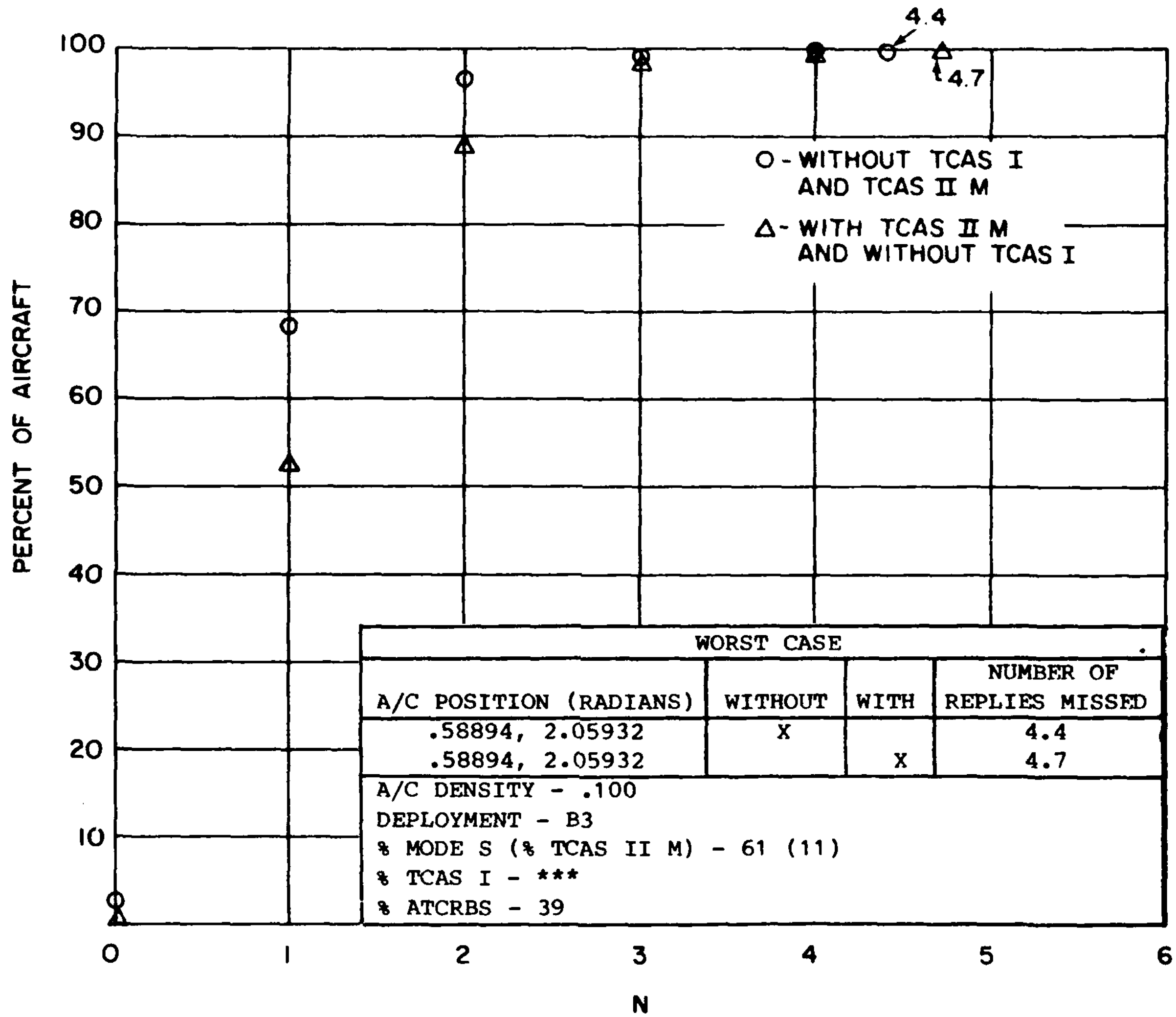


Figure B-2. Cumulative distribution for the number of missed interrogations (N) out of a possible 21 or 22 per mainbeam dwell for the Long Beach ATCRBS interrogator.

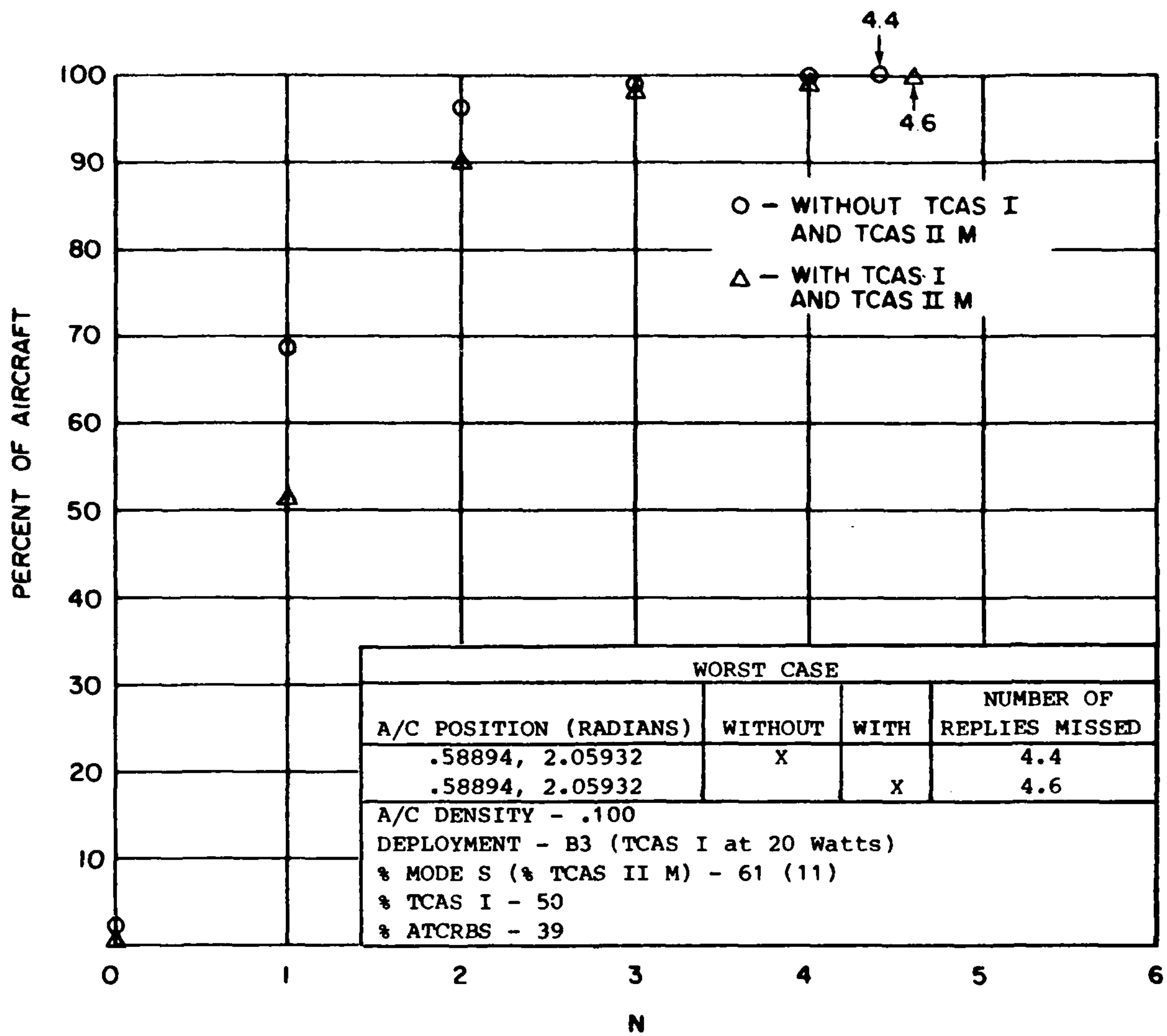
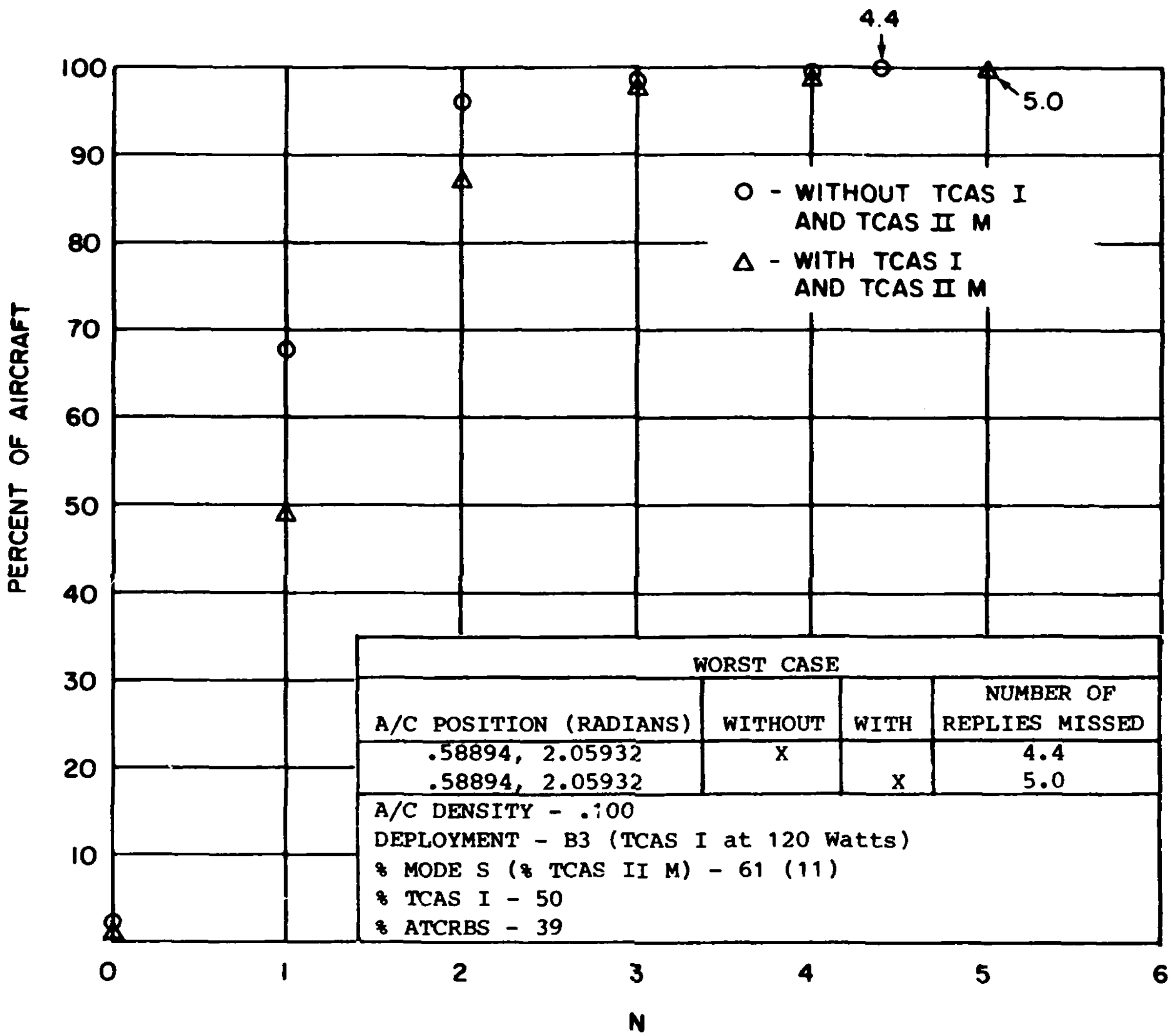


Figure B-3. Cumulative distribution for the number of missed interrogations (N) out of a possible 21 or 22 per mainbeam dwell for the Long Beach ATCRBS interrogator.



WORST CASE			
A/C POSITION (RADIANS)	WITHOUT	WITH	NUMBER OF REPLIES MISSED
.58894, 2.05932	X		4.4
.58894, 2.05932		X	5.0

A/C DENSITY - .100
DEPLOYMENT - B3 (TCAS I at 120 Watts)
% MODE S (% TCAS II M) - 61 (11)
% TCAS I - 50
% ATCRBS - 39

Figure B-4. Cumulative distribution for the number of missed interrogations (N) out of a possible 21 or 22 per mainbeam dwell for the Long Beach ATCRBS interrogator.

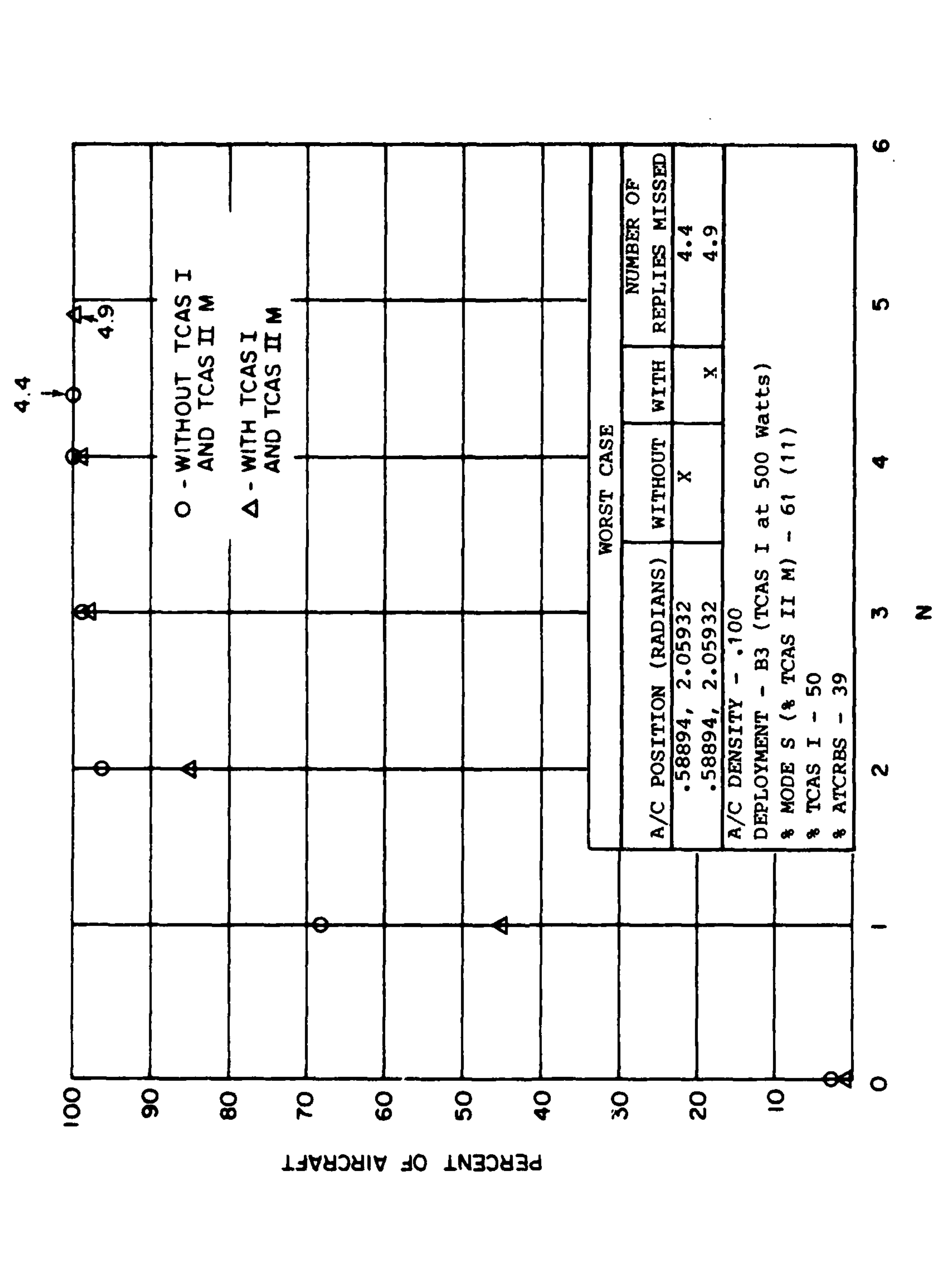
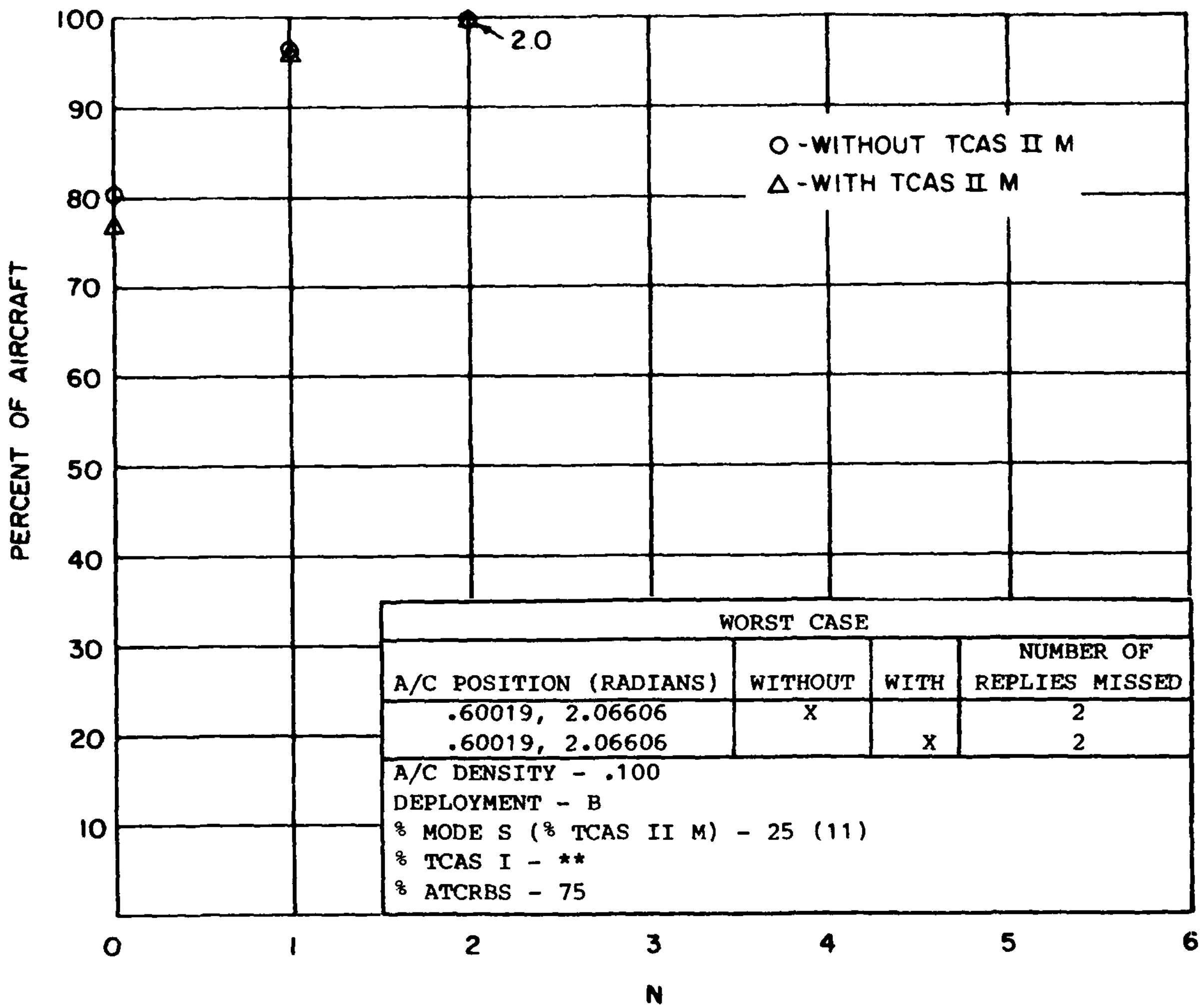


Figure B-5. Cumulative distribution for the number of missed interrogations (N) out of a possible 21 or 22 per mainbeam dwell for the long Beach ATCRBS interrogator.



WORST CASE			
A/C POSITION (RADIANS)	WITHOUT	WITH	NUMBER OF REPLIES MISSED
.60019, 2.06606	X		2
.60019, 2.06606		X	2

A/C DENSITY - .100
DEPLOYMENT - B
% MODE S (% TCAS II M) - 25 (11)
% TCAS I - **
% ATCRBS - 75

Figure B-6. Cumulative distribution for the number of missed interrogations (N) out of a possible 6 or 7 per mainbeam dwell for the Los Angeles DABS sensor (ATCRBS transponders only).

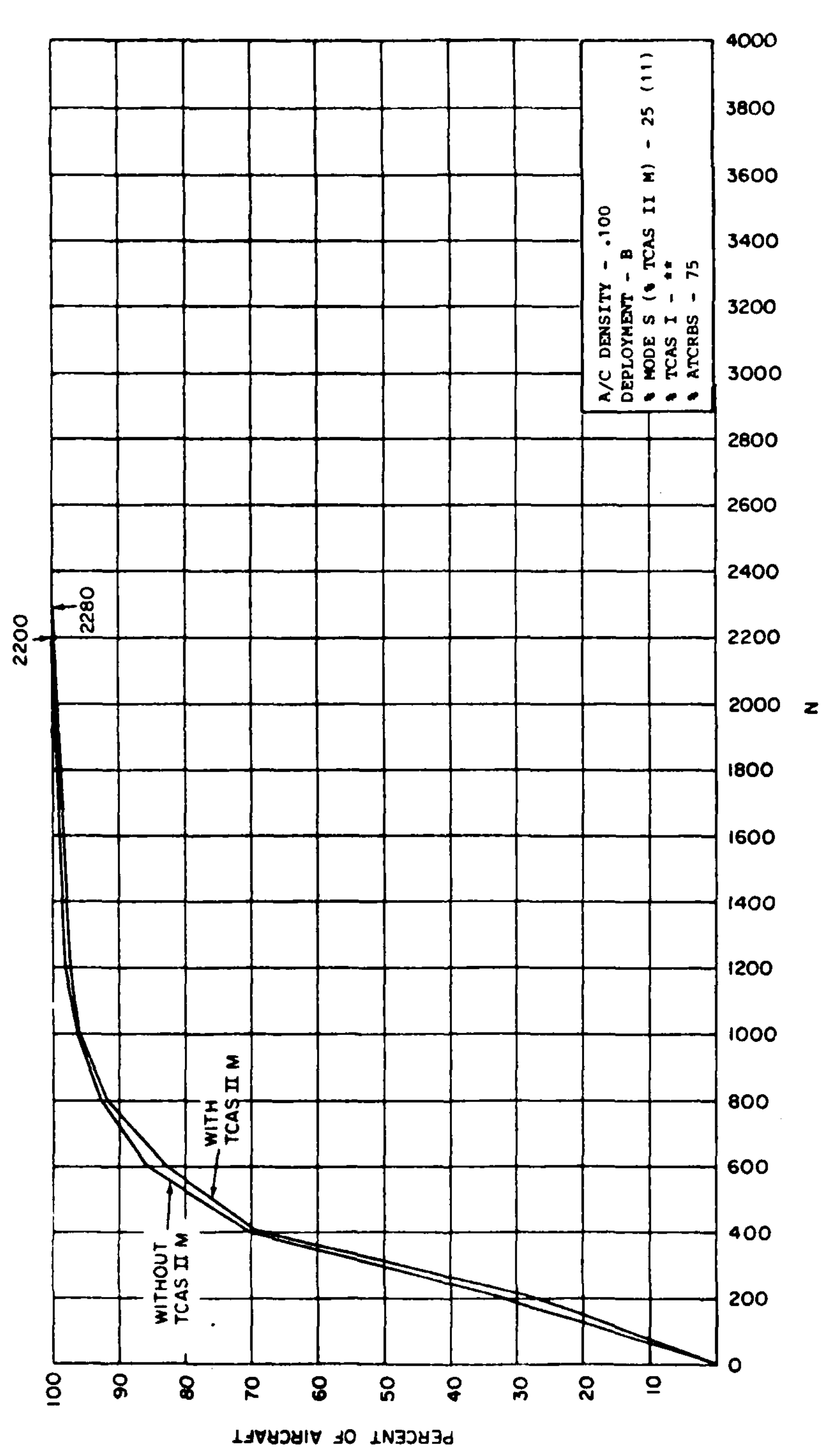


Figure B-7. Cumulative distribution for the total number of ATCRBS interrogations per second (N) received at the transponders. Long Beach simulations - no Mode S sensors in the environment.

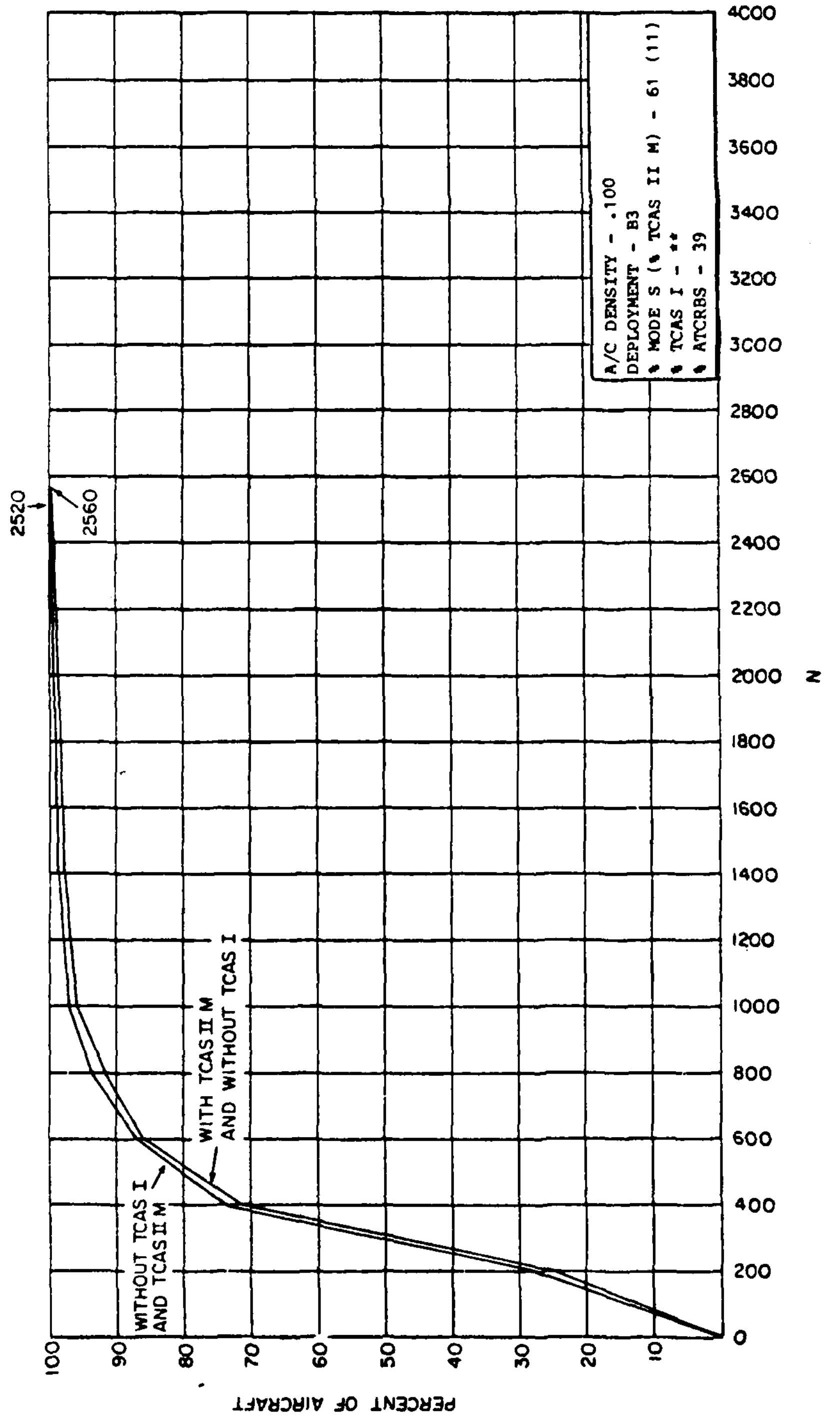


Figure B-8. Cumulative distribution for the total number of ATCRBS interrogations per second (N) received at the transponders. Long Beach simulations - no Mode S sensors in the environment.

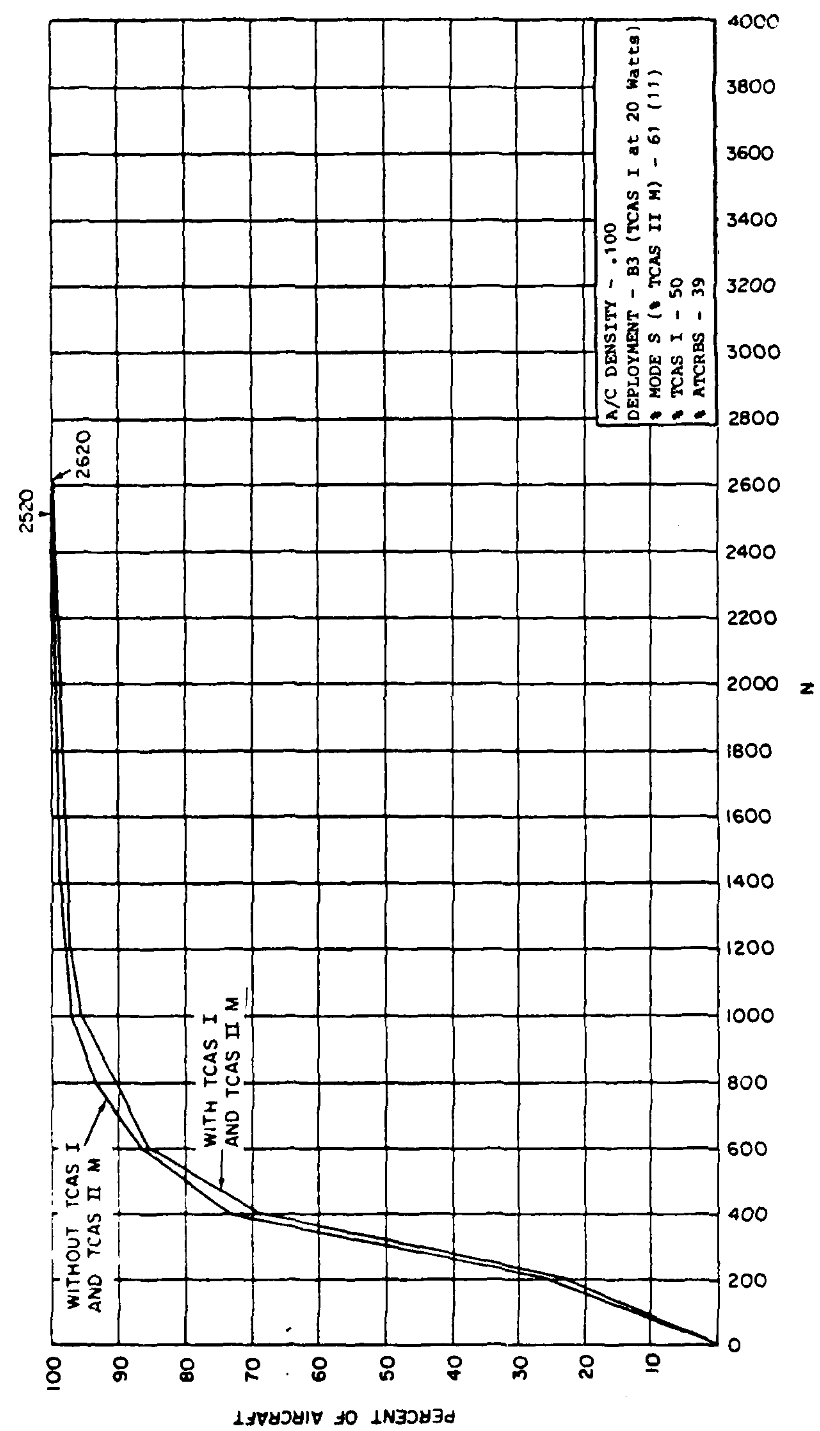


Figure B-9. Cumulative distribution for the total number of ATCRBS interrogations per second (N) received at the transponders. Long Beach simulations - no Mode S sensors in the environment.

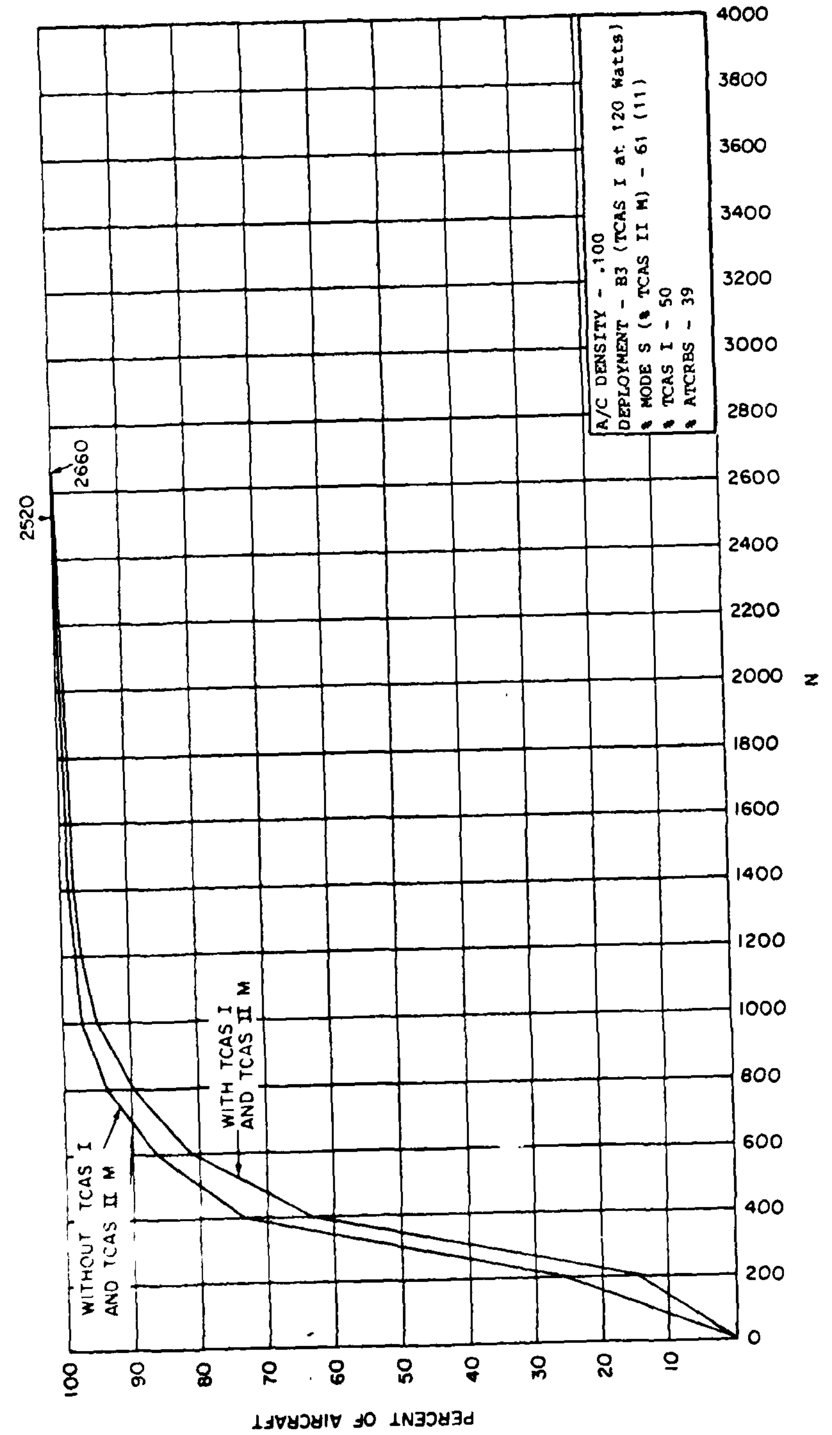


Figure B-10. Cumulative distribution for the total number of ATCRBS interrogations per second (N) received at the transponders. Long Beach simulations - no Mode S sensors in the environment.

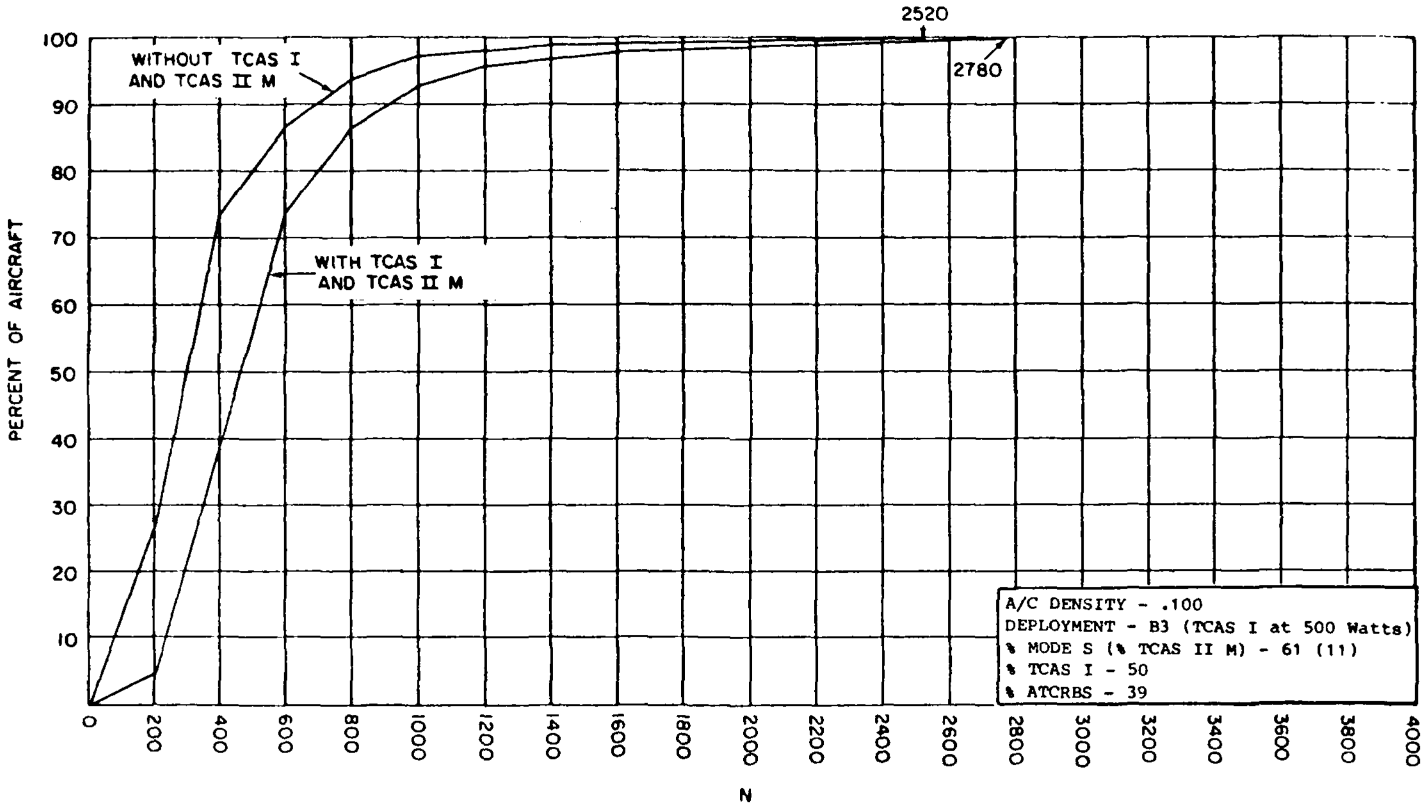


Figure B-11. Cumulative distribution for the total number of ATCRBS interrogations per second (N) received at the transponders. Long Beach sumulations - no Mode S sensors in the environment.

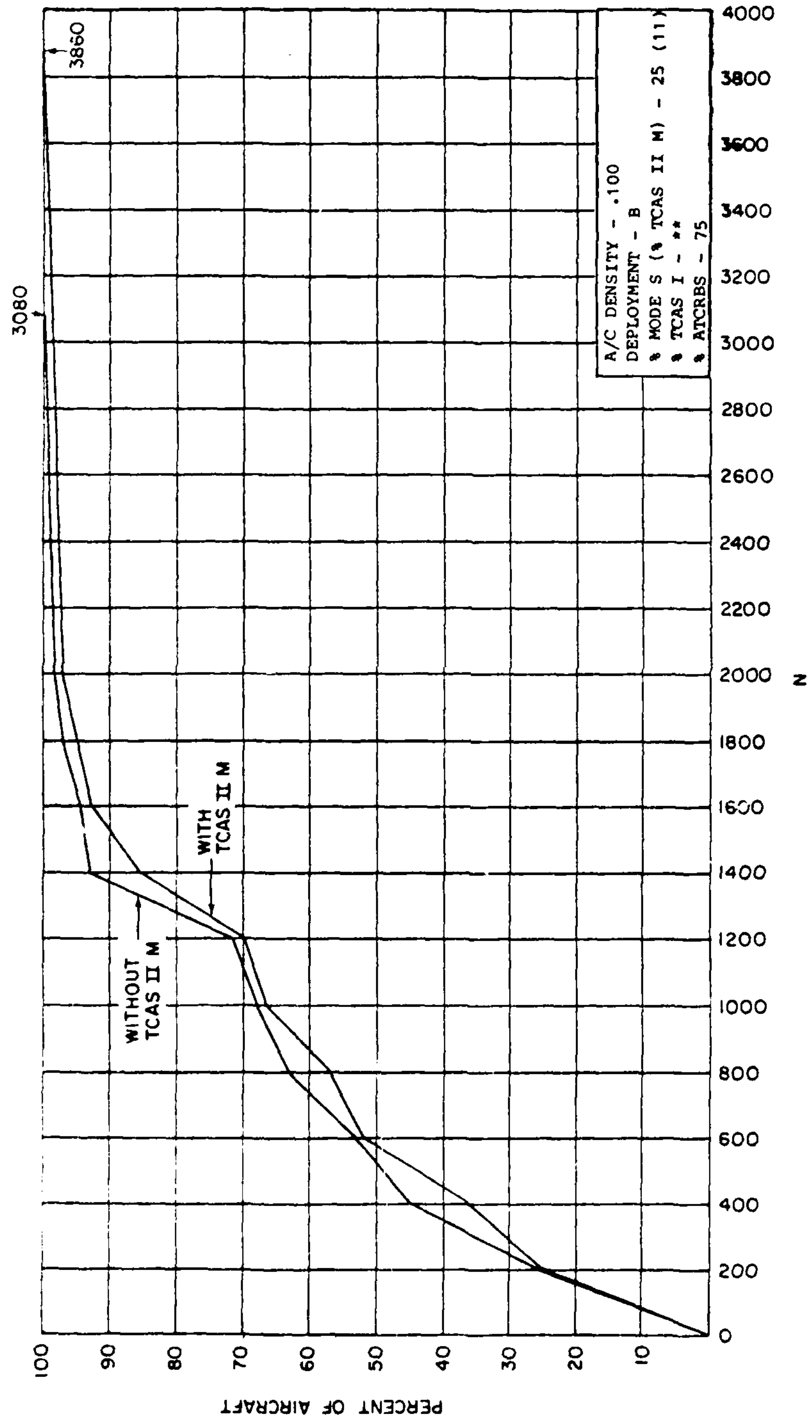


Figure B-12. Cumulative distribution for the total number of suppressions per second (N) received at the transponders. Long Beach simulation - no Mode S sensors in the environment.

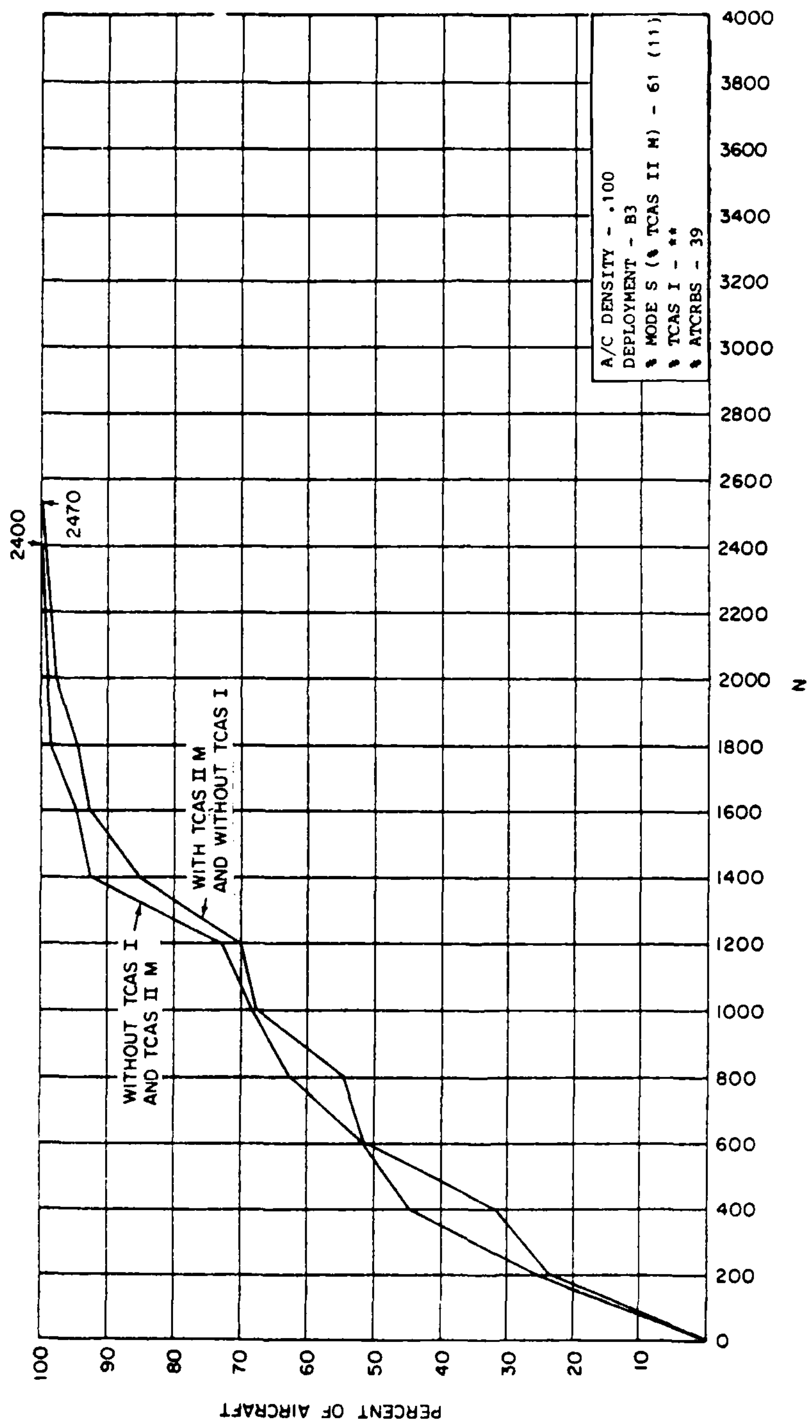


Figure B-13. Cumulative distribution for the total number of suppressions per second (N) received at the transponders. Long Beach simulation - no Mode S sensors in the environment.

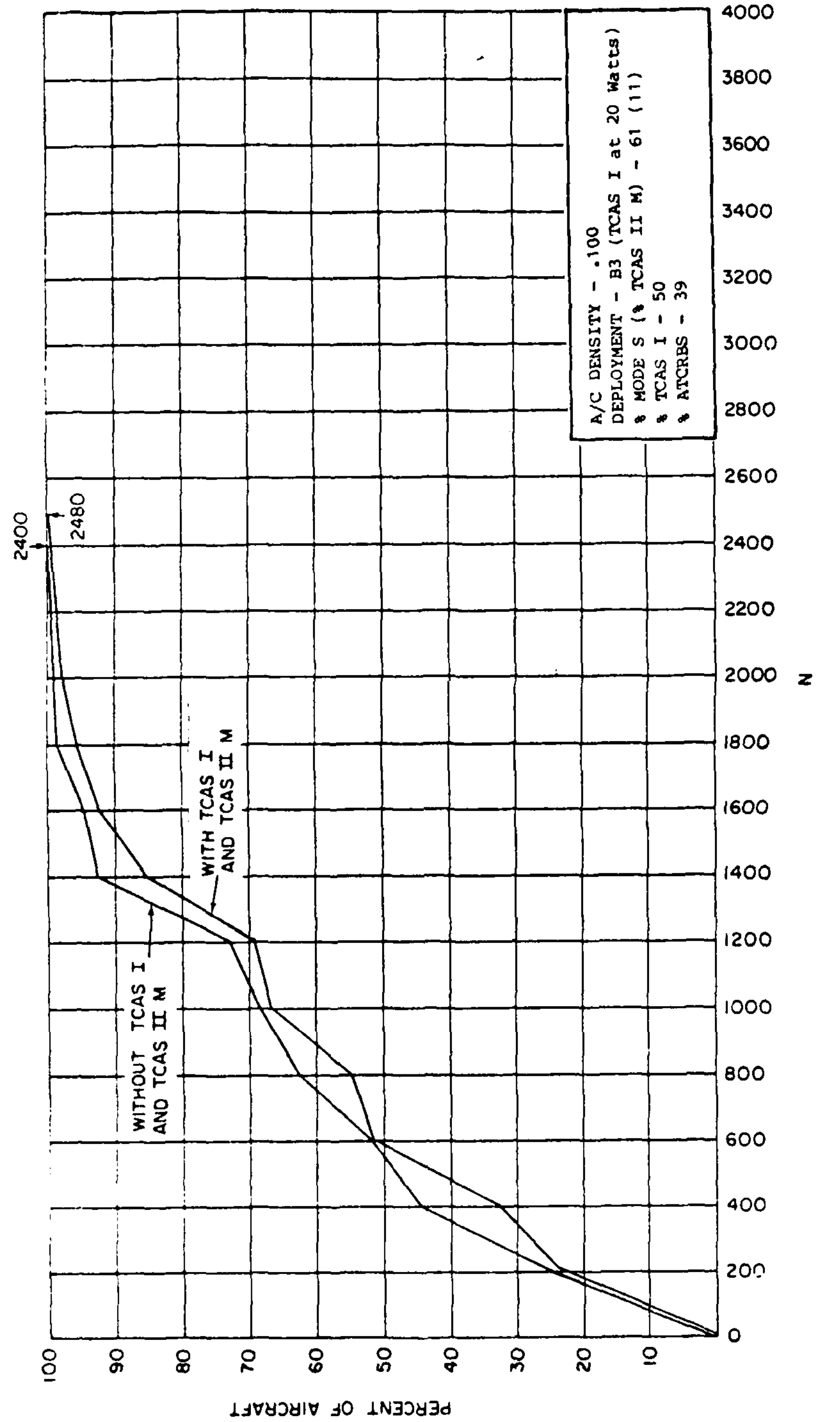


Figure B-14. Cumulative distribution for the total number of suppressions per second (N) received at the transponders. Long Beach simulation - no Mode S sensors in the environment.

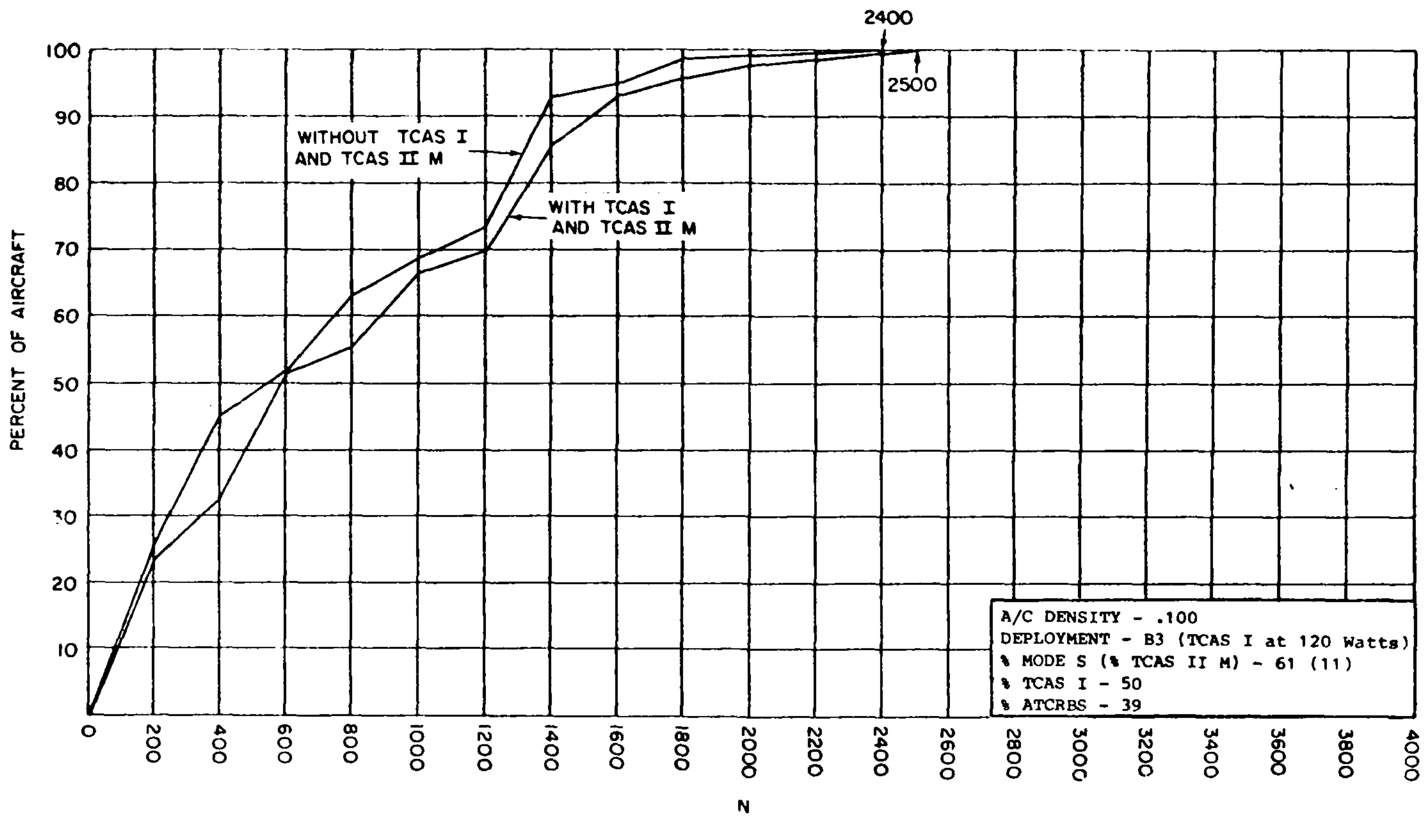


Figure B-15. Cumulative distribution for the total number of suppressions per second (N) received at the transponders. Long Beach simulation - no Mode S sensors in the environment.

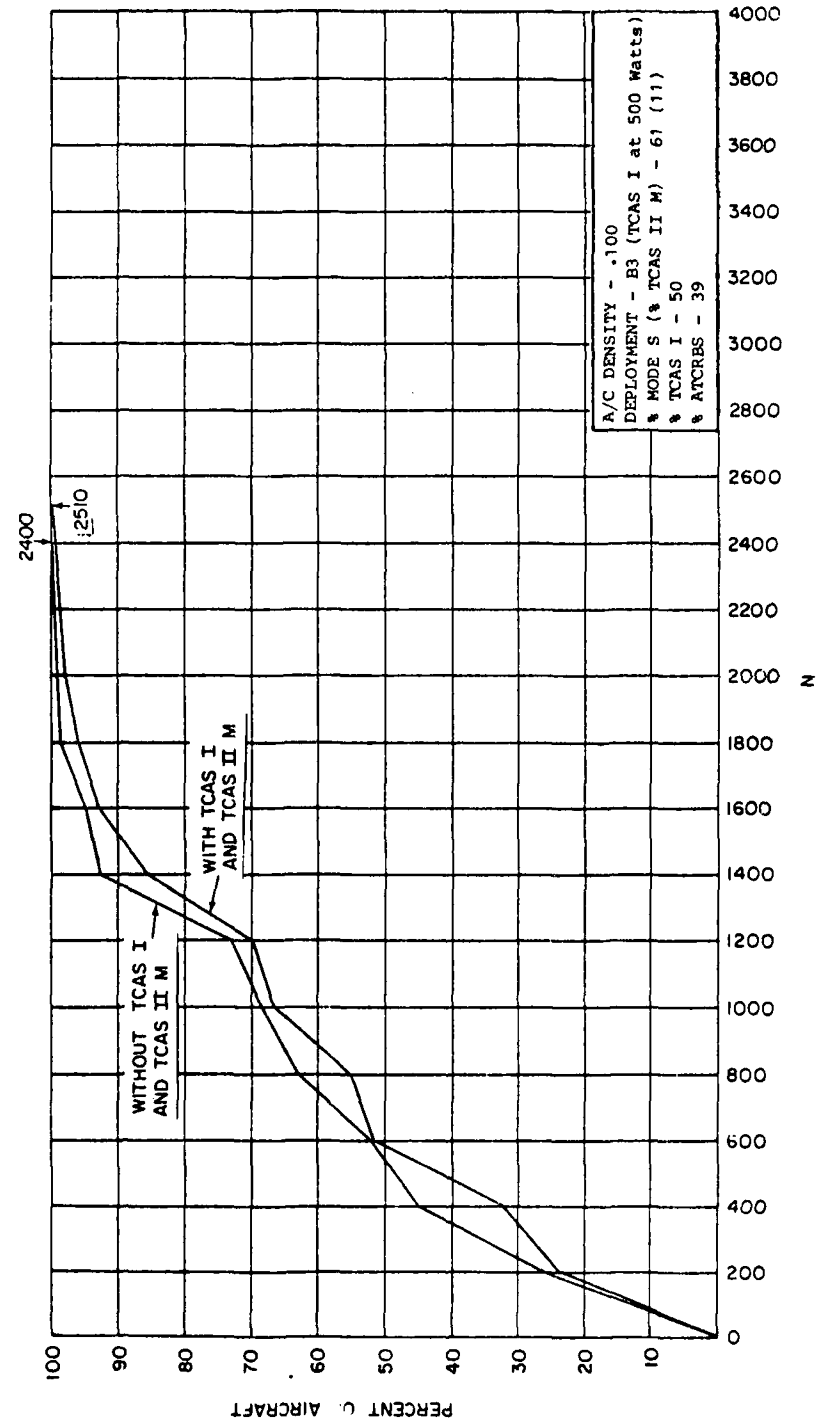


Figure B-16. Cumulative distribution for the total number of suppressions per second (N) received at the transponders. Long Beach simulation - no Mode S sensors in the environment.

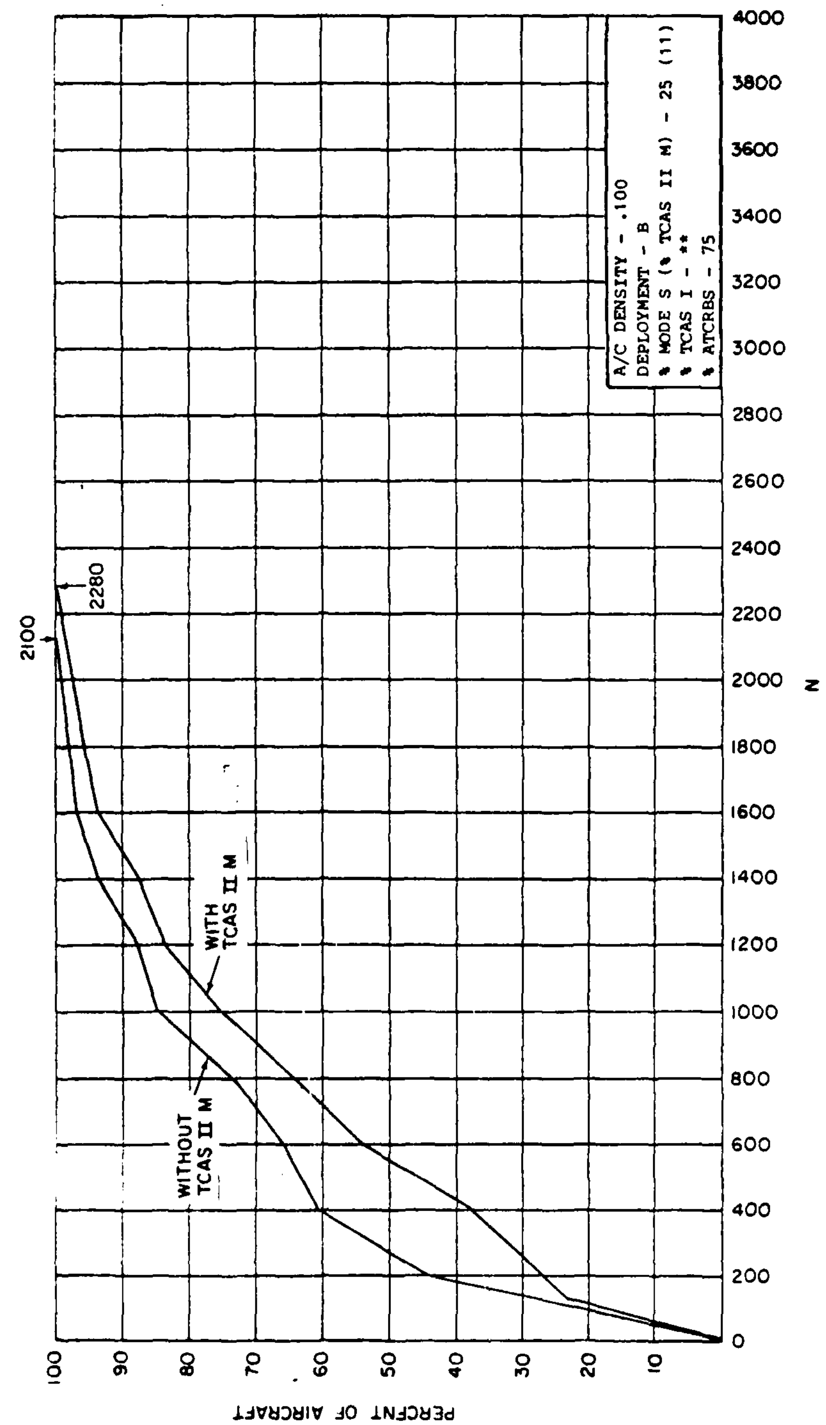


Figure B-17. Cumulative distribution for the total number of ATCRBS interrogations per second (N) received at the transponders. Los Angeles simulations.

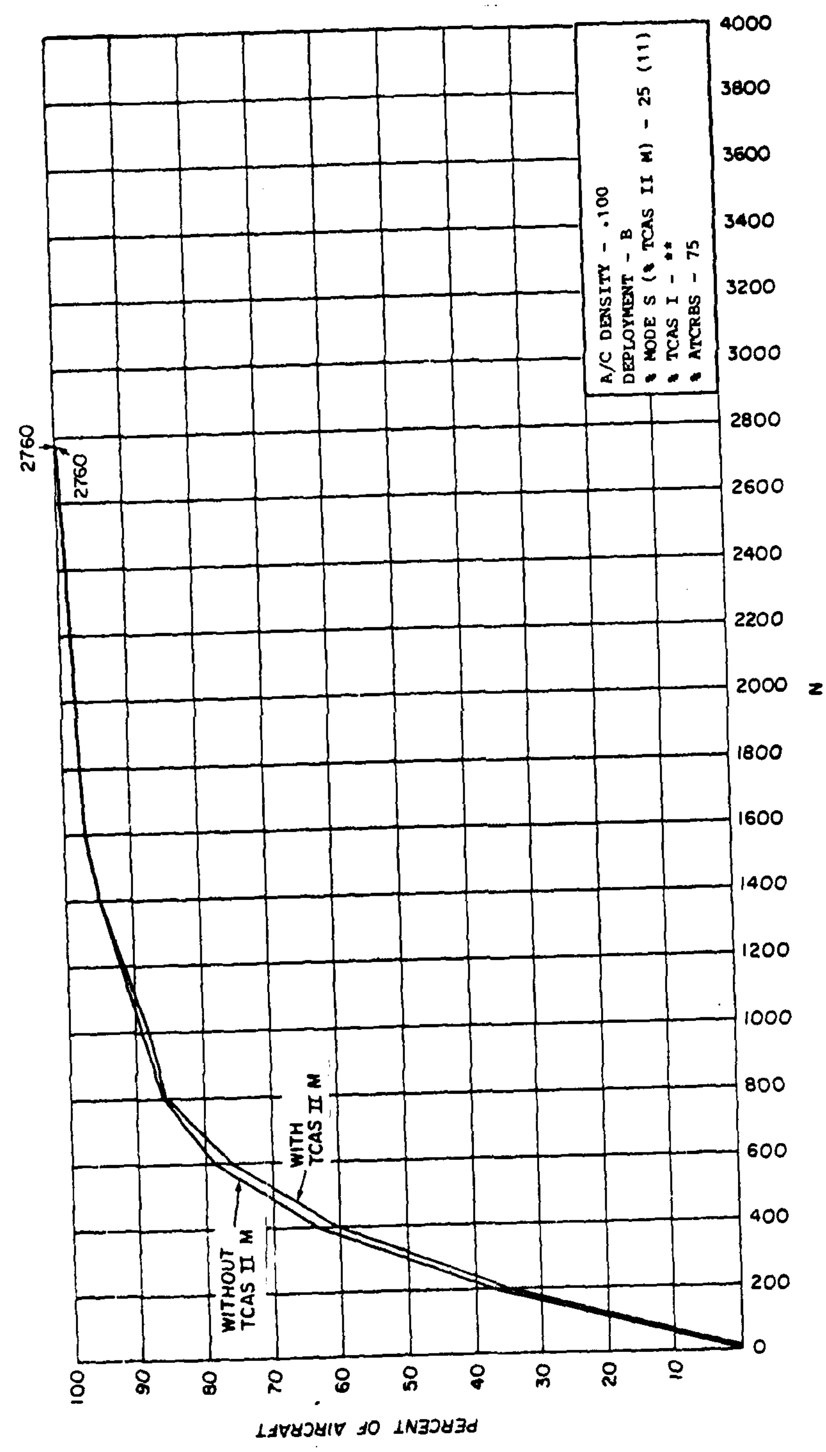


Figure B-18. Cumulative distribution for the total number of suppressions per second (N) received at the transponders. Los Angeles simulations.

APPENDIX C

TCAS SEM RESULTS

The following TABLES C-1 through C-9 give TCAS SEM results for each of the simulations conducted in this analysis. Given are: (1) TCAS II M aircraft position (in radians), (2) the density of aircraft per square nmi within 5, 10 and 30 nmi about the TCAS II M-equipped aircraft, (3) the number of Whisper-Shout interrogations transmitted by TCAS II M, (4) the rate at which a TCAS II M-equipped aircraft transmits discretely addressed interrogations, (5) the Mode S transmission power (of the transmitter) of the TCAS II M-equipped aircraft, and (6) the Mode S power reductions (in dB) due to TCAS II M interference-limiting.[a]

The information in the tables is presented for the configurations shown in the following matrix:

TABLE	DEPLOYMENT	#AIRCRAFT	#ATCRBS	#MODE S	#TCAS I	#TCAS II
C1	A	743	555	188	0	83
C2	B	474	362	112	0	49
C3	C	328	256	72	0	34
C4	B_1	474	362	112	0	65
C5	B_2	474	362	112	0	83
C6	B_3	474	185	289	240[b]	49
C7	B_3	474	185	289	240[b]	49
C8	B_3	474	185	289	240[b]	49
C9	B_3	474	185	289	240[b]	49

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[a] Results contained in (3) through (6) above are given at TIME=120 seconds. This time was determined to be sufficient for the TCAS II M to reach steady state.

[b] For deployment B_3 in TABLES C-6, C-7, C-8, and C-9, the TCAS I power output was 0, 20, 120, and 500 watts respectively.

TABLE C-1

TCAS II M RESULTS - DEPLOYMENT A

(Page 1 of 3)

TCAS ID	Latitude	Longitude	Altitude (ft)	Densities 5 nmi	Densities 10 nmi	Densities 30 nmi	Whisper-Shout Levels Transmitted	TCAS II M/Mode S Int. Rate	TCAS II M/Mode S Int. Power[a]	TCAS II M/Mode S Power Reduction (dB)
1	.60425	2.06149	24218	.0255	.0414	.0534	83	4	246	0
2	.60665	2.05881	28719	.0127	.0095	.0290	83	2	224	0
3	.59980	2.05244	9000	.0255	.0255	.0195	83	0	237	0
4	.59655	2.05389	8502	.0509	.0414	.0428	83	4	229	0
5	.59541	2.05044	7500	.0891	.0477	.0177	83	4	241	0
6	.59226	2.05525	6000	.0509	.0382	.0927	83	3	255	0
7	.59005	2.06067	1998	.3310	.3501	.1510	78	6	129	4
8	.58765	2.05206	16000	.0127	.0032	.0562	83	3	265	0
9	.58621	2.05547	10992	.0255	.0255	.0987	83	3	223	0
10	.58422	2.05830	3503	.0764	.1401	.1146	83	5	216	0
11	.58967	2.06168	1494	.4711	.3820	.1546	83	26	76	6
12	.58099	2.05899	23851	.0255	.0541	.0877	83	0	218	0
13	.58198	2.05949	10994	.0382	.1146	.0997	83	10	236	0
14	.58674	2.06119	10494	.3056	.3947	.1471	83	39	49	6
15	.58467	2.06087	18320	.4202	.2355	.1248	83	0	285	0
16	.58433	2.06116	2470	.3565	.2355	.1227	83	15	278	0
17	.58242	2.06188	3992	.1019	.1910	.1050	83	11	240	0
18	.58521	2.06215	3506	.3947	.3247	.1365	83	27	96	4
19	.57477	2.06323	4006	.0127	.0159	.0244	83	3	284	0
20	.58550	2.06251	5493	.2419	.3374	.1401	80	25	63	6
21	.57909	2.06605	9492	.1783	.1273	.0615	83	8	227	0
22	.57905	2.06616	5500	.1783	.1210	.0615	83	14	229	0
23	.58768	2.06303	5491	.3947	.3820	.1524	82	20	59	6
24	.58157	2.06594	1268	.2292	.1528	.0923	83	7	254	0
25	.57821	2.06914	24486	.0000	.0255	.0350	83	0	241	0
26	.58717	2.06641	4504	.1401	.1560	.1517	80	4	134	2
27	.58614	2.06847	7539	.0255	.0509	.1390	83	0	232	0
28	.58873	2.06555	4203	.1655	.2451	.1570	78	11	82	4
29	.58861	2.07280	7000	.0127	.0127	.0849	83	0	309	0

TABLE C-1

(Page 2 of 3)

TCAS ID	Latitude	Longitude	Altitude (ft)	Densities 5 nmi	Densities 10 nmi	Densities 30 nmi	Whisper-Shout Levels Transmitted	TCAS II M/Mode S Int. Rate	TCAS II M/Mode S Int. Power[a]	TCAS II M/Mode S Power Reduction (dB)
30	.59004	2.06573	2861	.2292	.2642	.1613	83	14	69	5
31	.59020	2.06580	3876	.2165	.2674	.1627	83	18	113	4
32	.59033	2.06907	6000	.0382	.0891	.1461	74	12	96	4
33	.59202	2.08046	2500	.0382	.0223	.0325	83	6	259	0
34	.59040	2.06322	2503	.5348	.3756	.1592	77	12	82	5
35	.59210	2.07871	16000	.0255	.0382	.0364	83	0	276	0
36	.59358	2.08122	2698	.0382	.0318	.0304	83	3	302	0
37	.59112	2.06602	2943	.3056	.3088	.1620	76	21	45	7
38	.59168	2.06706	2920	.3056	.2355	.1574	78	34	48	7
39	.59155	2.06592	1344	.3310	.3151	.1645	74	23	45	7
40	.59232	2.06814	2987	.2674	.2260	.1489	75	19	84	5
41	.59216	2.06756	1919	.2674	.2165	.1535	80	15	73	5
42	.59568	2.07684	3008	.0382	.0668	.0559	83	13	289	0
43	.59378	2.07125	800	.3056	.1401	.1220	77	5	165	2
44	.59237	2.06740	1289	.3438	.2355	.1542	78	14	71	5
45	.59260	2.06792	1066	.3056	.2387	.1496	75	25	74	5
46	.59234	2.06710	656	.3438	.2483	.1567	74	11	58	6
47	.59591	2.07604	8502	.0637	.0764	.0605	83	4	277	0
48	.59920	2.08409	9500	.0509	.0255	.0195	83	1	217	0
49	.59374	2.07031	3655	.2928	.1655	.1305	77	12	151	3
50	.59584	2.07492	8491	.0637	.0923	.0707	82	15	233	1
51	.59486	2.07086	4996	.2546	.1369	.1213	78	6	146	3
52	.59230	2.06564	100	.3565	.3183	.1627	71	20	74	6
53	.59925	2.07815	11002	.0127	.0350	.0492	83	14	212	1
54	.59256	2.06577	100	.4584	.3056	.1606	74	24	67	6
55	.59759	2.07349	4995	.0891	.0700	.0937	82	11	213	2
56	.60129	2.07925	17000	.0000	.0223	.0368	83	4	261	0
57	.59411	2.06753	6438	.2292	.2133	.1531	73	10	130	3
58	.59742	2.07222	9500	.1273	.0732	.1065	83	12	131	3
59	.59366	2.06675	3988	.3565	.2196	.1567	75	15	57	6

TABLE C-1

(Page 3 of 3)

TCAS ID	Latitude	Longitude	Altitude (ft)	Densities 5 nmi	Densities 10 nmi	Densities 30 nmi	Whisper-Shout Levels Transmitted	TCAS II M/Mode S Int. Rate	TCAS II M/Mode S Int. Power[a]	TCAS II M/Mode S Power Reduction (dB)
60	.59854	2.07306	5003	.0637	.0573	.0973	83	12	166	2
61	.59718	2.07057	23000	.0255	.0828	.1195	83	0	229	0
62	.60237	2.07633	21000	.0382	.0509	.0410	83	1	312	0
63	.59837	2.07026	7004	.0382	.0732	.1157	76	13	114	3
64	.60432	2.07462	24000	.0764	.0509	.0435	83	0	278	0
65	.60412	2.07430	6147	.0764	.0700	.0477	83	5	253	0
66	.60118	2.07111	5497	.1019	.0637	.0909	83	6	260	0
67	.60485	2.07389	7500	.0764	.0573	.0442	83	5	233	0
68	.59481	2.06520	3800	.1655	.2387	.1538	71	7	144	3
69	.59568	2.06547	8000	.1146	.2069	.1450	78	12	83	4
70	.60196	2.06948	24000	.1019	.0764	.0849	83	0	236	0
71	.60202	2.06907	7177	.0891	.0828	.0842	82	8	197	1
72	.60008	2.06780	23994	.0637	.1401	.1093	83	1	304	0
73	.60229	2.06870	3810	.0891	.0987	.0792	78	9	133	2
74	.59715	2.06445	2995	.3056	.1878	.1330	74	18	58	7
75	.59825	2.06440	6236	.3692	.2133	.1217	82	29	102	4
76	.59810	2.06408	689	.3692	.1910	.1238	81	19	81	5
77	.59697	2.06370	8996	.3056	.1719	.1355	77	15	105	4
78	.59814	2.06385	558	.3438	.1878	.1227	74	14	85	5
79	.60105	2.06448	3994	.3310	.1910	.0905	83	9	160	2
80	.60146	2.06414	4292	.2546	.1687	.0824	83	7	247	0
81	.60122	2.06308	10498	.2292	.1592	.0778	83	12	219	1
82	.59894	2.06266	2806	.2037	.1878	.1139	80	14	111	3
83	.59376	2.06220	2151	.2674	.2546	.1524	78	19	82	6

[a] Equivalent Isotropically Radiated Power (EIRP) on the horizon.

TABLE C-2

TCAS II M RESULTS - DEPLOYMENT B

(Page 1 of 2)

TCAS ID	Latitude	Longitude	Altitude (ft)	Densities 5 nmi	Densities 10 nmi	Densities 30 nmi	Whisper-Shout Levels Transmitted	TCAS II M/Mode S Int. Rate	TCAS II M/Mode S Int. Power[a]	TCAS II M/Mode S Power Reduction (dB)
1	.60665	2.05881	28719	.0127	.0032	.0184	83	0	304	0
2	.59541	2.05044	7500	.0764	.0414	.0113	83	2	300	0
3	.59005	2.06067	1998	.1783	.1974	.0976	83	12	236	0
4	.58621	2.05547	10992	.0255	.0191	.0622	83	5	286	0
5	.58967	2.06168	1494	.2674	.2260	.0994	83	13	238	0
6	.58198	2.05949	10994	.0255	.0796	.0640	83	8	261	0
7	.58674	2.06119	10494	.2292	.2483	.0944	83	26	110	3
8	.58467	2.06087	18320	.2674	.1623	.0785	83	0	257	0
9	.58433	2.06116	2470	.2037	.1687	.0771	83	7	234	0
10	.58242	2.06188	3992	.0764	.1241	.0676	83	6	212	0
11	.57477	2.06323	4006	.0127	.0032	.0163	83	0	270	0
12	.57909	2.06605	9492	.1273	.0732	.0410	83	2	296	0
13	.57905	2.06616	5500	.1273	.0700	.0410	83	9	200	0
14	.58768	2.06303	5491	.2674	.2355	.0980	83	11	207	2
15	.58157	2.06594	1268	.1401	.1082	.0615	83	7	223	0
16	.57821	2.06914	24486	.0000	.0191	.0233	83	0	249	0
17	.58614	2.06847	7539	.0000	.0286	.0891	83	0	262	0
18	.58873	2.06555	4203	.1019	.1560	.1008	83	5	278	0
19	.59020	2.06580	3876	.1273	.1592	.1036	83	9	255	0
20	.59033	2.06907	6000	.0255	.0637	.0937	83	3	295	0
21	.59202	2.08046	2500	.0382	.0191	.0198	83	3	230	0
22	.59210	2.07871	16000	.0255	.0255	.0219	83	0	253	0
23	.59358	2.08122	2698	.0382	.0255	.0173	83	4	246	0
24	.59155	2.06592	1344	.1910	.1974	.1047	83	7	174	1
25	.59216	2.06756	1919	.1783	.1432	.0969	83	14	242	0
26	.59568	2.07684	3008	.0255	.0318	.0347	83	4	255	0
27	.59237	2.06740	1289	.2165	.1560	.0969	83	10	220	1
28	.59260	2.06792	1066	.2165	.1560	.0941	83	12	254	0
29	.59234	2.06710	656	.2165	.1592	.0990	83	9	299	0

TABLE C-2

(Page 2 of 2)

TCAS ID	Latitude	Longitude	Altitude (ft)	Densities 5 nmi	Densities 10 nmi	Densities 30 nmi	Whisper-Shout Levels Transmitted	TCAS II M/Mode S Int. Rate	TCAS II M/Mode S Int. Power[a]	TCAS II M/Mode S Power Reduction (dB)
30	.59591	2.07604	8502	.0382	.0414	.0368	83	3	332	0
31	.59920	2.08409	9500	.0127	.0064	.0110	83	0	285	0
32	.59374	2.07031	3655	.1910	.1241	.0828	83	5	193	0
33	.59486	2.07086	4996	.1783	.0859	.0764	83	4	236	0
34	.59925	2.07815	11002	.0000	.0127	.0301	83	4	239	0
35	.59256	2.06577	100	.3056	.1910	.1012	83	14	153	2
36	.59759	2.07349	4995	.0127	.0318	.0601	83	2	292	0
37	.60237	2.07633	21000	.0382	.0286	.0230	83	0	287	0
38	.59837	2.07026	7004	.0127	.0350	.0732	83	4	232	0
39	.60485	2.07389	7500	.0382	.0414	.0262	83	6	226	0
40	.59481	2.06520	3800	.1019	.1496	.0937	81	7	244	0
41	.60196	2.06948	24000	.0637	.0477	.0534	83	5	268	0
42	.60008	2.06780	23994	.0509	.0923	.0700	83	3	238	0
43	.59715	2.06445	2995	.2037	.1210	.0824	83	11	265	0
44	.59825	2.06440	6236	.2292	.1401	.0757	83	16	255	0
45	.59810	2.06408	689	.2292	.1210	.0775	83	10	193	2
46	.60105	2.06448	3994	.2037	.1210	.0584	83	6	245	0
47	.60146	2.06414	4292	.1401	.1050	.0523	83	10	281	0
48	.60122	2.06308	10498	.1146	.0955	.0492	83	12	255	0
49	.59894	2.06266	2806	.1273	.1273	.0707	83	11	228	0

[a] Equivalent Isotropically Radiated Power (EIRP) on the horizon.

TABLE C-3

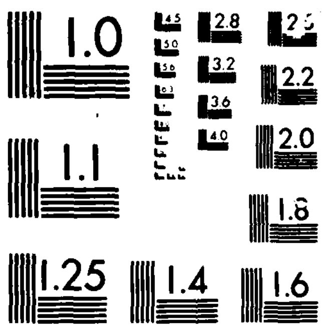
TCAS II M RESULTS - DEPLOYMENT C

(Page 1 of 2)

TCAS ID	Latitude	Longitude	Altitude (ft)	Densities			Whisper-Shout Levels Transmitted	TCAS II M/Mode S		
				5 nmi	10 nmi	30 nmi		Int. Rate	Int. Power[a]	Power Reduction (dB)
1	.60665	2.05881	28719	.0000	.0000	.0131	83	0	304	0
2	.59005	2.06067	1998	.1528	.1464	.0661	83	5	267	0
3	.58621	2.05547	10992	.0255	.0159	.0410	83	4	300	0
4	.58967	2.06168	1494	.2037	.1560	.0679	83	3	207	0
5	.58198	2.05949	10994	.0127	.0446	.0424	83	4	299	0
6	.58674	2.06119	10494	.1783	.1592	.0651	83	22	215	0
7	.58467	2.06087	18320	.1655	.1050	.0538	83	0	244	0
8	.58433	2.06116	2470	.1146	.1082	.0527	83	9	280	0
9	.57477	2.06323	4006	.0000	.0000	.0120	83	0	271	0
10	.57905	2.06616	5500	.0891	.0541	.0279	83	3	251	0
11	.58157	2.06594	1268	.1401	.0732	.0400	83	3	232	0
12	.57821	2.06914	24486	.0000	.0127	.0166	83	0	267	0
13	.58614	2.06847	7539	.0000	.0159	.0615	83	0	223	0
14	.58873	2.06555	4203	.0382	.0891	.0697	83	2	261	0
15	.59033	2.06907	6000	.0255	.0414	.0654	83	1	236	0
16	.59202	2.08046	2500	.0382	.0159	.0149	83	3	296	0
17	.59210	2.07871	16000	.0255	.0191	.0163	83	0	200	0
18	.59358	2.08122	2698	.0255	.0191	.0138	83	5	237	0
19	.59155	2.06592	1344	,1146	.1369	.0700	83	3	242	0
20	.59563	2.07684	3008	.0255	.0286	.0248	83	1	257	0
21	.59237	2.06740	1289	.1273	.0987	.0672	83	3	208	0
22	.59260	2.06792	1066	.1401	.1050	.0658	83	2	224	0
23	.59501	2.07104	8502	.0382	.0382	.0262	83	4	229	0
24	.59920	2.08409	9500	.0127	.0064	.0081	83	0	249	0
25	.59486	2.07086	4996	.1146	.0605	.0527	83	3	215	0

AD-A166 914 THE IMPACT OF A TRAFFIC ALERT AND COLLISION AVOIDANCE 2/2
SYSTEM ON THE AIR T..(U) ELECTROMAGNETIC COMPATIBILITY
ANALYSIS CENTER ANNAPOLIS MD MAY 85 ECAC-PR-84-003

UNCLASSIFIED DOT/FAA/PM-84/30 F19628-80-C-0042 F/G 17/7 NL



MICROCOP' CHART

TABLE C-3

(Page 2 of 2)

TCAS ID	Latitude	Longitude	Altitude (ft)	Densities			Whisper-Shout Levels Transmitted	TCAS II M/Mode S		
				5 nmi	10 nmi	30 nmi		Int. Rate	Int. Power[a]	Power Reduction (dB)
26	.59759	2.07349	4995	.0000	.0223	.0424	83	2	283	0
27	.60237	2.07633	21000	.0255	.0191	.0163	83	0	261	0
28	.59837	2.07026	7004	.0000	.0191	.0516	83	7	327	0
29	.59431	2.06520	3800	.0637	.1019	.0658	83	0	305	0
30	,60196	2.06948	24000	.0637	.0286	.0378	83	0	241	0
31	.59825	2.06440	6236	.1528	.0955	.0552	83	6	292	0
32	.59810	2.06408	689	.1528	.0764	.0559	83	4	211	0
33	.60105	2.06448	3994	.1273	.0828	.0410	83	7	260	0
34	.60122	2.06308	10498	.0764	.0605	.0350	83	5	254	0

[a]Equivalent Isotropically Radiated Power (EIRP) on the horizon.

TABLE C-4

TCAS II M RESULTS - DEPLOYMENT B1

(Page 1 of 3)

TCAS ID	Latitude	Longitude	Altitude (ft)	Densities 5 nmi	Densities 10 nmi	Densities 30 nmi	Whisper-Shout Levels Transmitted	TCAS II M/Mode S Int. Rate	TCAS II M/Mode S Int. Power[a]	TCAS II M/Mode S Power Reduction (dB)
1	.60665	2.05881	28719	.0127	.0032	.0184	83	0	304	0
2	.59560	2.05145	3500	.1146	.0414	.0131	83	4	203	0
3	.59541	2.05044	7500	.0764	.0414	.0113	83	2	300	0
4	.59082	2.05606	3405	.0127	.0127	.0732	83	4	222	0
5	.59005	2.06067	1998	.1783	.1974	.0976	83	12	236	0
6	.58621	2.05547	10992	.0255	.0191	.0622	83	3	286	0
7	.58808	2.06053	1997	.2801	.1910	.0934	83	7	263	0
8	.58778	2.06048	1225	.2546	.2101	.0930	83	8	220	1
9	.58537	2.05941	3003	.1783	.1496	.0806	83	11	261	0
10	.58967	2.06168	1494	.2674	.2260	.0994	83	6	188	1
11	.58720	2.06096	.000	.2546	.2451	.0944	83	19	131	2
12	.58198	2.05949	10994	.0255	.0796	.0640	83	5	261	0
13	.58674	2.06119	10494	.2292	.2483	.0944	83	32	68	5
14	.58467	2.06087	18320	.2674	.1623	.0785	83	0	257	0
15	.58433	2.06116	2470	.2037	.1687	.0771	83	6	234	0
16	.58242	2.06188	3992	.0764	.1241	.0676	83	6	212	0
17	.57477	2.06323	4006	.0127	.0032	.0163	83	0	270	0
18	.58016	2.06353	4497	.0382	.1050	.0548	83	8	209	0
19	.57909	2.06605	9492	.1273	.0732	.0410	83	2	296	0
20	.57905	2.06616	5500	.1273	.0700	.0410	83	4	200	0
21	.58768	2.06303	5491	.2674	.2355	.0980	83	19	129	3
22	.58157	2.06594	1268	.1401	.1082	.0615	83	5	223	0
23	.58399	2.06499	2505	.2165	.1623	.0782	83	1	242	0
24	.57821	2.06914	24486	.0000	.0191	.0233	83	0	249	0
25	.58572	2.06465	7491	.2546	.1655	.0927	82	11	278	0

TABLE C-4

(Page 2 of 3)

TCAS ID	Latitude	Longitude	Altitude (ft)	Densities			Whisper-Shout Levels Transmitted	TCAS II M/Mode S		
				5 nmi	10 nmi	30 nmi		Int. Rate	Int. Power[a]	Power Reduction (dB)
26	.58614	2.06847	7539	.0000	.0286	.0891	83	0	262	0
27	.58873	2.06555	4203	.1019	.1560	.1008	83	8	278	0
28	.59020	2.06580	3876	.1273	.1592	.1036	83	4	255	0
29	.59033	2.06907	6000	.0255	.0637	.0937	83	4	295	0
30	.59202	2.08046	2500	.0382	.0191	.0198	83	3	230	0
31	.59210	2.07871	16000	.0255	.0255	.0219	83	0	253	0
32	.59358	2.08122	2698	.0382	.0255	.0173	83	5	246	0
33	.59402	2.07891	4502	.0000	.0382	.0233	83	3	282	0
34	.59607	2.08040	8498	.0000	.0255	.0219	83	4	276	0
35	.59155	2.06592	1344	.1910	.1974	.1047	81	7	108	3
36	.59216	2.06756	1919	.1783	.1432	.0969	82	11	151	2
37	.59568	2.07684	3008	.0255	.0318	.0347	83	2	255	0
38	.59237	2.06740	1289	.2165	.1560	.0969	82	7	220	2
39	.59260	2.06792	1066	.2165	.1560	.0941	83	11	201	1
40	.59234	2.06710	656	.2165	.1592	.0990	81	11	186	2
41	.59591	2.07604	8502	.0382	.0414	.0368	83	8	332	0
42	.59920	2.08409	9500	.0127	.0064	.0110	83	0	285	0
43	.59374	2.07031	3655	.1910	.1241	.0828	83	4	193	0
44	.59486	2.07086	4996	.1783	.0859	.0764	83	4	236	0
45	.59925	2.07815	11002	.0000	.0127	.0301	83	4	239	0
46	.59256	2.06577	100	.3056	.1910	.1012	82	17	121	3
47	.59759	2.07349	4995	.0127	.0318	.0601	83	8	292	0
48	.60237	2.07633	21000	.0382	.0286	.0230	83	0	287	0
49	.59837	2.07026	7004	.0127	.0350	.0732	83	7	232	0
50	.60485	2.07389	7500	.0382	.0414	.0262	83	1	226	0
51	.59481	2.06520	3800	.1019	.1496	.0937	83	3	244	0
52	.60196	2.06948	24000	.0637	.0477	.0534	83	1	268	0

TABLE C-4

(Page 3 of 3)

TCAS ID	Latitude	Longitude	Altitude (ft)	Densities 5 nmi	Densities 10 nmi	Densities 30 nmi	Whisper-Shout Levels Transmitted	TCAS II M/Mode S Int. Rate	TCAS II M/Mode S Int. Power[a]	TCAS II M/Mode S Power Reduction (dB)
53	.60008	2.06780	23994	.0509	.0923	.0700	83	5	238	0
54	.59715	2.06445	2995	.2037	.1210	.0824	83	4	209	1
55	.59794	2.06469	1017	.2037	.1241	.0778	83	15	157	2
56	.59825	2.06440	6236	.2292	.1401	.0757	83	11	255	0
57	.59810	2.06408	689	.2292	.1210	0775	82	8	152	2
58	.60112	2.06458	2303	.1910	.1114	.0576	83	13	290	0
59	.60105	2.06448	3994	.2037	.1210	.0584	83	9	245	0
60	.60424	2.06486	1341	.1019	.0637	.0361	83	3	277	0
61	.60369	2.06461	5494	.1019	.0637	.0364	83	3	222	0
62	.60146	2.06414	4292	.1401	.1050	.0523	83	13	281	0
63	.60122	2.06308	10498	.1146	.0955	.0492	83	10	255	0
64	.59894	2.06266	2806	.1273	.1273	.0707	83	8	228	0
65	.60893	2.06299	8500	.0000	.0127	.0166	83	1	194	0

[a]Equivalent Isotropically Radiated Power (EIRP) on the horizon.

TABLE C-5

TCAS II M RESULTS - DEPLOYMENT B2

(Page 1 of 3)

TCAS ID	Latitude	Longitude	Altitude (ft)	Densities			Whisper-Shout Levels Transmitted	TCAS II M/Mode S		
				5 nmi	10 nmi	30 nmi		Int. Rate	Int. Power[a]	Power Reduction (dB)
1	.59329	2.06173	1255	.1910	.1496	.0987	83	2	246	0
2	.60665	2.05881	28719	.0127	.0032	.0184	83	0	304	0
3	.59560	2.05145	3500	.1146	.0414	.0131	83	7	203	0
4	.59541	2.05044	7500	.0764	.0414	.0113	83	3	300	0
5	.59082	2.05606	3405	.0127	.0127	.0732	83	1	222	0
6	.59005	2.06067	1998	.1783	.1974	.0976	80	10	116	3
7	.58621	2.05547	10992	.0255	.0191	.0622	83	2	286	0
8	.58253	2.05610	5492	.0891	.0414	.0559	83	5	269	0
9	.58808	2.06053	1997	.2801	.1910	.0934	82	11	208	1
10	.58398	2.05805	4513	.0382	.0987	.0707	82	12	221	1
11	.58778	2.06048	1225	.2546	.2101	.0930	82	12	220	1
12	.58537	2.05941	3003	.1783	.1496	.0806	82	6	261	1
13	.58967	2.06168	1494	.2674	.2260	.0994	82	14	117	3
14	.58720	2.06096	0	.2546	.2451	.0944	80	13	104	3
15	.58198	2.05949	10994	.0255	.0796	.0640	83	7	261	0
16	.58674	2.06119	10494	.2292	.2483	.0944	76	28	43	7
17	.58467	2.06087	18320	.2674	.1623	.0785	83	0	257	0
18	.58433	2.06116	2470	.2037	.1687	.0771	83	8	146	2
19	.58242	2.06188	3992	.0764	.1241	.0676	82	11	132	2
20	.58833	2.06193	4500	.3820	.2165	.0958	81	25	93	4
21	.58229	2.06207	1994	.0637	.1146	.0676	82	14	216	0
22	.57477	2.06323	4006	.0127	.0032	.0163	83	0	270	0
23	.58016	2.06353	4497	.0382	.1050	.0548	83	10	209	0
24	.58624	2.06330	3498	.2037	.2355	.0969	77	7	132	4
25	.57972	2.06563	2503	.1146	.0828	.0463	83	10	236	0
26	.57909	2.06605	9492	.1273	.0732	.0410	83	2	296	0
27	.57905	2.06616	5500	.1273	.0700	.0410	83	7	200	0
28	.58768	2.06303	5491	.2674	.2355	.0980	78	12	102	4
29	.58119	2.06592	2166	.1146	.1050	.0580	83	2	277	0

TABLE C-5

(Page 2 of 3)

TCAS ID	Latitude	Longitude	Altitude (ft)	Densities			Whisper-Shout Levels Transmitted	TCAS II M/Mode S		
				5 nmi	10 nmi	30 nmi		Int. Rate	Int. Power[a]	Power Reduction (dB)
30	.58157	2.06594	1268	.1401	.1082	.0615	82	5	223	0
31	.58399	2.06499	2505	.2165	.1623	.0782	78	8	242	0
32	.57821	2.06914	24486	.0000	.0191	.0233	83	0	249	0
33	.58572	2.06465	7491	.2546	.1655	.0927	78	7	220	1
34	.58614	2.06847	7539	.0000	.0286	.0891	80	0	262	0
35	.58873	2.06555	4203	.1019	.1560	.1008	82	8	137	3
36	.59020	2.06580	3876	.1273	.1592	.1036	80	7	159	2
37	.59033	2.06907	6000	.0255	.0637	.0937	80	2	233	1
38	.59032	2.06567	8500	.1528	.1751	.1029	78	6	137	2
39	.59202	2.08046	2500	.0382	.0191	.0198	83	3	230	0
40	.59210	2.07871	16000	.0255	.0255	.0219	83	0	253	0
41	.59358	2.08122	2698	.0382	.0255	.0173	83	2	246	0
42	.59402	2.07891	4502	.0000	.0382	.0233	83	6	282	0
43	.59607	2.08040	8498	.0000	.0255	.0219	83	4	276	0
44	.59155	2.06592	1344	.1910	.1974	.1047	76	7	108	3
45	.59216	2.06756	1919	.1783	.1432	.0969	78	9	151	2
46	.59568	2.07684	3008	.0255	.0318	.0347	83	6	255	0
47	.59237	2.06740	1289	.2165	.1560	.0969	78	8	137	3
48	.59260	2.06792	1066	.2165	.1560	.0941	80	14	159	2
49	.59234	2.06710	656	.2165	.1592	.0990	76	6	147	3
50	.59591	2.07604	8502	.0382	.0414	.0368	83	4	332	0
51	.59920	2.08409	9500	.0127	.0064	.0110	83	0	285	0
52	.59374	2.07031	3655	.1910	.1241	.0828	83	7	193	0
53	.59705	2.07550	4007	.0127	.0318	.0414	83	4	269	0
54	.59486	2.07086	4996	.1783	.0859	.0764	83	8	236	0
55	.59925	2.07815	11002	.0000	.0127	.0301	83	7	239	0
56	.59256	2.06577	100	.3056	.1910	.1012	76	9	95	4
57	.59682	2.07246	7464	.0637	.0477	.0668	81	7	254	0
58	.59759	2.07349	4995	.0127	.0318	.0601	83	4	292	0

TABLE C-5

(Page 3 of 3)

TCAS ID	Latitude	Longitude	Altitude (ft)	Densities 5 nmi	Densities 10 nmi	Densities 30 nmi	Whisper-Shout Levels Transmitted	TCAS II M/Mode S Int. Rate	TCAS II M/Mode S Int. Power[a]	TCAS II M/Mode S Power Reduction (dB)
59	.60237	2.07633	21000	.0382	.0286	.0230	83	0	287	0
60	.59837	2.07026	7004	.0127	.0350	.0732	83	5	232	0
61	.59374	2.06536	2991	.1910	.2005	.0969	75	11	89	4
62	.60380	2.07349	6500	.0382	.0446	.0332	83	1	253	0
63	.60485	2.07389	7500	.0382	.0414	.0262	83	3	226	0
64	.59481	2.06520	3800	.1019	.1496	.0937	74	1	192	1
65	.60196	2.06948	24000	.0637	.0477	.0534	83	1	268	0
66	.60008	2.06780	23994	.0509	.0923	.0700	83	5	238	0
67	.59817	2.06577	3493	.1401	.1273	.0764	82	16	107	3
68	.59715	2.06445	2995	.2037	.1210	.0824	78	6	209	1
69	.59794	2.06469	1017	.2037	.1241	.0778	80	12	157	2
70	.59825	2.06440	6236	.2292	.1401	.0757	83	12	159	2
71	.59810	2.06408	689	.2292	.1210	.0775	78	12	120	3
72	.60112	2.06458	2303	.1910	.1114	.0576	83	10	181	2
73	.60020	2.06432	4500	.2419	.1401	.0686	83	11	182	1
74	.60105	2.06448	3994	.2037	.1210	.0584	83	9	245	0
75	.60424	2.06486	1341	.1019	.0637	.0361	83	3	277	0
76	.59798	2.06350	5830	.2037	.1146	.0775	83	10	168	3
77	.60369	2.06461	5494	.1019	.0637	.0364	83	3	222	3
78	.60146	2.06414	4292	.1401	.1050	.0523	83	7	281	3
79	.59576	2.06292	4497	.1019	.1432	.0902	83	11	232	3
80	.59447	2.06241	7500	.2037	.1560	.0941	78	9	145	5
81	.60122	2.06308	10498	.1146	.0955	.0492	83	21	255	3
82	.59894	2.06266	2806	.1273	.1273	.0707	82	8	180	4
83	.60893	2.06299	8500	.0000	.0127	.0166	83	1	194	3

[a]Equivalent Isotropically Radiated Power (EIRP) on the horizon.

TABLE C-6
TCAS II M RESULTS - DEPLOYMENT B3
(Page 1 of 2)

TCAS ID	Latitude	Longitude	Altitude (ft)	Densities 5 nmi	Densities 10 nmi	Densities 30 nmi	Whisper-Shout Levels Transmitted	TCAS II M/Mode S Int. Rate	TCAS II M/Mode S Int. Power[a]	TCAS II M/Mode S Power Reduction (dB)
1	.60665	2.05881	28719	.0127	.0032	.0184	83	0	304	0
2	.59541	2.05044	7500	.0764	.0414	.0113	83	5	300	0
3	.59005	2.06067	1998	.1783	.1974	.0976	83	32	72	5
4	.58621	2.05547	10992	.0255	.0191	.0622	83	18	286	0
5	.58967	2.06168	1494	.2674	.2260	.0994	83	33	73	5
6	.58198	2.05949	10994	.0255	.0796	.0640	83	30	162	2
7	.58674	2.06119	10494	.2292	.2483	.0944	77	67	54	6
8	.58467	2.06087	18320	.2674	.1623	.0785	83	0	257	0
9	.58433	2.06116	2470	.2037	.1687	.0771	83	23	185	2
10	.58242	2.06188	3992	.0764	.1241	.0676	83	33	105	3
11	.57477	2.06323	4006	.0127	.0032	.0163	83	0	270	0
12	.57909	2.06605	9492	.1273	.0732	.0410	83	12	296	0
13	.57905	2.06616	5500	.1273	.0700	.0410	83	10	200	0
14	.58768	2.06303	5491	.2674	.2355	.0980	83	39	80	5
15	.58157	2.06594	1268	.1401	.1082	.0615	83	19	176	2
16	.57821	2.06914	24486	.0000	.0191	.0233	83	0	249	0
17	.58614	2.06847	7539	.0000	.0286	.0891	83	2	262	0
18	.58873	2.06555	4203	.1019	.1560	.1008	83	21	137	3
19	.59020	2.06580	3876	.1273	.1592	.1036	82	38	99	4
20	.59033	2.06907	6000	.0255	.0637	.0937	83	11	184	2
21	.59202	2.08046	2500	.0382	.0191	.0198	83	6	230	0
22	.59210	2.07871	16000	.0255	.0255	.0219	83	4	253	0
23	.59358	2.08122	2698	.0382	.0255	.0173	83	5	246	0
24	.59155	2.06592	1344	.1910	.1974	.1047	83	31	53	6
25	.59216	2.06756	1919	.1783	.1432	.0969	83	34	74	5
26	.59568	2.07684	3008	.0255	.0318	.0347	83	7	255	0
27	.59237	2.06740	1289	.2165	.1560	.0969	83	23	86	5
28	.59260	2.06792	1066	.2165	.1560	.0941	82	24	99	4
29	.59234	2.06710	656	.2165	.1592	.0990	83	32	92	5

TABLE C-6

(Page 2 of 2)

TCAS ID	Latitude	Longitude	Altitude (ft)	Densities			Whisper-Shout Levels Transmitted	TCAS II M/Mode S		
				5 nmi	10 nmi	30 nmi		Int. Rate	Int. Power[a]	Power Reduction (dB)
30	.59591	2.07604	8502	.0382	.0414	.0368	83	7	332	0
31	.59920	2.08409	9500	.0127	.0064	.0110	83	1	285	0
32	.59374	2.07031	3655	.1910	.1241	.0828	83	21	95	3
33	.59486	2.07086	4996	.1783	.0859	.0764	83	6	186	1
34	.59925	2.07815	11002	.0000	.0127	.0301	83	10	239	0
35	.59256	2.06577	100	.3056	.1910	.1012	83	46	59	6
36	.59759	2.07349	4995	.0127	.0318	.0601	83	6	292	0
37	.60237	2.07633	21000	.0382	.0286	.0230	83	0	287	0
38	.59837	2.07026	7004	.0127	.0350	.0732	83	6	232	1
39	.60485	2.07389	7500	.0382	.0414	.0262	83	10	226	0
40	.59481	2.06520	3800	.1019	.1496	.0937	81	9	95	4
41	.60196	2.06948	24000	.0637	.0477	.0534	83	5	268	0
42	.60008	2.06780	23994	.0509	.0923	.0700	83	5	238	0
43	.59715	2.06445	2995	.2037	.1210	.0824	82	29	103	4
44	.59825	2.06440	6236	.2292	.1401	.0757	83	23	159	2
45	.59810	2.06408	689	.2292	.1210	.0775	83	29	75	5
46	.60105	2.06448	3994	.2037	.1210	.0584	83	21	245	0
47	.60146	2.06414	4292	.1401	.1050	.0523	83	23	281	0
48	.60122	2.06308	10498	.1146	.0955	.0492	83	35	255	0
49	.59894	2.06266	2806	.1273	.1273	.0707	83	11	228	0

[a]Equivalent Isotropically Radiated Power (EIRP) on the horizon.

TABLE C-7

TCAS II M RESULTS - DEPLOYMENT B3[a]

(Page 1 of 2)

TCAS ID	Latitude	Longitude	Altitude (ft)	Densities			Whisper-Shout Levels Transmitted	TCAS II M/Mode S		
				5 nmi	10 nmi	30 nmi		Int. Rate	Int. Power[b]	Power Reduction (dB)
1	.60665	2.05881	28719	.0127	.0032	.0184	83	0	304	0
2	.59541	2.05044	7500	.0764	.0414	.0113	83	5	300	0
3	.59005	2.06067	1998	.1783	.1974	.0976	83	36	72	5
4	.58621	2.05547	10992	.0255	.0191	.0622	83	10	286	0
5	.58967	2.06168	1494	.2674	.2260	.0994	83	36	92	4
6	.58198	2.05949	10994	.0255	.0796	.0640	83	25	206	1
7	.58674	2.06119	10494	.2292	.2483	.0944	77	53	54	6
8	.58467	2.06087	18320	.2674	.1623	.0785	83	0	257	0
9	.58433	2.06116	2470	.2037	.1687	.0771	83	22	185	1
10	.58242	2.06188	3992	.0764	.1241	.0676	83	24	105	3
11	.57477	2.06323	4006	.0127	.0032	.0163	83	0	270	0
12	.57909	2.06605	9492	.1273	.0732	.0410	83	11	296	0
13	.57905	2.06616	5500	.1273	.0700	.0410	83	14	200	0
14	.58768	2.06303	5491	.2674	.2355	.0980	83	30	102	4
15	.58157	2.06594	1268	.1401	.1082	.0615	83	20	110	3
16	.57821	2.06914	24486	.0000	.0191	.0233	83	0	249	0
17	.58614	2.06847	7539	.0000	.0286	.0891	83	7	262	0
18	.58873	2.06555	4203	.1019	.1560	.1008	83	18	137	4
19	.59020	2.06580	3876	.1273	.1592	.1036	82	40	125	3
20	.59033	2.06907	6000	.0255	.0637	.0937	83	15	184	2
21	.59202	2.08046	2500	.0382	.0191	.0198	83	4	230	0
22	.59210	2.07871	16000	.0255	.0255	.0219	83	1	253	0
23	.59358	2.08122	2698	.0382	.0255	.0173	83	3	246	0
24	.59155	2.06592	1344	.1910	.1974	.1047	83	26	53	6
25	.59216	2.06756	1919	.1783	.1432	.0969	83	23	74	5
26	.59568	2.07684	3008	.0255	.0318	.0347	83	6	255	0
27	.59237	2.06740	1289	.2165	.1560	.0969	83	34	86	5
28	.59260	2.06792	1066	.2165	.1560	.0941	82	25	125	3
29	.59234	2.06710	656	.2165	.1592	.0990	83	28	92	5

TABLE C-7

(Page 2 of 2)

TCAS ID	Latitude	Longitude	Altitude (ft)	Densities 5 nmi	Densities 10 nmi	Densities 30 nmi	Whisper-Shout Levels Transmitted	TCAS II M/Mode S Int. Rate	TCAS II M/Mode S Int. Power[b]	TCAS II M/Mode S Power Reduction (dB)
30	.59591	2.07604	8502	.0382	.0414	.0368	83	6	332	0
31	.59920	2.08409	9500	.0127	.0064	.0110	83	3	285	0
32	.59374	2.07031	3655	.1910	.1241	.0828	83	24	95	3
33	.59486	2.07086	4996	.1783	.0859	.0764	83	23	186	1
34	.59925	2.07815	11002	.0000	.0127	.0301	83	12	239	0
35	.59256	2.06577	100	.3056	.1910	.1012	83	32	59	6
36	.59759	2.07349	4995	.0127	.0318	.0601	83	12	292	0
37	.60237	2.07633	21000	.0382	.0286	.0230	83	0	287	0
38	.59837	2.07026	7004	.0127	.0350	.0732	83	7	232	1
39	.60485	2.07389	7500	.0382	.0414	.0262	83	11	226	0
40	.59481	2.06520	3800	.1019	.1496	.0937	81	18	95	3
41	.60196	2.06948	24000	.0637	.0477	.0534	83	5	268	0
42	.60008	2.06780	23994	.0509	.0923	.0700	82	3	238	0
43	.59715	2.06445	2995	.2037	.1210	.0824	83	34	103	4
44	.59825	2.06440	6236	.2292	.1401	.0757	83	19	159	2
45	.59810	2.06408	689	.2292	.1210	.0775	83	32	75	5
46	.60105	2.06448	3994	.2037	.1210	.0584	83	19	245	0
47	.60146	2.06414	4292	.1401	.1050	.0523	83	21	281	0
48	.60122	2.06308	10498	.1146	.0955	.0492	83	20	255	0
49	.59894	2.06266	2806	.1273	.1273	.0707	83	19	228	1

[a] Assuming TCAS I emission power of 20 watts.

[b] Equivalent Isotropically Radiated Power (EIRP) on the horizon.

TABLE C-8

TCAS II M RESULTS - DEPLOYMENT B3[a]
(Page 1 of 2)

TCAS ID	Latitude	Longitude	Altitude (ft)	Densities 5 nmi	Densities 10 nmi	Densities 30 nmi	Whisper-Shout Levels Transmitted	TCAS II M/Mode S Int. Rate	TCAS II M/Mode S Int. Power[b]	TCAS II M/Mode S Power Reduction (dB)
1	.60665	2.05881	28719	.0127	.0032	.0184	83	0	304	0
2	.59541	2.05044	7500	.0764	.0414	.0113	83	5	300	0
3	.59005	2.06067	1998	.1783	.1974	.0976	83	40	57	6
4	.58621	2.05547	10992	.0255	.0191	.0622	83	16	286	0
5	.58967	2.06168	1494	.2674	.2260	.0994	83	42	92	4
6	.58198	2.05949	10994	.0255	.0796	.0640	83	18	206	1
7	.58674	2.06119	10494	.2292	.2483	.0944	79	51	34	8
8	.58467	2.06087	18320	.2674	.1623	.0785	83	0	257	0
9	.58433	2.06116	2470	.2037	.1687	.0771	83	24	146	2
10	.58242	2.06188	3992	.0764	.1241	.0676	83	28	105	3
11	.57477	2.06323	4006	.0127	.0032	.0163	83	0	270	0
12	.57909	2.06605	9492	.1273	.0732	.0410	83	10	296	0
13	.57905	2.06616	5500	.1273	.0700	.0410	83	12	200	0
14	.58768	2.06303	5491	.2674	.2355	.0980	83	26	102	4
15	.58157	2.06594	1268	.1401	.1082	.0615	83	18	176	1
16	.57821	2.06914	24486	.0000	.0191	.0233	83	0	249	0
17	.58614	2.06847	7539	.0000	.0286	.0891	83	6	262	0
18	.58873	2.06555	4203	.1019	.1560	.1008	83	30	108	4
19	.59020	2.06580	3876	.1273	.1592	.1036	82	45	125	3
20	.59033	2.06907	6000	.0255	.0637	.0937	83	22	233	1
21	.59202	2.08046	2500	.0382	.0191	.0198	83	4	230	0
22	.59210	2.07871	16000	.0255	.0255	.0219	83	1	253	0
23	.59358	2.08122	2698	.0382	.0255	.0173	83	5	246	0
24	.59155	2.06592	1344	.1910	.1974	.1047	83	22	67	5
25	.59216	2.06756	1919	.1783	.1432	.0969	83	33	74	6
26	.59568	2.07684	3008	.0255	.0318	.0347	83	12	255	0
27	.59237	2.06740	1289	.2165	.1560	.0969	83	24	86	5
28	.59260	2.06792	1066	.2165	.1560	.0941	83	23	125	4
29	.59234	2.06710	656	.2165	.1592	.0990	83	19	72	6

TABLE C-8

(Page 2 of 2)

TCAS ID	Latitude	Longitude	Altitude (ft)	Densities 5 nmi	Densities 10 nmi	Densities 30 nmi	Whisper-Shout Levels Transmitted	TCAS II M/Mode S Int. Rate	TCAS II M/Mode S Int. Power[b]	TCAS II M/Mode S Power Reduction (dB)
30	.59591	2.07604	8502	.0382	.0414	.0368	83	6	332	0
31	.59920	2.08409	9500	.0127	.0064	.0110	83	1	285	0
32	.59374	2.07031	3655	.1910	.1241	.0828	83	25	95	3
33	.59486	2.07086	4996	.1783	.0859	.0764	83	9	186	1
34	.59925	2.07815	11002	.0000	.0127	.0301	83	11	239	0
35	.59256	2.06577	100	.3056	.1910	.1012	83	38	47	7
36	.59759	2.07349	4995	.0127	.0318	.0601	83	4	292	0
37	.60237	2.07633	21000	.0382	.0286	.0230	83	0	287	0
38	.59837	2.07026	7004	.0127	.0350	.0732	83	10	232	0
39	.60485	2.07389	7500	.0382	.0414	.0262	83	11	226	0
40	.59481	2.06520	3800	.1019	.1496	.0937	83	18	152	2
41	.60196	2.06948	24000	.0637	.0477	.0534	81	4	268	0
42	.60008	2.06780	23994	.0509	.0923	.0700	83	4	238	0
43	.59715	2.06445	2995	.2037	.1210	.0824	83	27	81	5
44	.59825	2.06440	6236	.2292	.1401	.0757	83	23	159	2
45	.59810	2.06408	689	.2292	.1210	.0775	83	35	75	5
46	.60105	2.06448	3994	.2037	.1210	.0584	83	19	245	0
47	.60146	2.06414	4292	.1401	.1050	.0523	83	24	281	0
48	.60122	2.06308	10498	.1146	.0955	.0492	83	23	255	0
49	.59894	2.06266	2806	.1273	.1273	.0707	83	11	180	1

[a] Assuming TCAS I emission power of 120 watts.

[b] Equivalent Isotropically Radiated Power (EIRP) on the horizon.

TABLE C-9

TCAS II M RESULTS - DEPLOYMENT B3[a]

(Page 1 of 2)

TCAS ID	Latitude	Longitude	Altitude (ft)	Densities 5 nmi	Densities 10 nmi	Densities 30 nmi	Whisper-Shout Levels Transmitted	TCAS II M/Mode S Int. Rate	TCAS II M/Mode S Int. Power[b]	TCAS II M/Mode S Power Reduction (dB)
1	.60665	2.05881	28719	.0127	.0032	.0184	83	0	304	0
2	.59541	2.05044	7500	.0764	.0414	.0113	83	7	300	0
3	.59005	2.06067	1998	.1783	.1974	.0976	83	44	72	5
4	.58621	2.05547	10992	.0255	.0191	.0622	83	17	286	0
5	.58967	2.06163	1494	.2674	.2260	.0994	83	47	73	5
6	.58198	2.05949	10994	.0255	.0796	.0640	83	21	206	1
7	.58674	2.06119	10494	.2292	.2483	.0944	82	62	54	6
8	.58467	2.06087	18320	.2674	.1623	.0785	83	0	257	0
9	.58433	2.06116	2470	.2037	.1687	.0771	83	31	146	2
10	.58242	2.06188	3992	.0764	.1241	.0676	83	28	82	4
11	.57477	2.06323	4006	.0127	.0032	.0163	83	0	270	0
12	.57909	2.06605	9492	.1273	.0732	.0410	83	8	296	0
13	.57905	2.06616	5500	.1273	.0700	.0410	83	12	200	0
14	.58768	2.06303	5491	.2674	.2355	.0980	83	17	102	4
15	.58157	2.06594	1268	.1401	.1082	.0615	83	20	176	1
16	.57821	2.06914	24486	.0000	.0191	.0233	83	0	249	0
17	.58614	2.06847	7539	.0000	.0286	.0891	83	5	262	0
18	.58873	2.06555	4203	.1019	.1560	.1008	83	22	108	4
19	.59020	2.06580	3876	.1273	.1592	.1036	82	37	125	3
20	.59033	2.06907	6000	.0255	.0637	.0937	83	14	233	1
21	.59202	2.08046	2500	.0382	.0191	.0198	83	7	230	0
22	.59210	2.07871	16000	.0255	.0255	.0219	83	2	253	0
23	.59358	2.08122	2698	.0382	.0255	.0173	83	7	246	0
24	.59155	2.06592	1344	.1910	.1974	.1047	83	34	53	6
25	.59216	2.06756	1919	.1783	.1432	.0969	83	25	74	5
26	.59568	2.07684	3008	.0255	.0318	.0347	83	8	255	0
27	.59237	2.06740	1289	.2165	.1560	.0969	83	28	86	6
28	.59260	2.06792	1066	.2165	.1560	.0941	83	17	125	3
29	.59234	2.06710	656	.2165	.1592	.0990	83	29	92	5

TABLE C-9
(Page 2 of 2)

TCAS ID	Latitude	Longitude	Altitude (ft)	Densities 5 nmi	Densities 10 nmi	Densities 30 nmi	Whisper-Shout Levels Transmitted	TCAS II M/Mode S Int. Rate	TCAS II M/Mode S Int. Power[b]	TCAS II M/Mode S Power Reduction (dB)
30	.59591	2.07604	8502	.0382	.0414	.0368	83	5	332	0
31	.59920	2.08409	9500	.0127	.0064	.0110	83	1	285	0
32	.59374	2.07031	3655	.1910	.1241	.0828	83	16	120	2
33	.59486	2.07086	4996	.1783	.0859	.0764	83	10	186	1
34	.59925	2.07815	11002	.0000	.0127	.0301	83	13	239	0
35	.59256	2.06577	100	.3056	.1910	.1012	83	37	47	7
36	.59759	2.07349	4995	.0127	.0318	.0601	83	8	292	0
37	.60237	2.07633	21000	.0382	.0286	.0230	83	0	287	0
38	.59837	2.07026	7004	.0127	.0350	.0732	83	10	232	0
39	.60485	2.07389	7500	.0382	.0414	.0262	83	10	226	0
40	.59481	2.06520	3800	.1019	.1496	.0937	81	15	120	3
41	.60196	2.06948	24000	.0637	.0477	.0534	83	4	268	0
42	.60008	2.06780	23994	.0509	.0923	.0700	83	0	238	0
43	.59715	2.06445	2995	.2037	.1210	.0824	82	33	103	4
44	.59825	2.06440	6236	.2292	.1401	.0757	83	26	159	2
45	.59810	2.06408	689	.2292	.1210	.0775	83	26	75	5
46	.60105	2.06448	3994	.2037	.1210	.0584	83	13	245	0
47	.60146	2.06414	4292	.1401	.1050	.0523	83	34	281	0
48	.60122	2.06308	10498	.1146	.0955	.0492	83	28	255	0
49	.59894	2.06266	2806	.1273	.1273	.0707	83	16	228	0

[a] Assuming TCAS I emission power of 500 watts.

[b] Equivalent Isotropically Radiated Power (EIRP) on the horizon.

APPENDIX D

UPDATED INTERROGATOR ANALYSIS

INTRODUCTION

During FY-84, the FAA requested that ECAC compare the environment of ATCRBS interrogators located in the Los Angeles Basin area used in the analysis, to the actual operational environment of such emitters. This request was made because the fruit rates predicted by ECAC's computer simulation model were higher in comparison to those measured during a Lincoln Laboratory flight test (see Reference 12). As a possible source of the discrepancy between predicted and measured fruit rates, the location, status, and operational characteristics for each of the interrogator sites used in the current analysis was investigated. The results of this investigation were used to define an updated interrogator deployment. This updated interrogator deployment was limited to new data received before 15 May 1984.

A computer simulation using the updated interrogator deployment with Long Beach as the interrogator of interest (I_O) was performed to compare predicted fruit rates with the Lincoln Laboratory flight test measurements. In addition, the air traffic deployment C discussed in the body of this report was used for this simulation in order to approximate the aircraft density that was observed during the Lincoln Laboratory flight test.

Contained in this appendix are 1) the rationale used to determine the updated interrogator deployment and 2) the fruit rate predicted by the TCAS simulation model using the updated interrogator deployment.

Updated Interrogator Deployment

To investigate the location and operational characteristics for each of the various ATCRBS interrogator sites, data was compiled from various sources. The sources are:

1. Direct contacts with site personnel to obtain operational characteristics for that site.
2. Contacts with both DoD and FAA Western Area Frequency Coordinators.
3. Formal ECAC letters requesting operational characteristics from each interrogator site.
4. Government Master File (GMF) data file.

The GMF was found to be an accurate source of information relative to site location. The site contacts were essential in obtaining data not routinely found in the GMF but necessary for the analysis.

Once the data was compiled, two operational considerations were used to cull the environment. These considerations are:

1. Some DoD interrogator facilities are used for training exercises and operate infrequently with no fixed schedule. Due to the sporadic and unpredictable operating times of these facilities, they are not considered as part of the updated interrogator deployment. Other DoD interrogator training facilities that operate on a fixed schedule (e.g., 5 days per week, 8 hrs per day) are considered as part of the updated interrogator deployment.
2. Interrogator sites that are used for testing purposes by various private contractors are infrequently used and therefore not considered for the analysis. The operational time for these types of facilities is on the average of two hours per month.

Of the original 61 interrogator sites identified in the existing ECAC ATCRBS data base (see Section 2), 23 were found to be no longer operational, therefore not considered as part of the updated interrogator deployment. An additional 11 sites, although operational, were eliminated due to infrequent operating time. These 11 sites include 1) DoD training facilities operating sporadically with no fixed schedule, and 2) private contractors facilities used for equipment testing that operate on the average two hours per month. The survey also indicated that there were 8 new interrogator facilities within the Los Angeles region. The resulting 35 interrogator sites which constitute the updated deployment are:

Angel Peak	Laurel Mountain	Palm Springs
Bakersfield	Lemoore	Paso Rables
Boron	Long Beach	Point Mugu
Burbank	Los Alamitos	San Clemente
China Lake	Los Angeles (2)	San Nicolas (2)
Edwards	March	San Pedro
El Toro	Miramar	Santa Anna
Fremont Valley	Mount Laguna	Santa Barbara
George	North Island	Searles Valley
Imperial Beach	Norton	Vandenberg
Indian Wells	Ontario	Velvet Peak

Figure D-1 illustrates the location of these 35 sites.

In addition, the updated interrogator deployment also contains the new equipment characteristics obtained for each site. These characteristics include updated interrogator output power, Pulse Repetition Frequency (PRF), antenna gain and mode interlace.

Predicted TCAS Simulation Results

Using the updated interrogator deployment and aircraft deployment C, a computer simulation was conducted comparing simulation results with Lincoln Laboratory flight test data.

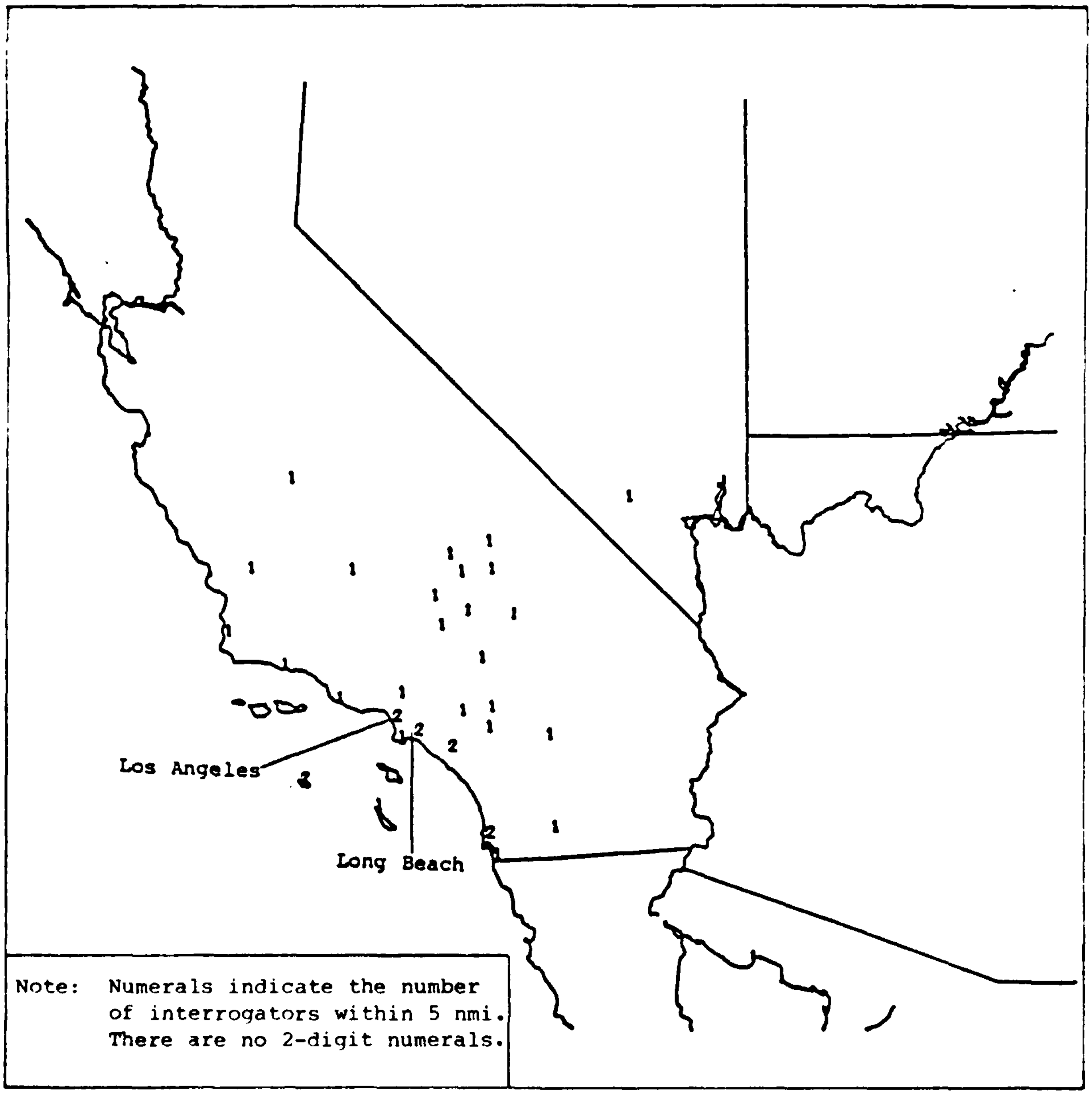
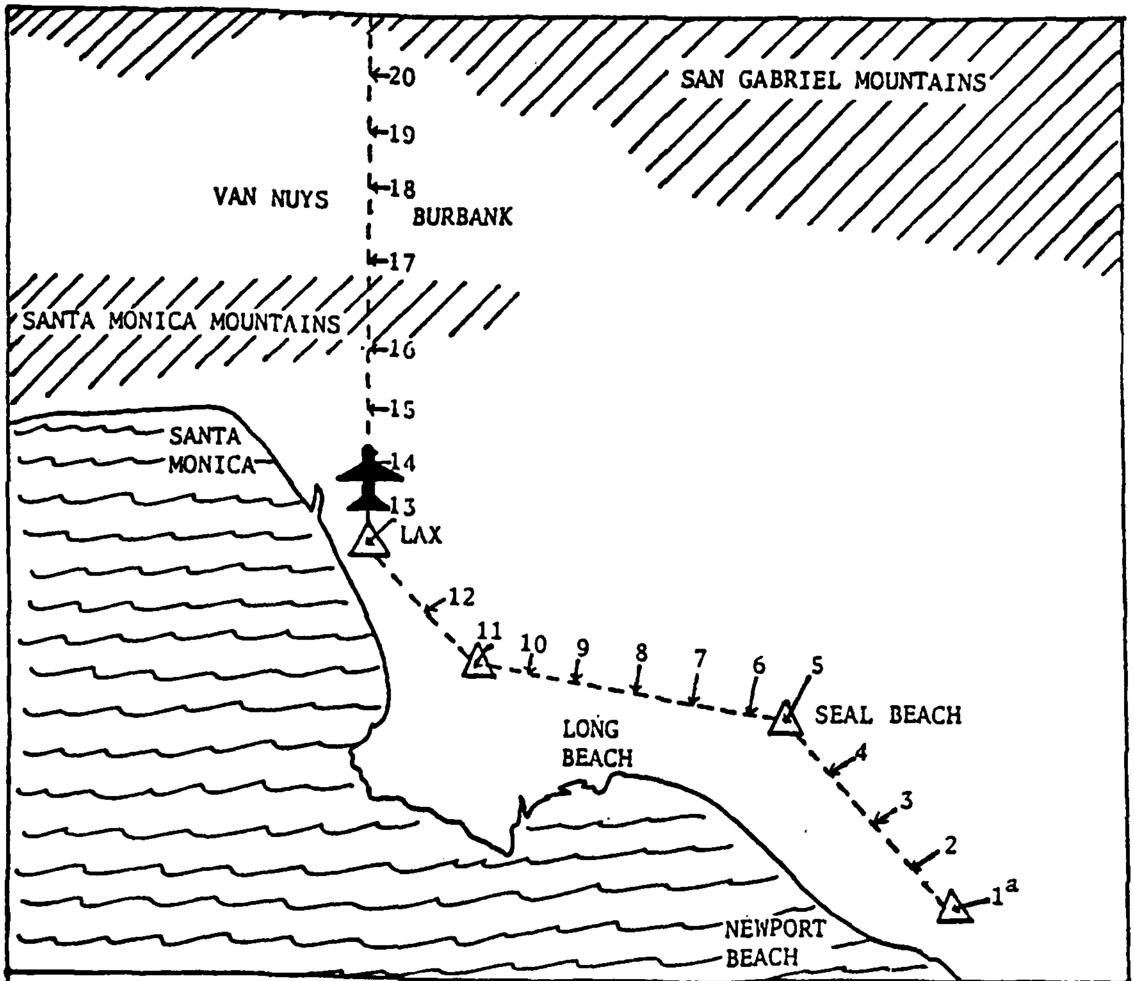


Figure D-1. Updated interrogator environment (35 ground interrogators).

The Lincoln Laboratory test flight, illustrated in Figure D-2, followed a path from Newport Beach to the San Gabriel Mountains. Fruit rates were measured along the flight path by a TCAS II M-equipped aircraft utilizing only the top antenna at altitudes of 5500 and 8500 feet with a nominal sensitivity of -77 dBm. Fruit rate data was available from Lincoln Laboratory only for the altitude of 5500 feet.

For the computer simulation, 20 data points were placed along the measurement flight path shown in Figure D-2. These simulation results are presented in Figure D-3. The average fruit rate predicted for the altitude of 5500 feet was 11466 per second. These predictions compare favorably with the Lincoln Laboratory's measured average fruit rate of 12,300 per second. This represents a difference of 7.2% between the predicted and measured data.



[a]Numbers indicate the test data points.

Figure D-2. Lincoln Laboratory flight test path.

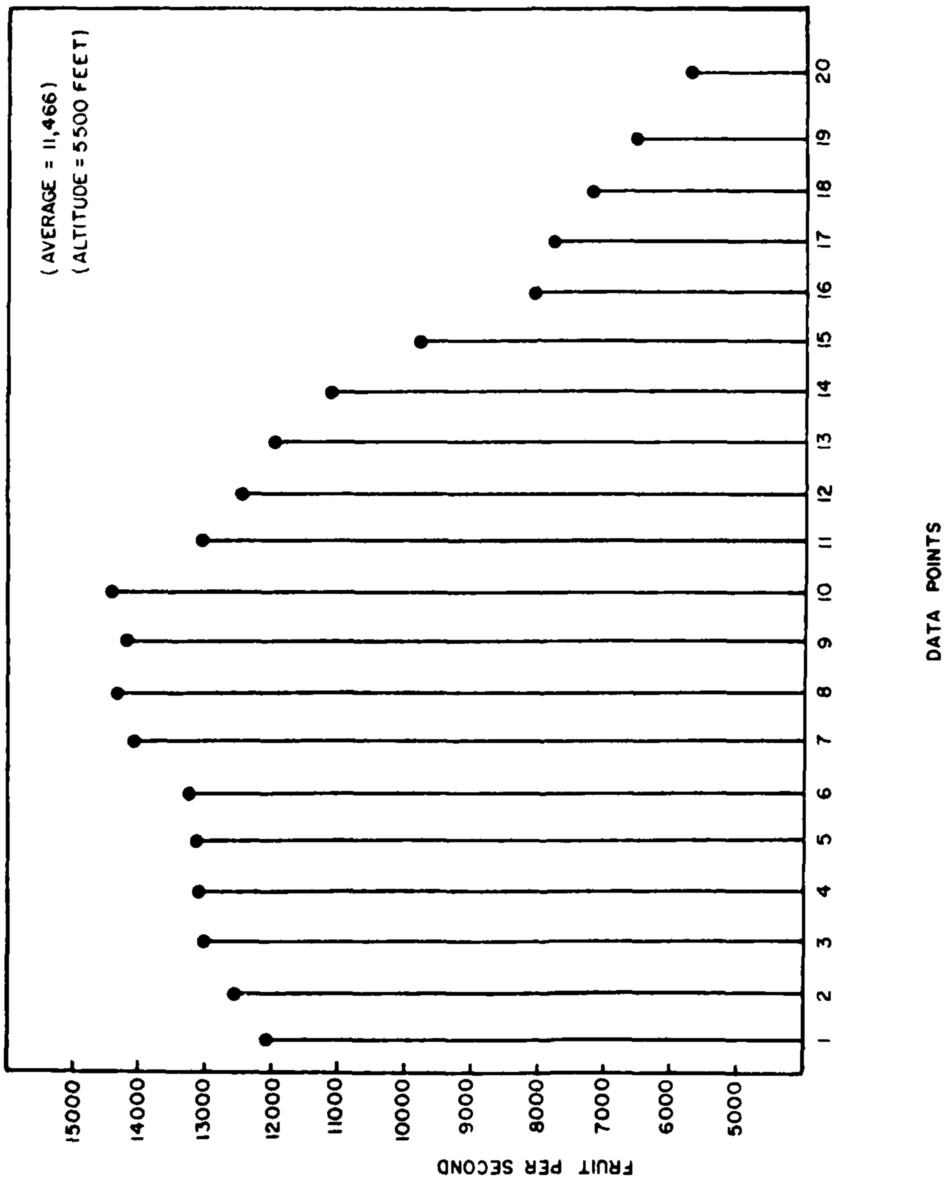


Figure D-3. Predicted fruit rate at the data points (see Figure D-2) along Lincoln Laboratory's flight test path.

APPENDIX E
ARTS III TRACKER RESULTS

The following Figures E-1 through E-11 present the ARTS III tracker results for transponder deployments A, B, B_3 and C both with and without TCAS II M operating and with the combined TCAS I and TCAS II M operating. Each figure graphically illustrates for each scan (1-10) the number of aircraft in each track firmness state. The two tables are included as examples to show the relationship between actual numbers and graphical representation. TABLES E-1 and E-2 correspond to Figures E-1 and E-2 respectively.

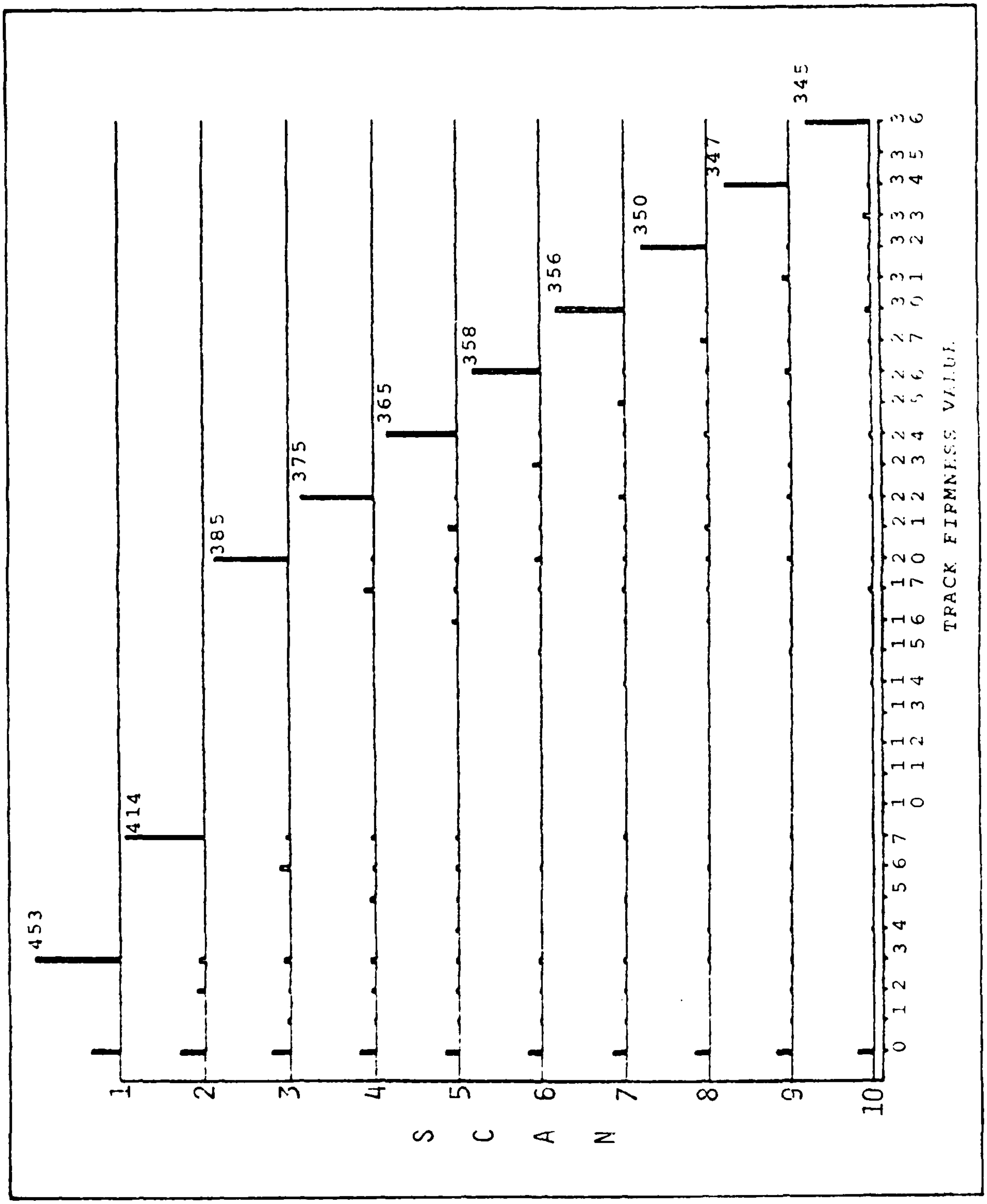


Figure E-1. ARTS III Tracker results for Long Beach simulations - Deployment A (without TCAS II M).

TABLE E-1

ARTS III TRACKER RESULTS FOR LONG BEACH SIMULATIONS - DEPLOYMENT A (WITHOUT TCAS II M)

NUMBER OF AIRCRAFT FOR EACH TRACK FIRMNESS VALUE

SCAN	TRACK FIRMNESS VALUE 0	1	2	3	4	5	6	7	10	11	12	13	14	15	16	17	20	21	22	23	24	25	26	27	30	31	32	33	34	35	36	37
1	153	0	0	453	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	125	0	39	28	0	0	0	414	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	94	14	9	32	0	0	54	19	0	0	0	0	0	0	0	0	385	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	80	4	17	23	0	26	11	15	0	0	0	0	0	0	0	43	13	0	375	0	0	0	0	0	0	0	0	0	0	0	0	0
5	72	9	10	12	14	5	11	13	0	0	0	0	0	0	23	10	12	42	9	0	365	0	0	0	0	0	0	0	0	0	0	0
6	75	10	8	17	3	4	6	4	0	0	0	0	0	11	3	11	33	8	9	39	9	0	358	0	0	0	0	0	0	0	0	0
7	72	6	7	12	2	8	2	10	0	0	0	0	6	1	6	14	10	8	33	5	8	33	8	0	356	0	0	0	0	0	0	0
8	77	4	4	6	5	3	5	8	0	0	0	0	1	0	10	6	14	22	5	0	21	5	8	36	8	0	350	0	0	0	0	0
9	81	2	3	7	2	4	4	3	0	0	0	0	0	6	4	1	24	3	15	10	5	8	25	4	7	32	5	0	347	0	0	0
10	82	2	2	3	4	2	1	5	0	0	0	0	5	4	0	17	4	2	15	3	16	9	4	7	25	5	7	38	7	0	345	0

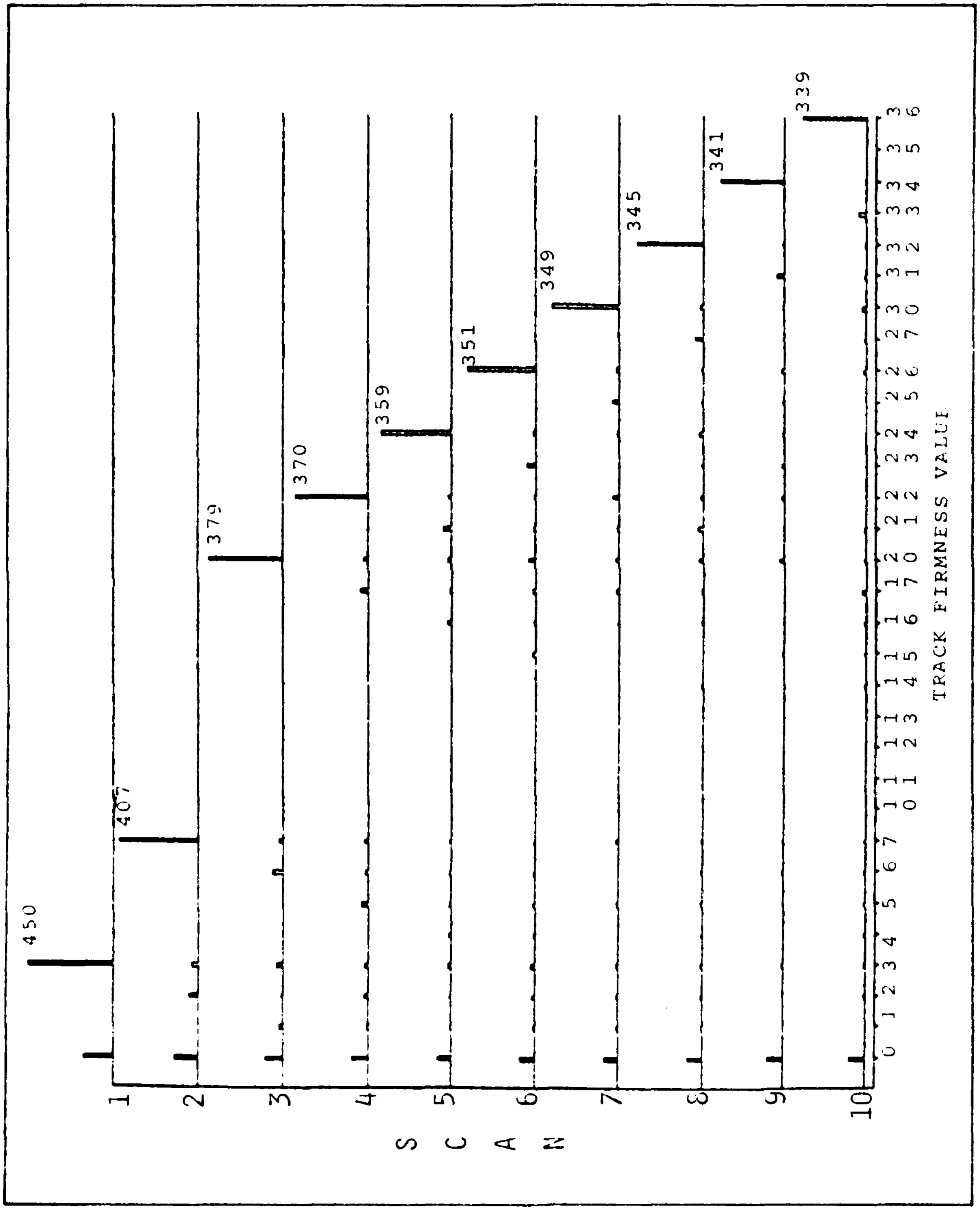


Figure E-2. ARTS III Tracker results for Long Beach simulations - Deployment A (with TCAS II M).

TABLE E-2

ARTS III TRACKER RESULTS FOR LONG BEACH SIMULATIONS - DEPLOYMENT A (WITH TCAS II M)

	TRACK FIRMNESS VALUE																														
	0	1	2	3	4	5	6	7	10	11	12	13	14	15	16	17	20	21	22	23	24	25	26	27	30	31	32	33	34	35	36	37
SCAN	NUMBER OF AIRCRAFT FOR EACH TRACK FIRMNESS VALUE																															
1	156	0	0	450	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	123	0	43	33	0	0	0	407	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	92	20	10	32	0	0	51	23	0	0	0	0	0	0	0	0	379	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0
4	84	4	16	19	0	29	13	16	0	0	0	0	0	0	0	40	16	8	370	0	0	0	0	0	0	0	0	0	0	0	0	0
5	73	9	8	15	16	6	11	11	0	0	0	0	0	0	21	11	12	43	12	0	359	0	0	0	0	0	0	0	0	0	0	0
6	76	8	9	17	3	5	5	6	0	0	0	0	0	11	5	11	31	8	8	42	12	0	351	3	0	0	0	0	0	0	0	0
7	74	6	5	9	3	8	4	12	0	0	0	0	4	2	5	15	13	9	32	3	6	35	12	0	349	0	9	0	0	0	0	0
8	78	3	4	5	6	4	5	5	0	0	0	0	2	1	8	6	17	24	9	7	20	4	5	35	11	0	345	3	0	0	0	0
9	82	1	0	7	3	4	5	5	0	0	0	0	1	6	4	4	20	3	15	14	10	7	17	3	5	37	11	0	341	3	0	0
10	83	0	2	2	4	2	2	5	0	0	0	0	4	5	2	19	4	5	11	4	14	11	9	6	20	4	3	34	10	0	339	0

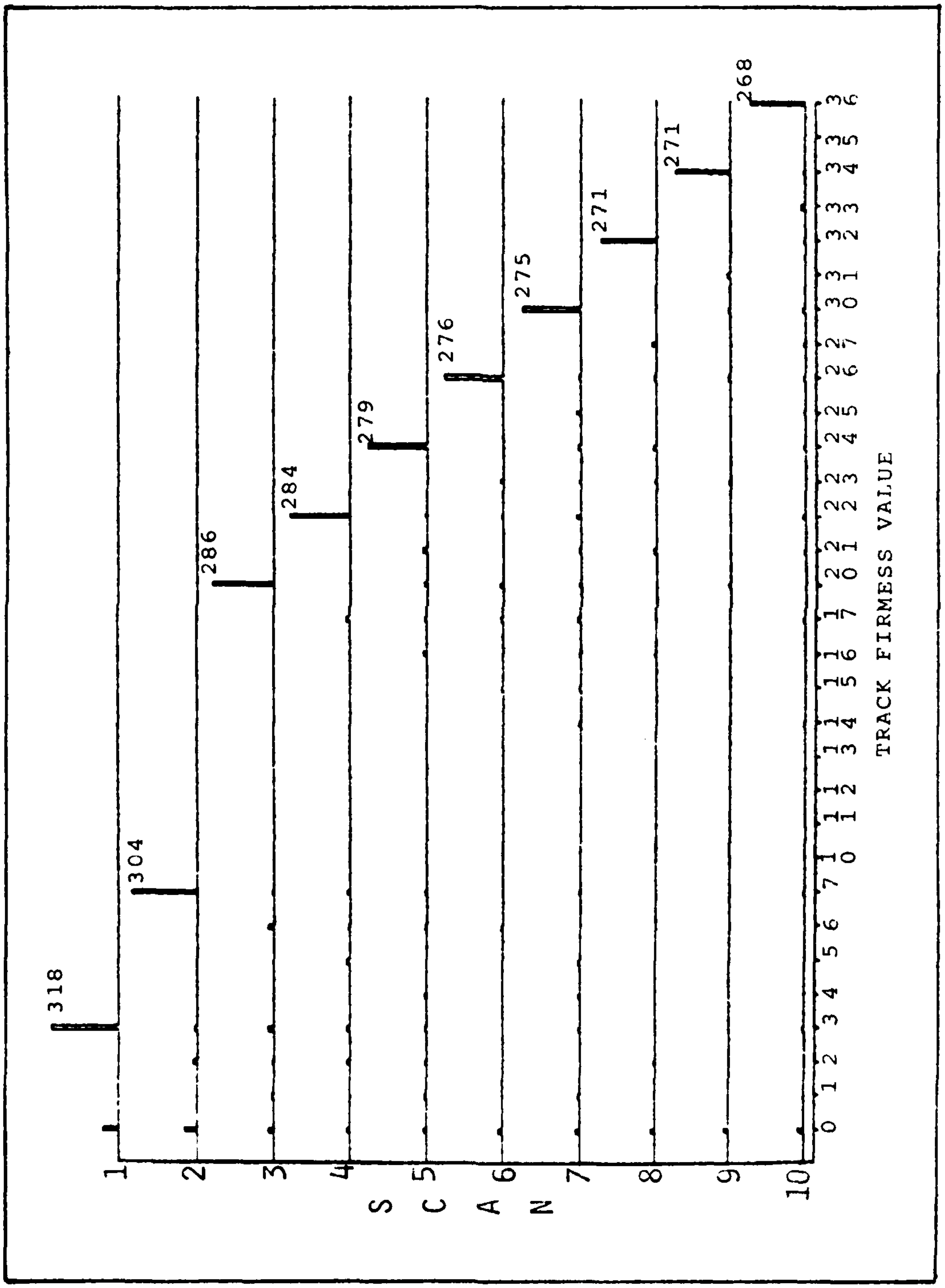


Figure E-3. ARTS III Tracker results for Long Beach simulations - Deployment B (without TCAS II M).

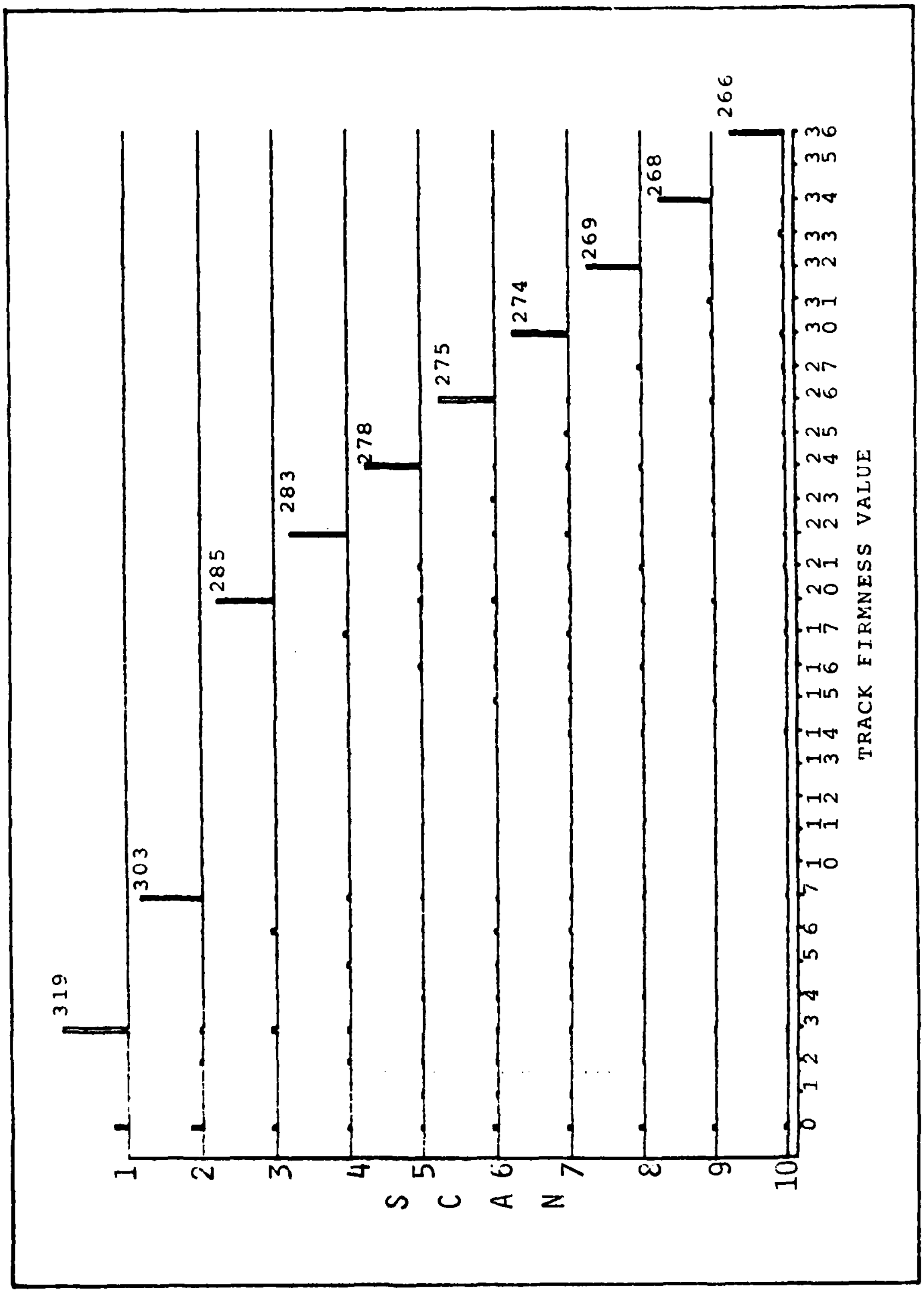


Figure E-4. ARTS III Tracker results for Long Beach simulations - Deployment B (with TCAS II M).

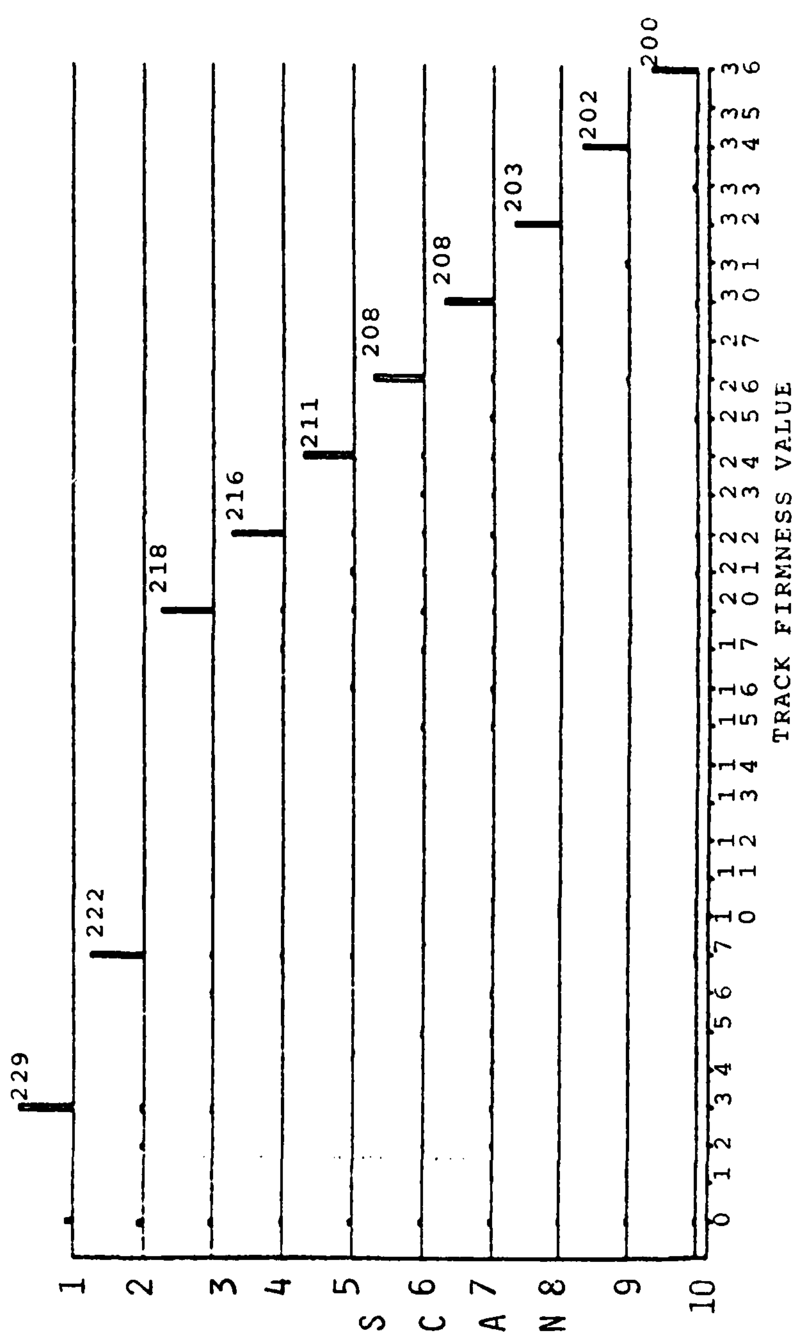


Figure E-5. ARTS III Tracker results for Long Beach simulations - Deployment C (without TCAS II M).

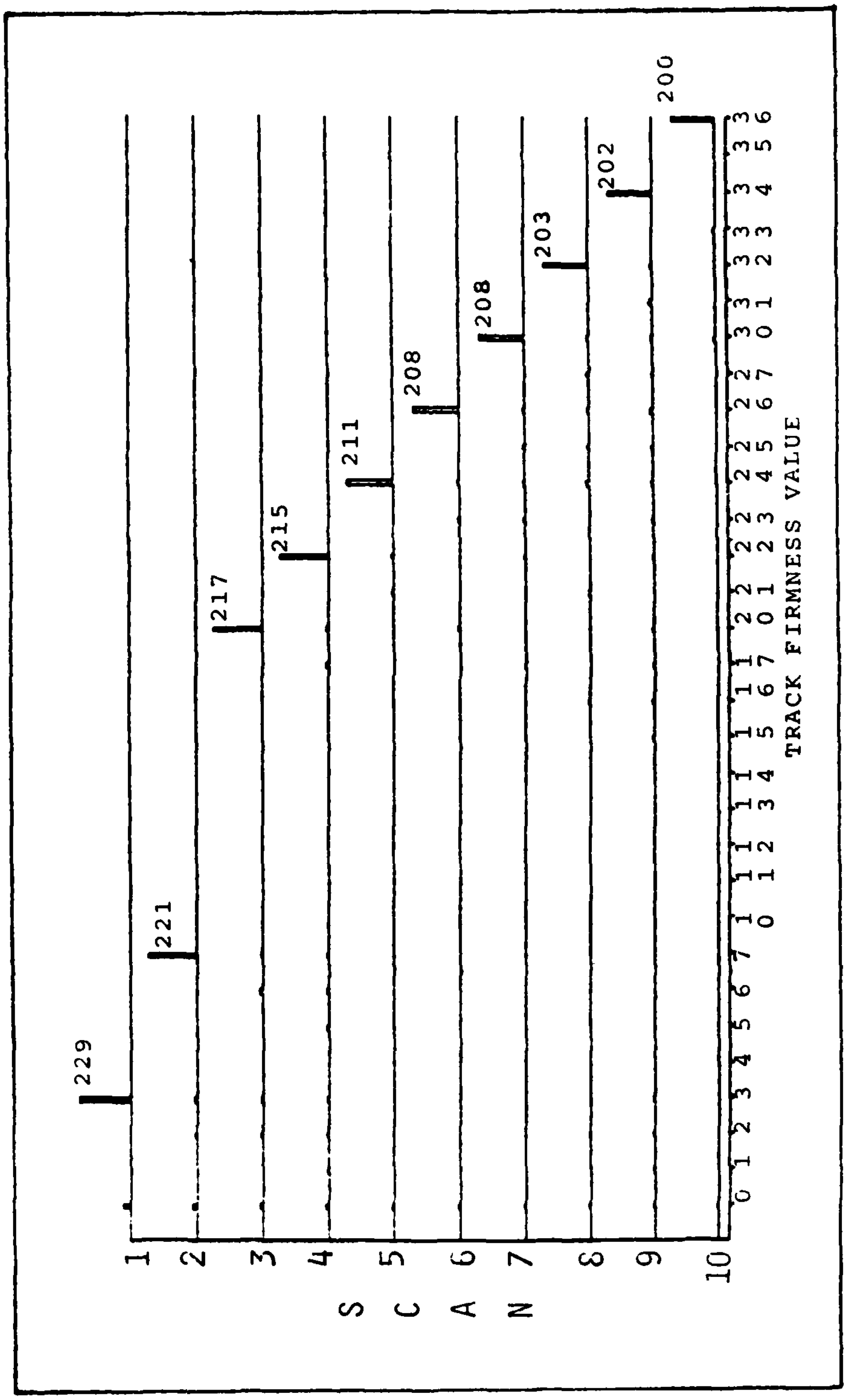


Figure E-6. ARTS III Tracker results for Long Beach simulations - Deployment C (with TCAS II M).

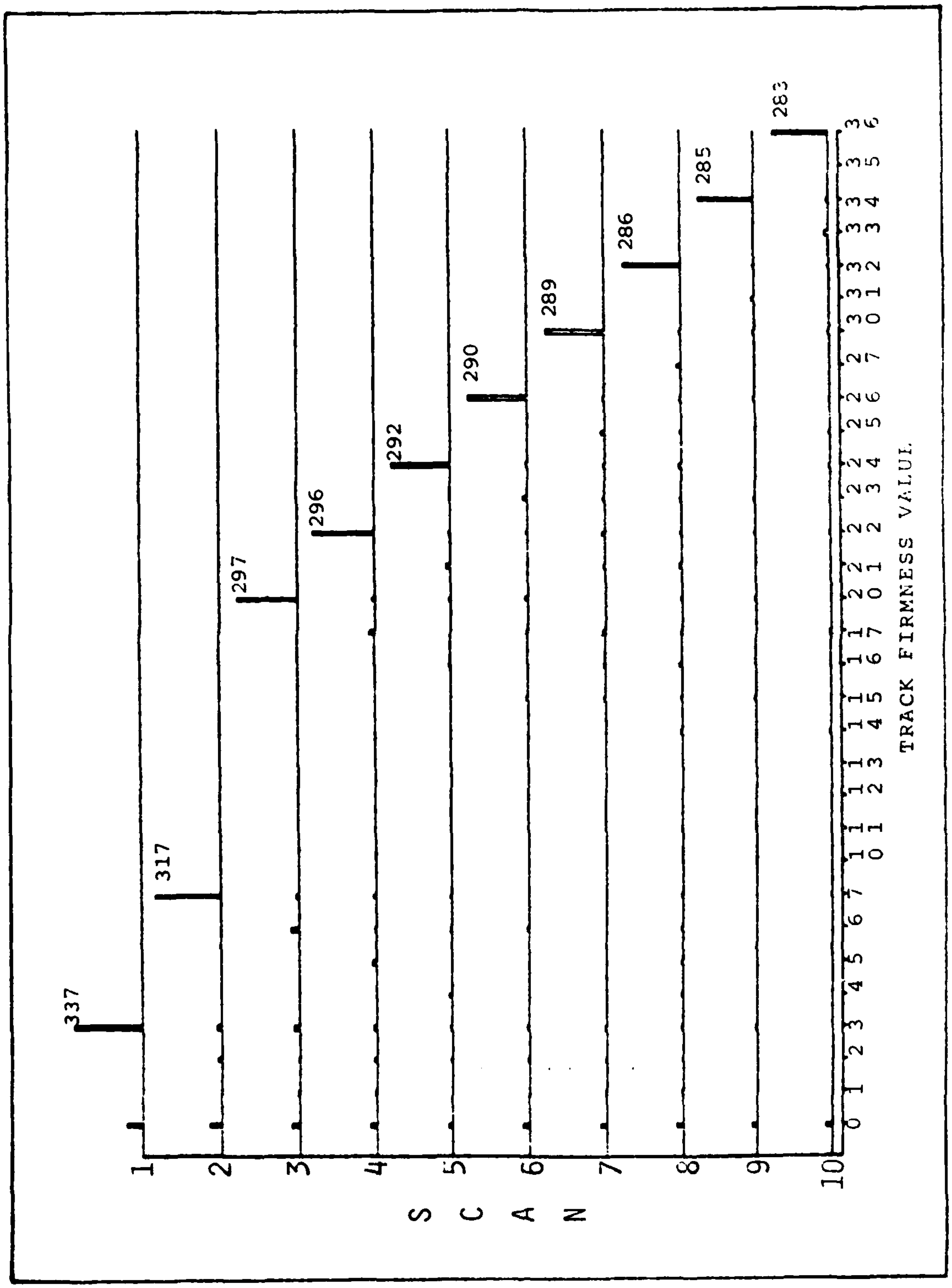


Figure E-7. ARTS III Tracker results for Long Beach simulations - Deployment B3 (without TCAS II M, without TCAS I).

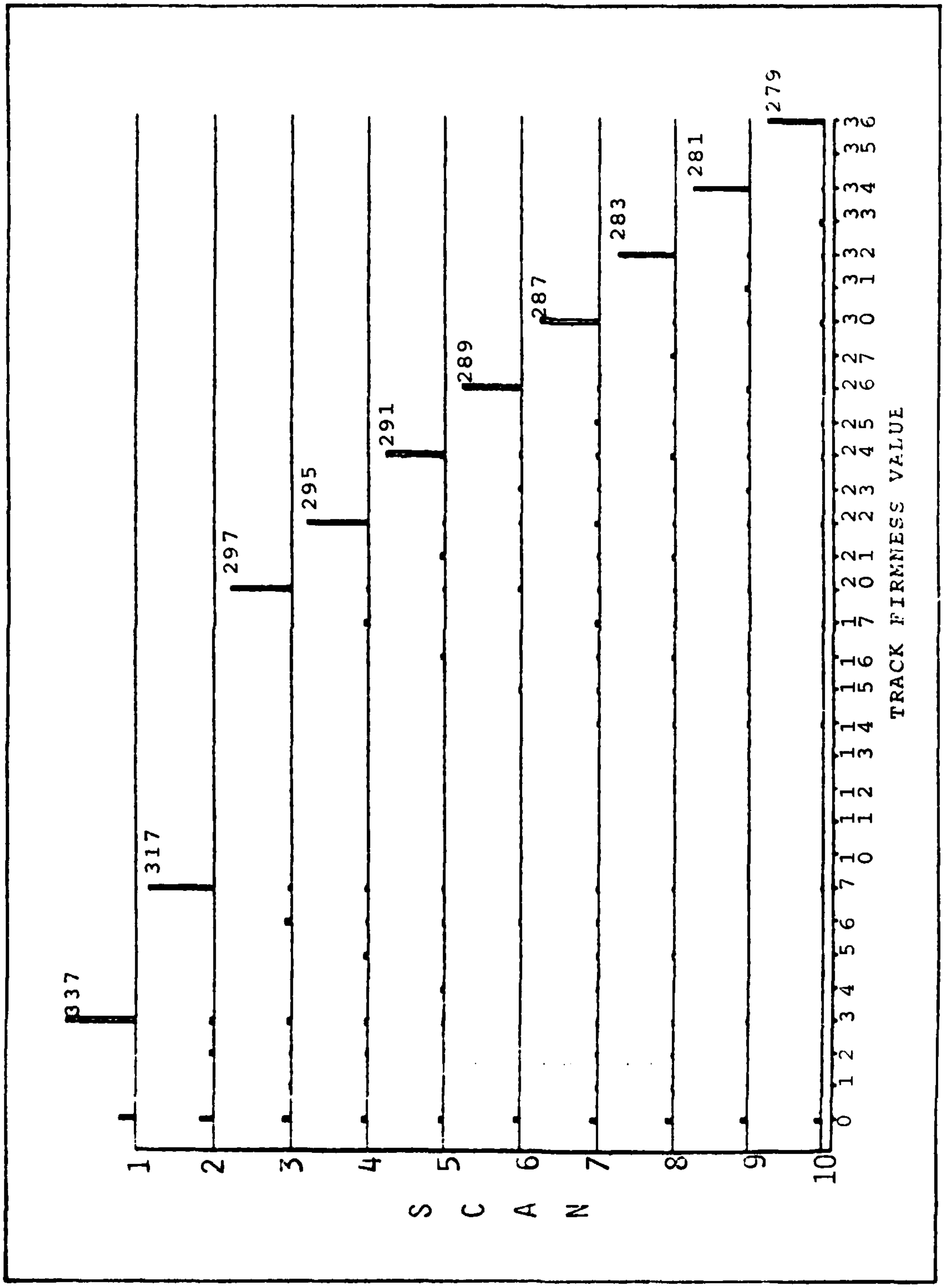


Figure E-8. ARTS III Tracker results for Long Beach simulations - Deployment B3 (with TCAS II M, without TCAS I).

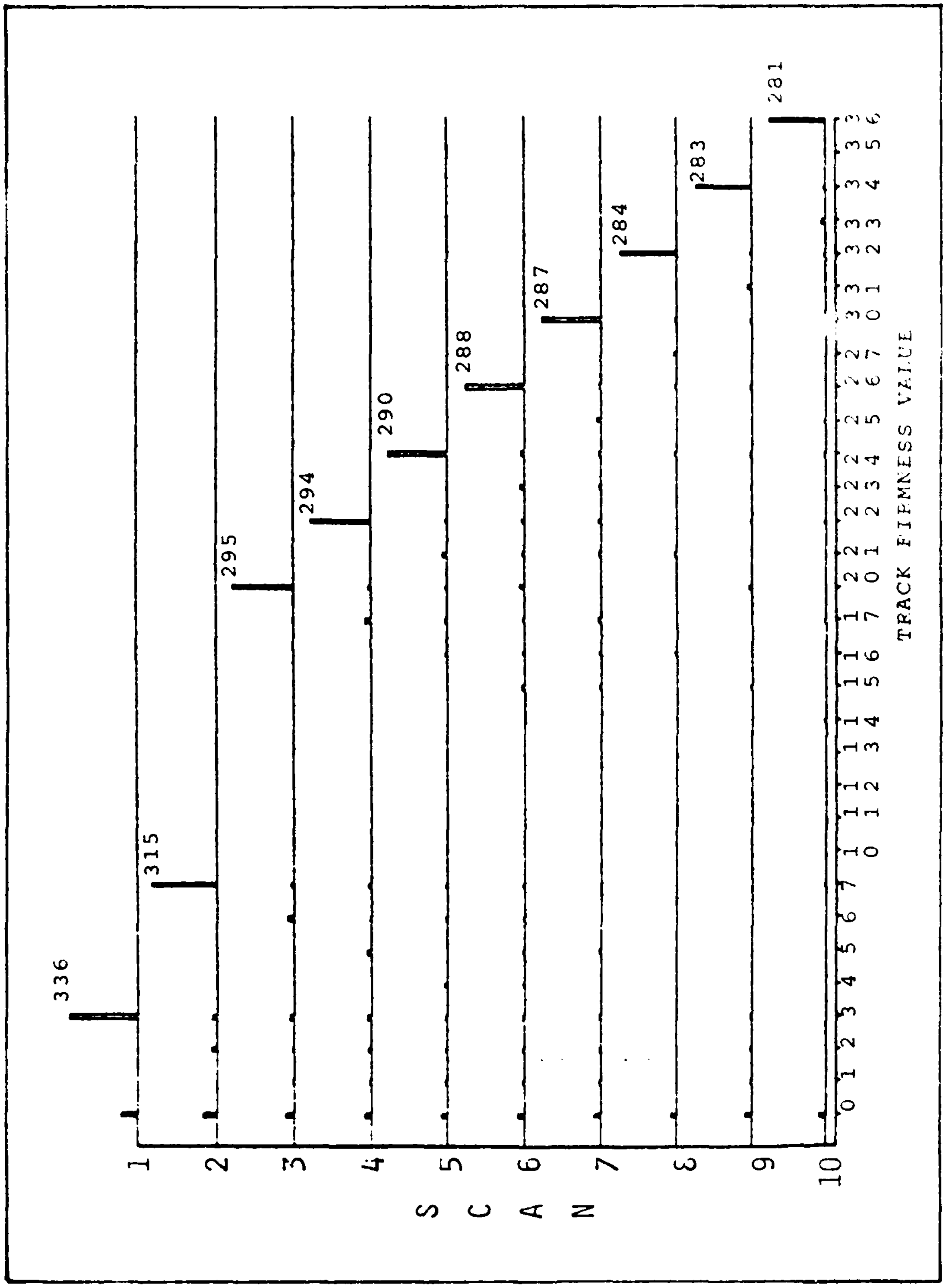


Figure E-9. ARTS III Tracker results for Long Beach simulations - Deployment B3 (with TCAS II M, with TCAS I at 20 watts).

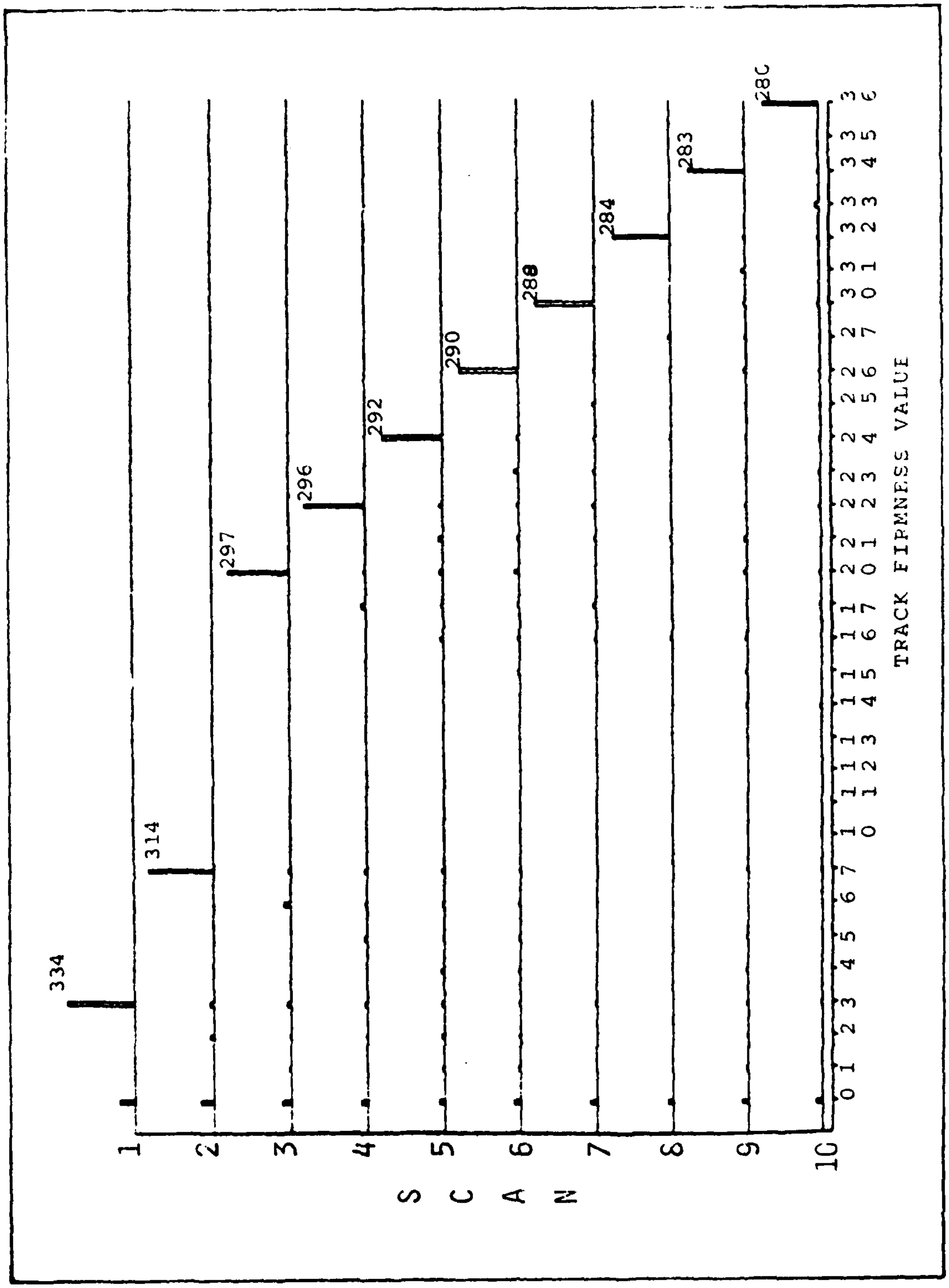


Figure E-10. ARTS III Tracker results for Long Beach simulations - Deployment B3 (with TCAS II M, with TCAS I at 120 watts).

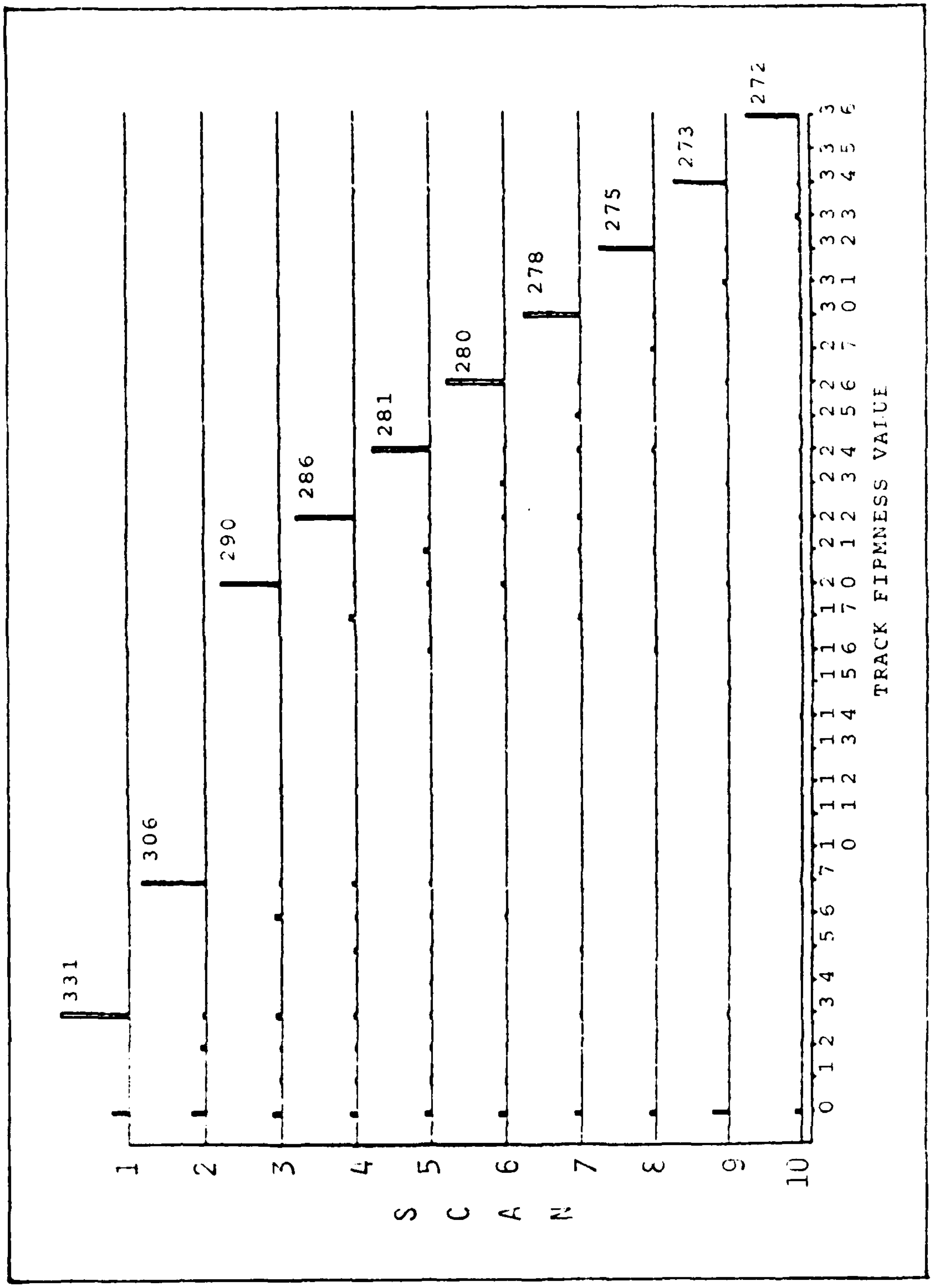


Figure E-11. ARTS III Tracker results for Long Beach simulations - Deployment B3 (with TCAS II M, with TCAS I at 500 watts).

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