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LEVEL II

THE DISCRETE ADDRESS BEACON SYSTEM/ AIR TRAFFIC CONTROL RADAR BEACON SYSTEM/ATCRBS IFF MARK XII SYSTEM PERFORMANCE PREDICTION MODEL

IIT Research Institute
Under Contract to
DEPARTMENT OF DEFENSE
Electromagnetic Compatibility Analysis Center
Annapolis, Maryland 21402

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16. Abstract

A description is given for a Discrete Address Beacon System (DABS)/Air Traffic Control Radar Beacon System (ATCRBS)/ATCRBS IFF MARK XII System (AIMS) Performance Prediction Model. In a given environment of DABS, ATCRBS, and AIMS sensors and transponders, the computer model predicts the intra- and inter-system interference that arises within this mixed secondary-surveillance radar system.

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METRIC CONVERSION FACTORS

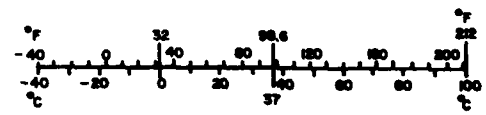
Approximate Conversions to Metric Measures

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

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

Approximate Conversions from Metric Measures

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



PREFACE

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 ITT Research Institute (IITRI).

This report was prepared for the Systems Research and Development Service of the Federal Aviation Administration in accordance with Interagency Agreement DOT-FA70WA1-175, as part of AF Project 649E under Contract F-19628-78-C-0006, 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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FAA-RD-79- 88

FEDERAL AVIATION ADMINISTRATION
SYSTEMS RESEARCH AND DEVELOPMENT SERVICE
SPECTRUM MANAGEMENT STAFF

STATEMENT OF MISSION

The mission of the Spectrum Management Staff is to assist the Department of State, Office of Telecommunications Policy, and the Federal Communications Commission in assuring the FAA's and the nation's aviation interests with sufficient protected electromagnetic telecommunications resources throughout the world to provide for the safe conduct of aeronautical flight by fostering effective and efficient use of a natural resource--the electromagnetic radio-frequency spectrum.

This objective is achieved through the following services:

- Planning and defending the acquisition and retention of sufficient radio-frequency spectrum to support the aeronautical interests of the nation, at home and abroad, and spectrum standardization for the world's aviation community.

- Providing research, analysis, engineering, and evaluation in the development of spectrum related policy, planning, standards, criteria, measurement equipment, and measurement techniques.

- Conducting electromagnetic compatibility analyses to determine intra/inter-system viability and design parameters, to assure certification of adequate spectrum to support system operational use and projected growth patterns, to defend the aeronautical services spectrum from encroachment by others, and to provide for the efficient use of the aeronautical spectrum.

- Developing automated frequency-selection computer programs/routines to provide frequency planning, frequency assignment, and spectrum analysis capabilities in the spectrum supporting the National Airspace System.

- Providing spectrum management consultation, assistance, and guidance to all aviation interests, users, and providers of equipment and services, both national and international.

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EXECUTIVE SUMMARY

The Discrete Address Beacon System (DABS) is to be gradually phased into the existing Air Traffic Control Radar Beacon System (ATCRBS) in the 1980's. The DABS selective address feature is designed to alleviate the ATCRBS problems of over-interrogation and synchronous garble. The FAA requested that the Electromagnetic Compatibility Analysis Center (ECAC) develop a computer model with the capability to predict mutual interference arising in a mixed secondary-surveillance radar environment.

The nature of the DABS interrogation schedule required that the model be a time-event store simulation. The model inputs are selected from the ECAC data base and consist of the characteristics of a ground and air deployment of sensors and transponders. Detailed characteristics of a sensor-of-interest (S_o) are among the inputs.

The model output is primarily a record of the events that were predicted to occur during a simulation period. The performance of each transponder is described by its reply history during the time in which the equipped aircraft is in the S_o mainbeam. The fruit rate at the S_o is predicted, and the performance of the subject sensor is represented by the results of DABS transactions and ATCRBS target evaluations. Other summary outputs are available from the model, including interrogation rates, sidelobe suppression rates, and the identity of equipments that cause observable interference.

EXECUTIVE SUMMARY (Continued)

The model is described by a general flow chart, flow charts of major submodels, lists of input and output variables, and accompanying discussions.

The model user's guide describes S_o input parameters, model outputs, applicable environmental scenarios, and modeling assumptions.

A description of the modeling of the components of the AIMS mode 4 will be published later in an APPENDIX B to this report.

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GLOSSARY

AIMS	ATCRBS IFF MARK XII System
A/C	Aircraft
ATC	Air Traffic Control
ATCRBS	Air Traffic Control Radar Beacon System
BCAS	Beacon Collision Avoidance System
DABS	Discrete Address Beacon System
Fruit	ATCRBS or DABS replies received by an interrogator that were elicited by other interrogators.
I_o	Interrogator-of-interest
PPM	Performance Prediction Model
PRF	Pulse Repetition Frequency
SLS	Sidelobe suppression
S_o	Sensor-of-interest
STC	Sensitivity time control
Submodel	A group of subroutines that simulate a portion of the system.
Subroutine	A set of FORTRAN statements that perform a function of a submodel.

SECTION 1
INTRODUCTION

BACKGROUND

The Discrete Address Beacon System (DABS), which is an evolutionary upgrading of the Air Traffic Control Radar Beacon System (ATCRBS), is intended to cooperate with and eventually to replace the ATCRBS in the performance of Air Traffic Control (ATC) surveillance and data acquisition functions. The DABS is to be gradually phased in during the 1980's as part of the FAA ATC system.

The ATCRBS is presently used by the FAA as the primary means of surveillance for ATC. The continuous-interrogation feature of the ATCRBS gives rise to an excessive number of unwanted replies in dense regions of cooperating aircraft (A/C). In addition, overlapping replies from closely spaced A/C (synchronous garble) occur in these dense A/C environments. Given the projected increase in transponder-equipped A/C, the occurrence of intrasystem interference can be expected to increase.

The use of a selective-address ATC system is designed to alleviate these problems. The capability of selectively interrogating DABS-equipped A/C coupled with limited interrogations of ATCRBS-equipped A/C (enabled by monopulse) will allow a reduction in the total number of transmitted interrogations and, consequently, in the fruit rate at ground system. Also, discretely addressed interrogations will not elicit overlapping responses from closely spaced A/C because a DABS reply will only be generated by the A/C to which the interrogation is addressed.

It is important that the transition to DABS be made while services are continuing to be provided to ATCRBS-equipped A/C and while interference to the existing ATCRBS is being minimized. In addition, during the transition period DABS must be able to operate successfully in an ATCRBS interference environment. As a result, the FAA tasked ECAC to develop a DABS/ATCRBS/ATCRBS

IFF Mark XII System (AIMS) Performance Prediction Model (DABS/ATCRBS/AIMS/PPM) that would enable an evaluation of the mutual interference arising from the various system interactions.

OBJECTIVE

The objective of this analysis was to develop a DABS/ATCRBS/AIMS Performance Prediction Model.

APPROACH

The initial step in developing the DABS PPM was to define a method for characterizing the different secondary radar processes. The interspersion of DABS transactions with ATCRBS reply-requests, combined with the aperiodic DABS interrogation schedule and considerations of computer resources, directed the model development effort to a time-event store simulation.

The model inputs were structured in a fashion similar to those used with other ECAC ATCRBS/IFF models.[1,2] An interrogator/sensor environment selected from ECAC data base files was used as input along with an A/C deployment consisting of ATCRBS- and DABS-equipped targets. The location and characteristics of each of these equipments established the scenario for each model exercise. Detailed characteristics of a selected sensor-of-interest (S_O) are also among the model inputs.

The simulation was built around the operation of a selected ATCRBS interrogator or DABS sensor. A simulation cycle is defined as the pulse repetition period for an ATCRBS interrogator-of-interest (I_O) or as the time between ATCRBS/DABS all-calls for a DABS S_O.

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[1] Sutton, S. J. and Ehler, C. W., "Application of Markov Chain Theory to the Modeling of IFF/SSR Systems," AGARD Conference Proceedings No. 159, NATO, November 1975.

[2] Theberge, Norman, Transient Effects Performance Prediction Model, FAA-RD-77-75, ECAC, Annapolis, MD, June 1976.

The simulation cycle starts with the construction of the signal environment at each transponder-equipped A/C as represented by the time-of-arrival and the structure of each signal received above transponder receiver sensitivity during the present cycle. Transponder operation was simulated based on the predicted signal environment and the characteristics of the subject transponder. The downlink signal environment at the S_o was characterized by arrival time, signal strength, and reply type. DABS and ATCRBS reply/target processors were modeled to represent the time-ordered DABS transaction and ATCRBS target-detection processes.

The simulation output is essentially a record of the occurrences of various events. These events include the predicted reply history of each transponder, the predicted synchronous and nonsynchronous reply arrival history at a selected sensor, and the results of victim processor-of-interest target transactions. Other outputs, including predicted interrogation and suppression rate breakdowns, are available from the model.

SECTION 2

DABS SYSTEM DESCRIPTION

GENERAL

This section describes the DABS[3] and its relationship with the ATCRBS. Descriptions of the ATCRBS are widely available (References 1 and 2, for example), and Reference 1 contains a description of the AIMS.

The Discrete Address Beacon System (DABS) will coexist with the present Air Traffic Control Radar Beacon System (ATCRBS) during the phase-in period. Because a large number of ATCRBS-only transponders and ATCRBS-only interrogators will continue for some time to be a part of the beacon environment, DABS sensors are designed to include an ATCRBS interrogation capability and DABS transponders are designed to include an ATCRBS reply capability. In this mixed secondary-radar system, DABS and ATCRBS transponders will have the capability to respond to DABS sensors or ATCRBS interrogators.

The fundamental difference between DABS and ATCRBS transactions is that DABS interrogations are encoded with the identification number of the A/C to which they are addressed. A DABS interrogation elicits a response from only the addressed DABS transponder; an ATCRBS interrogation elicits a response from all transponders capable of decoding the interrogation. The selective address procedure reduces the number of unwanted replies and eliminates synchronous garble. To discretely interrogate A/C, a DABS sensor maintains a target file containing the identity and position of all A/C in the sensor's coverage area.

In addition to the discrete address function, DABS provides an air-to-ground data link whereby messages concerning weather, ATC function, etc., can be encoded onto the uplink and downlink signals.

[3] DABS Functional Description, FAA-RD-80-41, Lincoln Laboratory, Lexington, MA, April 1980.

The principal DABS features include: a unique 24-bit address/parity field, range-ordered interrogations with adaptive reinterrogation, and monopulse azimuth determination. Tracks are established via all-call interrogation (no encoded address) or sensor-to-sensor data link. Another feature of the DABS is the lockout of DABS transponders to other interrogations once a transponder is on a sensor's roll call list.

The DABS sensor software will employ error detection and correction techniques to reconstruct a garbled address using the parity-check bits. The DABS transponder may detect errors but does not have error-correction capabilities.

DABS SENSOR CHANNEL MANAGEMENT

The DABS sensor intersperses interrogations of ATCRBS-equipped A/C with transactions with DABS-equipped A/C. The functions of interrogating ATCRBS-equipped A/C and acquiring DABS-equipped A/C are combined in the ATCRBS/DABS all-call interrogation.

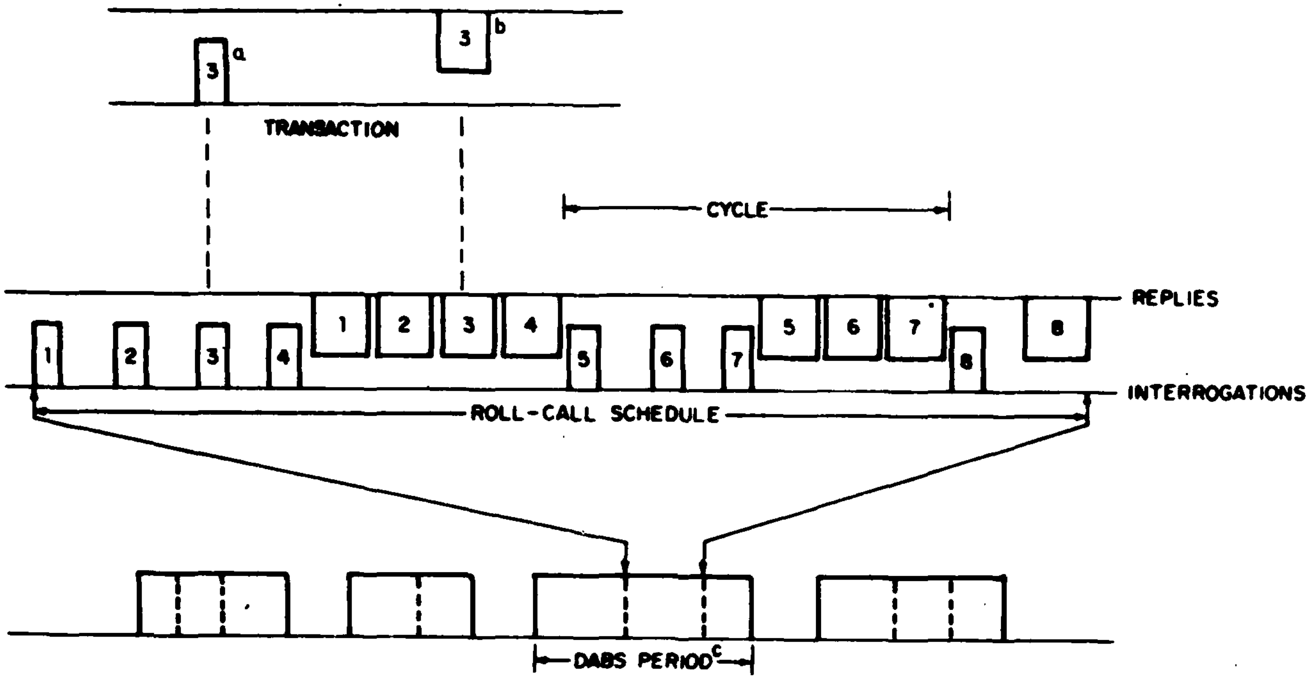
The use of monopulse direction-finding on ATCRBS replies permits operation at a reduced ATCRBS interrogation rate, nominally four ATCRBS/DABS all-call interrogations per mainbeam dwell. However, rates resulting in up to eight interrogations per mainbeam dwell can be employed. The interval between these interrogations, referred to as the DABS period, is reserved for DABS roll-call interrogations. For the period following each all-call interrogation, a check is performed of the active target list to determine what DABS A/C will be in the beam. DABS-equipped targets are acquired by a sensor either by all-call interrogation or by sensor-to-sensor data link. The system design allows DABS-equipped aircraft to be "locked out" from replying to ATCRBS/DABS all-call interrogations. All-call lockout is under the positive control of the DABS sensor and, if desired, its use can be limited to certain situations and to certain geographical regions of airspace.

The DABS-equipped A/C already acquired by the sensor are normally interrogated for surveillance purposes by the sensor mainbeam for each illumination of the A/C. DABS also provides for a re-interrogation feature whereupon those DABS-equipped A/C that do not reply after being interrogated can be reinterrogated at a higher power level. The A/C are interrogated in decreasing range order to avoid overlap of the interrogation and reply functions, and interrogations are scheduled in time so as to avoid overlapping replies. This series of interrogations and replies is called a roll-call schedule.

Figure 1 illustrates a sample group of interrogations and replies that occur during a hypothetical DABS period. The smaller subgroups of interrogations and replies are termed cycles. A single DABS roll-call interrogation coupled with the appropriate response is termed a roll-call transaction, as indicated by the transaction labeled '3" in the figure. New cycles occur (e.g., 5 through 7 in Figure 1) when the next scheduled interrogation would overlap the first reply of the present cycle. The various interrogation and reply lengths are taken into account when devising the roll-call schedule.

The typical DABS roll-call schedule is modified if it is desired to provide Extended Length Message (ELM) service to a mainbeam A/C on the active target list. The uplink ELM service consists of transmitting a series of comm-C roll-call interrogations (segments) to a specific A/C.[a] All but two of the segments are contained within a schedule precursor which precedes the main roll-call schedule. Precursor segments do not elicit replies and therefore may be scheduled arbitrarily provided that no less than 50 μs separate any two segments. This minimum spacing is imposed to assure resuppression of ATCRBS transponders, thus eliminating spurious responses initiated by the comm-C data-block. The precursor may consist of up to 30 segments with no more than 14 addressed to any one A/C. The remaining two comm-C segments, each of which

[a]Comm-C and other roll-call interrogation and reply formats are defined in the following subsection.



[a]DABS roll-call interrogation (see Figure 4).

[b]DABS roll-call reply (see Figure 5).

[c]This DABS period comprises three schedules. The second schedule includes eight transactions, grouped in three cycles of four, three, and one transactions, respectively.

Figure 1. DABS roll-call schedule.

elicits a comm-D reply, are scheduled in separate roll-call schedules (main and supplementary) following the precursor.[b] Figure 2 illustrates a hypothetical DABS roll-call schedule containing a precursor. Note that two A/C are addressed in the precursor and that each receives a different number of segments. The number of segments addressed to a particular A/C is a model input variable.

DABS INTERROGATIONS

DABS All-Call Interrogations

Two types of DABS interrogations are transmitted by a DABS sensor. The first, an ATCRBS/DABS all-call interrogation, is transmitted regularly and performs the functions of interrogating ATCRBS-equipped A/C and acquiring a track on DABS-equipped A/C that are not yet in the sensor's target file. Another form of all-call, the DABS-only all-call, is a special form of the DABS roll-call. It is expected to be infrequently used and, as a result, is not considered further. The ATCRBS/DABS all-call interrogation format is shown in Figure 3. When receiving an all-call interrogation, an ATCRBS transponder will recognize the first two pulses as the P_1 and P_3 pulses of an ATCRBS interrogation and will transmit the standard ATCRBS response, depending on the pulse spacing.

A DABS transponder will detect the P_4 pulse, located 2.0 μs after P_3, as an indication that an all-call response is requested. (DABS replies will be described later.) The standard ATCRBS P_2 sidelobe suppression (SLS) pulse will also be transmitted 2.0 μs after the P_1 pulse, and will result in both types of transponders being suppressed for approximately 35 μs when P_2 is stronger than P_1.[*]

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[b]Main and supplementary schedules are discussed in the subsection Roll-Call Scheduling.

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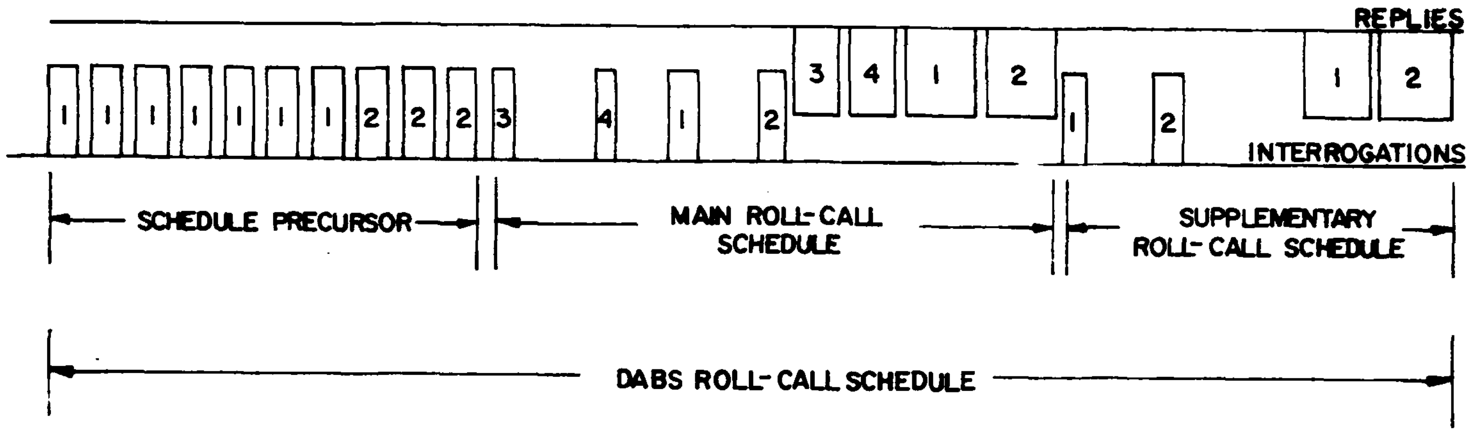
[*]U.S. National Aviation Standard for the Mark X (SIF) Air Traffic Control Radar Beacon System (ATCRBS) Characteristics, 1010.51A, DOT/FAA, March 1971.



NOTE: The precursor segments (comm-C) addressed to A/C 1 and 2 do not elicit replies. A/C 3 and 4 receive surveillance (short-19.75 μs) interrogations which elicit surveillance (short-64 μs) replies. The main and supplementary schedule comm-C (long 33.75 μs) interrogations addressed to A/C 1 and 2 elicit comm-D (long-120 μs) replies.

Figure 2. DABS roll-call schedule containing a precursor.

DABS Roll-Call Interrogations

The DABS roll-call interrogation format is shown in Figure 4. The roll-call interrogation is transmitted to all DABS-equipped A/C for which the sensor has already established a track. The P_1 pulse-P_2 pulse preamble acts as a pseudo-SLS for ATCRBS transponders and causes them to go into suppression time.

The remaining portion of the interrogation is a data block consisting of a single RF pulse (16.25 or 30.25 μs in length when an optional message is included). The data block modulation is differential-phase-shift keying at a data rate of 4 megabits per second (Mbps). The sync phase reversal located 4.75 μs after the leading edge of the P_1 pulse indicates to a DABS transponder that a data block with an encoded transponder address is to follow. If the transponder decodes its own address upon receiving a DABS roll-call interrogation, it will transmit a DABS reply. If another transponder's address is decoded, or if an error occurs in its own address, a DABS transponder will go into recovery time and will not transmit a reply. When a roll-call transaction is unsuccessful, reinterrogation is initiated in the next schedule at a higher power.

The SLS of DABS transponders is accomplished by transmitting a P_5 pulse on an SLS pattern at the same time as the sync phase reversal. If the received P_5 pulse amplitude exceeds that of the data block, the DABS transponder will not detect the sync phase reversal, and thus will not attempt to decode the remainder of the data block.

DABS REPLY

Figure 5 shows the signal format for a DABS reply. The preamble consists of four 0.5 μs pulses. The data block is either 56 or 112 μs depending on the amount of information transmitted and is pulse-position modulated (PPM). Data is transmitted at the rate of 1 Mbps. A similar reply format is generated in response to all-call and roll-call interrogations. A pulse in the first half

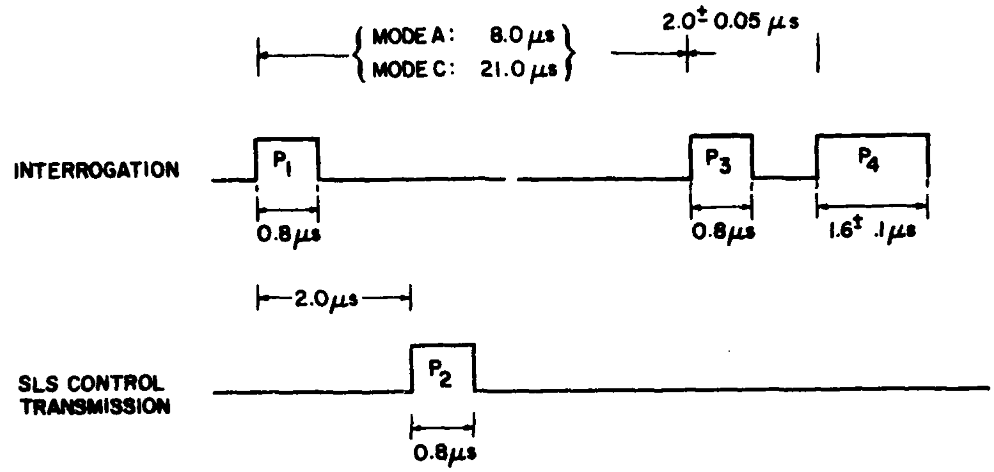


Figure 3. ATCRBS/DABS all-call interrogation format.

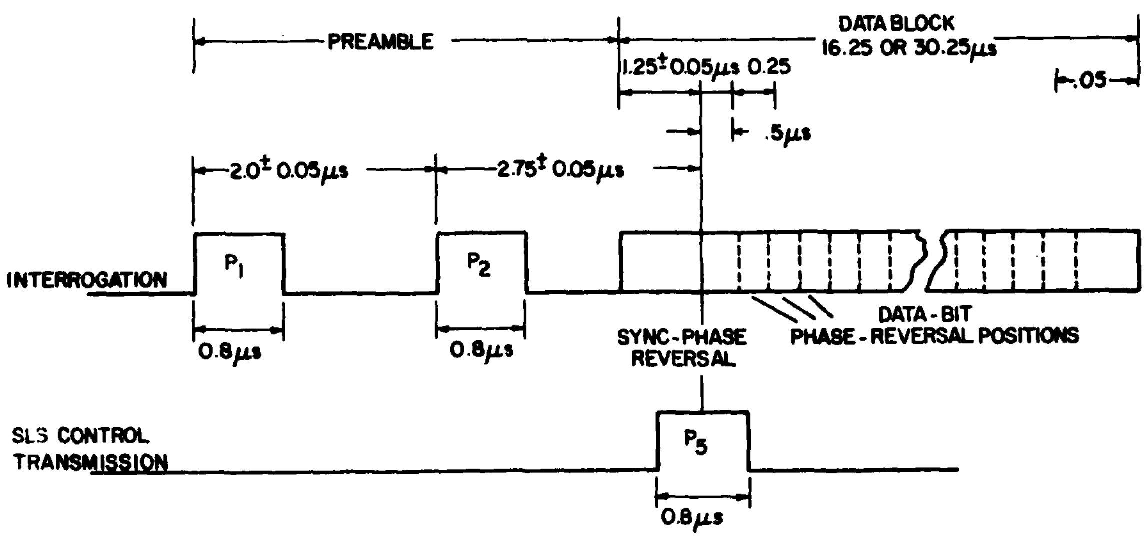


Figure 4. DABS interrogation format.

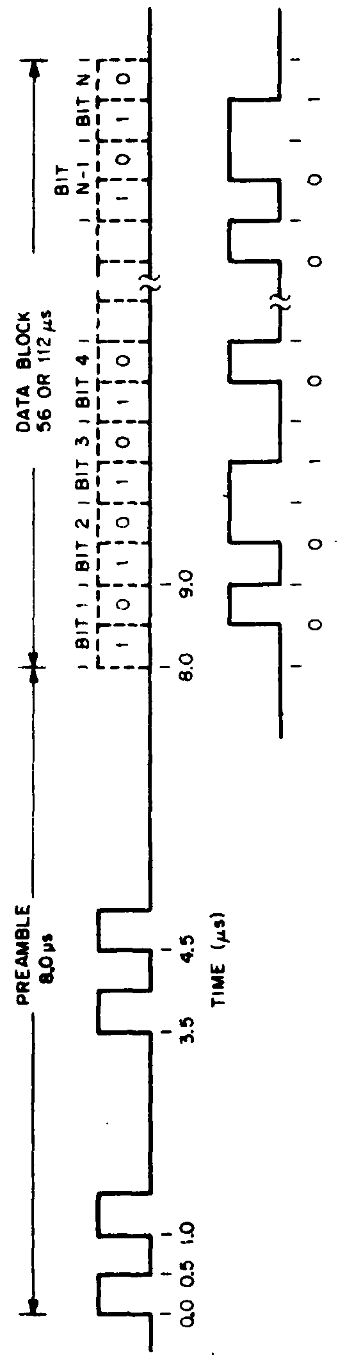


Figure 5. Signal format for a DABS reply.

of a bit interval corresponds to a 1, while a pulse in the second half of an interval is recognized as 0.

The data block format is, in general, the same for interrogations and replies. The standard format consists of the following fields:

1. Link control field identifies the type of transmission, controls transponder lockout and data link transmissions, and contains message acknowledgements (16 bits),

2. Standard message field (optional) contains the data link message text (56 bits),

3. Address/parity field contains the 24-bit unique address code summed modulo-2 with 24 parity check bits that are generated from the 3 previous information fields (24 bits).

The parity check bits are generated by an arithmetic operation on the information field by the bit sequence corresponding to an encoding polynomial.

If an error occurs in an uplink transmission, the DABS transponder will not respond because the interrogation does not appear to be addressed to it. If an error occurs in a downlink transmission, the sensor can perform a limited amount of error-correction. Downlink error-correction potential is maximized for errors spanning no more than 24 contiguous bits.

In addition to the data block formats discussed above, other formats have been defined for special functions; e.g., DABS-only, all-call, and extended length messages. For reference, the complete set of DABS data-block formats is illustrated in Figures 6a and 6b.

DABS SENSOR ANTENNA

The DABS sensor antennas generate a sum and difference pattern and a separate pattern for radiating the SLS control pulses. The sum and difference

Format No.	UF	Description
0	(0 0000)(AQ:1)(BI:26)(AP:24).	Short Special Surveillance
1	(0 0001)--------------27------------(AP:24)	
2	(0 0010)(EP:8)-------19------------(AP:24).	Short Synchr. Surveillance
3	(0 0011)--------------27------------(AP:24)	
4	(0 0100)(PC:3)(RR:5)(DI:3)(SD:16)(AP:24).	Surveillance, Altitude
5	(0 0101)(PC:3)(RR:5)(DI:3)(SD:16)(AP:24).	Surveillance, Identity
6	(0 0110)--------------27------------(AP:24).	Ground-Air Coordination
7	(0 0111)--------------27------------(AP:24)	
8	(0 1000)--------------27------------(AP:24)	
9	(0 1001)--------------27------------(AP:24)	
10	(0 1010)--------------27------------(AP:24)	
11	(0 1011)(PR:4)(II:4)(--19 one's--)(AP:24).	DABS-Only All-Call
12	(0 1100)--------------27------------(AP:24)	
13	(0 1101)--------------27------------(AP:24)	
14	(0 1110)--------------27------------(AP:24)	
15	(0 1111)--------------27------------(AP:24)	
16	(1 0000)(AQ:1)(BI:26)(MU:56)(AP:24). .	Long Special Surveillance
17	(1 0001)--------------83-------------------(AP:24)	
18	(1 0010)(EP:8)-------19------------(MS:56)(AP:24). .	Long Synchr. Surveillance
19	(1 0011)--------------83-------------------(AP:24)	
20	(1 0100)(PC:3)(RR:5)(DI:3)(SD:16)(MA:56)(AP:24). .	Comm-A, Altitude
21	(1 0101)(PC:3)(RR:5)(DI:3)(SD:16)(MA:56)(AP:24). .	Comm-A, Identity
22	(1 0110)--------------83-------------------(AP:24). .	Ground-Air Coordination
23	(1 0111)--------------83-------------------(AP:24)	
24	(11)(RC:2)(NC:4)(MC:80)(AP:24). .	Comm-C (ELM)

AA Address, Announced
AC Altitude Code
AP Address/Parity
AQ Acquisition, Special
BI BCAS Interrogation Data
BR BCAS Reply Data
CA Capability
DF Downkink Format
DI Designator Identification
DR Downlink Request
EP Epoch
FS Flight Status
ID Identification (4096 code)
II Interrogator Identification
KE Control, ELM
MA Message, Comm-A
MB Message, Comm-B
MC Message, Comm-C
MD Message, Comm-D
MS Message, Synchronized, Interrogation
MT Message, Synchronized, Reply
MU Message, Interrogation
NC Number of C-Segment
ND Number of D-Segment
PC Protocol
PI Parity/Interrogator Identifier
PR Probability of Reply
RC Reply Control
RR Reply Request
SC Special Communication
SD Special Designator
UF Uplink Format
UM Utility Message

Notes: (1) (XX:M) denotes a field designated "XX" which is assigned M bits,

(2) ---N--- denotes free coding space with N available bits,

(3) UF (Uplink Format) codes 24 through 31 are reserved for Comm-C transmissions. The leading bits of these codes are always "11"; the remaining bits vary with the content of the RC and NC fields

Figure 6a. Summary of DABS Interrogation or Uplink Formats.

Format No.	DF / Fields	
0	(0 0000)(AQ:1)(BR:13)(AC:13)(AP:24)	. . . . . Short Special Surveillance
1	(0 0001)--------------27------------(AP:24)	
2	(0 0010)(EP:8)--------6-----(AC:13)(AP:24)	. . . . . Short Synchr. Surveillance
3	(0 0011)--------------27------------(AP:24)	
4	(0 0100)(FS:3)(DR:5)(UM:6)(AC:13)(AP:24)	. . . . . Surveillance, Altitude
5	(0 0101)(FS:3)(DR:5)(UM:6)(ID:13)(AP:24)	. . . . . Surveillance, Identity
6	(0 0110)--------------27------------(AP:24)	. . . . . Not Used
7	(0 0111)--------------27------------(AP:24)	
8	(0 1000)--------------27------------(AP:24)	
9	(0 1001)--------------27------------(AP:24)	
10	(0 1010)--------------27------------(AP:24)	
11	(0 1011)(CA:3)(AA:24)(PI:24)	. . . . . All-Call Reply
12	(0 1100)--------------27------------(AP:24)	
13	(0 1101)--------------27------------(AP:24)	
14	(0 1110)--------------27------------(AP:24)	
15	(0 1111)--------------27------------(AP:24)	
16	(1 0000)(AQ:1)(BR:13)(AC:13)(SC:56)(AP:24)	. .Long Special Surveillance
17	(1 0001)--------------83------------------(AP:24)	
18	(1 0010)(EP:8)--------6-----(AC:13)(MT:56)(AP:24)	. .Long Synchr. Surveillance
19	(1 0011)--------------83------------------(AP:24)	
20	(1 0100)(FS:3)(DR:5)(UM:6)(AC:13)(MB:56)(AP:24)	. .Comm-B, Altitude
21	(1 0101)(FS:3)(DR:5)(UM:6)(ID:13)(MB:56)(AP:24)	. .Comm-B, Identity
22	(1 0110)--------------83------------------(AP:24)	. .Not Used
23	(1 0111)--------------83------------------(AP:24)	
24	(11)--1--(KE:1)(ND:4)(MD:80)(AP:24)	. .Comm-D (ELM)

AA Address, Announced
AC Altitude Code
AP Address/Parity
AQ Acquisition, Special
BI BCAS Interrogation Data
BR BCAS Reply Data
CA Capability
DF Downkink Format
DI Designator Identification
DR Downlink Request
EP Epoch
FS Flight Status
ID Identification (4096 code)
II Interrogator Identification
KE Control, ELM
MA Message, Comm-A
MB Message, Comm-B
MC Message, Comm-C
MD Message, Comm-D
MS Message, Synchronized, Interrogation
MT Message, Synchronized, Reply
MU Message, Interrogation
NC Number of C-Segment
ND Number of D-Segment
PC Protocol
PI Parity/Interrogator Identifier
PR Probability of Reply
RC Reply Control
RR Reply Request
SC Special Communication
SD Special Designator
UF Uplink Format
UM Utility Message

Notes: (1) (XX:M) denotes a field designated "XX" which is assigned M bits,

(2) ---N--- denotes free coding space with N available bits,

(3) DF (Downlink Format) codes 24 through 31 are reserved for Comm-D transmissions. The leading bits of these codes are always "11"; the remaining bits vary with the content of the KE and ND fields.

Figure 6b. Summary of DABS Reply or Downlink Formats.

pattern is used on receive for off-boresight angle estimation. The basic antenna will be a rotating narrow-beam type.

Receive SLS is accomplished by comparing the received amplitudes on the sum and control channels. Sum pattern sidelobe responses are rejected on the basis of relative signal strength.

Amplitude-comparison monopulse is accomplished by using the sum and difference patterns. A prestored calibration curve is accessed via a function of the sum and difference channel signal strengths to obtain an off-boresight angle estimation.

DABS TRANSPONDER

The DABS transponder has, in addition to the same characteristics as an ATCRBS transponder, the ability to process and to reply to interrogations from DABS sensors. Output power and receiver sensitivity specifications are similar to those in the ATCRBS National Standard (Reference 4).

The DABS transponder timing diagram is shown in Figure 7. After receiving a DABS roll-call interrogation with either 56 or 112 bits of data, a reply delay of 128 μs provides processing time prior to transmission of a reply. The reply length is either 64 or 120 μs depending on the amount of data to be transmitted.

Extended-length message formats will be available on both the uplink and downlink transmissions where messages may be sent in segments.[5]

DABS REPLY PROCESSING

The DABS reply processor obtains range and azimuth estimates for DABS replies as shown in Figure 8. Ranging is performed on the four-pulse DABS

[5]"Discrete Address Beacon System (DABS); Proposed U.S. National Aviation Standard," Federal Register, Vol. 45, No. 46/Thursday, March 6, 1980.

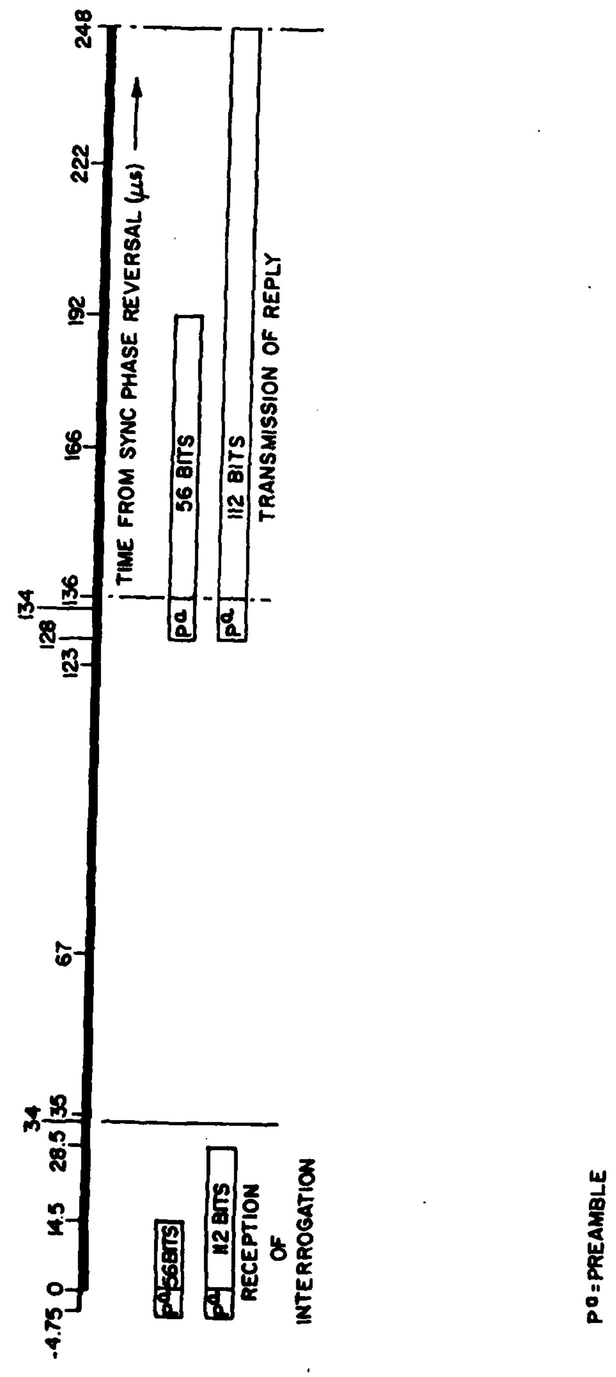


Figure 7. DABS transponder timing diagram.

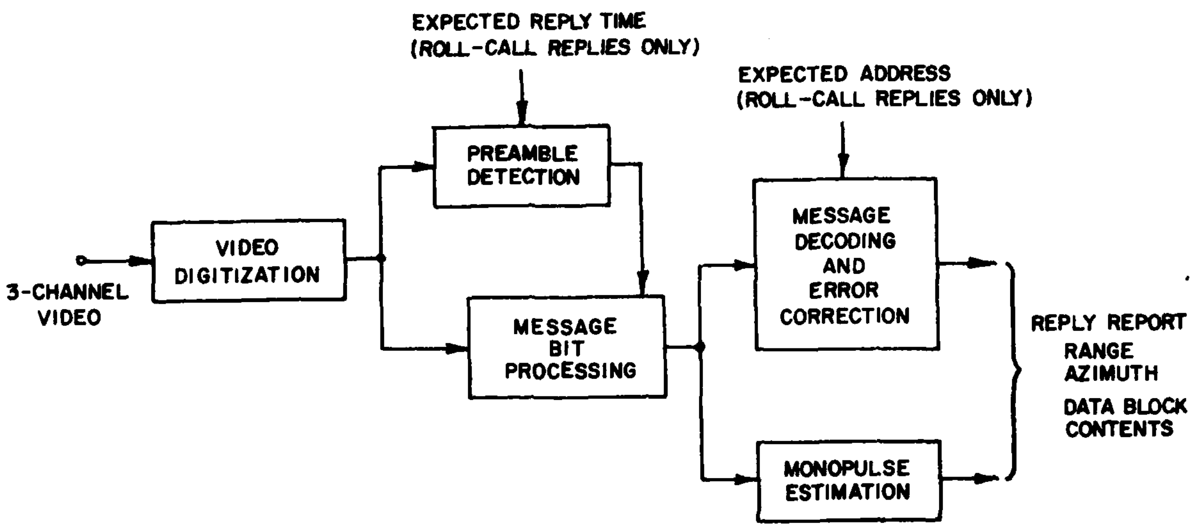


Figure 8. Block diagram of DABS reply processing.

reply preamble. A significant feature of preamble processing is that only one preamble may be detected at a time. An "uncertainty window" is established for replies to roll-call interrogations to minimize the effects of DABS fruit replies.

The message-bit processing of the pulse-position-modulated data block consists of bit decisions based primarily on the relative amplitude of the bit positions. A confidence bit is also set associated with the bit value. A high-confidence bit is declared only if a mainbeam signal is in one of the pulse positions and either no signal or a sidelobe signal is in the other pulse position.

The 24 parity-check bits accompanying the transponder address in the downlink data block are used for error-correction purposes. An attempt to correct an error in a transponder address is made only if the low-confidence bit rate is less than a threshold value. The low-confidence bit rate threshold check is adjustable from 4 to 14 bits.[6] The purpose of the threshold check is to minimize the probability of "error-correcting" a misdirected message with no errors but an unexpected address.

The criteria for successful correction of an error are that: 1) all errors be confined to 24 contiguous bits, and 2) all errors occur in low confidence bits. These criteria attempt to make a DABS data block error correctable when overlapped by a single ATCRBS reply.

ATCRBS MODE OF DABS PROCESSOR

The primary differences between target detection for the ATCRBS processor associated with the DABS sensor and the traditional ATCRBS processor are azimuth determination via monopulse and target-to-track correlation. Because amplitude-monopulse azimuth determination can be accomplished with a single

[6]Barrows, J. T., DABS Downlink Coding, FAA-RD-75-61, Lincoln Laboratory, Lexington, MA, September 1975.

pulse, the number of desired target replies can be minimized. Improved target records can be obtained via the target-to-track update process.

Approximately 4 to 8 ATCRBS/DABS all-call interrogations will be transmitted during the mainbeam dwell time of a DABS sensor. These replies are correlated in range, azimuth, and high-confidence code bits to obtain target declaration and code estimates. Target parameters are updated on each scan based on the new target formations.

SURVEILLANCE PROCESSING

The DABS surveillance processing can predict next-scan position for DABS-equipped targets, and can correct ATCRBS target reports based on updated information.

The DABS surveillance processing functions also include false-target check supported by prior knowledge of reflecting surfaces in the environment.

SECTION 3
MODEL DESCRIPTION

GENERAL DESCRIPTION

The DABS PPM is a time-event store simulation programmed in FORTRAN V that is based on the time between ATCRBS interrogations of a selected ATCRBS interrogator or ATCRBS/DABS all-call interrogations of a DABS sensor. One simulation cycle for ATCRBS interrogators is one pulse repetition period (PRP) of the S_o. One simulation cycle for DABS sensors is the time between all-call interrogations.

Figure 9 is a flow chart of the DABS PPM and its major submodel functions. The basic cycle of the model simulation is as follows. First, the input data, including the data files and special characteristics of the S_o, are read in. The S_o may be either a DABS sensor or an ATCRBS interrogator. Second, the channel management portion of the program accesses the stored target files and determines (based on last reported position) which A/C are in the mainbeam of the S_o on the present cycle. Channel management functions are performed for all DABS sensors in the environment.

The roll-call schedules are then established for each sensor. Interrogation and supppression times-of-arrival are determined from all interacting DABS sensors and ATCRBS interrogators at each A/C in the S_o mainbeam.

The operation of the transponder is based on the equipment parameters selected as model inputs. These characteristics and the signal environment at the transponder (as characterized by arrival time, signal strength, and modulation type) determine what replies are generated by the transponder. All signal strength calculations include the following parameters: transmitter power, transmitter and receiver antenna gains, free-space path loss, and transmission line loss. Receiver sensitivities are adjusted to take into account the effects of sensitivity-time control, when appropriate. All of

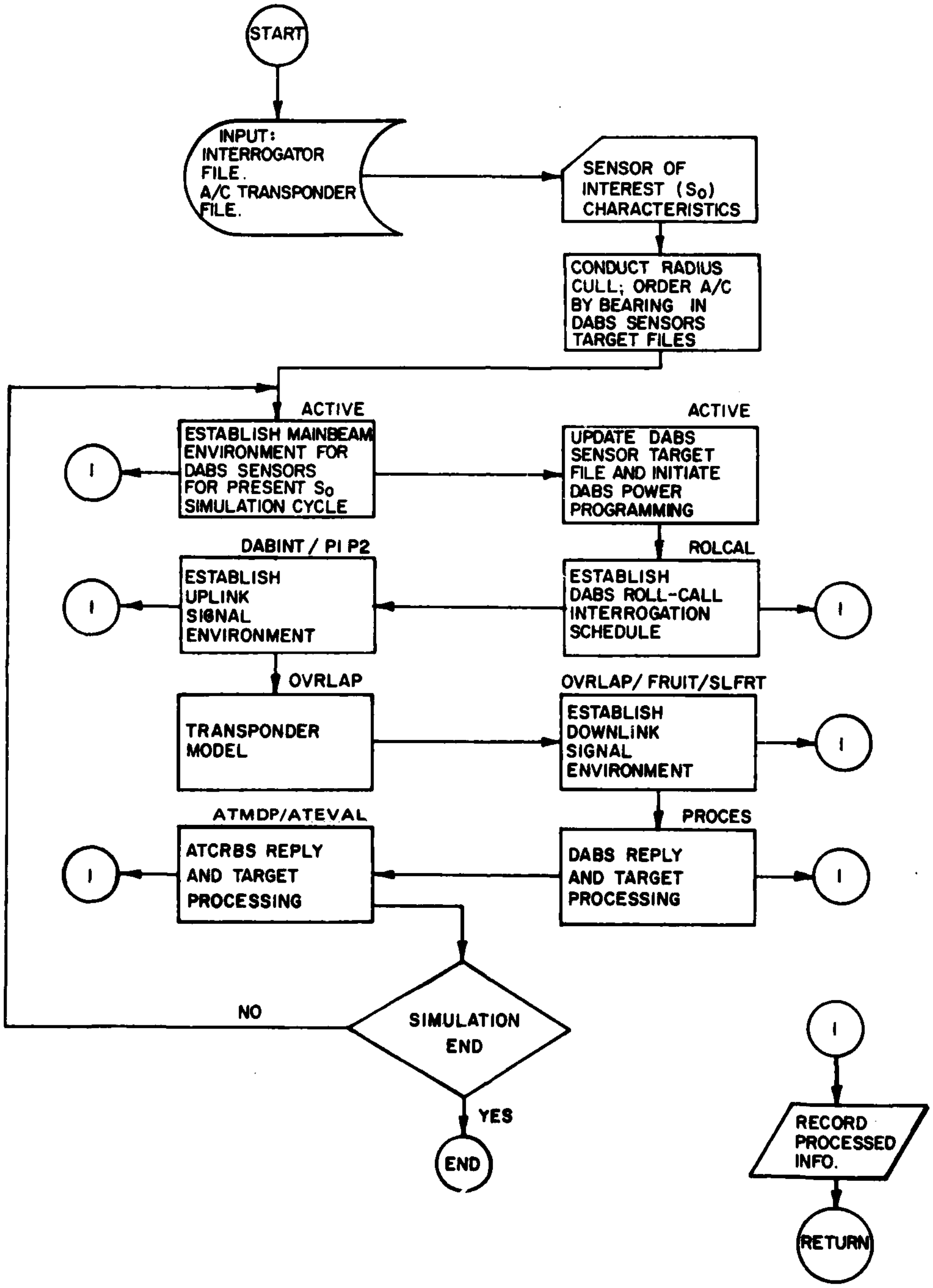


Figure 9. Flow chart of DABS PPM major submodel functions.

these parameters are run-time dependent, with the exception of free-space path loss calculations. Similar calculations are made for targets in the S_o sidelobes to generate the sidelobe fruit characterization.

The arrival times, signal strengths, and signal types of all downlink transmissions are fed to the processor models for target evaluation procedures. For DABS processors, reply overlaps are evaluated for error-correction potential; the appropriate modifications to the target files are made based on the success of the roll-call transactions. All-call responses are evaluated and provisions are made for adding new targets to the active target list. When appropriate, target detection and code validation records are maintained for each target based on the type of ATCRBS processor associated with the subject interrogator or sensor.

Outputs are extracted from the model at the various locations noted in Figure 9.

CHANNEL MANAGEMENT (ACTIVE)

A flow chart detailing the submodel of DABS sensor channel management is shown in Figure A-1 of APPENDIX A. The first operation of this submodel is to select the active target list for the S_o. The general procedure is the same whether the S_o is a DABS sensor or an ATCRBS interrogator. Some of the procedures described herein apply only when the S_o is a DABS sensor.

After accessing the active target list for the S_o, the target file is updated by adding new DABS targets acquired by all-call on the previous sweep. On the initial cycle, certain targets can be specified as on the active target list. The start azimuth of the S_o is established pseudorandomly on the first cycle.

Once the azimuth of the trailing-edge of the mainbeam is established for the present sweep, the cutoff azimuth is calculated using the mainbeam width of the S_o directional antenna. The ATCRBS- and DABS-equipped targets on the active target list are stored in bearing order. Based on the S_0 start and cutoff azimuths and the target bearings stored in the active target list records, the submodel determines the targets that are in the S_0 mainbeam.

If DABS-equipped A/C are located in the S_0 mainbeam on the present sweep, a reinterrogation check is performed. Records of the previous sweep are accessed to determine whether unsuccessful roll-call interrogations were made for those DABS A/C that are present in the S_0 mainbeam. If a roll-call transaction was unsuccessful on the previous sweep, a reinterrogation bit is set in the target record for that A/C. A DABS-equipped A/C scheduled for reinterrogation will automatically be interrogated at a higher power. The power programming increment is an input variable. Provisions are also made for repeated interrogations of DABS-equipped A/C, as instructed by the user, to simulate the transmission of additional data-link information.

Those A/C records selected in the S_0 mainbeam are loaded into temporary files that include range, azimuth, and identification number. The ATCRBS-equipped and DABS-equipped A/C are loaded into separate files.

The channel management submodel now determines if any other DABS sensors are contained in the environment. For those sensors, the start azimuth is updated based on the elapsed time. A procedure similar to that used for a DABS S_0 is followed for each of the other DABS sensors in the environment. Temporary files are maintained containing ATCRBS and DABS target ranges, azimuths, and identification numbers. Reinterrogation and power programming bits are set in each DABS target record that is selected in a sensor's mainbeam for which an unsuccessful roll-call transaction occurred on the previous sweep. Upon completion of the channel management functions, control is returned to the main program. Inputs and outputs of the channel management submodel are listed in TABLE 1.

TABLE 1

INPUTS/OUTPUTS FOR CHANNEL MANAGEMENT

INPUTS
Active target files (DABS sensors)
Transaction records from last cycle
Antenna mainbeam azimuth (DABS sensors)
OUTPUTS
Range and ID of all A/C in the antenna mainbeam of all DABS sensors
Updated antenna mainbeam azimuth
Updated active target files
Power programming indicator

ROLL-CALL SCHEDULING (ROLCAL)

The roll-call scheduling submodel establishes all-call and roll-call transmission times for all DABS sensors in the simulated environment, as seen in Figure A-2 of APPENDIX A. The DABS target lists that were created in the channel management submodel are used as input to the roll-call scheduling process.

The first operation in the submodel establishes the all-call transmission times for all DABS sensors for the present S_o cycle.

If the S_o is a DABS sensor, the roll-call scheduling loop is entered. The DABS-equipped A/C list is arranged in decreasing range order in preparation for scheduling (except for the schedule precursor).

The roll-call scheduling procedure is the same for the S_o as for all other DABS sensors and is as follows.

1. The ELM precursor is scheduled after waiting an appropriate length of time for all-call and ATCRBS responses to the all-call interrogation to be received from A/C located at the limits of the coverage area.

2. The first roll-call transmission that elicits a reply is scheduled for the A/C at the greatest range from the sensor.

3. The expected reply time from the A/C at greatest range is calculated by adding the transmission time to the round-trip propagation time and allowing for transponder processing time.

4. The submodel now calculates the range difference between the last reported A/C at greatest range and the next A/C on the roll-call list. The interrogation and reply message length differences are also calculated.

5. The transmission of the succeeding roll-call interrogation is established allowing a delay, if necessary, for the range and message length differences calculated above.

6. A check is made to determine whether an overlap will occur between the established interrogation time and the predicted arrival time of the first reply of the present roll-call cycle. If an overlap is predicted, a new roll-call cycle is initiated as shown in Figure 1.

7. The submodel now checks to determine if any more DABS-equipped A/C are scheduled; if so, it establishes the interrogation and reply times in the same manner as for the previous A/C.

8. Following the main schedule, a check is performed to determine if additional data-link transactions are pending for any of the A/C on the roll-call list. A supplementary roll-call list is then established and steps 2-7 are repeated. If any A/C are to receive more than one additional data-link transaction, additional supplementary roll-call lists are established and scheduled as above.

The simulated roll-call scheduling process continues until roll-call interrogation and reply times have been established for each DABS-sensor DABS-equipped A/C pair. Inputs and outputs of the submodel roll-call scheduling are listed in TABLE 2.

TABLE 2

INPUTS/OUTPUTS FOR ROLL-CALL SCHEDULING

INPUTS	
Range and ID of DABS A/C in roll-call schedule	
Preceding simulation cycle all-call times	
OUTPUTS	
All-call transmission time	DABS sensors
Roll-call interrogation times	DABS sensors
Roll-call expected reply times	DABS sensors

TRANSPONDER SIGNAL ENVIRONMENT (DABINT)

The purpose of the uplink submodel is to characterize (in terms of arrival time, signal strength, and signal structure) the signal environment at transponder-equipped A/C in the mainbeam of the antenna of the S_o. The submodel is divided in half, one for DABS-equipped A/C and one for ATCRBS targets, as seen in Figure A-3 of APPENDIX A.

After selecting a DABS-equipped A/C for processing, the simulation first determines the relationship of the A/C to all DABS sensors in the environment. The simulation proceeds as follows.

1. The uplink mainbeam signal strength for the transponder/sensor pair is calcuated. DABS-sensor output power on roll-call is adjusted if the sensor is in power programming, as determined by channel management. If the power cull is not passed, the program selects another sensor for evaluation.

2. If the mainbeam signal strength is calculate' to be above transponder receiver sensitivity, a relative bearing calculation is made. If the bearing from the sensor to the target falls between the leading- and trailing-edge bearings established by the present pointing angle of the sensor antenna, the simulated target is processed in the sensor antenna mainbeam.

3. Three signal types are characterized as emanating from a DABS sensor at the simulated DABS transponder. The three types are: the ATCRBS/DABS all-call interrogation, the roll-call interrogation addressed specifically to the DABS-equipped target, and the roll-call interrogation addressed to another DABS target in the sensor mainbeam.

4. Each type of interrogation is represented by an arrival time (transmission time plus propagation time) that is loaded into an array established for the signal type. The transmission times for roll-call interrogations are established in the roll-call scheduling submodel.

5. The above process is repeated for each DABS sensor in the simulated environment.

6. After determining the contribution of DABS sensors to the signal environment at the DABS-equipped A/C in the S_o antenna mainbeam, the program processes the ATCRBS uplink interference.

7. A mainbeam power cull is performed for the interrogator/transponder pair.

8. The azimuth of each ATCRBS and AIMS interrogator is updated; the bearing from the interrogator to the target is checked against the leading- and trailing-edges of the interrogator antenna mainbeam to determine if the target is in the mainbeam.

9. If the A/C is in the antenna mainbeam, the interrogation arrival times (transmission time plus propagation time) are calculated for the simulation cycle interval.

10. After the mainbeam arrival times are established for each DABS-equipped A/C in the S_o mainbeam, the program executes an almost identical coding set for each simulated ATCRBS-equipped A/C, but the DABS roll-call interrogation times are loaded directly into the SLS arrival time array.

For each uplink transmitter/receiver pair evaluated in the preceding steps, an auxiliary subroutine is implemented when the target falls in the sidelobes of the interfering antenna. For this sidelobe interference routine, a check was made to determine whether the interrogator is or is not equipped with SLS, or is equipped with improved interrogator SLS.

In any case, a cull of uplink power is conducted at the azimuth where the target is located. If the power cull is passed, and the interrogator is not equipped with any form of SLS, control is returned to the main uplink interference submodel. The appropriate interrogation arrival time arrays are then loaded.

If the interrogator is equipped with a form of SLS, the arrival times of the suppression transmissions occurring during the present simulation cycle are calculated and loaded into the appropriate SLS arrival-time array. Inputs and outputs of the transponder signal environments submodel are listed in TABLE 3.

TRANSPONDER MODEL (OVERLAP)

The purpose of submodel OVERLAP is to model transponder operation based upon the characteristics of the transponder and the uplink signal environment. Reply arrival times at the S_O are calculated. The flow chart for this submodel is shown in Figure A-4 of APPENDIX A and is described below.

The mode that the S_O is presently using (based upon elapsed time) is first determined. If there are DABS A/C in the mainbeam of the S_O and the selected transponder has sufficient effective radiated power to produce a reply at the S_O, the time of arrival of the all-call, roll-call or ATCRBS interrogation at the A/C is calculated. A series of checks is made to determine if the interrogation is received without any interference. These checks include the possibility that the transponder is in dead time caused by a previous interrogation or SLS from another interrogator or that the transponder is receiving another interrogation, thereby causing SLS or intermode garble.

TABLE 3

INPUTS/OUTPUTS FOR TRANSPONDER SIGNAL ENVIRONMENT

INPUTS	
Range and ID of DABS and ATCRBS A/C in DABS sensors antenna mainbeam	
Roll-call interrogation schedule	
Interrogator file	
Antenna mainbeam azimuth	
OUTPUTS	
DABS all-call arrival times	At all A/C in S_o mainbeam
DABS roll-call arrival times	At all A/C in S_o mainbeam
ATCRBS/AIMS interrogation arrival times	At all A/C in S_o mainbeam
Sidelobe suppression (SLS) arrival times	At all A/C in S_o mainbeam
Updated ATCRBS interrogator antenna azimuth	

The following relationships between interfering signals and desired signals are considered in OVERLAP in determining the success or failure of a transponder to reply to a desired interrogation.

For an ATCRBS transponder:

1. Intentional suppression time induced by $P_1 - P_2$ pulse pairs transmitted by ATCRBS/Mark X interrogators,
2. Intentional suppression time induced by $P_1 - P_2$ pulse pairs transmitted by DABS sensors as part of ATCRBS/DABS all-call interrogations and roll-call interrogations,
3. Interrogation suppression time induced by ATCRBS interrogations and ATCRBS/DABS all-call interrogations,
4. Conversion of an ATCRBS interrogation to a false sidelobe suppression by the first pulse of an ATCRBS interrogation, ATCRBS/DABS all-call interrogation, or a DABS roll-call interrogation,

5. Conversion of an ATCRBS mode C interrogation to an ATCRBS mode A interrogation via intermode garble resulting from an overlap of the P_3 pulse position for a mode A interrogation with the first pulse of an ATCRBS interrogation, ATCRBS/DABS all-call interrogation, or a DABS roll-call interrogation.

For a DABS transponder:

1. Intentional suppression time induced by $P_1 - P_2$ pulse pairs transmitted by ATCRBS/Mark X interrogators,

2. Intentional suppression time induced by $P_1 - P_2$ pulse pairs transmitted by DABS sensors as part of ATCRBS/DABS all-call interrogations and by the P_5 SLS control pulse transmitted by DABS sensors as part of DABS roll-call interrogations,

3. Suppression time caused by the decoding of a DABS roll-call interrogation that contains an address different from that of the transponder that has received it,

4. Interrogation suppression time caused by ATCRBS interrogations, ATCRBS/DABS all-call interrogations, and DABS roll-call interrogations,

5. Conversion of an ATCRBS interrogation or an ATCRBS/DABS all-call interrogation to a false $P_1 - P_2$ pulse pair by the first pulse of an ATCRBS interrogation, ATCRBS/DABS all-call interrogation, or a DABS roll-call interrogation,

6. Conversion of an ATCRBS mode C interrogation to an ATCRBS mode A interrogation via intermode garble resulting from an overlap of the P_3 pulse position for a mode A interrogation with the first pulse of an ATCRBS interrogation, ATCRBS DABS all-call interrogation, or a DABS roll-call interrogation,

7. Overlap of the interval between the P_3 and P_4 pulses of an ATCRBS/DABS all-call interrogation, resulting in failure of the transponder to reply,

8. Overlap of the DABS roll-call interrogation data block, resulting in failure of the transponder to reply.

If the S_o is an ATCRBS interrogator, the ATCRBS interrogation may be changed into a false all-call by other interrogations by placing a pulse in the P_4 position. If this occurs, a false all-call reply is generated.

If no interference to interrogations from the S_o occurs, then either the all-call or ATCRBS reply time-of-arrival at the S_o is calculated.

If the S_o is a DABS sensor and the A/C being interrogated is on the roll-call list, then the submodel goes into the roll-call interrogation checking procedure. Here the time of arrival of the roll-call interrogation is checked to see if the transponder is in dead time, or if an overlapping interrogation erases a sync-phase reversal, or if a data block error exists, in which cases no reply is prepared. If none of these conditions exist, a roll-call arrival time at the S_o is calculated.

The DABS roll-call checking procedure completes the evaluation of the interrogations arriving at the DABS-equipped A/C. If there are more DABS-equipped A/C, they are similarly evaluated. If there are no nore DABS-equipped A/C in the mainbeam of the S_o, then ATCRBS-equipped A/C transponder performance is evaluated.

As in the DABS-equipped A/C analysis, a check is made to see if the ATCRBS-equipped A/C transponder effective radiated power is sufficient for the signal to be detected by the S_o. If so, the all-call or ATCRBS interrogation time of arrival from the S_o is calculated. The interrogation arrival time is analyzed to see if the A/C transponder is in dead time, if a sidelobe interrogation is created by garble, or if an intermode garble occurs. The dead time or sidelobe interrogation again precludes the transponder from replying, and the intermode garble produces a wrong mode reply.

If no interference from other interrogators is present, then the ATCRBS reply arrival time at the S_o is calculated. When all ATCRBS-equipped A/C in the mainbeam of the S_o have been evaluated, an output routine produces (by type of reply: ATCRBS, all-call and roll-call) the identification numbers of the A/C and the reply arrival times at the S_O. The total number of suppressions and garbles of all-calls and roll-calls as well as the total number of replies made to interrogations from the S_O are also produced. Inputs and outputs of the transponder model are listed in TABLE 4.

TABLE 4

INPUTS/OUTPUTS FOR TRANSPONDER MODEL

INPUTS	
Transponder signal environment (S_O mainbeam)	
Transponder characteristics	
Sensor/interrogator file characteristics	
OUTPUTS	
All-call reply times	At S_O
Roll-call reply times	At S_O
ATCRBS reply times (including false replies)	At S_O

DOWNLINK INTERFERENCE (FRUIT/SLFRT)

The purpose of the FRUIT/SLFRT submodel as seen in Figure A-5 of APPENDIX A is to determine at the S_O the arrival times of roll-call, all-call, and ATCRBS fruit replies as seen in the mainbeam and sidelobes of the antenna of the S_O.

If there are DABS-equipped A/C in the mainbeam, and the replies to S_O interrogations have sufficient effective radiated power to be detected, the DABS fruit arrival times (roll-call, all-call, and ATCRBS) are recorded. If there are ATCRBS or AIMS-equipped A/C in the mainbeam and their replies have sufficient effective radiated power to reach the S_o, the appropriate fruit arrival times are recorded.

After all A/C in the mainbeam of the S_o have been considered, the sidelobe and backlobe fruit arrival times from A/C in the sidelobes or backlobes of the antenna of the S_o are determined. A power cull is made based upon sidelobe or backlobe gain and transmitter power of the A/C. Each DABS-equipped or ATCRBS-equipped A/C which passes the sidelobe or backlobe power cull is played against all DABS sensors to see if a reply is elicited by their mainbeam interrogations of that A/C. If so, the time-of-arrival of the fruit reply is recorded.

When all DABS sensors have been processed, all ATCRBS interrogators are checked to see if any fruit is produced which the S_o will receive in the antenna sidelobes.

When all A/C in the sidelobes of the antenna of the S_o have been checked, control is returned to the main program. Inputs and outputs of the downlink signal environment submodel are listed in TABLE 5.

TABLE 5

INPUTS/OUTPUTS FOR DOWNLINK SIGNAL ENVIRONMENT

INPUTS	
Transponder signal environment	
Transponder characteristics	
Interrogator file characteristics	
OUTPUTS	
All-call fruit	At S_o
Roll-call fruit times	At S_o
ATCRBS fruit times	At S_o

DABS PROCESSOR (PROCES)

The DABS processor submodel as seen in Figure A-6 of APPENDIX A simulates the operation of the DABS sensor reply and target processor. The submodel receives as input the downlink signal environment that was previously generated. The downlink signal environment is characterized by the signal structure, arrival time, and signal strength of all replies elicited by the sensor and interrogator environment. The downlink reply environment consists of all ATCRBS, DABS all-call, and DABS roll-call replies generated by the mixed DABS/ATCRBS/AIMS sensor/interrogator environment.

The initial step in the DABS processor submodel is completion of the characterization of the interference environment by determining if any DABS reply preambles are generated by combinations of fruit pulses. The arrival times of the ATCRBS fruit replies are compared to determine if DABS preamble pulse spacing is created by the interleaving of the fruit pulses. The number of these false preambles and their time of occurrence is recorded.

The DABS processor submodel then simulates the processing of incoming all-call replies. Selecting one all-call reply at a time, the submodel begins to make overlap checks. The first checks made are for overlap of the all-call reply by ATCRBS and AIMS fruit replies and ATCRBS synchronous garble responses.

If no ATCRBS overlaps occur, the processor submodel calculates (based on relative arrival times) whether the reply is lost due to a previously detected DABS preamble. Sources of preamble interference are all-call synchronous garble, all-call and roll-call fruit replies, and false preambles created by ATCRBS replies. Overlaps created by DABS fruit and all-call synchronous garble are also evaluated. Both the number of overlaps and the length of any errors in the data block are calculated. Errors that span more than 24 contiguous bits of information are flagged.

If an ATCRBS reply overlaps the data block or the preamble of a DABS all-call reply, the span of the error is recorded. Additional overlaps by other fruit replies and by DABS fruit are also recorded. Data block errors of length greater than 24 μs are flagged.

The above error detection process is repeated for each all-call reply received on the present simulation cycle.

The roll-call reply interference check nearly duplicates the all-call reply interference check described above, except no synchronous garble check is made. In addition, all roll-call replies are checked for arrival time within an uncertainty window. All detected errors are flagged and the appropriate indicators are set in the target file.

A summary is printed of each cycle's roll-call transactions with each A/C on its roll-call schedule. The results of the error detection process are printed as part of the record of the transaction. Any replies lost during the simulation are also noted. Inputs and outputs of the DABS target processor submodel are listed in TABLE 6.

TABLE 6

INPUTS/OUTPUTS FOR DABS TARGET PROCESSOR

<u>INPUTS</u>
DABS A/C active target file
Downlink signal environment (all replies)
DABS processor characteristics
<u>OUTPUTS</u>
Updated DABS target files
DABS transaction results

ATCRBS TARGET PROCESSOR (ATEVAL)

The purpose of the ATEVAL submodel as seen in Figure A-7 of APPENDIX A is to simulate the performance of the ARTS III processor associated with ATCRBS terminal sites. The processor submodel keeps a target record on each A/C that replies to the ATCRBS S_o.

The submodel first selects a target record. It then calculates the time of occurrence of each ATCRBS reply, and by range correlation attempts to match the reply with the target record range. If a correlated reply has been received, then an interference check is made against roll-call, all-call, and ATCRBS fruit. If a roll-call or all-call reply overlaps the correlated ATCRBS reply, the reply is considered to be invalidated, and a missed reply routine is carried out.

The missed reply procedure first steps a miss counter. If the target hit count is above the leading-edge threshold and the miss-count threshold has been reached, target end is declared and target range, azimuth, identification number, and code validation information are printed. The target record is then cleared. If the target hit count is insufficient to declare a target, but the miss-count threshold has been reached, the target record is also cleared. If, during the overlap check, an ATCRBS overlap of a pulse position occurs, target range is updated, the hit count is stepped, the miss count is set to zero, and the code information is flagged as garbled.

If there is no overlap of the ATCRBS reply, the target range is updated, the hit count is stepped, the miss count is set to zero, and begin-validate and code-validation flags are checked. Code-validation checks for both modes 3/A and C are made; if validation occurs, an indicator is set.

If no correlated reply is obtained by matching framing pulses with the target record, the missed-reply routine is carried out. After either the missed reply or target update is completed, a new target record is accessed, and the process is continued until all target records have been updated.

A check is also made to see if any uncorrelated replies are present. If so, new targets are begun by loading ranges, identification numbers, and hit counts of 1 into a new target record. Control is then returned to the main program. Inputs and outputs of the ATCRBS target processor submodel are listed in TABLE 7.

TABLE 7

INPUTS/OUTPUTS FOR ATCRBS TARGET PROCESSOR

INPUTS
ATCRBS A/C target records
Downlink signal environment (all replies)
ATCRBS processor characteristics
OUTPUTS
Updated ATCRBS target records
ATCRBS target declarations

ATCRBS MODE OF DABS PROCESSOR (ATMDP)

The ATCRBS mode of DABS processor submodel, as seen in Figure A-8 of APPENDIX A, simulates the operation of the portion of the DABS processor that correlates ATCRBS replies to create ATCRBS target reports and subsequently, target tracks. The submodel receives as input the downlink signal environment generated in the preceding subroutines. The downlink signal environment is characterized by the signal structure, arrival time, and signal strength of all replies elicited by the sensor and interrogator environment and consists of ATCRBS, AIMS, DABS all-call, and DABS roll-call replies.

The ATCRBS mode of the DABS submodel is divided into the following areas: reply processing, reply correlation and target formation, target-to-track association and correlation, and track initiation. The modeling of each of these functions is described below.

The reply processing simulation analyzes the incoming desired reply arrays and fruit reply arrays to determine the time relationships between all replies. First, the arrival times of DABS all-call and roll-call replies are compared to the arrival times of all ATCRBS replies to determine whether any ATCRBS replies are lost due to a DABS all-call reply processing pre-emption. Those ATCRBS replies are eliminated from the in-process arrays.

After the ATCRBS reply arrays are modified according to the above procedure, the model proceeds to merge the arrival times of all ATCRBS replies to check for pulse position overlaps. Low-confidence zeros are declared for an ATCRBS reply if the arrival time of a reply pulse that does not correlate in azimuth with the reply azimuth reference places the pulse in a code pulse position of the reply. Low-confidence ones are declared whenever a mainbeam reply pulse arrival time occurs in a pulse position that correlates in azimuth with both the reply reference and one or more garbling replies. ATCRBS fruit replies are assumed to have all pulse positions filled or half of their pulse positions filled at the option of the user.

The reply processor supplies the following data to the reply correlation and target formation process: the mode of the sweep, the reply range and azimuth, and reply code information.

The reply correlation process groups ATCRBS replies received on the current sweep with replies received on previous sweeps by comparing: the range difference between the incoming reply and the existing reply group, the azimuth difference between the incoming reply and the existing reply group, and the code compatibility of the incoming reply and the existing reply group. If no match is obtained for an incoming reply, the reply is sorted by range and held for comparison on future sweeps. The completion of a reply group into a target formation is accomplished based on the number of sweeps that have elapsed since the oldest reply in the group was detected. The target formation array is passed to the surveillance processing portion of the submodel once per sector (nominally 11.25°).

The next step in the ATCRBS mode processor model is performed for each sector and consists of a target-to-track association and correlation process. This process results in track updates for targets that correlate with existing tracks.

The inputs to the target-to-track correlation and association portion of the submodel are the target formations generated by the reply correlation process and the existing track file. The first step in this surveillance processing sequence is to correlate targets for which no low-confidence code bits exist. The target range, azimuth, and code information are compared within computed tolerance with equivalent track parameters.

After all target formation records for which no low-confidence code bits exist have been processed, the submodel compares the range, azimuth, and code compatibility of the remaining targets and tracks to develop target-to-track association pairs. At this point, the submodel performs a code swapping check for target report pairs that associate in range and azimuth and meet the criterion that the track with which they associate has the mode A reply of one report and the mode C reply of the other report. In this case, the mode A replies are interchanged between the two target reports. Uncorrelated report records are passed on to the track initiation process. When more than one target report is associated with the same track, a report of occurrence is made in the model output.

Track initiation occurs when a target report associates with an uncorrelated target report for the first time on successive scans. Target report records that do not correlate with any existing report or track are held in storage until the next simulated antenna scan. When a target correlates with more than one target report, the condition is flagged by the model and the potential tracks are held until the next antenna scan. During the track initiation process, target reports that contain only one hit, consist of one mode A hit and one mode C hit, or are left over from code swapping, are eliminated from consideration.

Track updates are performed by the ATCRBS mode of DABS submodel from the results of the target-to-track correlation process. Reply code information is updated if the track was initiated in a garbled condition. The submodel reports the condition of the target codes after each track update. Target tracks are eliminated that have not correlated for a specified number of consecutive scans.

After completion of the track updates, the model makes some additional checks on the target reports to eliminate targets caused by fruit correlation. Targets consisting of only two hits, one of which is mode A and the other mode C, are eliminated from the target record array if they do not correlate with an existing track. In addition, those target reports consisting of only mode C replies and failing to correlate with an existing track are also eliminated.

TABLE 8 lists the inputs and outputs for the ATCRBS mode of DABS processor submodel.

TABLE 8

INPUTS/OUTPUTS FOR ATCRBS MODE OF DABS PROCESSOR

<u>INPUTS</u>
ATCRBS A/C target records and track files
Downlink signal environment (all replies)
Processor parameters
<u>OUTPUTS</u>
Updated track files
New target formations

SECTION 4
MODEL USER'S GUIDE

The model user's guide for the DABS PPM describes the following areas: S_O input parameters, model outputs, applicable environmental scenarios, modeling assumptions, and sample model output capabilities.

INPUTS AND OUTPUTS

Listings of the model inputs and outputs are contained in TABLES 9 through 12. TABLE 9 lists the transponder/interrogator/sensor characteristics. TABLE 10 contains the S_O input parameters with accompanying definitions and units. TABLE 11 describes units of other input parameters specified at run time. Finally, TABLE 12 contains available model outputs in two groups, one for outputs available on each simulation cycle and the other for summary outputs.

APPLICABLE ENVIRONMENTAL SCENARIOS

A deployment of transponder-equipped A/C and ships, and the ground, sea, and air environment of sensors and interrogators is used as a scenario for the DABS PPM. The characteristics of each of these equipments, plus the special characteristics of an S_O or an I_O, and a set of operating instructions comprise the inputs to the PPM. The deployments may consist of any combination of DABS, ATCRBS, and AIMS equipment.

Ground Environment

The ECAC IFF Master File contains the location and operating characteristics of U.S. and Canadian military and civilian interrogators. A West European deployment is also available. The model user may select an interrogator environment from this file by specifying a radius and center point. An auxiliary file containing DABS sensor locations and equipment characteristics at future FAA DABS sites was created for the use of the DABS PPM.

TABLE 9

TRANSPONDER/INTERROGATOR/SENSOR CHARACTERISTICS

Transponder Record Characteristics
Latitude
Longitude
Altitude (feet)
Transponder type
Sensitivity (dBm)
Power (kW)
Mode capability
Interrogator/Sensor Record Characteristics
Latitude
Longitude
Site elevation (feet)
Antenna height (feet)
Output power (kW)
PRF (pps)
SLS indicator
Mode interlace
Omni antenna gain (dB)
Antenna Characteristics
Mainbeam gain (dBi)[a]
Sidelobe gain (dBi)
Backlobe gain (dBi)
Mainbeam width (degrees)
Sidelobe width (degrees)
Backlobe width (degrees)
Scan rate (rpm)

[a]dBi = antenna gain in dB relative to an isotropic radiation.

TABLE 10

SENSOR-OF-INTEREST INPUT PARAMETERS

Coverage radius
ATCRBS/DABS all-call listening period, in μs
Sensitivity-time control characteristics
Depth of curve, in dB Plateau time, in μs
ATCRBS target range bin
Range tolerance in which ATCRBS reply correlates with existing target record, in nmi
ATCRBS target begin-validate threshold
Number of hits at which target code validation process begins
ATCRBS target-detection threshold
Number of hits required for target detection
ATCRBS target-end threshold
Number of consecutive misses required for completion of target processing
DABS uncertainty window
Period of time based on range uncertainty during which DABS sensor expects arrival of roll-call reply, in μs
Signal level-acceptance threshold
Power decrement from established DABS reply preamble signal level below which succeeding pulses are eliminated from processing
ATCRBS mode range difference
Maximum range difference between incoming reply range and reply group range for sweep-to-sweep reply correlation
ATCRBS mode azimuth difference
Maximum azimuth difference between incoming reply azimuth and reply group azimuth for sweep-to-sweep reply correlation
ATCRBS mode range bin
Range bin size for reply range sort table

TABLE 11

INPUT PARAMETERS

All-call suppression time

DABS transponder dead time after decoding of a DABS all-call interrogation including reply transmission time, in μs

ATCRBS suppression time

ATCRBS or DABS transponder dead time after decoding of an ATCRBS interrogation including reply transmission time, in μs

Roll-call suppression time (own address)

DABS transponder dead time after decoding of an own address DABS roll-call interrogation including reply transmission time, in μs

Roll-call suppression time (other address)

DABS transponder dead time after decoding a DABS roll-call interrogation addressed to another aircraft, in μs.

Sidelobe suppression (SLS) time

ATCRBS or DABS transponder dead time after decoding a DABS sensor or ATCRBS interrogator, SLS transmission, in μs

Roll-call interrogation message length

DABS sensor roll-call interrogation message length, normal format, in μs

DABS reply message length

DABS transponder all-call or roll-call reply message length, normal format, in μs

DABS reinterrogation power

DABS sensor increase in output power on roll-call re-interrogation, in dB

TABLE 12

MODEL OUTPUTS

Available on each Simulation Cycle	
Interrogator file listing, aircraft deployment listing	(INPUT)
Roll-call schedule for each DABS sensor, interrogation time and anticipated reply time for each DABS-equipped A/C	(ROLCAL)
Arrival time at each A/C in the S_o mainbeam of ATCRBS interrogations, DABS roll-calls, DABS all-calls, SLS's, and the identity of each interferer contributing to the signal environment at each A/C	(DABINT)
Identity and arrival time of all-call, roll-call, and ATCRBS replies from each A/C in the mainbeam of S_o	(OVRLAP)
Arrival times of all ATCRBS and DABS fruit replies as seen by S_o.	(FRUIT & SLFRT)
Results of all DABS transactions including range, identity, and error detection summary for DABS-equipped A/C	(PROCES)
Results of ATCRBS target detection and code-validation process including range and A/C identity	(ATEVAL) (ATMOP)
Summary Outputs	
At each DABS- and ATCRBS-equipped A/C, ATCRBS interrogation rate, DABS all-call interrogation rate, DABS roll-call interrogation rate, SLS	
Total number of suppressed interrogations for all A/C	
Total number of garbled interrogations for all A/C	
Probability of reply to S_o for all A/C	
ATCRBS, all-call, and roll-call fruit rate at the S_o	

The user may also augment the environment by creating or deleting records or by changing the characteristics of existing records. TABLE 9 lists the characteristics available in each record. Any or all of the characteristics in a record may be altered. A complete interrogator/sensor environment may also be created in a separate file for use by the DABS PPM.

To complete the interrogator sensor environment, the user must identify a S_o or I_o. The model will calculate the system performance at this site.

Airborne Environment

The airborne evironment consists of a deployment of A/C usually centered around the S_o. Each A/C is identified by its latitude, longitude, altitude, and transponder type.

To use the model, the user may create an A/C deployment by randomly distributing, in altitude and position, a number of A/C within a specified radius of the S_o. A second method is to deploy the A/C along high-altitude and low-altitude airways by using air traffic regulations and statistics for spacing in altitude and range as constraints. A third method is to take scope photographs of typical air traffic in the vicinity of the S_o. A fourth method is to obtain target report listings from an automated target processor of the S_o.

ECAC has a number of existing air traffic deployments, obtained previously from common digitizer and ARTS-III target report listings of various FAA facilities.

A maximum number of 800 A/C can be input to the model in its present configuration. The combined number of interrogators and sensors is limited to 250. Larger environments can be used, depending on the model options that are selected. The maximum transponder-equipped A/C figure of 800 allows for the use of a busy operational environment, such as the Los Angeles Basin area, through the 1980's.

MODELING ASSUMPTIONS

Two assumptions shaped the formulation of two separate model areas. To minimize model run time, the first assumption concerned the generation of sidelobe replies. The arrival times of all interrogations at all A/C in the sidelobes were calculated deterministically, but checks for pre-empted, overlapped, or garbled interrogations were not made. Instead, a Monte Carlo technique was used to determine whether or not a reply to the interrogation was elicited. To determine whether the reply occurred or not, a random number was compared to the cumulative reply probability obtained from the transponder performance in the mainbeam of the S_o. The Monte Carlo technique precluded the necessity of a series of checks requiring considerable run time.

The second assumption set up the approach to the DABS reply processor error-detection modeling. No attempt is made in this portion of the model to simulate in detail the error correction capability of the system. The reply processor model predicts the conditions that exist while processing each DABS reply. The outputs from the model place emphasis on the occurrence of error detection spanning more than 24 contiguous bits. This emphasis is derived from the statement that most "errors spanning less than 24 contiguous bits" are error-correctable (Reference 3).

The results of all overlap conditions are reported in the model, and error conditions of the above type are flagged for the user.

SECTION 5

SUMMARY

A description is given for a Discrete Address Beacon System (DABS)/ Air Traffic Control Radar Beacon System (ATCRBS)/ATCRBS IFF MARK XII System (AIMS) Performance Prediction Model. In a given environment of DABS, ATCRBS, and AIMS sensors and transponders, the computer model predicts the intra- and inter-system interference that arises within this mixed secondary surveillance radar system.

APPENDIX A

MODEL FLOW CHARTS

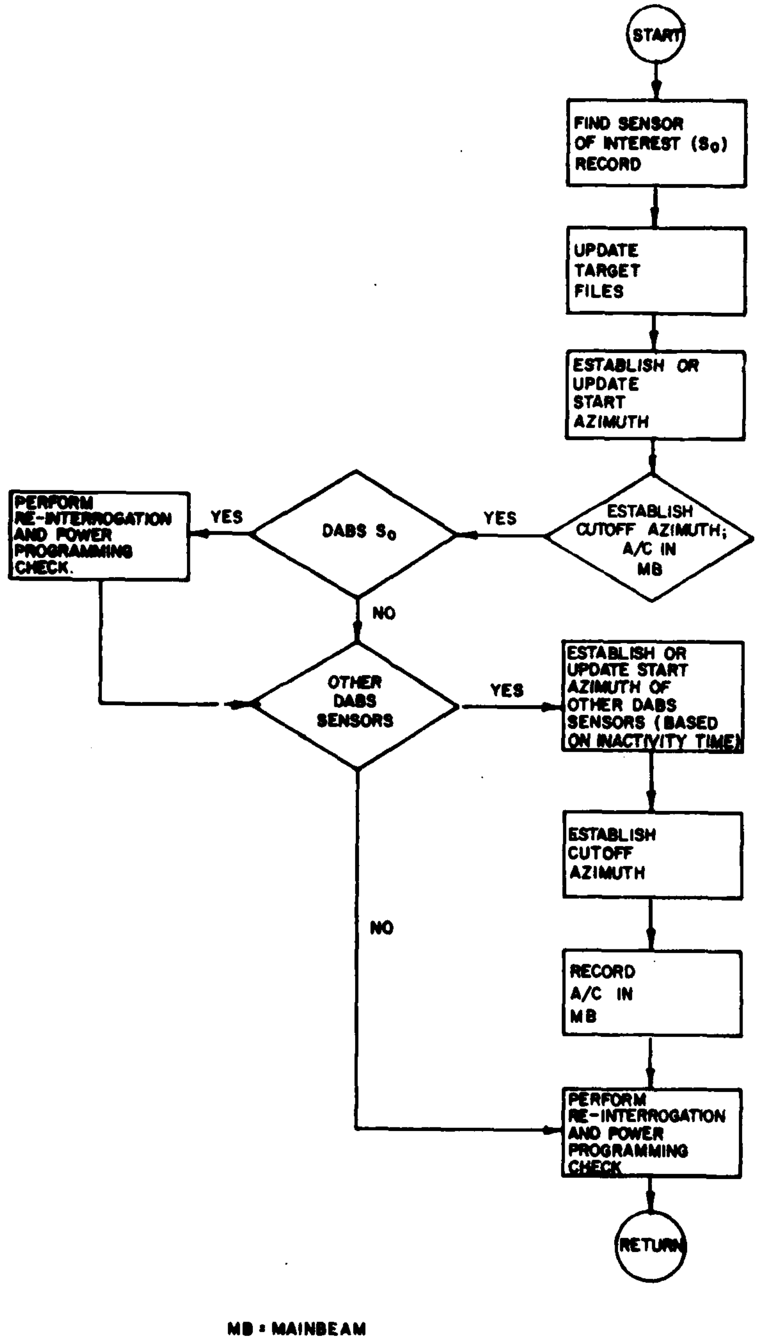


Figure A-1. Channel management (ACTIVE) flow chart.

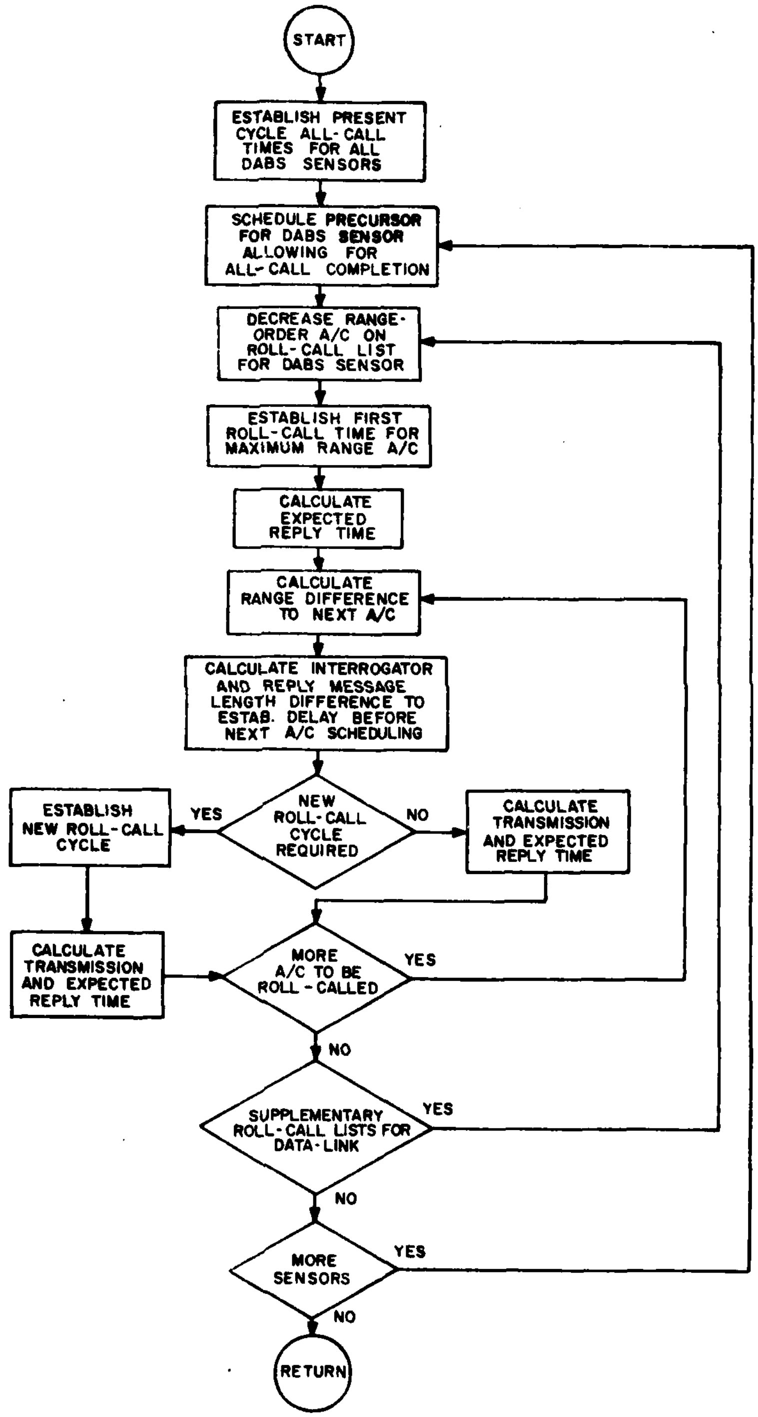
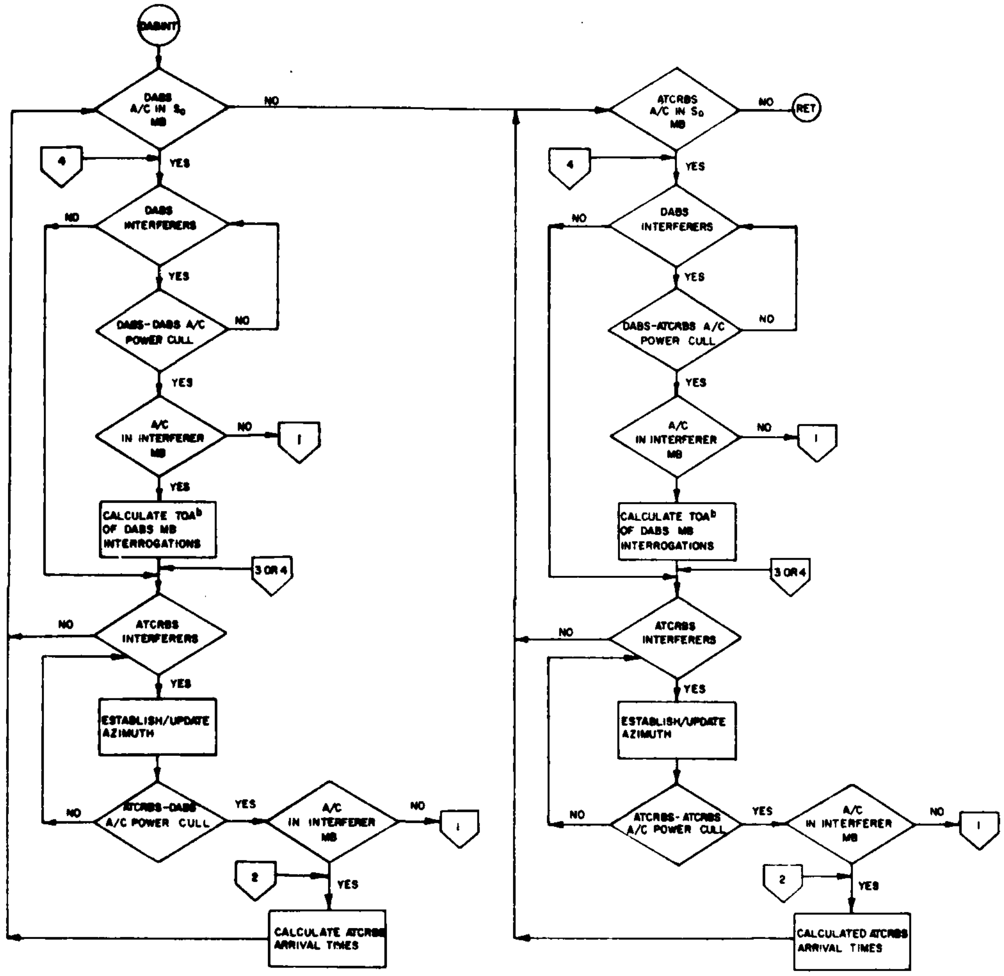


Figure A-2. Roll-call scheduling (ROLCAL) flow chart.



MB = MAINBEAM
TOA = TIME OF ARRIVAL

Figure A-3. Transponder signal environment (DABINT/P1P2) flow chart. (Page 1 of 2).

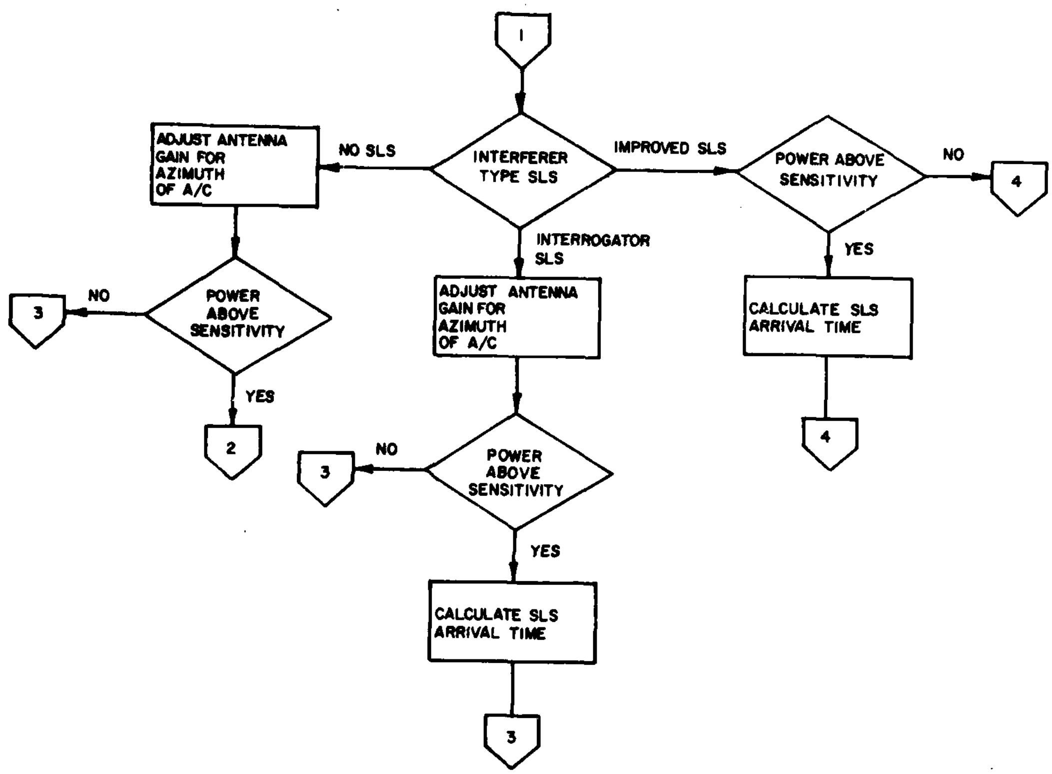


Figure A-3. (Page 2 of 2).

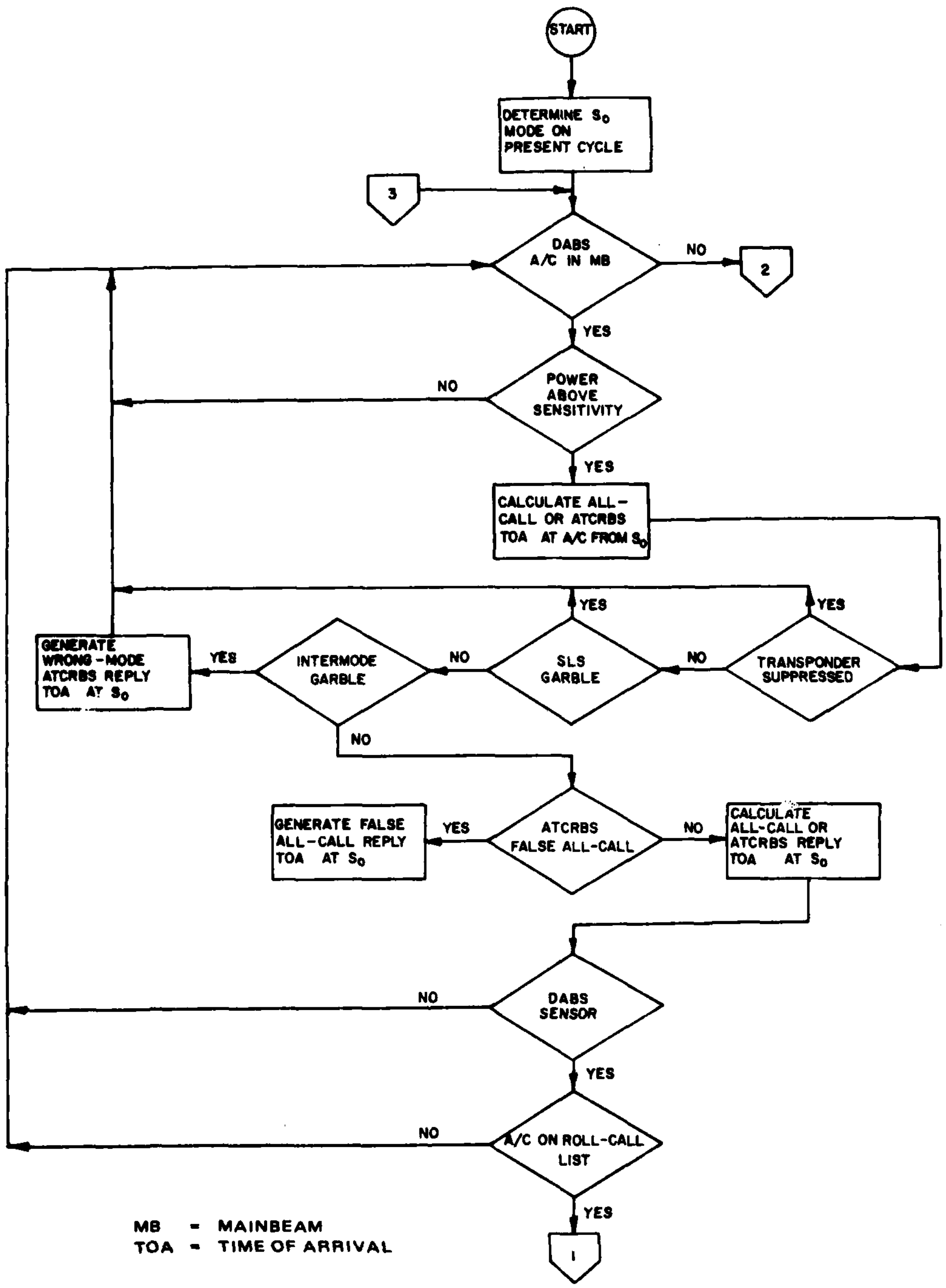


Figure A-4. Transponder model (OVRLAP) flow chart. (Page 1 of 3).

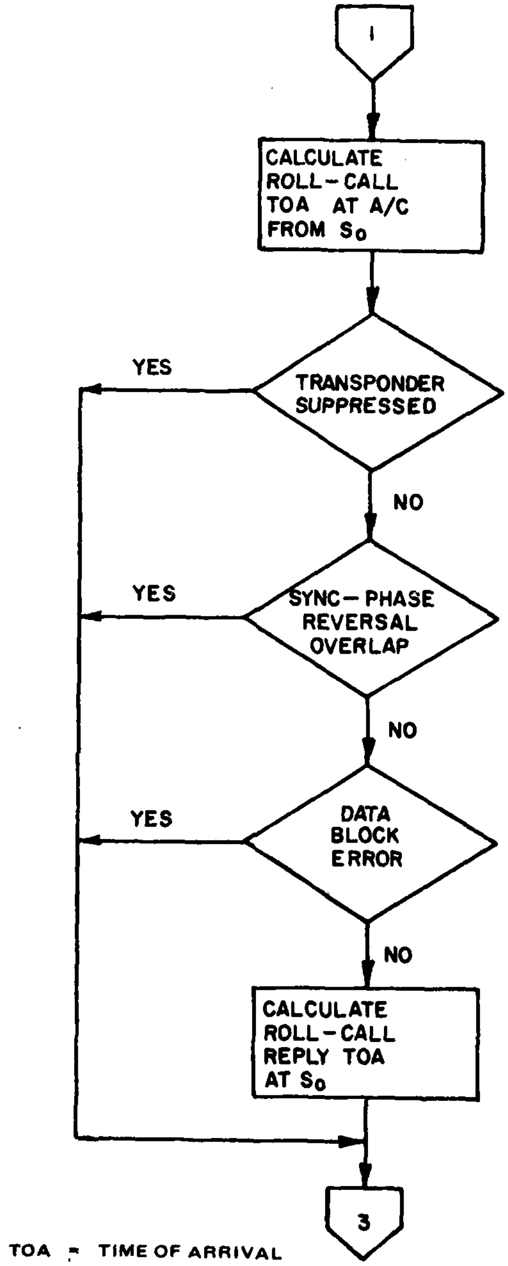


Figure A-4. (Page 2 of 3).

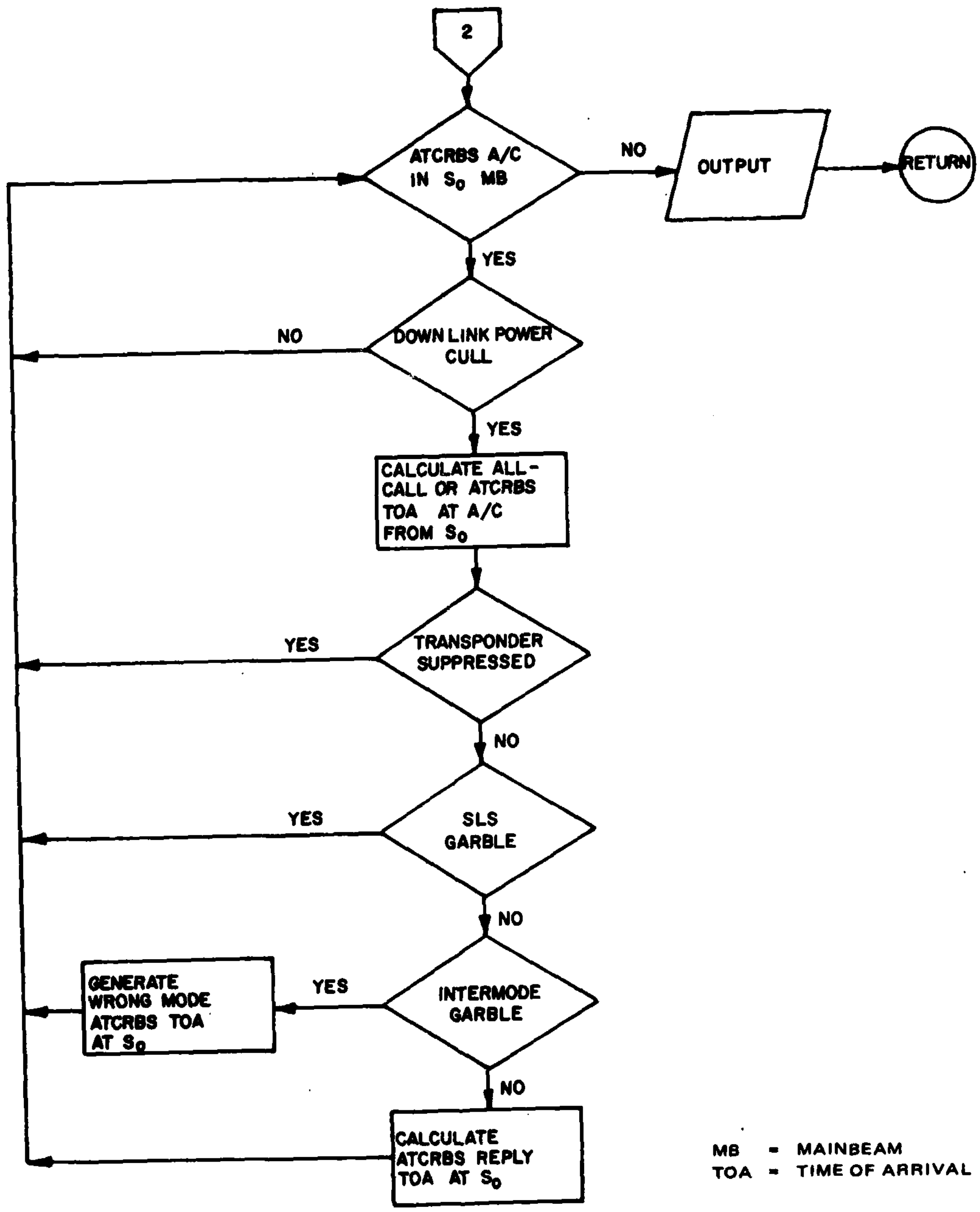


Figure A-4. (Page 3 of 3).

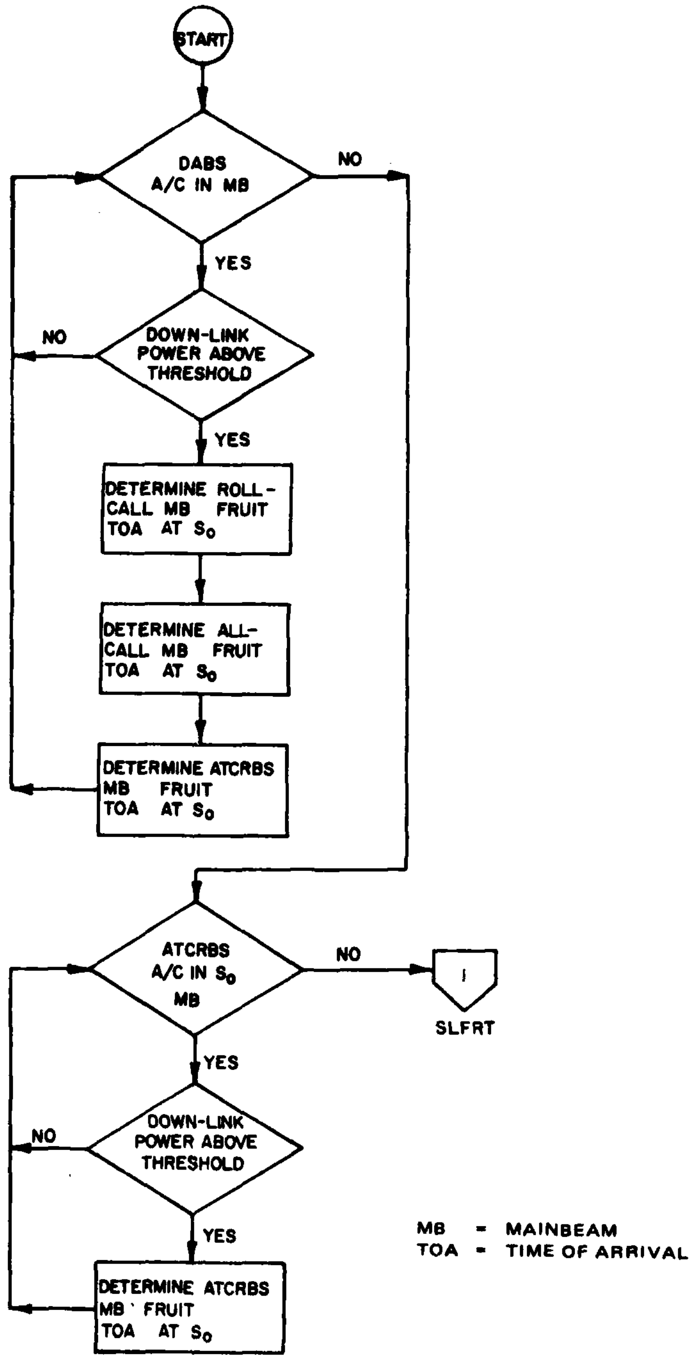


Figure A-5. Downlink signal environment (FRUIT/SLFRT) submodel flow chart. (Page 1 of 2).

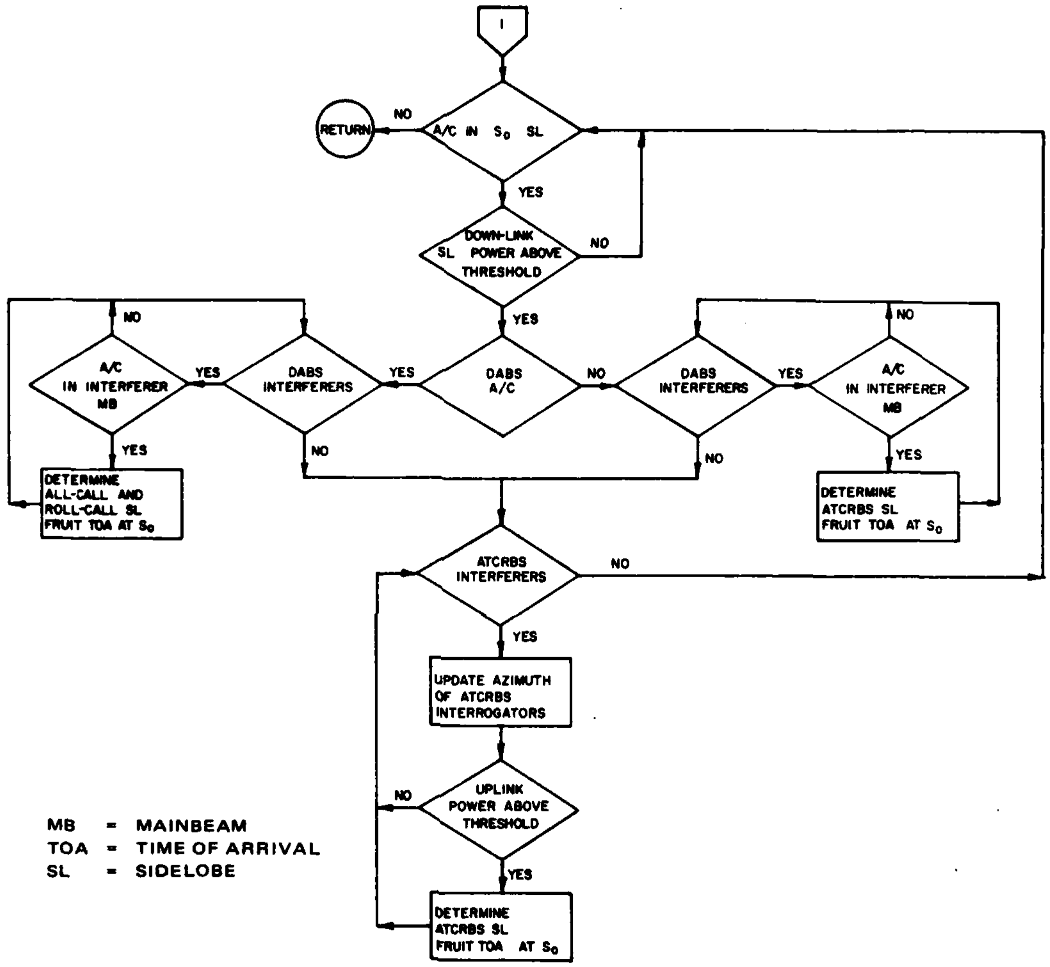


Figure A-5. (Page 2 of 2).

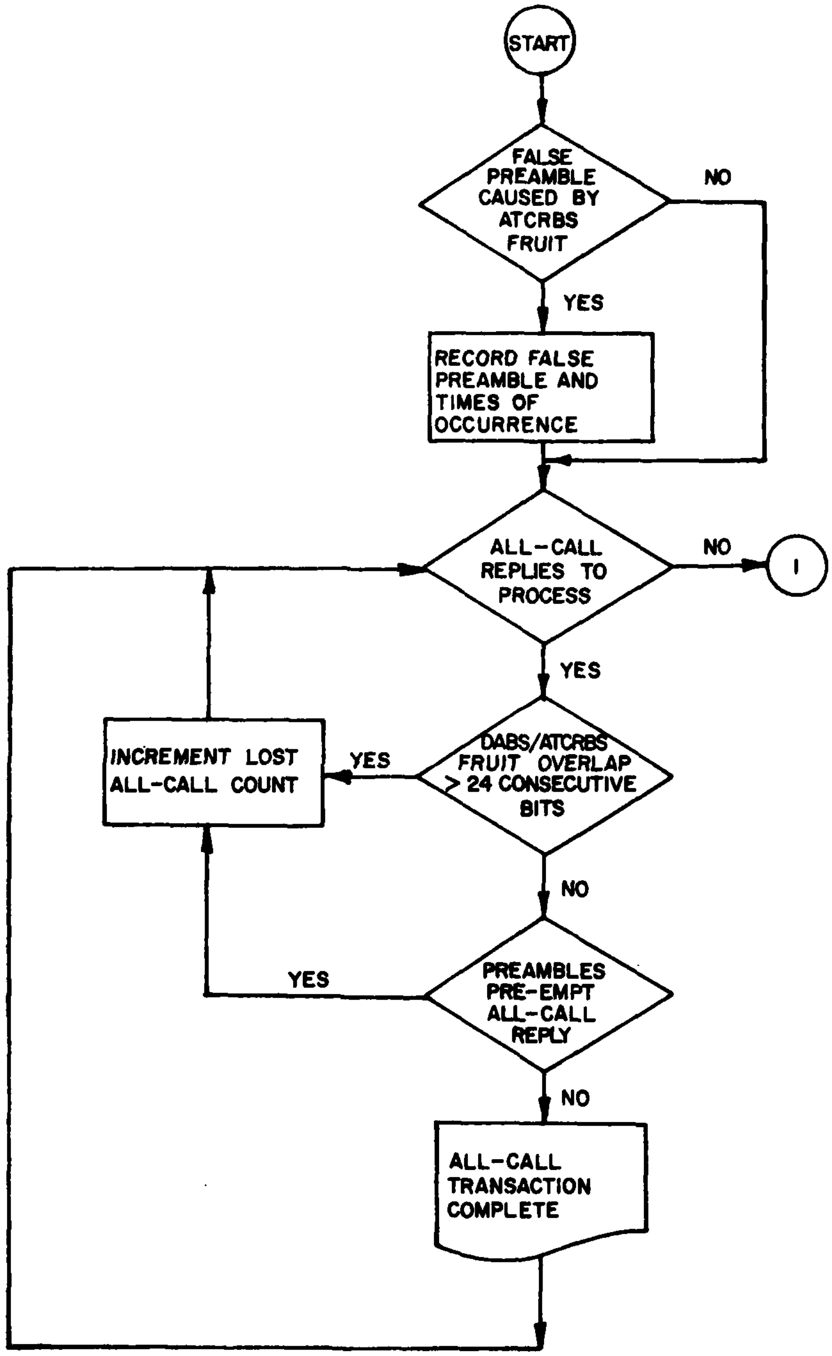


Figure A-6. DABS target processor (PROCES) subroutine flow chart. (Page 1 of 2).

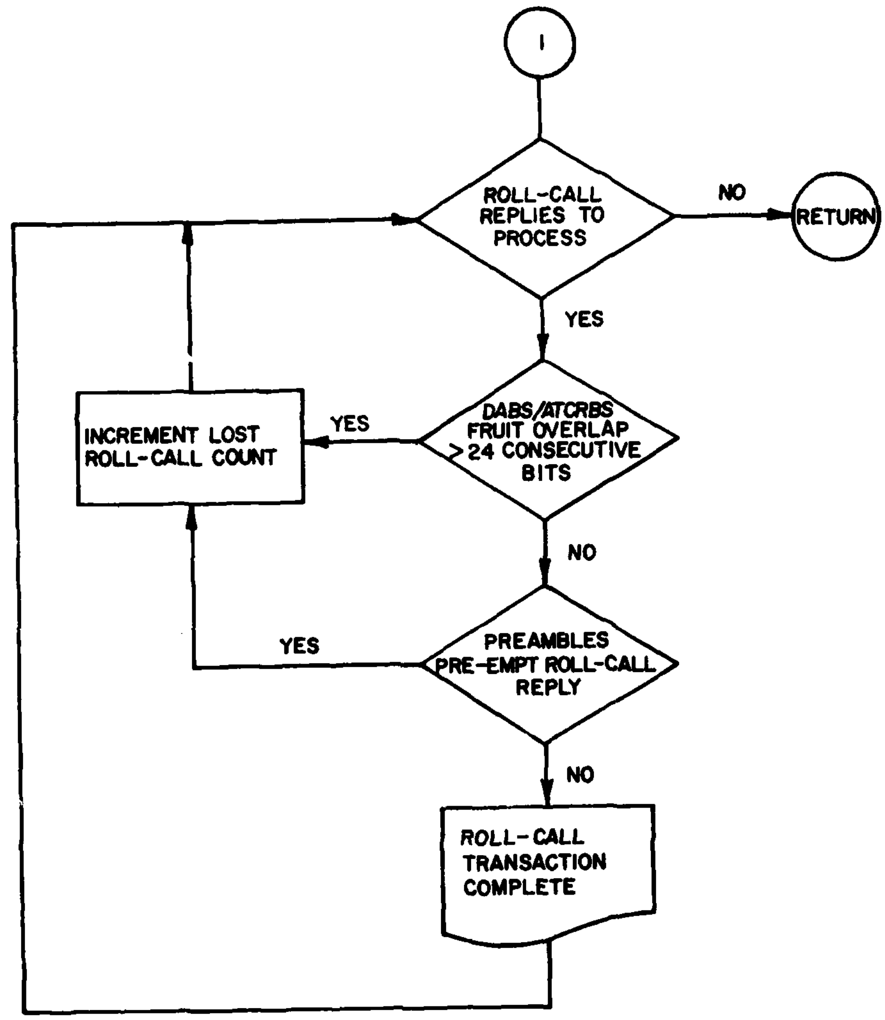


Figure A-6. (Page 2 of 2).

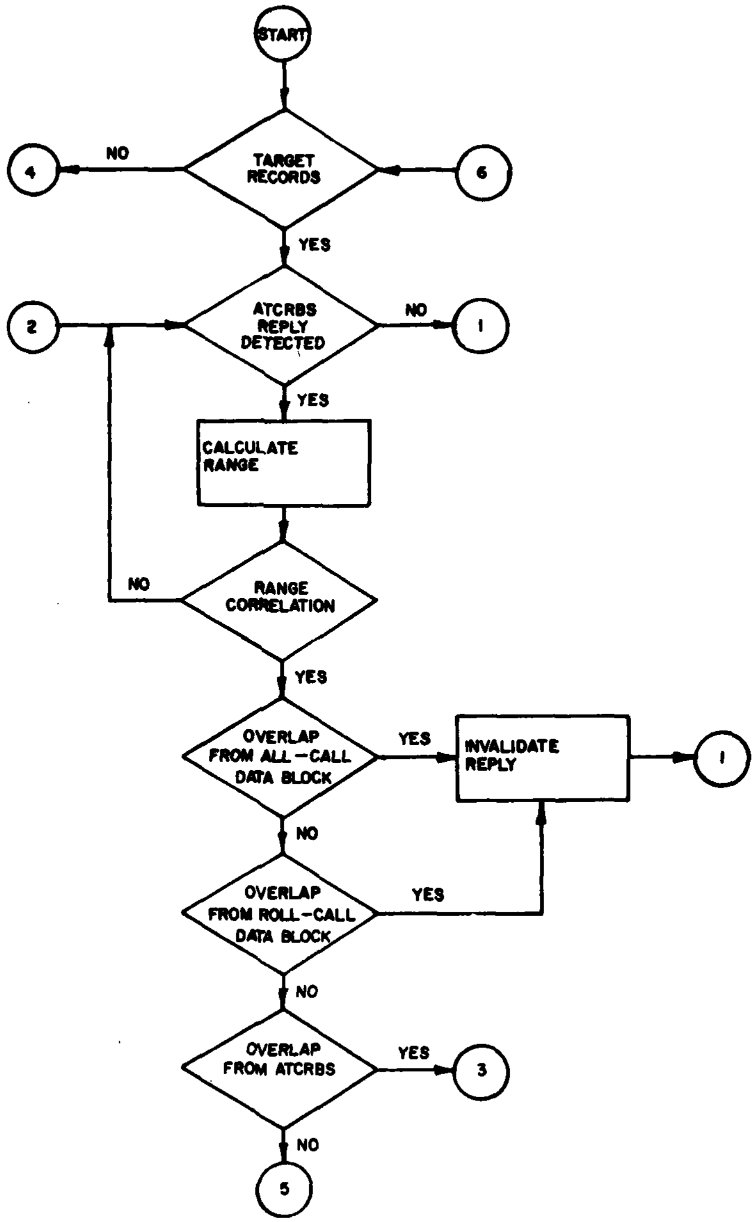


Figure A-7. ATCRBS target processor (ATEVAL) subroutine flow chart. (Page 1 of 3).

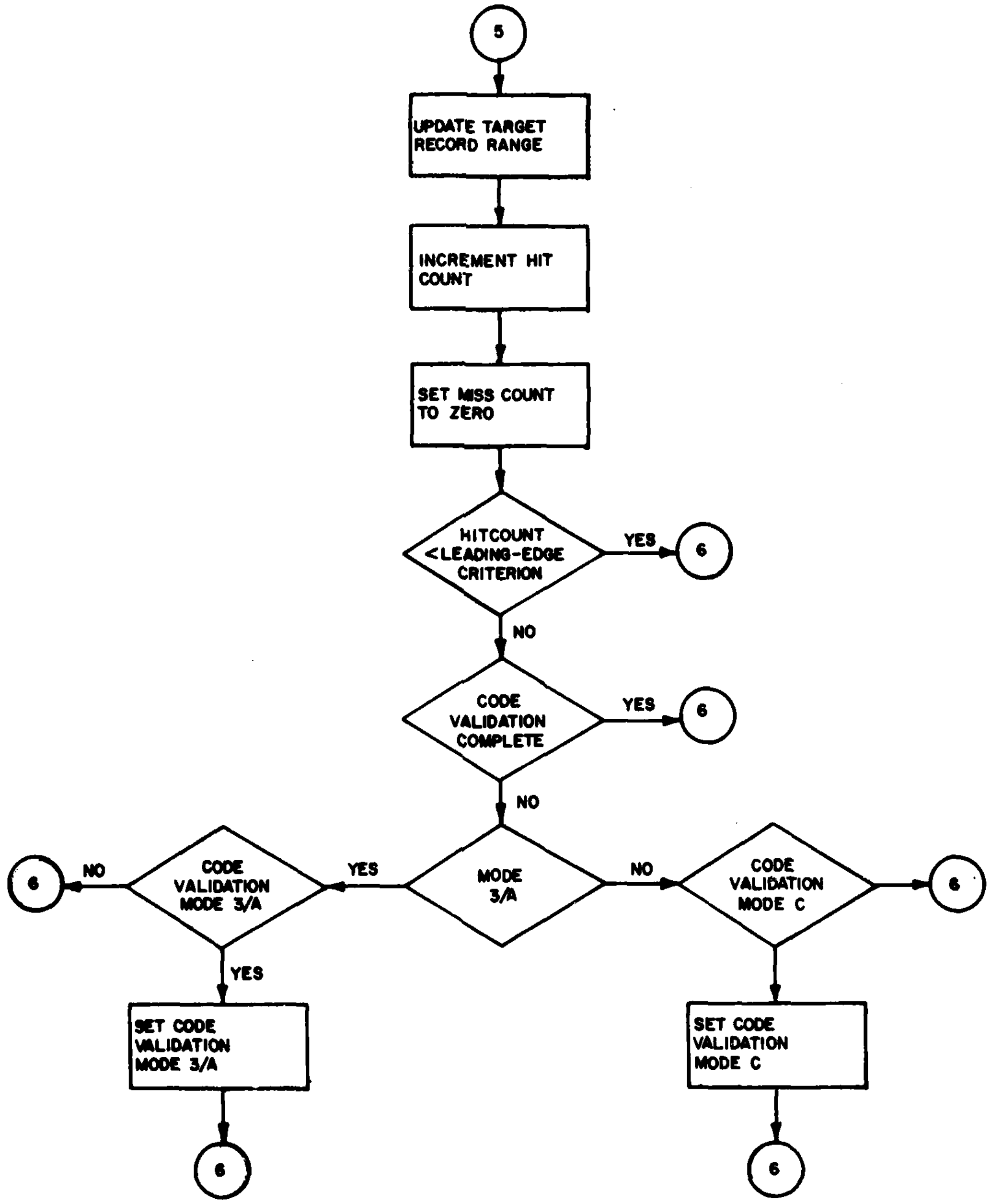


Figure A-7. (Page 2 of 3).

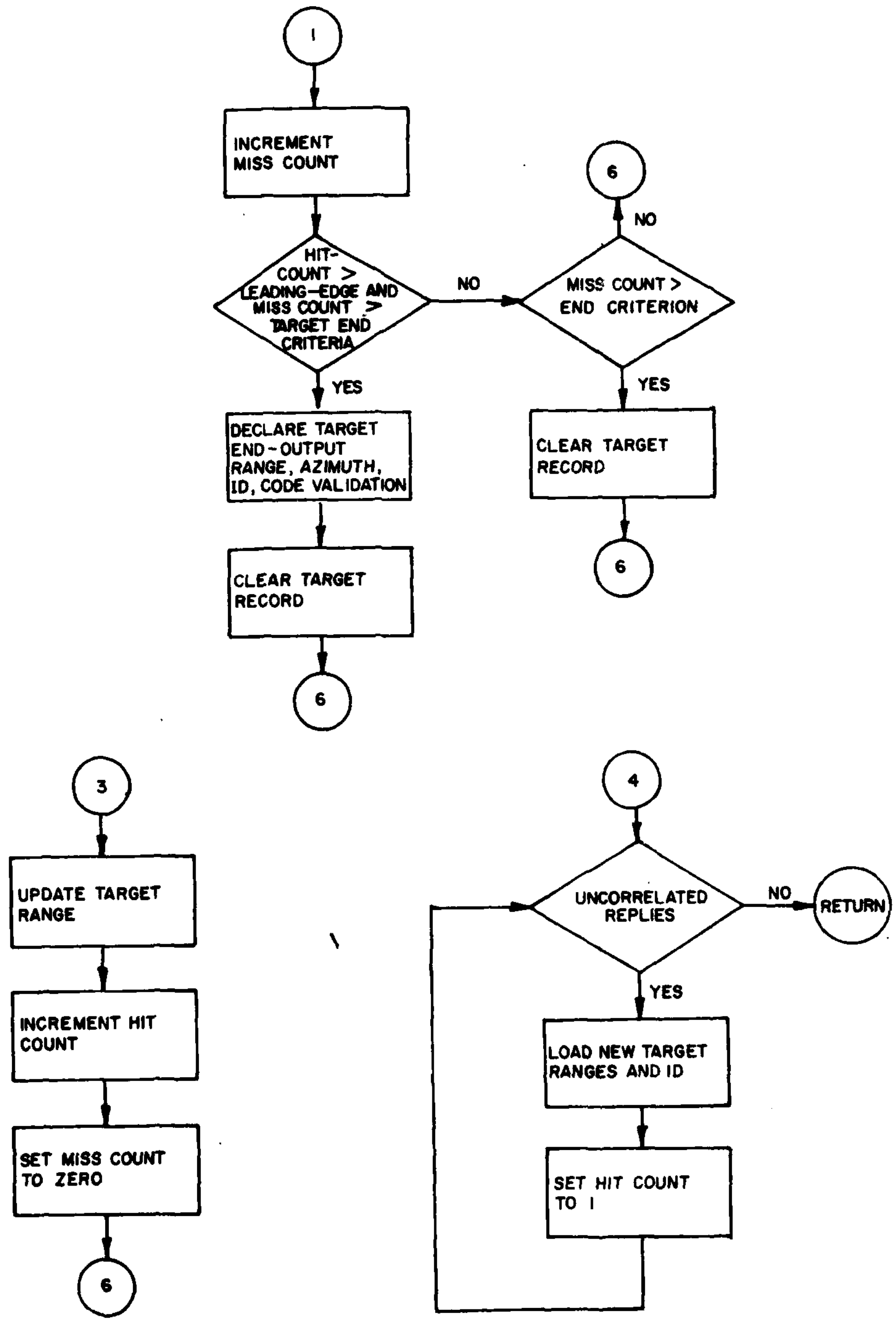


Figure A-7. (Page 3 of 3).

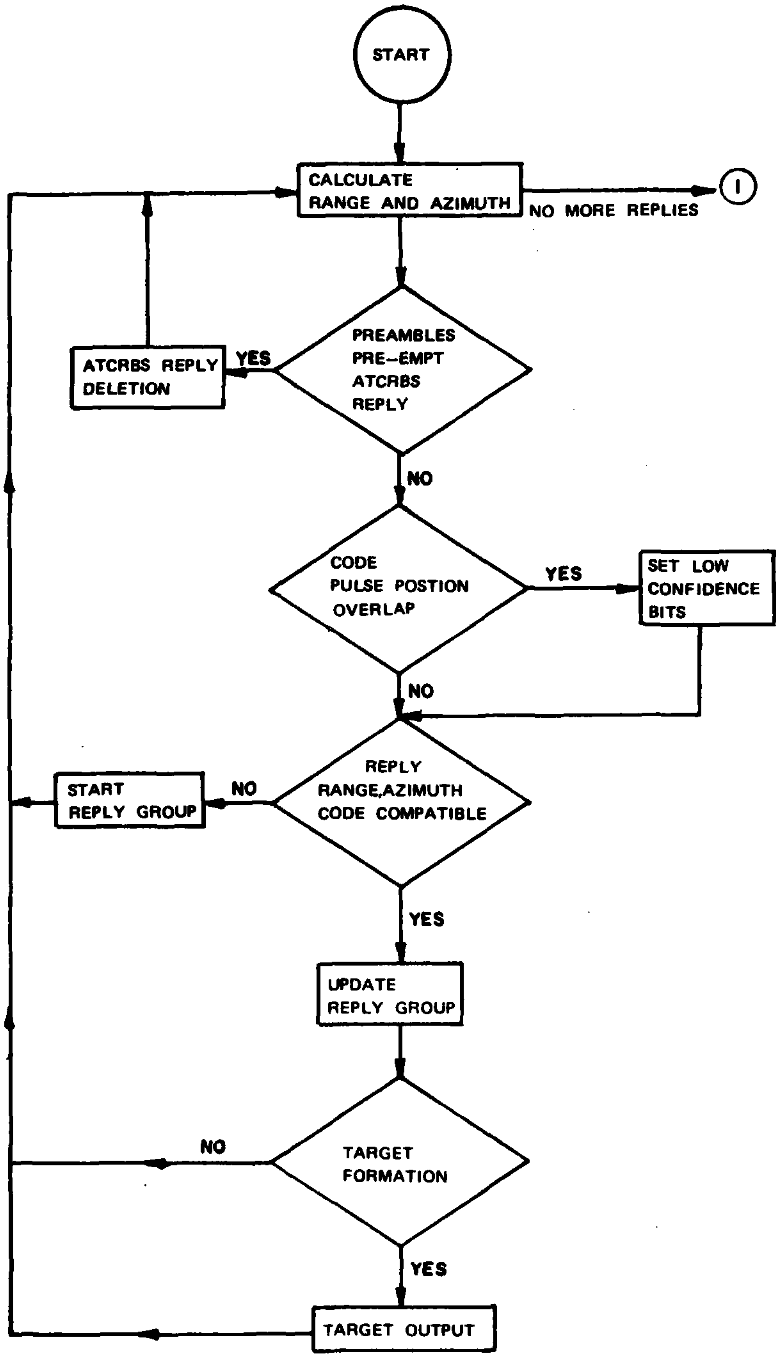


Figure A-8. ATCRBS mode of DABS processor (ATMDP) subroutine flow chart. (Page 1 of 3)

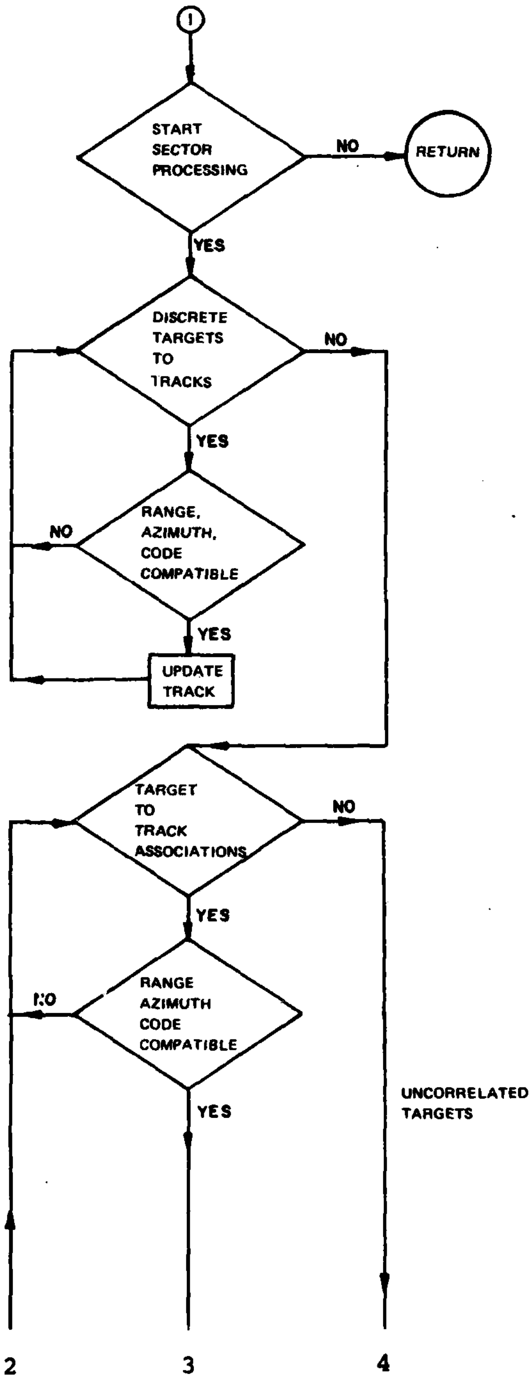


Figure A-8. (Page 2 of 3).

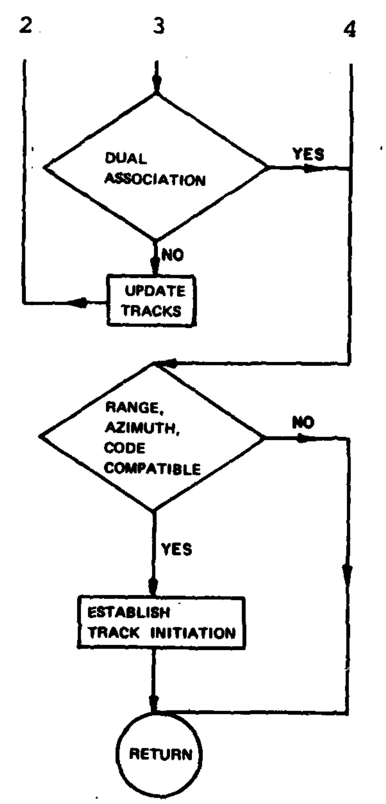


Figure A-8. (Page 3 of 3).