

84  
80  
51  
IV  
COPY 1 2  
note technical note techn

FEDERAL AVIATION ADMINISTRATION

FEB 18 1983

TECHNICAL CENTER LIBRARY  
ATLANTIC CITY, N.J. 08405

# Active Beacon Collision Avoidance Logic Evaluation: Volume IV, Interface (ATARS/BCAS/CIR) Phase

Barry Billmann  
Jacob Thomas  
James Windle

December 1982

DOT/FAA/CT-80/51-IV

Document is on file at the Technical Center  
Library, Atlantic City Airport, N.J. 08405



U.S. Department of Transportation  
**Federal Aviation Administration**

Technical Center  
Atlantic City Airport, N.J. 08405



00008482

**NOTICE**

This document is disseminated under the sponsorship of the Department of Transportation in the interest of information exchange. The United States Government assumes no liability for the contents or use thereof.

The United States Government does not endorse products or manufacturers. Trade or manufacturer's names appear herein solely because they are considered essential to the object of this report.

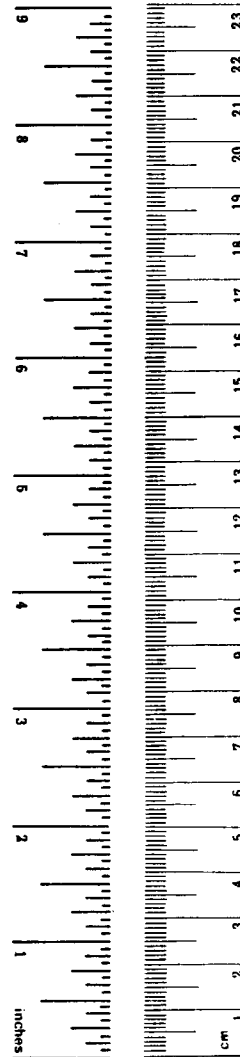
1. Report No. DOT/FAA/CT-80/51-IV		2. Government Accession No.		3. Recipient's Catalog No.	
4. Title and Subtitle ACTIVE BEACON COLLISION AVOIDANCE LOGIC EVALUATION: VOLUME IV, INTERFACE (ATARS/BCAS/CIR) PHASE				5. Report Date December 1982	
				6. Performing Organization Code	
7. Author(s) B. Billmann, J. Thomas, and J. Windle				8. Performing Organization Report No. DOT/FAA/CT-80/51-IV	
9. Performing Organization Name and Address Federal Aviation Administration Technical Center Atlantic City Airport, New Jersey 08405				10. Work Unit No. (TRAIS)	
				11. Contract or Grant No. 052-242-320	
12. Sponsoring Agency Name and Address U.S. Department of Transportation Federal Aviation Administration Technical Center Atlantic City Airport, New Jersey 08405				13. Type of Report and Period Covered Technical Note	
				14. Sponsoring Agency Code	
15. Supplementary Notes					
16. Abstract  An evaluation of the Active Beacon Collision Avoidance System (BCAS), Automated Traffic Advisory and Resolution Service (ATARS), and the Conflict Indicator Register (CIR) interface logic was conducted at the Federal Aviation Administration Technical Center. The evaluation was performed using dynamic simulation. The test bed for the evaluation was the Fast-Time Encounter Generator (FTEG). The FTEG was modified to simulate a single ATARS/Discrete Address Beacon System (DABS) site environment.  Current Active BCAS development plans are to replace the CIR with the resolution advisory register (RAR). Since the RAR must provide basically the same air-to-air BCAS coordination capability as the CIR logic, the deficiencies that were corrected in the CIR logic are relevant to the RAR logic.  In all cases tested, the ATARS/BCAS interface logic permitted BCAS to resolve pop-up threats which were initially not detected by ATARS. Encounter conditions which resulted in BCAS alarms when ATARS did not alarm because of large horizontal miss distances were identified. Suppression of BCAS PWI messages by ATARS in cases where BCAS had resolution responsibility was also detected.					
17. Key Words BCAS ATARS CIR			18. Distribution Statement		
19. Security Classif. (of this report) Unclassified		20. Security Classif. (of this page) Unclassified		21. No. of Pages 59	22. Price

## METRIC CONVERSION FACTORS

### Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
<b>LENGTH</b>				
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
<b>AREA</b>				
in <sup>2</sup>	square inches	6.5	square centimeters	cm <sup>2</sup>
ft <sup>2</sup>	square feet	0.09	square meters	m <sup>2</sup>
yd <sup>2</sup>	square yards	0.8	square meters	m <sup>2</sup>
mi <sup>2</sup>	square miles	2.6	square kilometers	km <sup>2</sup>
	acres	0.4	hectares	ha
<b>MASS (weight)</b>				
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
<b>VOLUME</b>				
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 <sup>3</sup>	cubic feet	0.03	cubic meters	m <sup>3</sup>
yd <sup>3</sup>	cubic yards	0.76	cubic meters	m <sup>3</sup>
<b>TEMPERATURE (exact)</b>				
°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. 013-10286.



### Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
<b>LENGTH</b>				
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
<b>AREA</b>				
cm <sup>2</sup>	square centimeters	0.16	square inches	in <sup>2</sup>
m <sup>2</sup>	square meters	1.2	square yards	yd <sup>2</sup>
km <sup>2</sup>	square kilometers	0.4	square miles	mi <sup>2</sup>
ha	hectares (10,000 m <sup>2</sup> )	2.5	acres	
<b>MASS (weight)</b>				
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
<b>VOLUME</b>				
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 <sup>3</sup>	cubic meters	35	cubic feet	ft <sup>3</sup>
m <sup>3</sup>	cubic meters	1.3	cubic yards	yd <sup>3</sup>
<b>TEMPERATURE (exact)</b>				
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F

## TABLE OF CONTENTS

	Page
INTRODUCTION	1
Purpose	1
Background	1
Objectives	1
Scope	1
SYSTEM DESCRIPTION	2
Simulated ATARS Service Zone	2
Squitter Lockout Region	2
System Protocols	3
Simulated ATARS Logic	5
ANALYSIS	7
Conflicts in the ATARS/BCAS Seam Region	7
Pop-Up Threat Analysis	24
Multiple Aircraft Conflict Across the ATARS Coverage Boundary	25
Multiple CIR Row Exchange Procedures	32
CONCLUSIONS AND RECOMMENDATIONS	38
REFERENCES	39
APPENDICES	
A — Conflict Indicator Register (CIR) Description	
B — Results of Modified Proximity Warning Indicator (PWI) Logic	

## LIST OF ILLUSTRATIONS

Figure		Page
1	Description of ATARS/BCAS Seam Region	3
2	High Level ATARS/BCAS Interface Logic	6
3	ATARS/BCAS Seam Encounter (ATCRBS Threat) Horizontal Separation	8
4	Threat Identity Correlator (TIC) Flow Chart	11
5	Encounter Conditions Which Inhibit Threat Correlation	12
6	Suggested ATCRBS Correlation Logic Change	14
7	Encounter Which Resulted in Large Bearing Change Near CPA	16
8	Encounter Which Caused Incorrect Setting of B Bits	17
9	High Level BCAS Flow Chart	18
10	BCAS Maneuver Coordination (COORD) Flow Chart	20
11	Revised COORD Logic	21
12	Pop-Up Threat Encounter Conditions	24
13	Pop-Up Threat Plot (Relative Range Versus Time)	26
14	Pop-Up Threat Plot (Altitude Versus Time)	26A
15	Multiple Aircraft Boundary Transition Coordination Scenario	27
16	Multiple Aircraft (Vertical) Plot	30
17	Multiple Aircraft (Horizontal) Plot	31
18	Suggested Change to TRIACT Logic	34
19	Modified PWIDET Logic	35
20	Encounter Condition Which Caused BCAS PWI Suppression	36
21	Modified DISPWI Logic	37

## LIST OF TABLES

Table		Page
1	Command Compatibility	4
2	ATARS Threat Declaration Volume	5
3	BCAS Commands for ATCRBS Encounter with 1-Nmi Miss Distance at Point of Closest Approach	9
4	ATARS Correlation Limitations	10
5	Uplinked ATARS Messages and CIR Status (2 Sheets)	13
6	Sequential Changes in Bearing and Bearing Rate	15
7	Sequential BCAS Conflict Data (2 Sheets)	19
8	Summary of Events	20
9	Sequential Conflict Data for Revised COORD Logic (2 Sheets)	23
10	Summary of Sequential BCAS Data for BCAS Equipped Pop-Up Threat	25
11	Multiple Encounter Planned CPA Conditions	28
12	Multiple Encounter Command and CIR Status	29
13	Vertical Separation at CPA for Three-Aircraft Encounter	32
14	Additional PWI Logic Threshold Values	33

## LIST OF ABBREVIATIONS

ACAS - Airborne Collision Avoidance System

Altimeter Correspondence Error - The error due to improper mode C altitude encoding

Alpha - The altitude tracking weighting constant in an Alpha-Beta tracking system

ASA - Aircraft separation assurance

ATARS - Automatic Traffic Advisory and Resolution Service

ATC - air traffic control

ATCRBS - Air Traffic Control Radar Beacon System

ATCSF - Air Traffic Control Simulation Facility

BCAS - Beacon Collision Avoidance System

Beta - The altitude rate tracking weighting constant in an Alpha-Beta tracking system

CIR - Conflict Indicator Register

CSC - Computer Sciences Corporation

DR&A - Data reduction and analysis

FTEG - Fast-Time Encounter Generator

g - Acceleration due to gravity, 32.16 feet per sec<sup>2</sup>

ID - Aircraft identification

IFR - Instrument Flight Rules

ILS - Instrument Landing System

IPD - Intruder positional data (proximity warning indication)

Mode C - Aircraft encoding altimeter capability

PPD - Partial positional data (proximity warning indication containing only range and altitude of threat)

VFR - Visual flight rules

VSL - Vertical speed limit

## LIST OF BCAS ALGORITHM TERMS

A	Absolute altitude separation
A BIT	ATARS service Bit
ADOT	Relative tracked altitude rate
ALIM	Altitude threshold for choice of positive or negative commands (470 feet)
ALPC	Threshold for high altitude threat declaration (18,000 feet)
ALUH	Threshold for ultrahigh altitude threat declaration (29,000 feet)
ASEPH	High altitude threshold for choice of positive or negative commands (670 feet)
ASEPU	Ultrahigh altitude threshold for choice of positive or negative commands (770 feet)
CLMRT	Assumed BCAS climb escape rate (16.67 feet per second)
CMDSAV	Previous command selected array
Command Sense	The vertical direction of a BCAS command
COMP Function	The function in the coordination logic that forms the complement of a threat message
CPA	Closest point of approach
D Field	Own maneuver intent field in the CIR
DESRT	Assumed BCAS descent escape rate (-25 feet per second)
DMOD	Modification distance applied to tracked range (0.1, 0.3, or 1 nautical mile)
DRACT	Detection and resolution module
DRPFLG	Flag indicating need to drop the command
EQ	Flag indicating intruder is BCAS equipped
INDEX	Performance level for selection of threat logic parameters
KHIT	Intruder detection counter
MTENT	Intruder's indicated maneuver intent
OWNTENT	Own aircraft maneuver intent for specified threat

R	Tracked range to intruder
RD	Tracked range rate
RZ	Tracked relative altitude
RZD	Tracked relative altitude rate
SLEVEL	Performance level value received from Air traffic control
T1	Estimated delay time for responding to vertical speed limit command
TAU	Ratio of distance to rate of change
TAUR	Modified range tau
TAUV	Vertical tau (time to coaltitude)
TCUR	Current time for internal clock
TCMD	Time latest command was selected
TDC	Time to establish climb escape rate
TDD	Time to establish descent escape rate
TDROP	Time without reported data to drop an intruder
TESC	Anticipated maneuver time before closest approach
TRIACT	Intruder tracking module
TROACT	Own aircraft tracking module
TRTRU	True range tau ( $-\text{range}/\text{range rate}$ )
TSSC	Length of time of maneuvering at climb escape rate
TSSD	Length of time of maneuvering at descent escape rate
TVPCMD	Look ahead time for altitude detection (40 to 45 seconds)
TVPESC	Look ahead time for altitude resolution (30 to 35 seconds)
TV1	Time delay provision for response to commands (8 seconds)
TZ3	Time required to achieve assumed escape rate
VACCEL	Assumed escape acceleration (8 feet per sec <sup>2</sup> )

VI	Calculated vertical rate (feet per second) for own aircraft to achieve vertical separation of ALIM feet at closet point of approach
VLIM	Selected magnitude of VSL
VMD	Projected vertical miss distance
VSL	Vertical speed limit command
ZDCLM	Achievable climb rate
ZDDES	Achievable descent rate
ZDINT YDINT XDINT	Tracked intruder's velocity coordinates
ZDOWN	Tracked own altitude rate
ZINT	Intruder tracked altitude
ZMPCLM	Predicted vertical miss distance after climb command
ZMPDES	Predicted vertical miss distance after descent command
ZOWN	Tracked own altitude
ZPINT	Predicted altitude for unequipped intruder
ZPOWN	Predicted own altitude at CPA when $TRTRU \leq 8$ seconds
ZTHR	Immediate altitude threshold used in threat detection (750 feet)
ZTHRH	Immediate altitude threshold used in threat detection in high altitude airspace (850 feet)
ZTHRU	Immediate altitude threshold used in threat detection in ultrahigh altitude airspace (950 feet)

## INTRODUCTION

### PURPOSE.

This report presents an evaluation of the Automated Traffic Advisory and Resolution Service (ATARS)/Beacon Collision Avoidance System (BCAS)/Conflict Indicator Register (CIR) Interface logic. The CIR functioned as the coordination interface between ATARS and BCAS. The functional description of the CIR is found in appendix C of reference 1. Evaluation of the logic performance was made through fast-time simulation using the Fast-Time Encounter Generator (FTEG) (reference 2).

### BACKGROUND.

ATARS and BCAS may simultaneously be in use onboard appropriately equipped aircraft. It is necessary to establish an interface which will enable the two systems to operate in a cooperative manner. This led to the definition of separate but continuous service zones of ATARS and BCAS. The operation of the CIR, in the boundary or transition area between ATARS service regions and BCAS-only service regions, was of particular interest. The CIR logic evaluated in this report was developed by MITRE Corporation and is described in references 3 and 4. The operational design of the CIR attempts to (1) resolve the coordination problems in the ATARS/BCAS seam area, (2) provide complementary coordinated commands in multiple threat situations involving both ATARS and BCAS threats, and (3) provide for a smooth transition in system performance when transmitting from one system's service region to another during conflict periods. A far simpler task of the CIR was the assignment of threat resolution responsibility for single threats which had been detected by both ATARS and BCAS.

### OBJECTIVES.

The primary objective of this research was to assess the performance of the CIR logic in terms of the functional requirements identified in appendix C of reference 1. Specifically, the CIR interface logic should provide unambiguous collision avoidance commands independent of own or threat aircraft position in the ATARS/BCAS seam area. Only one system, ATARS or BCAS, should be assigned responsibility for a particular threat.

Secondary objectives of this research included the following: (1) evaluation of an Active BCAS proximity warning indicator (PWI) logic, (2) analysis of the BCAS threat correlation logic module, Threat Identity Correlator (TIC), and (3) assessment of CIR logic performance during periods of missing reports.

### SCOPE.

The authors assume the reader is familiar with the CIR functional description found in appendix C of reference 1. For those not familiar with the functional requirements of the CIR, a description has been included in appendix A. The effectiveness of Active BCAS resolution logic performance has been documented previously (reference 5). The full ATARS CIR logic was not available for this simulation. As a result, the major focus of this study was on the proper coordination and compatibility of the two systems, rather than the separation generated by a particular system.

It was assumed that ATARS resolution logic would function properly and generate sufficient separation if the ATARS/CIR interface logic would promptly and properly assign system responsibility for a particular threat to ATARS. BCAS algorithm terms are used throughout the report. In order to assist the reader, a list of Active BCAS logic terms is included.

## SYSTEM DESCRIPTION

### SIMULATED ATARS SERVICE ZONE.

The ATARS/BCAS/CIR interface logic was designed to establish an orderly interface, so that the two systems operated in a cooperative manner. This led to a definition of separate but continuous ATARS and BCAS service zones. ATARS was a ground-based system. The ATARS coverage area was designed around an ATARS/Discrete Address Beacon System (DABS) site. The ATARS/BCAS seam region was designed to permit BCAS to function in the peripheral regions of ATARS coverage. In these regions, ATARS surveillance did not always provide sufficient lead time in threat detection to provide adequate separation following ATARS command generation. This was especially true of pop-up threats which entered the ATARS protected airspace through the floor of the ATARS coverage region. In the seam area, it was desirable to permit BCAS to continue to function since BCAS surveillance was not limited in this region as was the ATARS surveillance.

Figure 1 depicts the ATARS/BCAS seam region used in the simulation. The structure does not portray any intended ATARS coverage area, but rather provides the test bed for evaluating the CIR interface logic.

ATARS coverage extended to 50 nautical miles (nmi) from a DABS site, and altitudes above the floor of DABS coverage. The floor of DABS coverage extended down to  $0.7^\circ$  above the horizon. The boundary of ATARS coverage is indicated by a solid line in figure 1.

BCAS operated at all altitudes beyond 40 nmi from a DABS site, and at altitudes below  $0.9^\circ$  above a plane 1,000 feet above the ground when within 40 nmi of a DABS site. The boundary of BCAS operation is indicated by a broken line in figure 1.

The ATARS/BCAS seam region is within the shaded area (see figure 1) of overlap between ATARS and BCAS coverage.

### SQUITTER LOCKOUT REGION.

The squitter lockout region is within the unshaded area as shown in figure 1. A squitter transmission is a short message that is sent out periodically and spontaneously by a DABS transponder without being prompted by an interrogation. The squitter message is used to assist Active BCAS to acquire new threats. When inside this region, the ATARS site could uplink a lockout bit which prohibited the BCAS aircraft from making Active BCAS interrogations or squittering. This would ensure that the BCAS system would not degrade ATARS performance in this region. In case the DABS transponder failed to receive ATARS uplinked messages in this region, the squitter lockout would automatically unlock after a specified time period. Under such conditions, BCAS would begin to actively interrogate and would provide a backup to ATARS in case of system failure. Since the objective of the

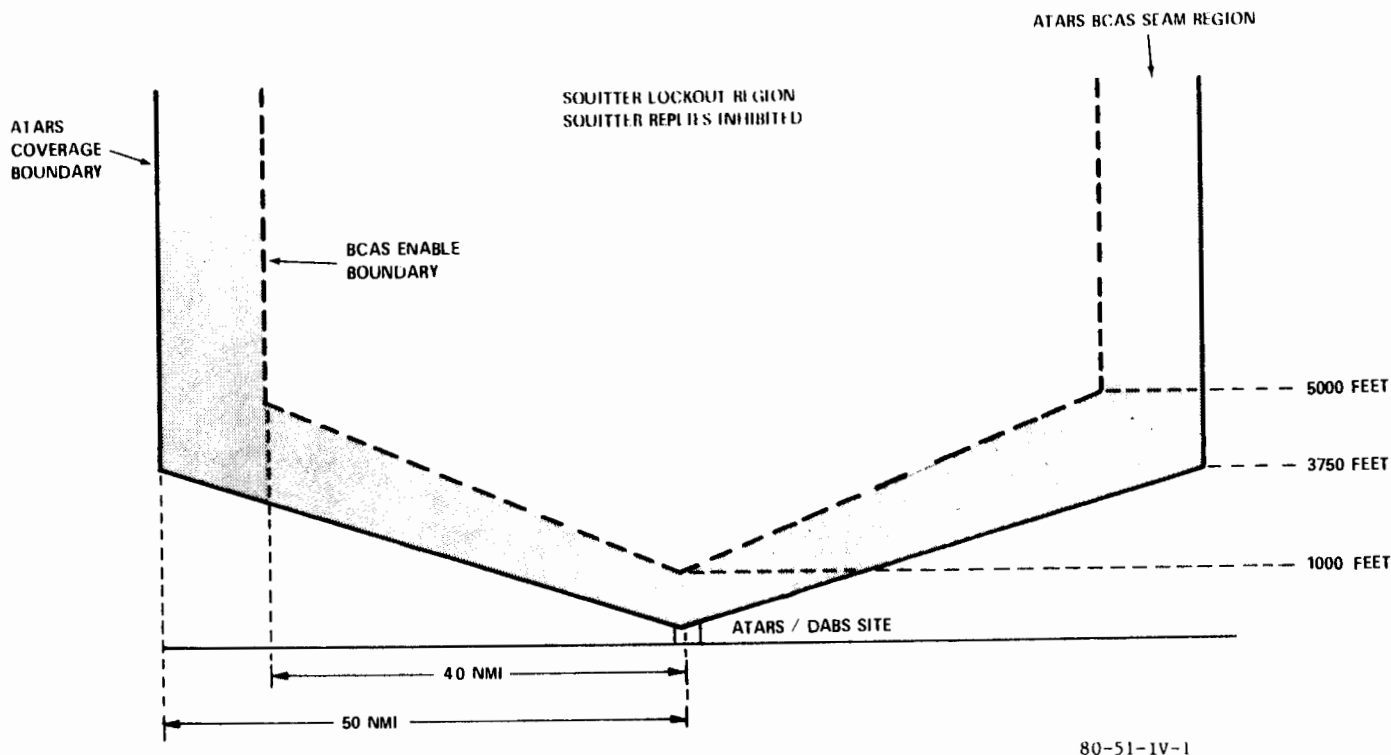


FIGURE 1. DESCRIPTION OF ATARS/BCAS SEAM REGION

experimentation was the evaluation of the ATARS/BCAS interface, most analysis was focused on conflicts which occurred in the ATARS/BCAS seam region or conflicts transitioned into or out of the seam area.

SYSTEM PROTOCOLS.

During conflict periods, including multiple aircraft conflicts, the ATARS/BCAS interface logic looked at each conflict in a pairwise manner and designated either ATARS or BCAS to resolve the conflict. The designation was dependent on the positions of the protected aircraft and threat aircraft and on which CAS system had detected the conflict. Whenever a new row (command) was posted in the CIR, its compatibility with already existing CIR rows was checked prior to the display of the new command. When an already existing command in the CIR was found to be incompatible, the system responsible for the new command recomputed the command and attempted to obtain a new compatible resolution. Command compatibility is shown in table 1.

The system which initiated the conflict resolution remained responsible for resolution until the conflict was terminated. Due to different update rates (BCAS was updated once a second and ATARS once every 4 seconds, BCAS could terminate alarms following conflict resolution more quickly than ATARS. However, Active BCAS could not determine the projected horizontal miss distance at CPA because it had no bearing information on threat aircraft. As a result, BCAS generated alarms in certain cases where adequate horizontal separation existed. ATARS did not generate an alarm for these same cases.

TABLE 1. COMMAND COMPATIBILITY TABLE

CIR Row Maneuver Intent Field

<u>Incoming ATARS Message</u>	<u>Turn Left</u>	<u>Turn Right</u>	<u>Don't Turn Left</u>	<u>Don't Turn Right</u>	<u>Climb</u>	<u>Don't Limit Climb</u>	<u>Descent</u>	<u>Don't Limit Descent</u>
Turn Left	C	NC	NC	C	C	C	C	C
Turn Right	NC	C	C	NC	C	C	C	C
Don't Turn Left	NC	C	C	C	C	C	C	C
Don't Turn Right	C	NC	C	C	C	C	C	C
Climb	C	C	C	C	C	NC	NC	C
Don't Limit Climb	C	C	C	C	NC	C	C	C
Descent	C	C	C	C	NC	C	C	NC
Don't Limit Descent	C	C	C	C	C	C	NC	C

Note: C - Compatible

NC - Not Compatible

All incoming BCAS complement messages are compatible since BCAS complement messages only contain a sense.

When the protected aircraft was in the squitter lockout region, only ATARS would issue commands to that aircraft. The region was designed so that no threats outside ATARS coverage could come in conflict with an aircraft in the squitter lockout region. When the protected aircraft was in ATARS/BCAS seam region, ATARS resolved the conflict if the threat aircraft was in ATARS coverage. When the protected aircraft or the threat aircraft left the ATARS coverage during the conflict resolution, the ATARS commands were displayed for an additional 16 seconds while the aircraft was outside ATARS coverage.

When the protected aircraft was in the ATARS/BCAS seam region and the threat was outside the ATARS coverage, the interface logic would designate BCAS to resolve the conflict. BCAS remained responsible for the conflict resolution following the threat aircraft's entrance into ATARS coverage. This is especially true when the threat came up through the floor of ATARS coverage as in the case of pop-up threats. Finally, when the protected aircraft was outside the ATARS coverage (including the region below the coverage floor), the interface logic designated BCAS to resolve the conflict. In this case, the position of the threat aircraft did not affect the designation of system responsibility. BCAS continued to resolve the conflict even when the protected aircraft entered the ATARS coverage during the conflict.

SIMULATED ATARS LOGIC.

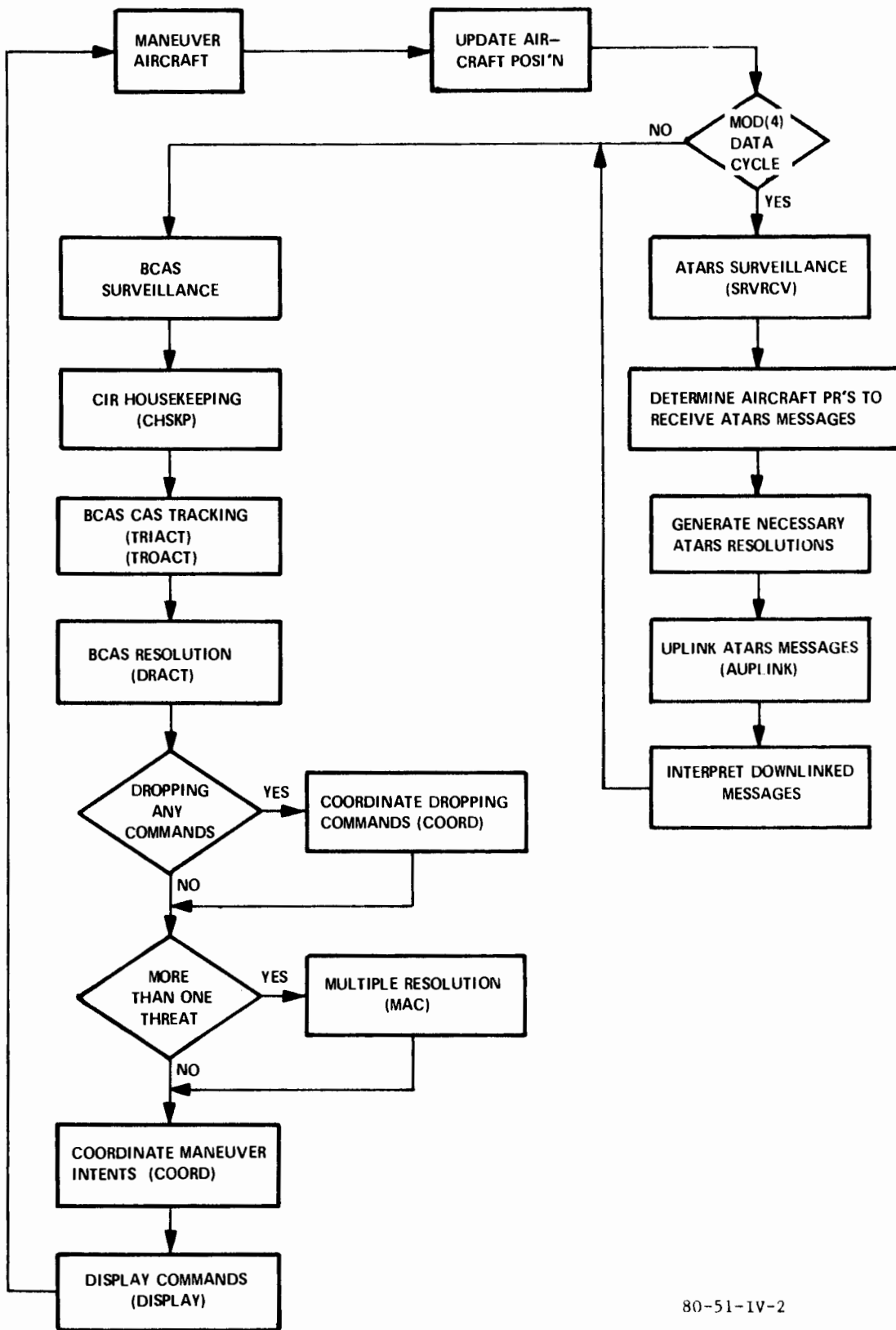
Since the full ATARS CIR resolution logic was not available for the simulation, a simplified ATARS logic was designed. The airborne CIR/ATARS interface logic was the same logic that was described in reference 2. The high level logic flow for the ATARS BCAS interface experiment is shown in figure 2. A full description of this logic is found in reference 6.

The logic was designed to determine when aircraft were in the various service zones shown in figure 1. The necessary message protocols based on aircraft position were then simulated. The threat volume used for ATARS resolution is shown in table 2.

TABLE 2. ATARS THREAT DECLARATION VOLUME

	<u>Range &lt; 1 nmi</u>	<u>Range Tau &lt; 40 sec</u>	<u>Range &lt; 1 nmi and Range Tau &lt; 40 sec</u>
Relative Altitude < 750 feet	D	D	N
Altitude Tau < 40 sec	D	D	N
Relative Altitude > 750 feet and Altitude Tau > 40 sec	N	N	N

D = Threat Declared  
N = No Threat Declaration



80-51-IV-2

FIGURE 2. HIGH LEVEL ATARS/BCAS INTERFACE LOGIC

The simulated ATARS logic also used a projected horizontal miss distance (MD) filter. When the projected horizontal MD was greater than 0.3 nmi, ATARS commands were not issued. The projected horizontal miss distance was calculated as follows:

$$MD = \left\{ \frac{(RX \cdot VRY - RY \cdot VRX)^2}{VRX^2 + VRY^2} \right\}^{1/2} > 0.3 \text{ nmi}$$

where:

- RX = X grid difference in aircraft positions
- RY = Y grid difference in aircraft positions
- VRX = relative change in X grid difference
- VRY = relative change in Y grid difference

This permitted the evaluation of ATARS to discriminate between safe and unsafe horizontal MD situations. It helped identify conditions where ATARS would not generate an alarm for an encounter with an ATCRBS threat and BCAS would generate an alarm for the same threat.

#### ANALYSIS

##### CONFLICTS IN THE ATARS/BCAS SEAM REGION.

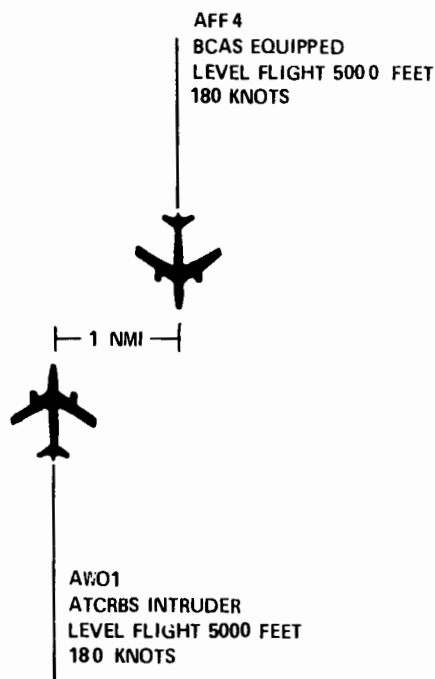
The initial analysis evaluated logic performance when both the threat aircraft and the protected aircraft remained in the BCAS/ATARS seam throughout the encounter period. Resolution difficulties for single threats are reviewed. It must be noted that ATCRBS threats must be mode C equipped for either BCAS or ATARS to provide protection against the threat.

LACK OF HORIZONTAL MISS DISTANCE INFORMATION. The ability of ATARS to filter commands based on horizontal separation was investigated. The encounter conditions analyzed are shown in figure 3. When the threat was DABS equipped, its ATARS service bit (A bit) would be set. This action prevented BCAS from displaying a command. When the threat was not DABS equipped, BCAS could determine that ATARS provided service for this threat. Because of this, BCAS generated an alarm even though ATARS had already sensed a safe condition (adequate projected horizontal miss distance) for the threat in question.

Table 3 presents the sequential BCAS results for an ATCRBS threat. A BCAS descent command occurred 23 seconds prior to closest point of approach (CPA) even though ATARS determined the projected horizontal miss distance to be greater than 0.3 nmi for this threat.

Using the smallest BCAS alarm volume threshold (DMOD = 0.1 nmi and TAUR = 18 sec), BCAS generated an alarm and ATARS sensed sufficient horizontal separation when both (1) and (2) hold.

ATARS COVERAGE BOUNDARY



80-51-IV-3

FIGURE 3. ATARS/BCAS SEAM ENCOUNTER (ATCRBS THREAT) HORIZONTAL SEPARATION

ATARS did not generate an advisory if 
$$\frac{(RX \cdot VRY - RY \cdot VRX)^2}{VRX^2 + VRY^2}^{1/2} > 0.3 \text{ nmi} \quad (1)$$

and BCAS did generate an advisory if 
$$\frac{R - DMOD}{-RD} < 18 \text{ seconds} \quad (2)$$

Letting  $h$  = horizontal MD projection at CPA,

$V_1$  = own aircraft velocity (nmi/sec),

and

$V_2$  = intruder aircraft velocity (nmi/sec);

then if

$$\frac{h - 0.1}{V_1 + V_2} < 18 \text{ seconds} \quad \text{and} \quad h > 0.3 \text{ nmi}$$

simultaneously hold for the encounter conditions shown in figure 3, BCAS would generate an alarm when ATARS would not. For  $V_1 + V_2 = 0.1$  nmi/sec (i.e., 360 knots closure),  $h$  can be as large as 1.9 nmi and a BCAS alarm would still result. If  $V_1 + V_2 = 0.14$  nmi/sec (500 knots closure), the projected horizontal separation can be as large as 2.6 nmi and a BCAS alarm would still result.

Simulation has shown that BCAS would generate an alarm for a wide variety of encounters in which the projected horizontal miss distance remained above 0.3 nmi which would suppress any ATARS alarm action.

TABLE 3. BCAS COMMANDS FOR ATCRBS ENCOUNTER WITH 1-NMI MISS DISTANCE AT POINT OF CLOSEST APPROACH

<u>Event</u>	<u>Time Prior to CPA</u>	<u>Range (nmi)</u>	<u>BCAS Range (Tau)</u>	<u>Command</u>
Tracking Begins	78	7.86	76.26	--
Own A Bit Set	76	7.07	76.00	--
B Bit Set	23	2.51	23.73	Descend
CPA	0	1.00	0.01	Descend
Command Termination	-2	1.02	50.71	--

ATCRBS THREAT CORRELATION. The BCAS threat logic used correlation logic in an attempt to uniquely identify individual threats in a multiple threat environment. If a threat was DABS equipped, its DABS ID uniquely identified it. However, ATCRBS threats did not possess a unique ID. The positive identification of an ATCRBS threat was attempted by the correlation of relative positional data. If correlation was based on BCAS surveillance, four elements were used: range, range rate, altitude, and altitude rate of the threat (R, RD, Z, ZD, respectively). The values of these four elements were compared with previous values which had been stored in the ATCRBS track blocks in the rows in the CIR for ATCRBS threats. If correlation was based on an ATARS uplinked message, two additional elements (bearing and bearing rate, THETA and THDOT, respectively) were added to the correlation scheme. A weighted sum of the squared differences for each track block element was used to find the best fit of the ATCRBS track block data. The equation used was:

$$\begin{aligned}
 \text{TEST} = & W_1 * \{R(\text{TRT}) - R(\text{I})\}^2 + W_2 * \{RD(\text{TRT}) - RD(\text{I})\}^2 \\
 & + W_3 * \{\text{THETA}(\text{TRT}) - \text{THEATA}(\text{I})\}^2 + W_4 * \{\text{THDOT}(\text{TRT}) - \text{THDOT}(\text{I})\}^2 \\
 & + W_5 * \{Z(\text{TRT}) - Z(\text{I})\}^2 + W_6 * \{ZD(\text{TRT}) - ZD(\text{I})\}^2
 \end{aligned} \tag{3}$$

where  $W_i$  = specific weights  $i = 1, \dots, 6$ ,  
TRT = elements of the incoming threat message,

and the I elements were the ATCRBS track block elements stored in row I of the CIR. Correlation was declared for the CIR row which yielded the smallest value of TEST (assuming it was less than a fixed threshold value). Figure 4 shows the entire threat correlation logic. Several problems have been detected which prevent the current ATCRBS threat correlation scheme in TIC from uniquely identifying ATCRBS threats.

Constant Data Rate Assumption. The current correlation scheme assumed a constant 1-second ATCRBS track block data rate. Although the ATCRBS threat track block data in the CIR was time tagged, no use of the time differences was made during correlation. Since the correlation equation used a sum of squares of the difference of each track block element, a large difference in just one element of the track block would prevent correlation. Assuming a 4-second update rate of ATARS, table 4 identifies the minimum change in each element that by itself would inhibit correlation.

TABLE 4. ATARS CORRELATION LIMITATIONS

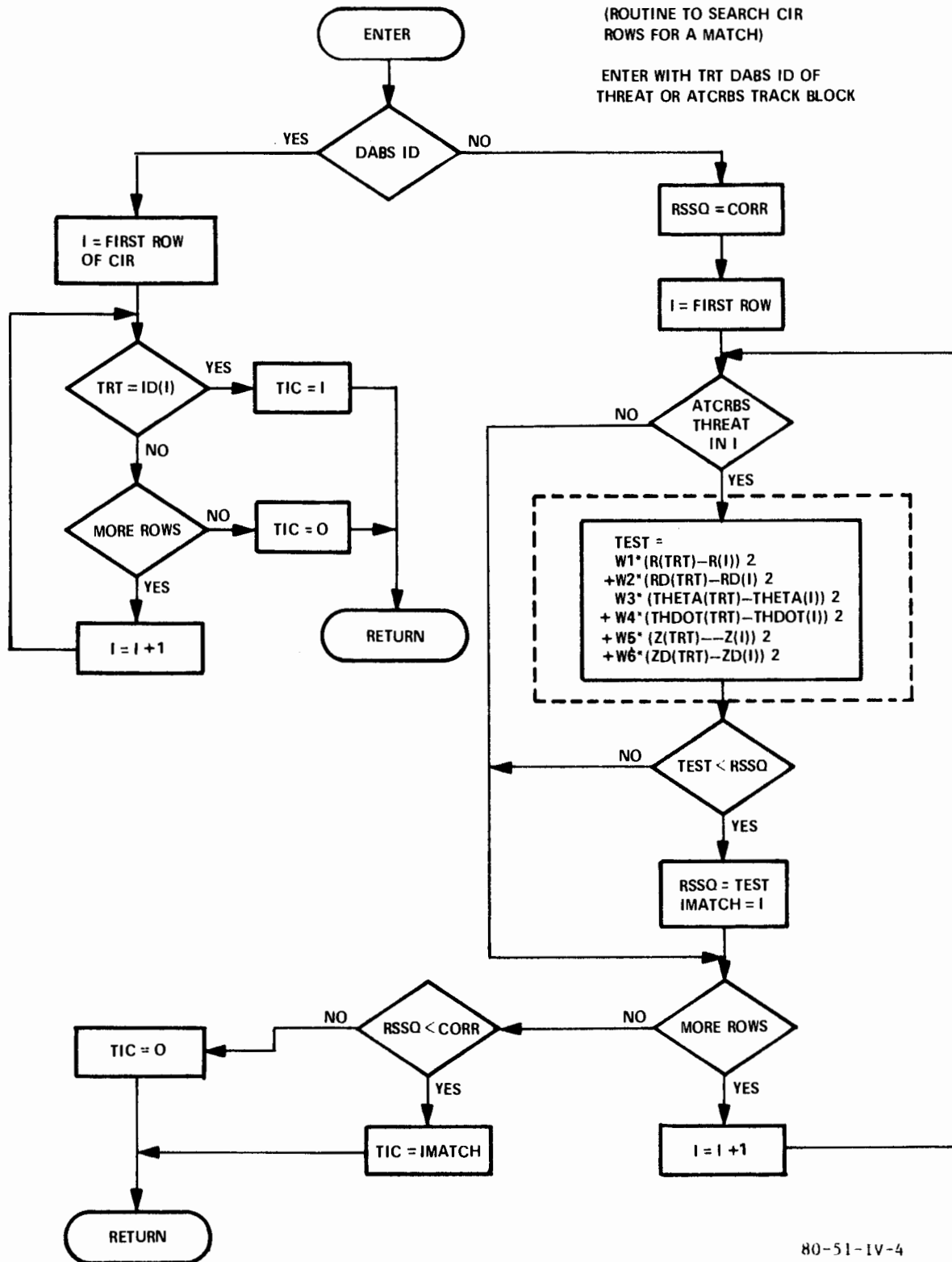
<u>Element</u>	<u>Minimum Difference That Inhibits Correlation</u>
Range	0.1732 nmi/sec (624 knots closure rate)
Range Rate	0.0217 nmi/sec <sup>2</sup>
Bearing	27.38°/sec
Bearing Rate	2.16°/sec <sup>2</sup>
Threat Altitude	173 ft/sec
Threat Altitude Rate	43 ft/sec <sup>2</sup> (1.35 g vertical acceleration)

Table 4 states that the current correlation scheme would not correlate consecutive ATARS threat messages for the same threat if (1) the change in range exceeded 0.1732 nmi from one update cycle to the next or (2) the threat experienced a 1.35 g vertical acceleration.

Figure 5 identifies the encounter conditions that were simulated using the FTEG. The crossing angle was 182°, and both aircraft were within ATARS coverage well prior to declaration of a threat condition. Both aircraft remained in ATARS coverage throughout the encounter. Table 5 presents the sequentially uplinked ATARS commands and threat track block data. The altitude and altitude rate elements of the threat track block data are based on mode C threat altitude. The other elements are pure data (no errors). However, since the intruder is in level flight at 15,000 feet, even the mode C reports contain no errors. Also included in table 5 is the number of rows and threat track block content of the CIR at each update epoch.

THREAT IDENTITY CORRELATOR  
(ROUTINE TO SEARCH CIR  
ROWS FOR A MATCH)

ENTER WITH TRT DABS ID OF  
THREAT OR ATRCBS TRACK BLOCK



80-51-IV-4

FIGURE 4. THREAT IDENTITY CORRELATOR (TIC) FLOW CHART

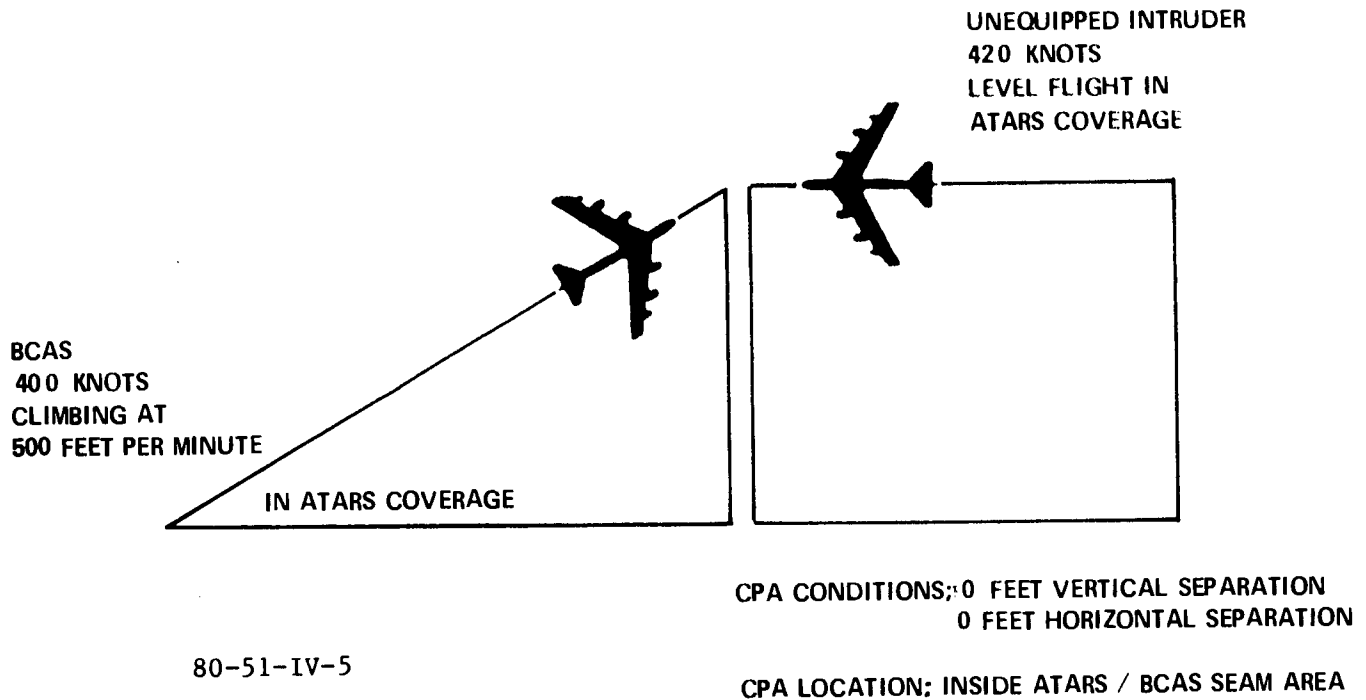


FIGURE 5. ENCOUNTER CONDITIONS WHICH INHIBIT THREAT CORRELATION

Review of table 5 indicates the initial ATARS command occurred 32 seconds prior to CPA. Many false entries were made in the CIR. Eight seconds prior to CPA, a null command was uplinked because the BCAS aircraft had responded to the threat, and sufficient vertical separation was generated. However, due to no correlation, the descent command was not removed until 12 seconds later. Removal occurred because CHSKP, the CIR housekeeping routine, deleted the row based on a 16-second ATARS time out.

Table 5 shows that the incoming Threat Track Block was never correlated to an existing row in the CIR. The reason for the noncorrelation was the difference in the range values for two successive updates. The threat correlation logic used the value TEST to define a match condition. In our example, the 28th-second threat message was uncorrelated because

$$\text{TEST} = 25 \cdot (7.7452 - 8.6542)^2 + \text{other positive elements} > 20.6570$$

Since TEST was greater than  $2 \cdot \text{CORR} = 12$ , no match was declared. The same problem occurred on all succeeding updates. Although, the data represented a perfect match for all other elements, the difference in the range alone caused the problem.

Figure 6 presents a new threat correlation scheme. It used the time difference, T, between the current time, T<sub>CUR</sub>, and the last CIR row i update time.

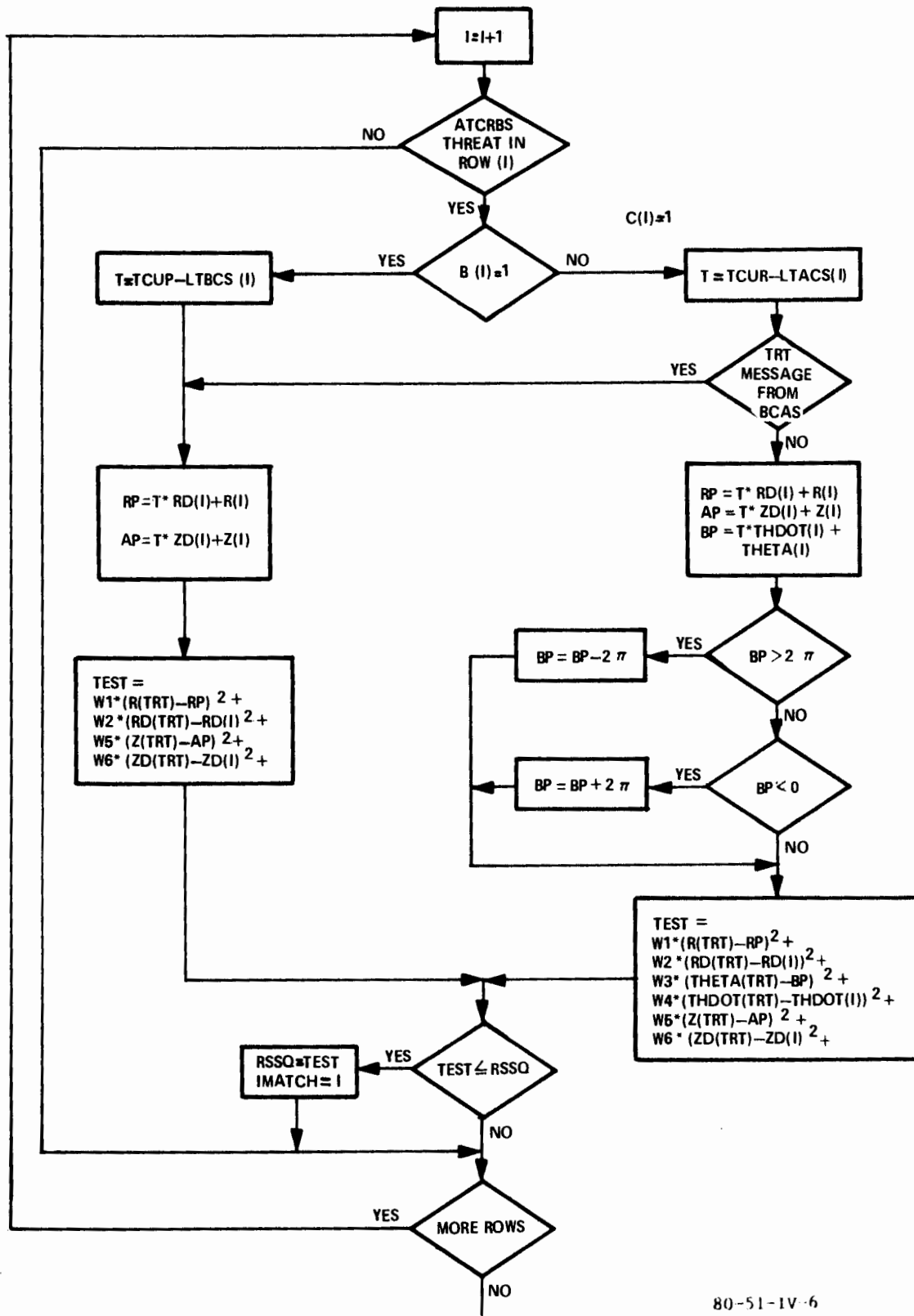
TABLE 5. UPLINKED ATARS MESSAGES AND CIR STATUS (Sheet 1 of 2)

Time Prior To CPA (sec)	CIR Row (nos.)	Uplinked Command And ATCRBS Threat Block	Correlate	Row (no.)	Content	CIR Content At End Of Update	Comment
32	0	Descend (8.6562,-0.2278,-2.3362,0,15000,0)*	--	1	(8.6562,-0.2278,-2.3562,0,15000,0)	True threat	Descent displayed
28	1	Descend (7.7452,-0.2278,-2.3562,0,15000,0)	No	1	(8.6562,-0.2278,-2.3562,0,15000,0)	32nd-sec threat message	New threat added — Descent displayed
				2	(7.7452,-0.2278,-2.3562,0,15000,0)		
24	2	Descend (6.8341,-0.2278,-2.3562,0,15000,0)	No	1	(8.6562,-0.2278,-2.3562,0,15000,0)	32nd-sec threat message	New threat added — Descent displayed
				2	(7.7452,-0.2278,-2.3562,0,15000,0)	28th-sec threat message	
				3	(6.8341,-0.2278,-2.3562,0,15000,0)		
20	3	Descend (5.8231,-0.2276,-2.3562,0,15000,0)	No	1	(8.6562,-0.2278,-2.3562,0,15000,0)	32nd-sec threat message	New threat added — Descent displayed
				2	(7.7452,-0.2278,-2.3562,0,15000,0)	28th-sec threat message	
				3	(6.8341,-0.2278,-2.3562,0,15000,0)	24th-sec threat message	
				4	(5.8231,-0.2278,-2.3562,0,15000,0)		
16	3*	Descend (5.8231,-0.2278,-2.3562,0,15000,0)	No	1	(7.7452,-0.2278,-2.3562,0,15000,0)	28th-sec threat message	New threat added — Descent displayed
				2	(6.8341,-0.2278,-2.3562,0,15000,0)	24th-sec threat message	
				3	(5.8231,-0.2278,-2.3562,0,15000,0)	20th-sec threat message	
				4	(5.0121,-0.2278,-2.3562,0,15000,0)		
12	3*	Descend (4.1011,-0.2278,-2.3562,0,15000,0)	No	1	(6.8341,-0.2278,-2.3562,0,15000,0)	24th-sec threat message	New threat added — Descent displayed
				2	(5.8231,-0.2278,-2.3562,0,15000,0)	20th-sec threat message	
				3	(5.0121,-0.2278,-2.3562,0,15000,0)	16th-sec threat message	
				4	(4.1011,-0.2278,-2.3562,0,15000,0)		
8	3*	NULL COMMAND THREAT BLOCK provided to coordinate dropping of command (3.1902,-0.2278,-2.3562,0,15000,0)	No	1	(5.8231,-0.2278,-2.3562,0,15000,0)	20th-sec threat message	No threat added — Descent displayed
				2	(5.0121,-0.2278,-2.3562,0,15000,0)	16th-sec threat message	
				3	(4.1011,-0.2278,-2.3562,0,15000,0)	12th-sec threat message	
							*24th-sec threat deleted by CHSKP (16-sec time out)

TABLE 5. UPLINKED ATARS MESSAGES AND CIR STATUS (Sheet 2 of 2)

<u>Time Prior To CPA (sec)</u>	<u>CIR Row (nos.)</u>	<u>Uplinked Command And ATCRBS Threat Block</u>	<u>Correlate</u>	<u>Row (no.)</u>	<u>Content</u>	<u>CIR Content At End Of Update</u>	<u>Comment</u>
4	2*	No UPLINK	--	1	(5.0221,-0.2278,-2.3562,0,15000,0)	16th-sec threat message	12th-sec threat message
				2	(4.1011,-0.2278,-2.3562,0,15000,0)		
0	1*	No UPLINK	--	1	(4.1011,-0.2278,-2.3562,0,15000,0)	12th-sec threat message	No threat added — Descent displayed
Vertical CPA			1				
-4	0*	No UPLINK	--	No rows in CIR		No threat added. No active rows in CIR. No command displayed.	*12th-sec threat deleted by CHSKP (16-sec time out)

\* The threat track data elements are (range, range rate, bearing, bearing rate, altitude, altitude rate).



80-51-1V-6

FIGURE 6. SUGGESTED ATCRBS CORRELATION LOGIC CHANGE

If B(I)=1 (BCAS assigned responsibility for the ith row), then the last update time was LTBCS(I); otherwise, the time of last update for row i was LTACS(I). T was then used to project the range (RP) and altitude (AP) using the previous range rate RD(I) and altitude rate ZD(I). When correlating ATARS ATRBS threat blocks, the bearing projection (BP) based on the previous bearing rate, THDOT(I), was also used.

The new logic also provided for correlation with BCAS rows (B(I)=1). This correlation was based only on range, range rate, altitude, and altitude rate.

Additionally, correlation of incoming BCAS messages with an existing ATARS row (C(I)=1) does not use bearing or bearing rate data in the correlation process. The only time the new scheme will permit correlation based on all six elements is when the incoming threat message is ATARS and the C bit is set to one for the row in question.

Use of Bearing and Bearing Rate in Correlation of ATRBS Threats. The use of bearing (THETA) and bearing rate (THDOT) to correlate ATRBS threats is questionable. Even in the absence of horizontal maneuvering by the threat aircraft, bearing and bearing rate were the most inconsistent data when horizontal miss distance at the CPA exists.

An example of a linear encounter which has a 0.25 nmi horizontal miss distance at CPA is shown in figure 7. Table 6 shows the changes in the true bearing ( $\omega$ ) and bearing rate ( $\frac{\Delta\omega}{\Delta t}$ ) that would occur in the ATARS track block updates for this encounter.

The largest changes in bearing and bearing rate occurred during the most critical phase of the encounter, near CPA. If horizontal maneuvering by the threat aircraft was considered, the feasibility of using bearing and bearing rate to correlate ATRBS data was further reduced.

TABLE 6. SEQUENTIAL CHANGES IN BEARING AND BEARING RATE

	Time						
	t-16	t-12	t-8	t-4	t	t+4	t+8
$\omega$	45°	42.7°	38.7°	29.8°	0.0°	-53.1°	-106°
$\frac{\Delta\omega}{\Delta t}$	-0.42	-0.58	-1.0	-2.25	-7.45	-13.28	-13.28

$\omega$  = bearing to intruder

Threat Merging. An example of threat track splitting (inability to sequentially correlate ATRBS threat block messages) was presented previously. Another possibility is that of threat merging. In this case, two different ATRBS

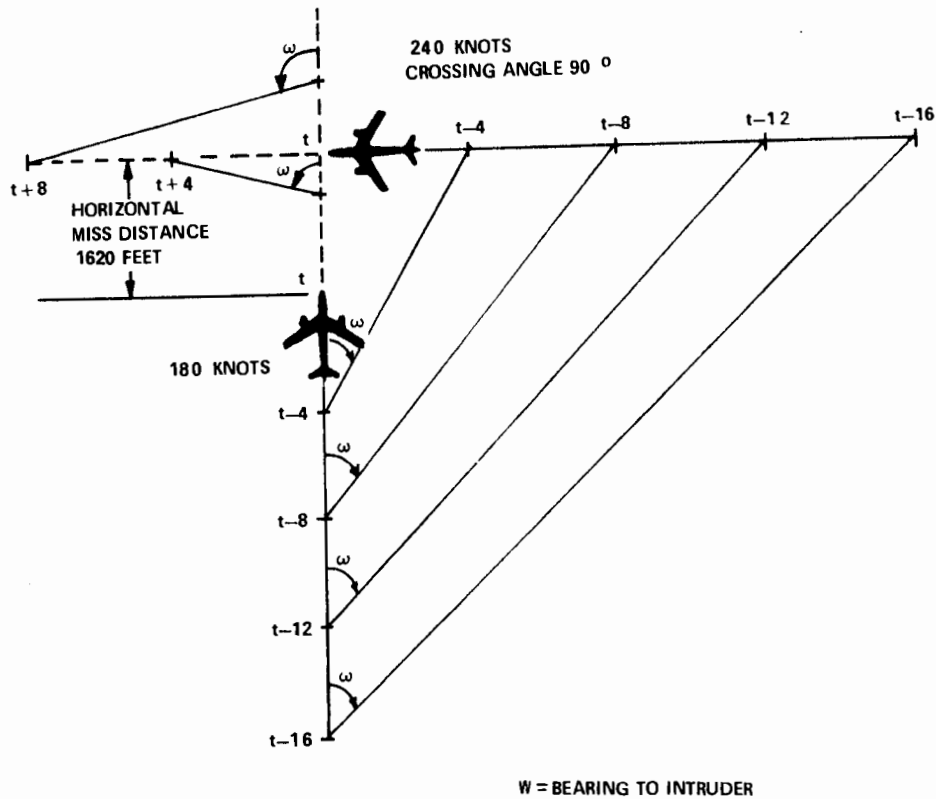


FIGURE 7. ENCOUNTER WHICH RESULTED IN LARGE BEARING CHANGE NEAR CPA

threats exist, one detected by BCAS and the other by ATARS. The positional data in the ATCRBS threat block was so similar that only one threat was declared. As a result, a situation which called for the use of multiple threat logic, in the case of Active BCAS, went undetected. In the case of ATARS, an entire constraint for resolution, caused by the presence of the second threat, was ignored.

INCORRECT SETTING OF B BITS IN THE CIR. The inability to reset DRPFLG (the indicator flag for dropping BCAS commands) in the coordination routine (COORD) under certain conditions led to the erroneous setting of B bits in the CIR.

An example of a geometry which caused this problem is shown along with the ATARS coverage area in figure 8. The BCAS aircraft, AFF4, was in level flight initially outside of ATARS coverage. The intruder, AW01 (which was unequipped) was within ATARS coverage throughout the encounter period. Although the CPA was near the ATARS coverage boundary, the problem was not an ATARS boundary problem. The flag, DRPFLG, was used by BCAS logic to coordinate the termination of BCAS commands by selectively accessing the COORD module to terminate BCAS commands. Figure 9 identifies the high level logic flow which accessed COORD when DRPFLG, for a particular intruder, was set to 1. DRPFLG was set to 1 by the detection and resolution logic, DRACT, when the logic determined that a BCAS command was no longer needed. DRACT had no knowledge of whether ATARS or BCAS had responsibility for resolving this threat.

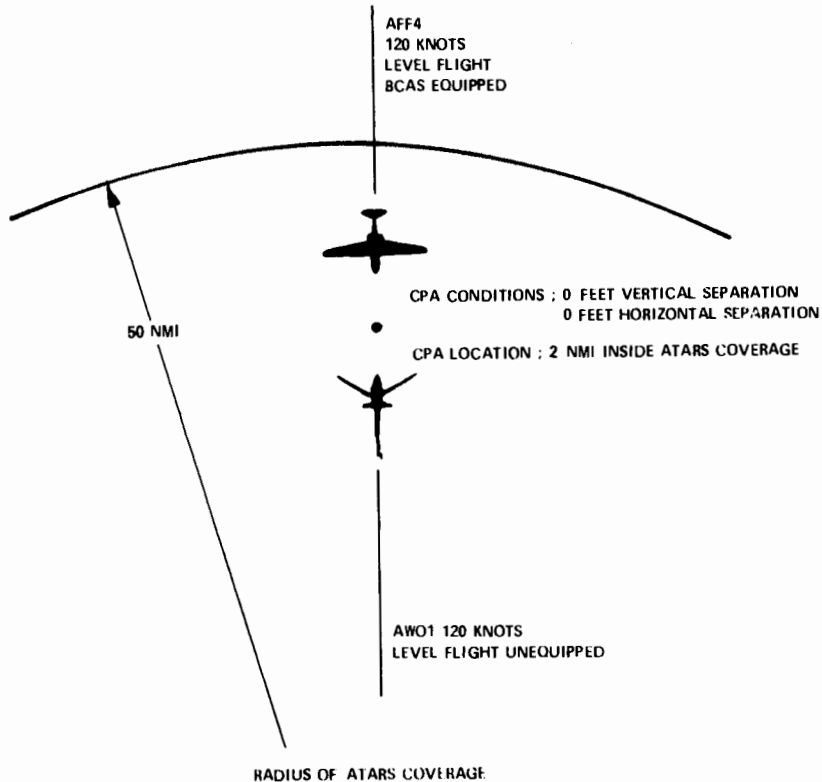


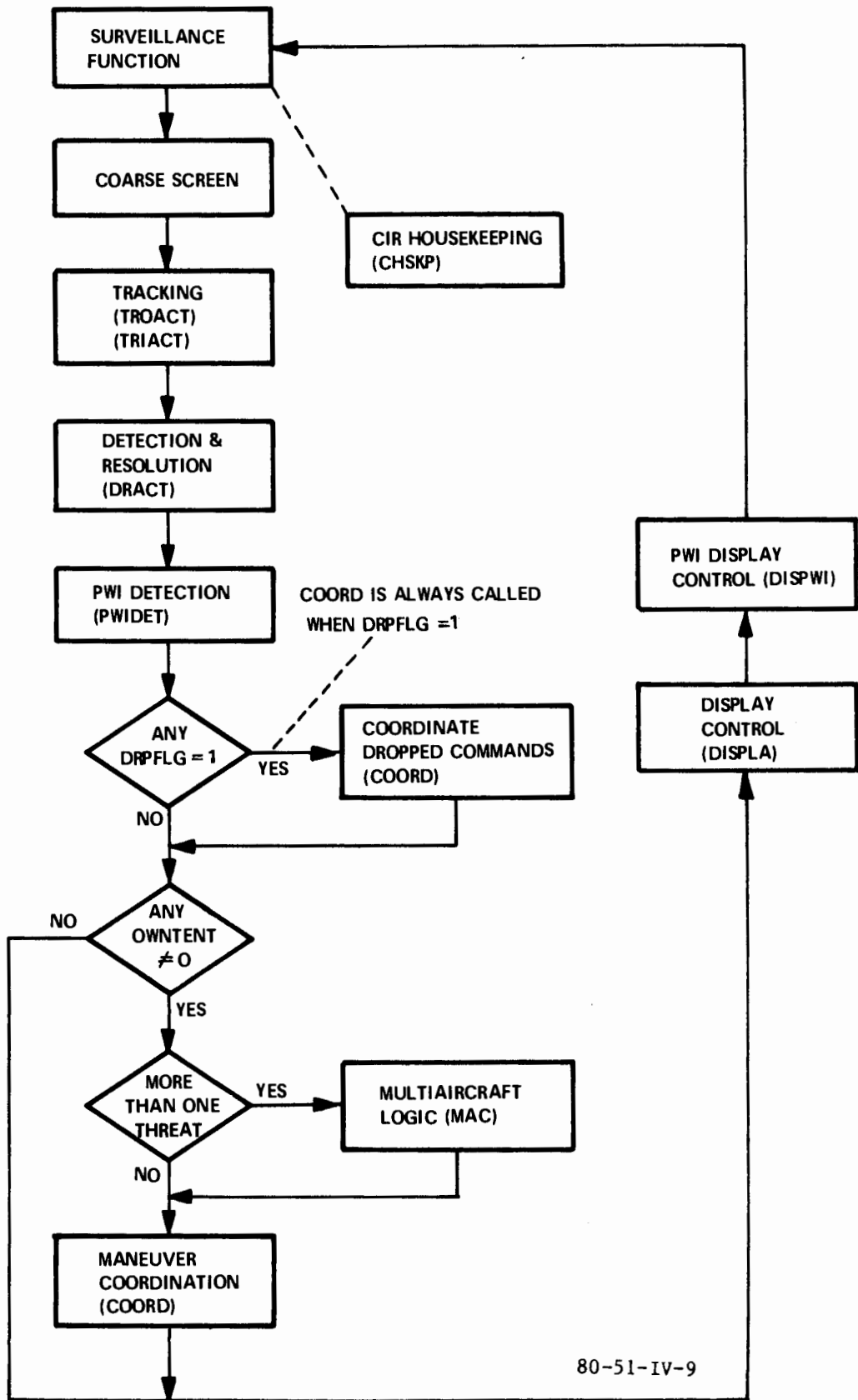
FIGURE 8. ENCOUNTER WHICH CAUSED INCORRECT SETTING OF B BITS

Once COORD had been called to drop a BCAS command for a particular threat (DRPFLG=1), DRPFLG must be reset to 0 prior to leaving COORD. This would prevent repeated calls of COORD to drop the BCAS command on succeeding logic cycles. The COORD logic prevented CAS detection and resolution logic from terminating a command which was generated by ATARS (C bit = 1). The sequential summary of BCAS resolution logic and the setting of the A bit (receiving ATARS service bit), B bit (BCAS responsible for this threat), and C bit (ATARS responsible for this threat) that resulted for the example is shown in table 7. The sequential events that led to the unwanted setting of B bits are summarized in table 8.

Figure 10 presents the initial portions of the COORD logic. It shows that if ATARS was responsible for the threat in question (C(I)=1) then DRPFLG would not get reset to 0 prior to leaving COORD, regardless of the equipment status of the threat. The only way that DRPFLG was reset in COORD was when C(I)=0 (BCAS was responsible for this threat).

The coordination logic must recognize that BCAS detection and resolution logic can set DRPFLG = 1 for any threat regardless of which system is responsible for resolution. In order to reset DRPFLG = 0 in COORD logic for all cases, additional code was required. The addition is shown in figure 11. The example geometry was repeated with the logic additions.

Table 9 presents the sequential BCAS results and status of the A, B, and C bits. Notes that the B bit is no longer being set to 1 on the 96th second following termination of the ATARS command.



80-51-IV-9

FIGURE 9. HIGH LEVEL BCAS FLOW CHART

TABLE 7. SEQUENTIAL BCAS CONFLICT DATA (Sheet 1 of 2)

Time	Range		Range Rate		Rel. Alt.		Horizontal TAU		Vertical TAU		Vertical Miss		Fields	CMD1	CMD2	CMD3
	Real/BCAS	Real/BCAS	Real/BCAS	Real/BCAS	Real/BCAS	Real/BCAS	Real/BCAS	Real/BCAS	Real/BCAS	Real/BCAS	THETA BCAS	THETA BCAS	ABC	VCMD	VCMD	HCMD
31	3.27	3.27	-0.07	-0.07	0.00	0.00	49.00	41.50	0.00	0.00	0.00	0.00	000	0	0	0
32	3.20	3.20	-0.07	-0.07	0.00	0.00	48.00	40.50	0.00	0.00	0.00	0.00	000	0	0	0
33	3.13	3.13	-0.07	-0.07	0.00	0.00	47.00	39.50	0.00	0.00	0.00	0.00	000	0	0	0
34	3.07	3.07	-0.07	-0.07	0.00	0.00	46.00	38.50	0.00	0.00	0.00	0.00	000	0	0	0
35	3.00	3.00	-0.07	-0.07	0.00	0.00	45.00	37.50	0.00	0.00	0.00	0.00	000	0	0	0
36	2.93	2.93	-0.07	-0.07	0.00	0.00	44.00	36.50	0.00	0.00	0.00	0.00	000	0	0	0
37	2.87	2.87	-0.07	-0.07	0.00	0.00	43.00	35.50	0.00	0.00	0.00	0.00	100	0	0	0
38	2.80	2.80	-0.07	-0.07	0.00	0.00	42.00	34.50	0.00	0.00	0.00	0.00	100	0	0	0
39	2.73	2.73	-0.07	-0.07	0.00	0.00	41.00	33.50	0.00	0.00	0.00	0.00	100	0	0	0
40	2.67	2.67	-0.07	-0.07	0.00	0.00	40.00	32.50	0.00	0.00	0.00	0.00	100	0	0	0
41	2.60	2.60	-0.07	-0.07	0.00	0.00	39.00	31.50	0.00	0.00	0.00	0.00	101	5	0	0
42	2.53	2.53	-0.07	-0.07	0.00	0.00	38.00	30.50	0.00	0.00	0.00	0.00	101	5	0	0
43	2.47	2.47	-0.07	-0.07	0.00	0.00	37.00	29.50	0.00	0.00	0.00	0.00	101	5	0	0
44	2.40	2.40	-0.07	-0.07	0.00	0.00	36.00	28.50	0.00	0.00	0.00	0.00	101	5	0	0
45	2.33	2.33	-0.07	-0.07	0.00	0.00	35.00	27.50	0.00	0.00	0.00	0.00	101	5	0	0
46	2.27	2.27	-0.07	-0.07	-16.67	0.00	34.00	26.50	0.00	0.00	0.00	0.00	101	5	0	0
47	2.20	2.20	-0.07	-0.07	-33.34	0.00	33.00	25.50	0.00	0.00	0.00	0.00	101	5	0	0
48	2.13	2.13	-0.07	-0.07	-50.00	-40.00	32.00	24.50	0.00	0.00	175.00	0.00	100	5	0	0
49	2.07	2.07	-0.07	-0.07	-66.67	-70.00	31.00	23.50	0.00	0.00	272.00	.00	101	5	0	0
50	2.00	2.00	-0.07	-0.07	-83.34	-91.00	30.00	22.50	0.00	0.00	313.00	0.00	101	5	0	0
51	1.93	1.93	-0.07	-0.07	-100.01	-104.50	29.00	21.51	0.00	0.00	317.00	0.00	101	5	0	0
52	1.87	1.87	-0.07	-0.07	-116.68	-112.16	28.00	20.51	0.00	0.00	297.00	0.00	101	5	0	0

TABLE 7. SEQUENTIAL BCAS CONFLICT DATA (Sheet 2 of 2)

Time	Range		Range Rate		Rel. Alt.		Horizontal TAU		Vertical TAU		Vertical Miss		Fields	CMD1	CMD2	CMD3
	Real/BCAS	BCAS/Real	Real/BCAS	BCAS/Real	Real/BCAS	BCAS/Real	Real/BCAS	BCAS/Real	Real/BCAS	BCAS/Real	THETA BCAS	BCAS THETA	ABC	VCHD	VCHD	HCHD
82	0.17	0.08	0.05	0.01	-616.71	-618.72	-2.00	-32.25	0.00	0.00	684.00	0.00	101	5	0	0
83	0.23	0.13	0.06	0.01	-633.38	-619.74	-3.00	1000.00	0.00	0.00	619.00	0.00	101	5	0	0
84	0.29	0.20	0.06	0.03	-650.05	-658.38	-4.00	1000.00	0.00	0.00	619.00	0.00	101	5	0	0
85	0.35	0.28	0.06	0.05	-666.72	-685.72	-5.00	1000.00	0.00	0.00	619.00	0.00	100	5	0	0
86	0.42	0.36	0.06	0.06	-683.39	-703.56	-6.00	1000.00	0.00	0.00	619.00	0.00	101	5	0	0
87	0.48	0.45	0.07	0.07	-700.05	-713.90	-7.00	1000.00	0.00	0.00	619.00	0.00	101	5	0	0
88	0.55	0.53	0.07	0.08	-716.72	-718.72	-8.00	1000.00	0.00	0.00	619.00	0.00	101	5	0	0
89	0.61	0.61	0.07	0.08	-733.39	-719.74	-9.00	1000.00	0.00	0.00	619.00	0.00	101	5	0	0
90	0.68	0.68	0.07	0.08	-750.06	-758.38	-10.00	1000.00	0.00	0.00	619.00	0.00	101	5	0	0
91	0.74	0.75	0.07	0.07	-766.73	-785.72	-11.00	1000.00	0.00	0.00	619.00	0.00	101	5	0	0
92	0.81	0.82	0.07	0.07	-783.39	-803.56	-12.00	1000.00	0.00	0.00	619.00	0.00	101	5	0	0
93	0.88	0.88	0.07	0.07	-800.06	-813.90	-13.00	1000.00	0.00	0.00	619.00	0.00	101	5	0	0
94	0.94	0.95	0.07	0.07	-816.73	-818.72	-14.00	1000.00	0.00	0.00	619.00	0.00	101	5	0	0
95	1.01	1.01	0.07	0.07	-833.40	-819.74	-15.00	1000.00	0.00	0.00	619.00	0.00	100	5	0	0
96	1.08	1.08	0.07	0.07	-850.07	-858.37	-16.00	1000.00	0.00	0.00	619.00	0.00	100	0	0	0
97	1.14	1.14	0.07	0.07	-866.73	-885.72	-34.00	1000.00	0.00	0.00	619.00	0.00	110	0	0	0
98	1.18	1.20	0.03	0.06	-866.73	-903.55	-35.00	1000.00	0.00	0.00	619.00	0.00	110	0	0	0
99	1.21	1.24	0.03	0.05	-866.73	-913.90	-36.00	1000.00	0.00	0.00	619.00	0.00	110	0	0	0
100	1.24	1.27	0.03	0.05	-866.73	-918.71	-37.00	1000.00	0.00	0.00	619.00	0.00	110	0	0	0

The minimum slant range for this conflict is 583.38 feet

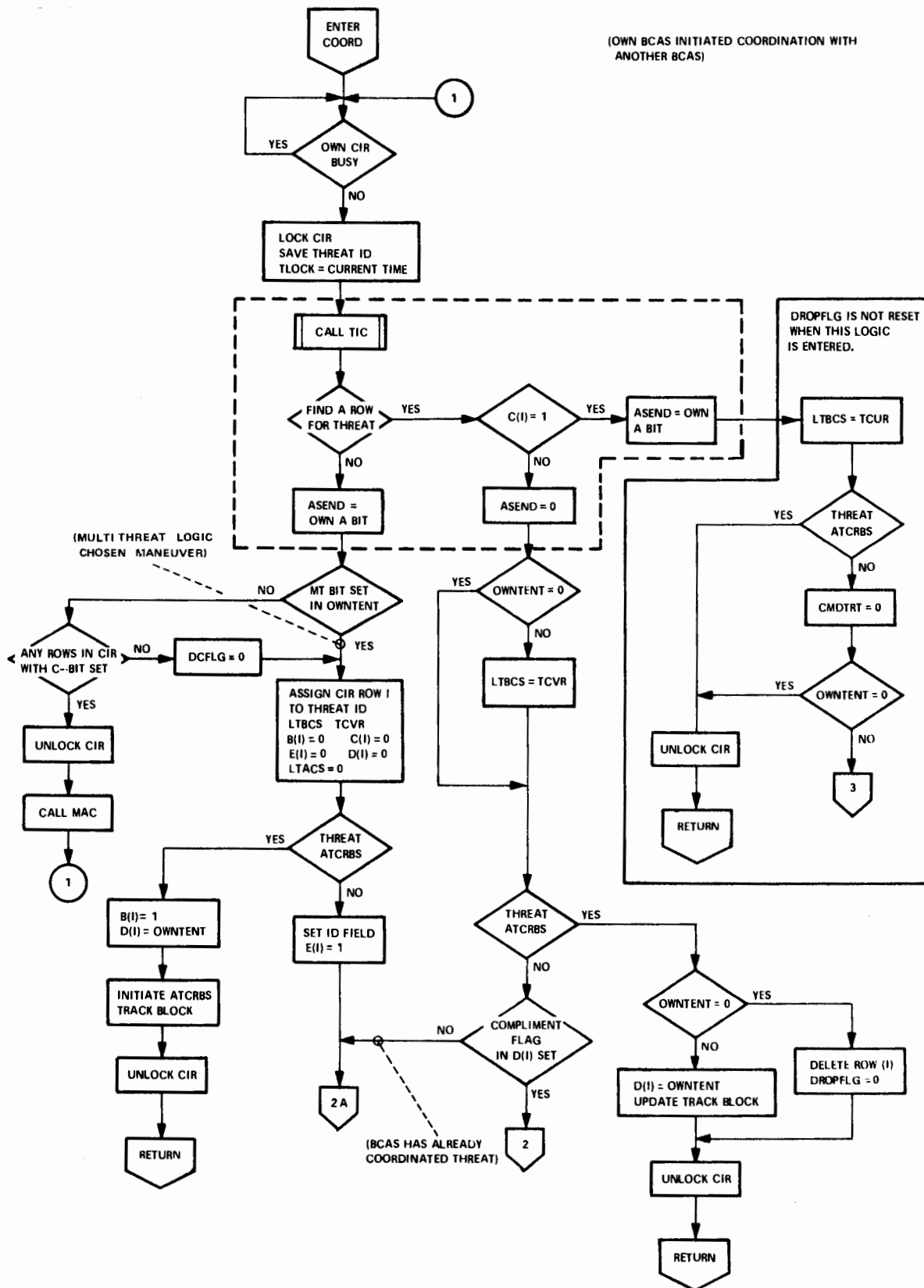
The last value for IRAND is 1979121 For IRANDX is 1979121 For IRANDY is 1049827719

\*Stop \* 0

TABLE 8. SUMMARY OF EVENTS

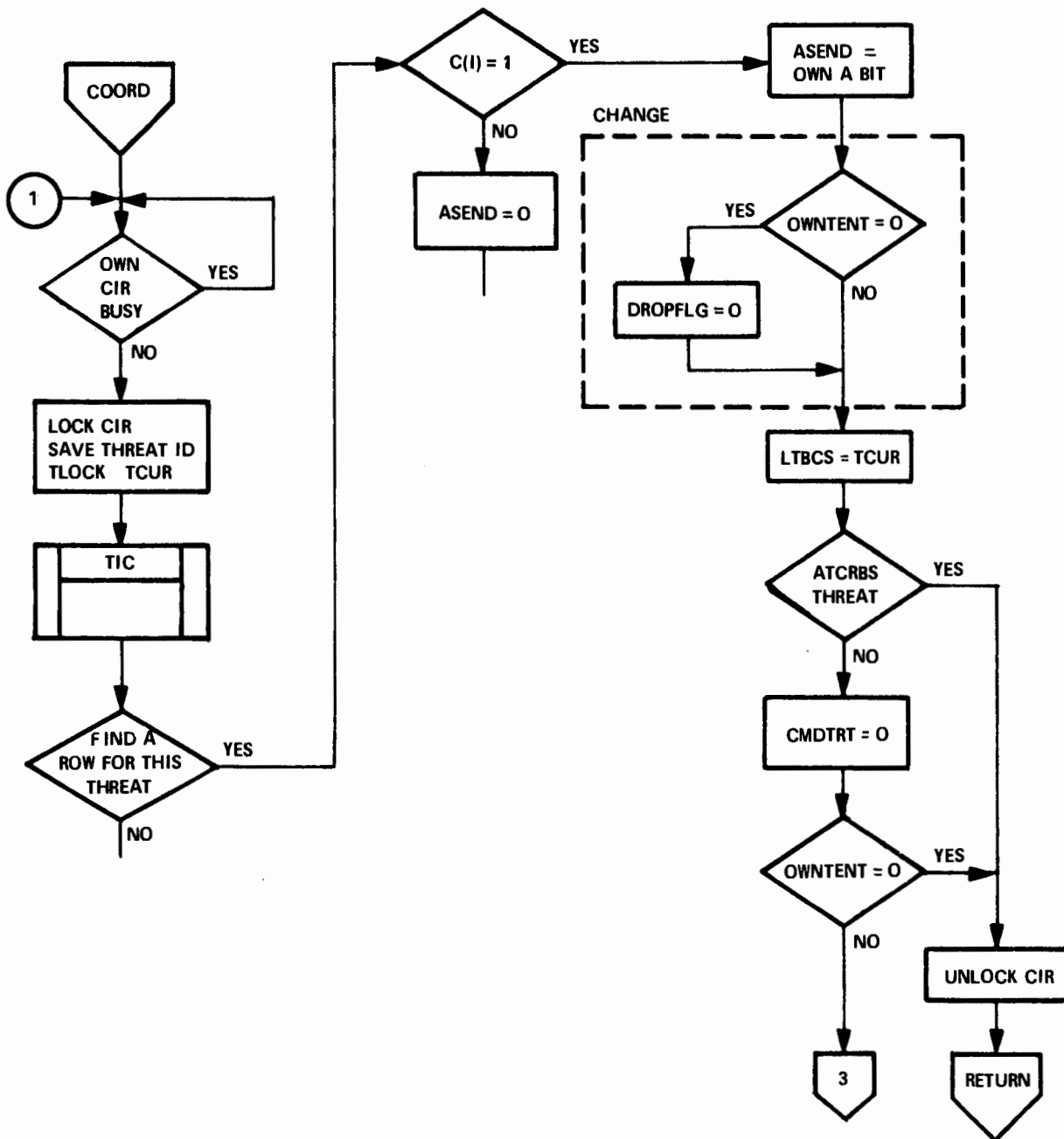
<u>Time (sec)</u>	<u>Event</u>	<u>Command</u>	<u>System Responsible</u>
36	1. AFF4 entered ATARS coverage and its A bit was set		
40	1. ATARS Uplinked Command		
	2. CIR row was filled (C=1)	Descent	ATARS(C=1)
48	1. BCAS generated OWNTENT=0		
	2. Since C=1 for CIR row in question, BCAS took no action	Descent	ATARS(C=1)
85	1. BCAS declared no threat OWNTENT=0		
	2. DRACT set DROPFLG=1		
	3. C still set to 1 so that DROPFLG could not be reset	Descent	ATARS(C=1)
86 to 95	1. COORD was called every BCAS Logic Cycle because DROPFLG=1		
	2. Since C=1 no BCAS action results		
	3. COORD is exited without DROPFLG being reset	Descent	ATARS(C=1)
96	1. ATARS declares no threat		
	2. ATARS row is deleted from CIR		
	3. BCAS calls COORD since DROPFLG=1		
	4. Since no row is found in CIR, BCAS establishes a row, sets B=1, fills the D field with a null command and puts meaningless data in the ATCRBS track block		
	5. COORD is exited with DROPFLG=1		
97	1. BCAS calls COORD since DROPFLG=1		
	2. Because of meaningless data in the ATCRBS Threat Track Block A, match is not found		
	3. BCAS fills a new row, sets B=1, fills the D field with a null command and puts meaningless data in the ATCRBS track block		
	4. COORD is exited with DROPFLG=1	No command	B=1

Note: Cycle continues indefinitely.



80-51-1V-10

FIGURE 10. BCAS MANEUVER COORDINATION (COORD) FLOW CHART



80-51-IV-11

FIGURE 11. REVISED COORD LOGIC

TABLE 9. SEQUENTIAL CONFLICT DATA FOR REVISED COORD LOGIC (Sheet 1 of 2)

Time	Range		Range Rate		Rel. Alt.		Horizontal TAU		Vertical TAU		Vertical Miss		Fields	CMD1	CMD2	CMD3
	Real/BCAS	Real/BCAS	Real/BCAS	Real/BCAS	Real/BCAS	Real/BCAS	Real/BCAS	Real/BCAS	Real/BCAS	Real/BCAS	THETA BCAS	THETA BCAS	ABC	VCMD	VCMD	HCMD
31	3.27	3.27	-0.07	-0.07	0.00	0.00	49.00	41.50	0.00	0.00	0.00	0.00	000	0	0	0
32	3.20	3.20	-0.07	-0.07	0.00	0.00	48.00	40.50	0.00	0.00	0.00	0.00	000	0	0	0
33	3.13	3.13	-0.07	-0.07	0.00	0.00	47.00	39.50	0.00	0.00	0.00	0.00	000	0	0	0
34	3.07	3.07	-0.07	-0.07	0.00	0.00	46.00	38.50	0.00	0.00	0.00	0.00	000	0	0	0
35	3.00	3.00	-0.07	-0.07	0.00	0.00	45.00	37.50	0.00	0.00	0.00	0.00	000	0	0	0
36	2.93	2.93	-0.07	-0.07	0.00	0.00	44.00	36.50	0.00	0.00	0.00	0.00	000	0	0	0
37	2.87	2.87	-0.07	-0.07	0.00	0.00	43.00	35.50	0.00	0.00	0.00	0.00	100	0	0	0
38	2.80	2.80	-0.07	-0.07	0.00	0.00	42.00	34.50	0.00	0.00	0.00	0.00	100	0	0	0
39	2.73	2.73	-0.07	-0.07	0.00	0.00	41.00	33.50	0.00	0.00	0.00	0.00	100	0	0	0
40	2.67	2.67	-0.07	-0.07	0.00	0.00	40.00	32.50	0.00	0.00	0.00	0.00	100	0	0	0
41	2.60	2.60	-0.07	-0.07	0.00	0.00	39.00	31.50	0.00	0.00	0.00	0.00	101	5	0	0
42	2.53	2.53	-0.07	-0.07	0.00	0.00	38.00	30.50	0.00	0.00	0.00	0.00	101	5	0	0
43	2.47	2.47	-0.07	-0.07	0.00	0.00	37.00	29.50	0.00	0.00	0.00	0.00	101	5	0	0
44	2.40	2.40	-0.07	-0.07	0.00	0.00	36.00	28.50	0.00	0.00	0.00	0.00	101	5	0	0
45	2.33	2.33	-0.07	-0.07	0.00	0.00	35.00	27.50	0.00	0.00	0.00	0.00	101	5	0	0
46	2.27	2.27	-0.07	-0.07	-16.67	0.00	34.00	26.50	0.00	0.00	0.00	0.00	101	5	0	0
47	2.20	2.20	-0.07	-0.07	-33.34	0.00	33.00	25.50	0.00	0.00	0.00	0.00	101	5	0	0
48	2.13	2.13	-0.07	-0.07	-50.00	-40.00	32.00	24.50	0.00	0.00	175.00	0.00	100	5	0	0
49	2.07	2.07	-0.07	-0.07	-66.67	-70.00	31.00	23.50	0.00	0.00	275.00	0.00	101	5	0	0
50	2.00	2.00	-0.07	-0.07	-83.34	-91.00	30.00	22.50	0.00	0.00	313.00	0.00	101	5	0	0
51	1.93	1.93	-0.07	-0.07	-100.01	-104.50	29.00	21.51	0.00	0.00	317.00	0.00	101	5	0	0
52	1.87	1.87	-0.07	-0.07	-116.68	-112.16	28.00	20.51	0.00	0.00	297.00	0.00	101	5	0	0

TABLE 9. SEQUENTIAL CONFLICT DATA FOR REVISED COORD LOGIC (Sheet 2 of 2)

Time	Range		Range Rate		Rel. Alt.		Horizontal TAU		Vertical TAU		Vertical Miss		Fields	CMD1	CMD2	CMD3
	Real/BCAS	BCAS	Real/BCAS	BCAS	Real/BCAS	BCAS	Real/BCAS	BCAS	Real/BCAS	BCAS	THETA	BCAS	ABC	VCHD	VCHD	HCMD
82	0.17	0.08	0.05	-0.01	-616.71	-618.72	-2.00	-32.25	0.00	0.00	684.00	0.00	101	5	0	0
83	0.23	0.13	0.06	0.01	-633.38	-619.74	-3.00	1000.00	0.00	0.00	619.00	0.00	101	5	0	0
84	0.29	0.20	0.06	0.03	-650.05	-658.38	-4.00	1000.00	0.00	0.00	619.00	0.00	101	5	0	0
85	0.35	0.28	0.06	0.05	-666.72	-685.72	-5.00	1000.00	0.00	0.00	619.00	0.00	101	5	0	0
86	0.42	0.36	0.06	0.06	-683.39	-703.56	-6.00	1000.00	0.00	0.00	619.00	0.00	101	5	0	0
87	0.48	0.45	0.07	0.07	-700.05	-713.90	-7.00	1000.00	0.00	0.00	619.00	0.00	101	5	0	0
88	0.55	0.53	0.07	0.08	-716.72	-718.72	-8.00	1000.00	0.00	0.00	619.00	0.00	101	5	0	0
89	0.61	0.61	0.07	0.08	-733.39	-719.74	-9.00	1000.00	0.00	0.00	619.00	0.00	101	5	0	0
90	0.68	0.68	0.07	0.08	-750.06	-758.38	-10.00	1000.00	0.00	0.00	619.00	0.00	101	5	0	0
91	0.74	0.75	0.07	0.07	-766.73	-785.72	-11.00	1000.00	0.00	0.00	619.00	0.00	101	5	0	0
92	0.81	0.82	0.07	0.07	-783.39	-803.56	-12.00	1000.00	0.00	0.00	619.00	0.00	101	5	0	0
93	0.88	0.88	0.07	0.07	-800.06	-813.90	-13.00	1000.00	0.00	0.00	619.00	0.00	101	5	0	0
94	0.94	0.95	0.07	0.07	-816.73	-818.72	-14.00	1000.00	0.00	0.00	619.00	0.00	101	5	0	0
95	1.01	1.01	0.07	0.07	-833.40	-819.74	-15.00	1000.00	0.00	0.00	619.00	0.00	101	5	0	0
96	1.08	1.08	0.07	0.07	-850.07	-858.87	-16.00	1000.00	0.00	0.00	619.00	0.00	100	0	0	0
97	1.14	1.14	0.07	0.07	-866.73	-885.72	-34.00	1000.00	0.00	0.00	619.00	0.00	100	0	0	0
98	1.18	1.20	0.03	0.06	-866.73	-903.55	-35.00	1000.00	0.00	0.00	619.00	0.00	100	0	0	0
99	1.21	1.24	0.03	0.05	-866.73	-913.90	-36.00	1000.00	0.00	0.00	619.00	0.00	100	0	0	0
100	1.24	1.27	0.03	0.05	-866.73	-918.71	-37.00	1000.00	0.00	0.00	619.00	0.00	100	0	0	0

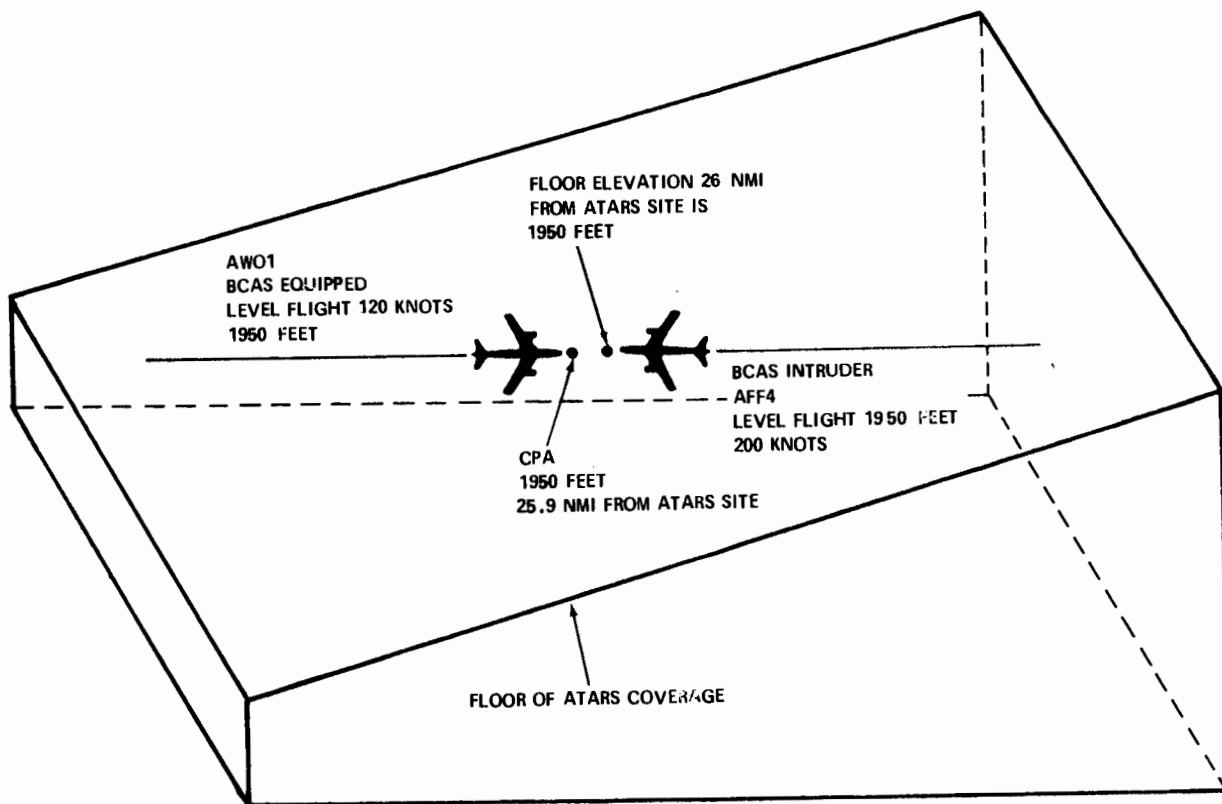
The Minimum Slant Range For This Conflict Is 583.38 Feet.

21A

POP-UP THREAT ANALYSIS.

Pop-up threats were those intruders which enter ATARS coverage area through the floor of the coverage and pose an immediate collision threat to a BCAS aircraft. ATARS was unable to see the threat until it was too late to provide sufficient separation. This section evaluates the ability of the CIR logic to resolve the pop-up threat while the BCAS aircraft was in ATARS coverage.

BCAS EQUIPPED POP-UP THREAT. The encounter conditions, for the evaluation of the CIR logic when the pop-up threat was BCAS equipped, are shown in figure 12. The intruder aircraft, AFF4, was below the floor of ATARS coverage. Both aircraft were in level flight at 1,950 feet. The primary BCAS aircraft, AW01, was in ATARS coverage throughout the encounter period. The summary of sequential BCAS data, which resulted for the encounter, is presented in table 10.



80-51-IV-12

FIGURE 12. POP-UP THREAT ENCOUNTER CONDITIONS

TABLE 10. SUMMARY OF SEQUENTIAL BCAS DATA FOR BCAS EQUIPPED POP-UP THREAT

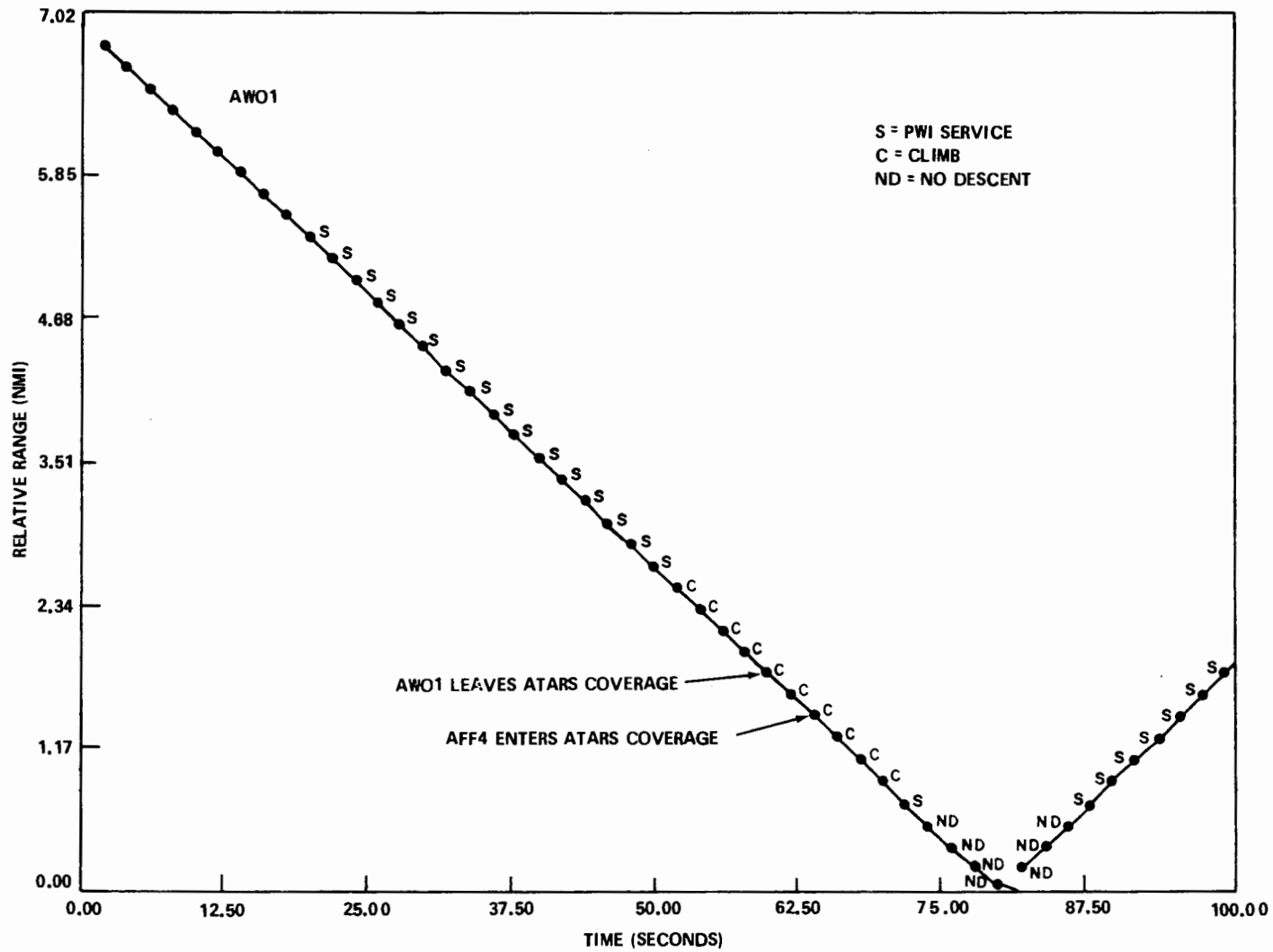
Time	Primary BCAS Aircraft				BCAS Equipped Threat			
	AW01			Command	AFF4			Command
	A Bit	B Bit	C Bit		A Bit	B Bit	C Bit	
50	1	0	0	--	0	0	0	--
51	1	1	0	Descent	0	1	0	Climb
64	1	1	0	Descent	1	1	0	Climb
73	1	1	0	No Climb	1	1	0	No Descend
76	0	1	0	No Climb	1	1	0	No Descend
85	0	0	0	No Command	0	0	0	No Command

Over 500 feet vertical separation resulted because of the BCAS-generated resolution. On the 29 seconds prior to CPA, BCAS generated coordinated positive commands because the A bit was not set in AFF4. Although the intruder originally would not have entered ATARS coverage until CPA, its response to the climb command caused it to enter ATARS coverage 16 seconds prior to CPA. At this time, AFF4's A bit was set. However, as required by the interface logic, BCAS continued to provide resolution. The positive commands transitioned to complementary negative commands 7 seconds prior to CPA because sufficient vertical separation had been generated. Because AW01 was forced to descend, its A bit was cleared 4 seconds prior to CPA (earlier than if it did not have to descend). The results indicate that the interface logic functioned properly and permitted BCAS to resolve the encounter with the BCAS equipped pop-up intruder. Plots of the sequential range and altitude data for the encounter are presented in figures 13 and 14.

ATCRBS POP-UP THREAT. The same encounter conditions shown in figure 13 were repeated. The only difference in the scenario was that the pop-up threat was an ATCRBS threat. The results were similar. In this case, only 410 feet of vertical separation resulted at CPA. The reduction occurred because only one aircraft received commands since the threat was ATCRBS. Command termination occurred properly.

MULTIPLE AIRCRAFT CONFLICT ACROSS THE ATARS COVERAGE BOUNDARY.

A three-aircraft encounter was designed to stress the CIR interface logic. The encounter scenario required that multiple commands be coordinated by the ATARS/CIR interface logic and the BCAS/CIR interface logic. Finally, commands had to be coordinated between ATARS and BCAS. Since the encounter occurred while one aircraft was outside ATARS coverage, the ability of the logic to use the existing ATARS commands as a constraint in forming BCAS resolutions for the threat outside ATARS coverage can be tested.



	AWO1	AFF4
SPEED (KNOTS)	120	200
A / C	1	1
EQUIPPED	YES	YES
FLIGHT PLAN DATA		
AFF4 (VEROUS)		AWC
CROSSING ANGLE		180 DEGREES
VERT. SEPARATION		0 FEET
HORZ. SEPARATION		0 NMI
CPA OCCURRED AT 80 SECONDS		
SLANT RANGE		583 FEET
VERT. SEPARATION		583 FEET
HORZ. SEPARATION		0 NMI
INCREASE DUE TO BCAS		
VERT. INCREASE		583 FEET
HORZ. INCREASE		0 NMI

80-51-IV-13

FIGURE 13. POP-UP THREAT PLOT (RELATIVE RANGE VERSUS TIME)

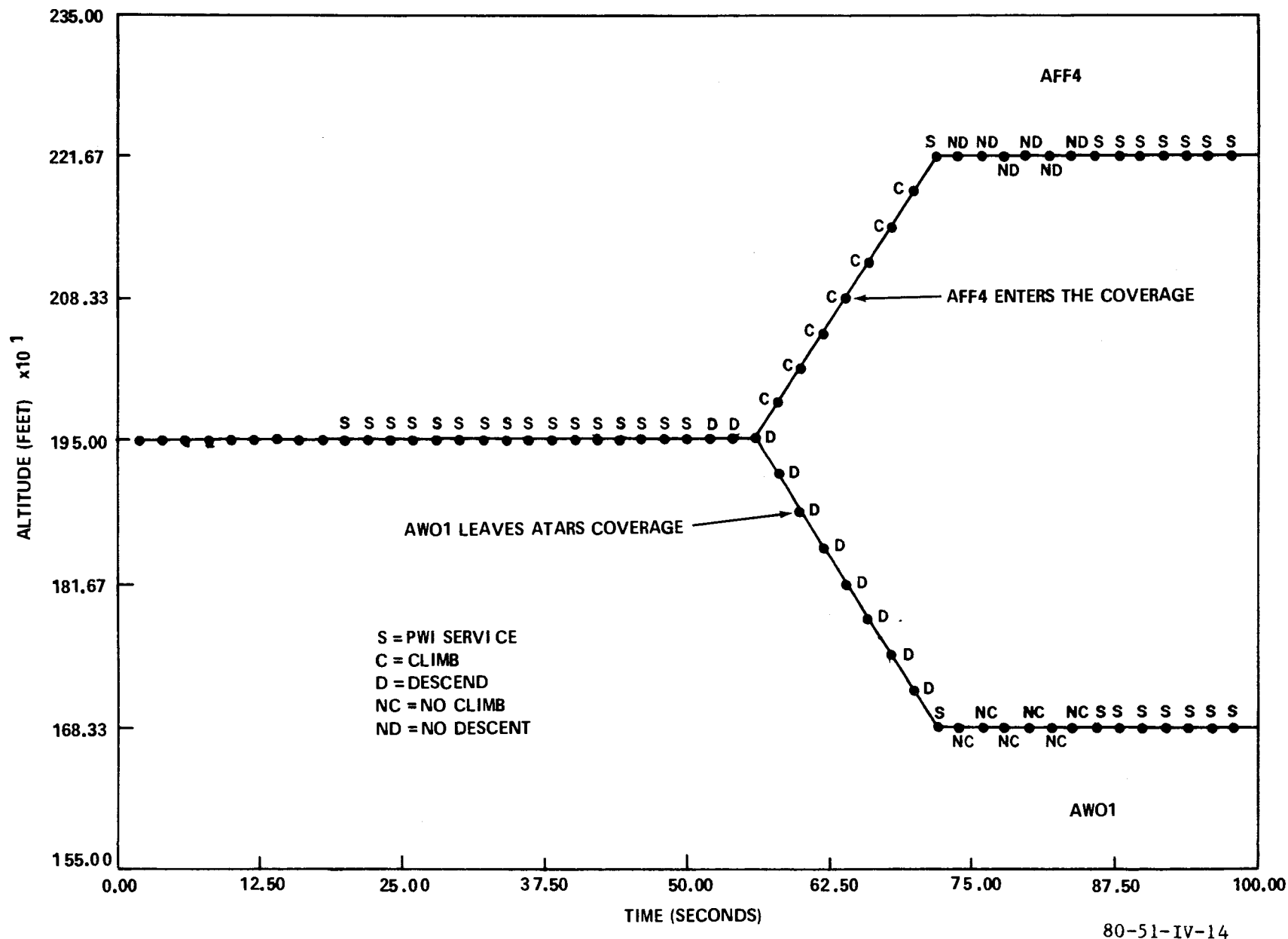
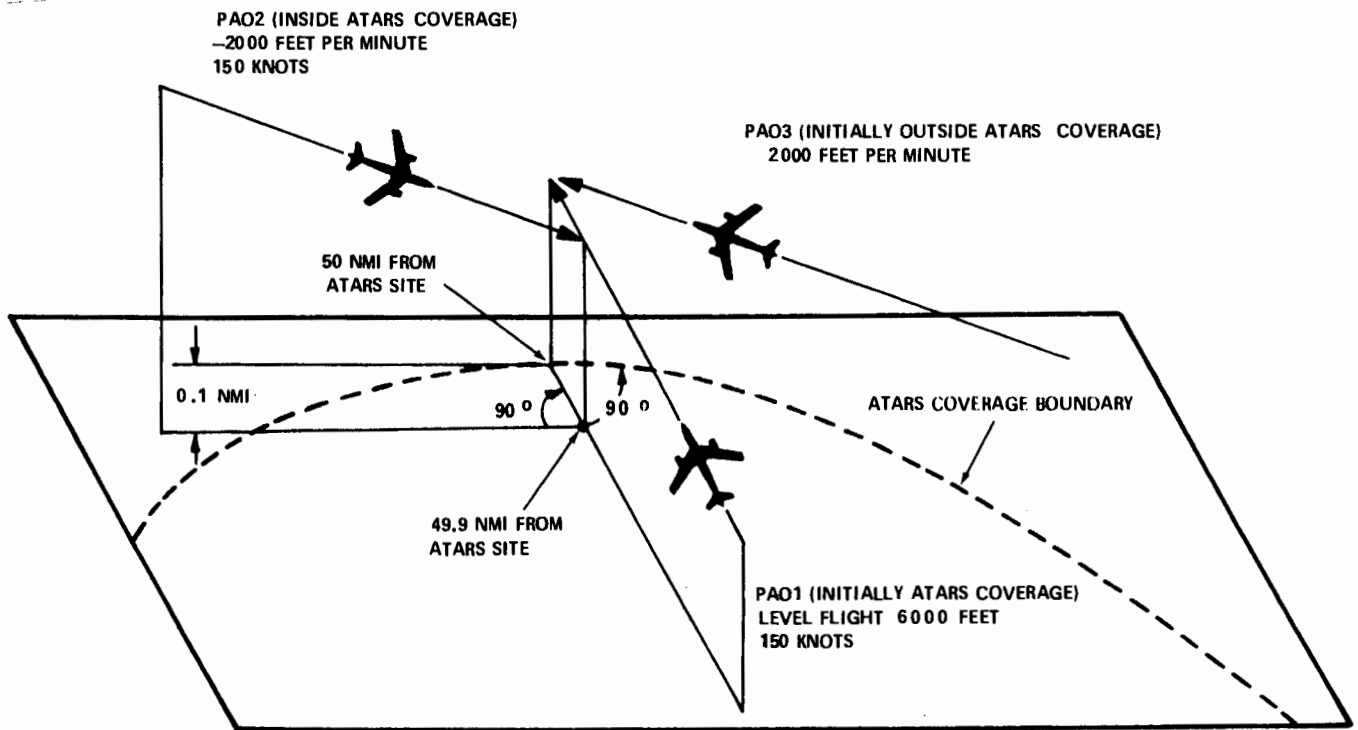


FIGURE 14. POP-UP THREAT PLOT (ALTITUDE VERSUS TIME)

The multiple aircraft scenario is shown in figure 15. All aircraft were BCAS equipped. The pairwise CPA was designed so as not to occur simultaneously. Table 11 identifies the planned time and conditions of each pair's CPA and the CAS system which would resolve the conflict.



80-51-IV-15

FIGURE 15. MULTIPLE AIRCRAFT BOUNDARY TRANSITION COORDINATION SCENARIO

TABLE 11. MULTIPLE ENCOUNTER PLANNED CPA CONDITIONS

<u>CPA Characteristic</u>	<u>Conflict Pair</u>		
	<u>PA01 Versus PA02</u>	<u>PA01 Versus PA03</u>	<u>PA02 Versus PA03</u>
Time	80th second	83rd second	81.5th second
Horizontal Separation	0 nmi	0 nmi	0.1 nmi
Vertical Separation	0 ft	0 ft	0 ft
Responsible System	ATARS	BCAS	BCAS

Throughout the encounter period, PA02 was in ATARS coverage. PA01 left ATARS coverage on the 84th second. PA03 was only in ATARS coverage between the 78th and 88th second.

The resulting CAS commands and the sequential settings of the A, B, and C bits in each aircraft's CIR are displayed in table 12. Each row entry in table 12 identifies a change in CIR status or command for at least one aircraft. Because PA02 received an ATARS climb command on the 60th second because of the threat PA01 and PA03 received a descent command (for PA01) on the 58th second, the planned conflict between PA02 and PA03 was delayed. The detection of this conflict did not occur until PA03 was in ATARS coverage. As a result, ATARS provided resolution service for this pair.

Between the 64th and 68th second, PA01 received multiple commands. One command was due to ATARS resolution (threat is PA02) and one was due to BCAS resolution (threat to PA03). Multiple threat logic properly coordinated these commands, this caused the BCAS-generated climb command for PA03 to change to a limit descent command. This was the proper result since PA01 is the middle aircraft.

Between the 80th and 88th second, PA03 received multiple commands. One command was due to ATARS resolution (threat is PA02), and one command was due to BCAS resolution (threat is PA01). Since PA03 is the bottom aircraft, the BCAS multiple aircraft logic, MAC, provided the proper multiple command, descend. All commands terminated properly. Plots of vertical and horizontal positions of the aircraft are presented in figures 16 and 17. Table 13 presents the increase in vertical separation which resulted for each pair.

TABLE 12. MULTIPLE ENCOUNTER COMMAND AND CIR STATUS

Time	PA01				Aircraft ID				PA02				PA03											
	PA02			Command	PA03			Command	CIR Row For PA01			Command	PA03			PA01			PA02					
	A Bit	B Bit	C Bit		A Bit	B Bit	C Bit		A Bit	B Bit	C Bit		A Bit	B Bit	C Bit	Command	A Bit	B Bit	C Bit	Command	A Bit	B Bit	C Bit	Command
39	1	0	0	--	1	0	0	--	1	0	0	--	1	0	0	--	0	0	0	--	0	0	0	--
40	1	0	1	Descent	1	0	0	--	1	0	1	Climb	1	0	0	--	0	0	0	--	0	0	0	--
48	1	0	0	--	1	0	0	--	1	0	0	--	1	0	0	--	0	0	0	--	0	0	0	--
52	1	0	0	--	1	1	0	No Descent	1	0	0	--	1	0	0	--	0	1	0	No Climb	0	0	0	--
58	1	0	0	--	1	1	0	Climb	1	0	0	--	1	0	0	--	0	1	0	Descent	0	0	0	--
60	1	0	0	--	1	1	0	Climb	1	0	1	Climb	1	0	0	--	0	1	0	Descent	0	0	0	--
64	1	0	1	Limit Climb*	1	1	0	Limit Descent*	1	0	1	Climb	1	0	0	--	0	1	0	Descent	0	0	0	--
68	1	0	0	--	1	0	0	--	1	0	1	Climb	1	0	0	--	0	0	0	--	0	0	0	--
72	1	0	0	--	1	0	0	--	1	0	0	--	1	0	0	--	0	0	0	--	0	0	0	--
76	1	0	0	--	1	1	0	No Descent	1	0	0	--	1	0	0	--	0	1	0	No Climb	0	0	0	--
80	1	0	0	--	1	1	0	No Descent	1	0	0	--	1	0	1	Climb	1	1	0	Descent*	1	0	1	Descent*
82	1	0	0	--	1	1	0	Climb	1	0	0	--	1	0	1	Climb	1	1	0	Descent*	1	0	1	Descent*
88	1	0	0	--	1	0	0	--	1	0	0	--	1	0	1	Climb	1	0	0	--	1	0	1	Descent
97	0	0	0	--	0	0	0	--	0	0	0	--	0	0	0	--	0	0	0	--	0	0	0	--

\*Multiple Threat Commands

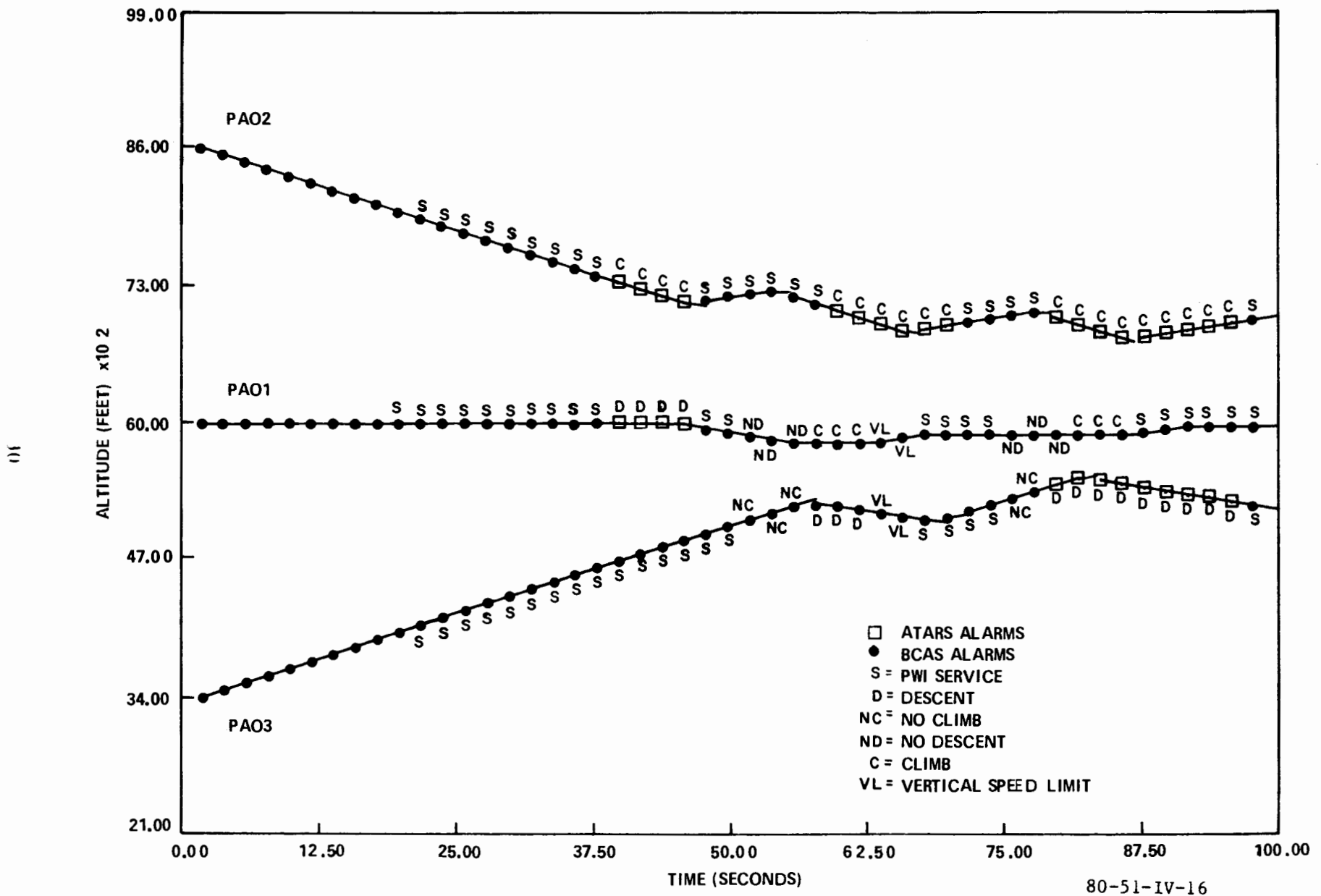
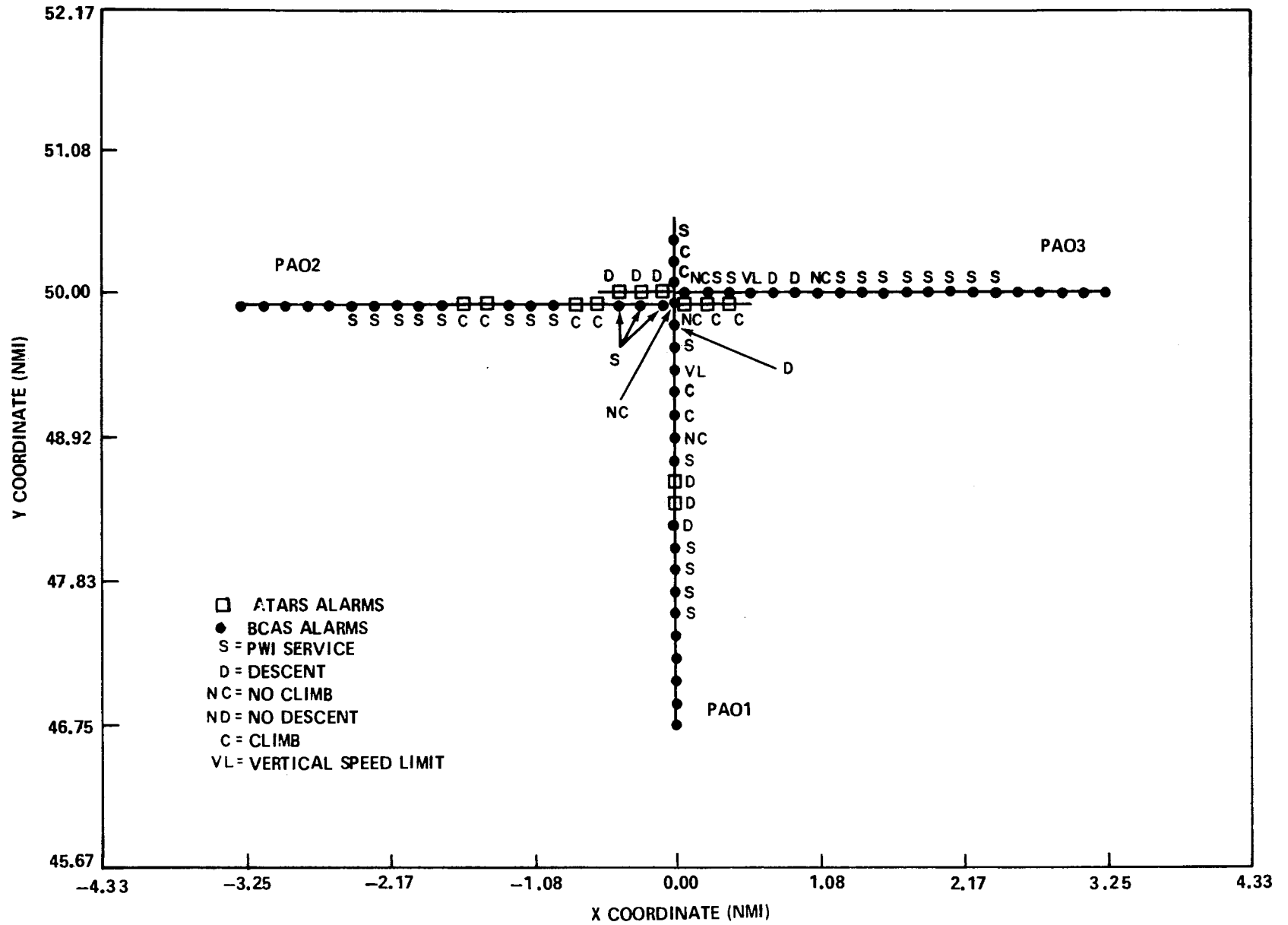


FIGURE 16. MULTIPLE AIRCRAFT (VERTICAL) PLOT



80-51-IV-17

FIGURE 17. MULTIPLE AIRCRAFT (HORIZONTAL) PLOT

TABLE 13. VERTICAL SEPARATION AT CPA FOR THREE-AIRCRAFT ENCOUNTER

<u>Pair</u>	<u>PA01 Versus PA02</u>	<u>PA01 Versus PA03</u>	<u>PA02 Versus PA03</u>
Increase In Vertical Separation	884 ft	416 ft	1,495 ft

MULTIPLE CIR ROW EXCHANGE PROCEDURES.

A major drawback to the CIR logic design was the requirement to interchange multiple rows of CIR data. Even in the Active BCAS air-to-air coordination procedures with another BCAS, the contents of all CIR rows were interchanged between aircraft. Though BCAS aircraft A received all the CIR rows from BCAS aircraft B, BCAS A only used information from one CIR row (the row that contained information about A). The remaining CIR rows that A received from BCAS aircraft B are totally ignored. The exchange of the additional CIR rows during BCAS-to-BCAS coordination only adds to the engineering complexity of BCAS. This exchange should be eliminated.

BCAS PWI LOGIC. The latest Active BCAS logic (reference 4) included logic to support a reduced capability (when compared to ATARS) PWI display. The Active BCAS surveillance system could not measure bearing to an intruder. As a result, BCAS PWI messages contained only altitude and range information on a particular threat. ATARS PWI messages also contained bearing information on threat aircraft. Previous experimentation (reference 7) indicated that pilots wanted range and altitude information on threats when bearing information was unavailable.

The Active BCAS PWI logic was analysed; several operational discrepancies were detected. The discrepancies are reviewed below. As a result of these discrepancies, a revised PWI logic was developed and tested.

PERFORMANCE LEVEL 2 REGION PWI'S. In performance level 2 regions, BCAS command action was suppressed. The detection and resolution logic (DRACT) was not exercised, although threat tracking (TRIACT) continued. The PWI detection logic (PWIDET), depicted in reference 3, required that the threat dependent values of R, RD, A, and ADOT be passed from the DRACT logic. As a result, the PWI logic (described in reference 3) could not support PWI message generation in performance level 2 areas. The ability to continue PWI messages in performance level 2 areas was desirable. This was especially true since the PWI display logic (DISPWI) could control the number of PWI messages being generated as the aircraft density increased.

To support PWI message generation in performance level 2 regions, the high level BCAS logic flow must be modified. The own aircraft altitude and altitude rate values (ZOWN and ZDOWN, respectively), can be supplied directly from the own aircraft tracking module, TROACT. The range and altitude values of R, RD, ZINT, and ZDINT for a particular intruder can be obtained directly from the intruder track file.

The advantage of basing PWI message generation on the status of the intruder track file will become more apparent. With a modification to the PWIDET logic, the values of altitude separation (A) and the relative vertical rate (ADOT) could be calculated by directly accessing the own and intruder track files.

FREEZING PWI DISPLAYS. PWI display logic shown in reference 2 has a minimum PWI display time of 30 seconds. Even if an intruder were dropped from surveillance in less than 30 seconds, the associated PWI message would only be terminated prior to 30 seconds if the number of PWI messages exceeded the display capability. An intruder track file could be deleted after 10 seconds of missing reports while the associated PWI message could continue to be displayed for 20 more seconds. If an intruder's track file were deleted, its associated displayed PWI data could not be updated. It is possible that PWI data for a threat remain frozen (not updated) for up to 20 seconds. To correct this problem, it is suggested that TRIACT logic (figure 3-2 of reference 3) be changed as shown in figure 18. With this change, any existing PWI message for a particular threat would be removed when the intruder state vector for that threat was deleted.

SETTING OF PWI THREAT PARAMETERS. In order to support PWI message generation in performance level 2 regions, PWI threat parameters should be set to the maximum value of own aircraft's performance level (INDEX), the BCAS equipped aircraft's performance level (PLINT), or 3.

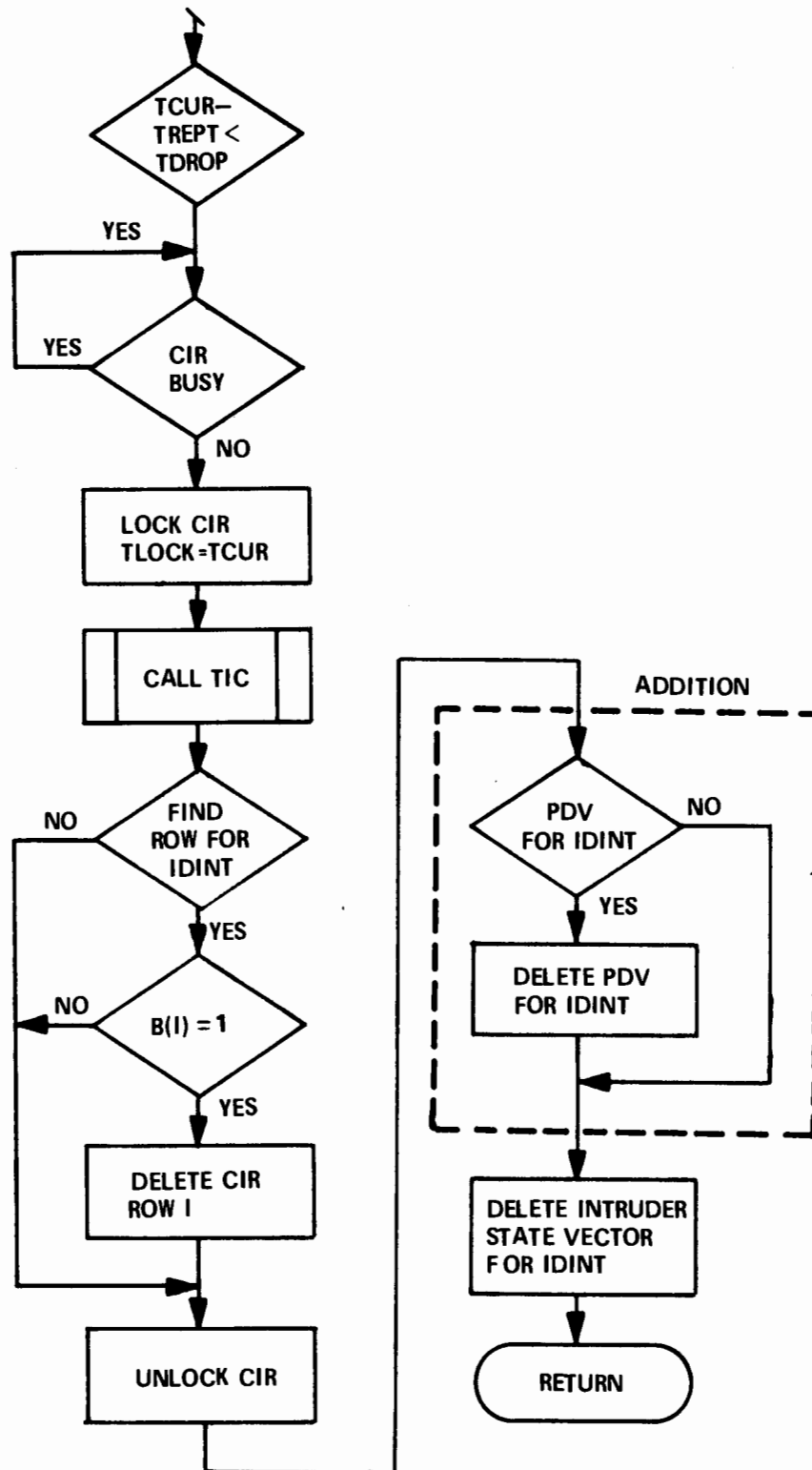
The parametric threshold values for PWI altitude detection (ZTHRP) and relative altitude rate detection (ZDTHRP) were not identified in reference 2. The parameter values used can be found in table 14.

TABLE 14. ADDITIONAL PWI LOGIC THRESHOLD VALUES

<u>Parameter</u>	<u>PWI Performance Level</u>		
	<u>3</u>	<u>4</u>	<u>5</u>
ZTHRP	875 ft	1,100 ft	1,800 ft
ZDTHRP	-25 ft/sec	-25 ft/sec	-20 ft/sec

An additional comment about the PWIDET logic in reference 2 is necessary. The intruder track file element for range rate, RD, can be reset in PWIDET. This could adversely affect the alpha-beta range and range rate trackers in TRIACT.

To verify the above suggestions, the PWIDET logic was redesigned as shown in figure 19. The modified PWIDET logic was interfaced with the PWI display logic (DISPW) and PWI coordination logic (PCCOR). The modified logic was thoroughly tested. Appendix B reviews sequential BCAS PWI messages that resulted while testing the modified PWIDET logic.



80-51-IV-18

FIGURE 18. SUGGESTED CHANGE TO TRIACT LOGIC

NOTE  
RDI IS LOCAL VALUE OF RD

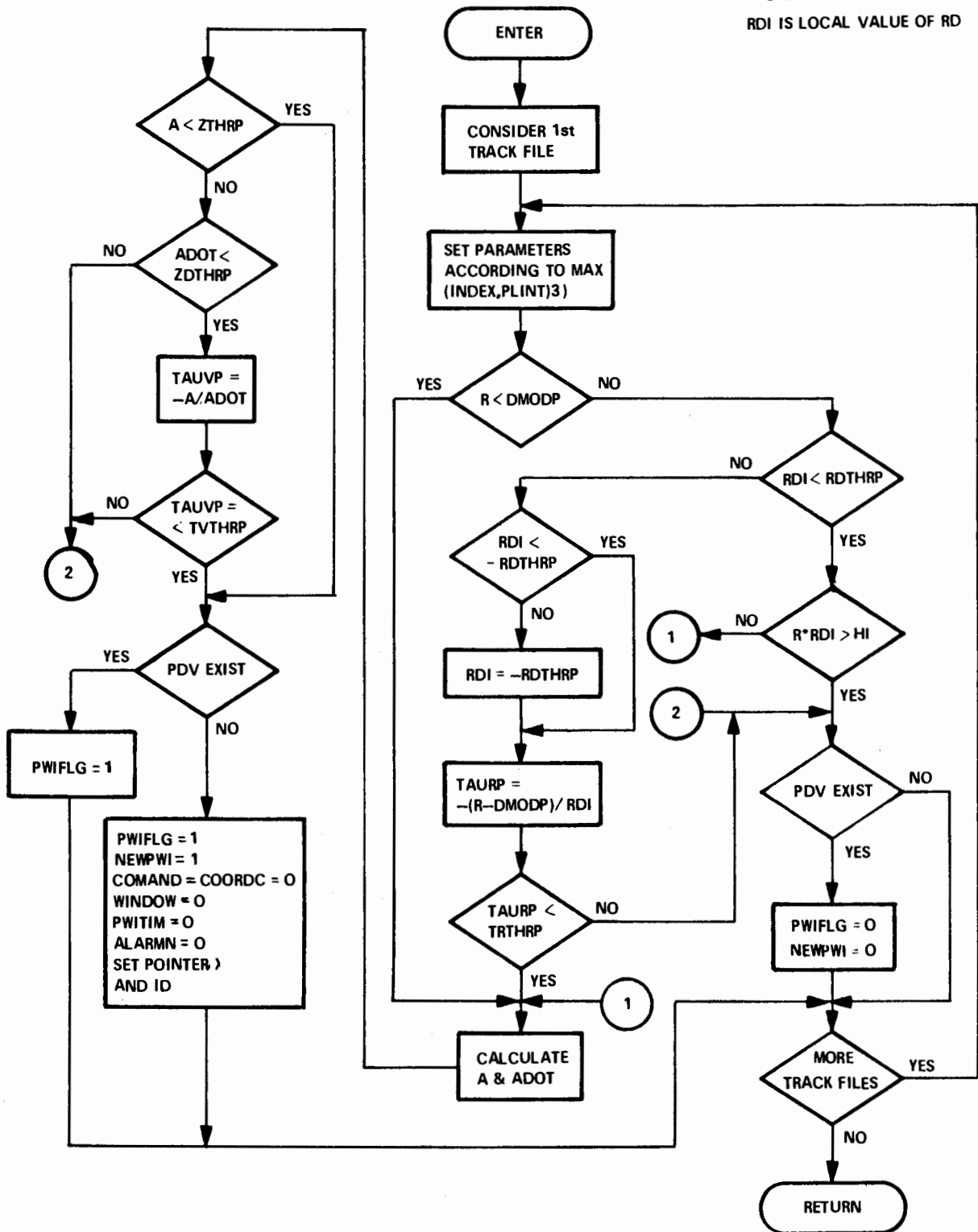


FIGURE 19. MODIFIED PWIDET LOGIC

80-51-IV-19

PWI ATARS COVERAGE BOUNDARY PROBLEMS. The present Active BCAS PWI display logic suppressed the display of Active BCAS PWI's when the own aircraft received ATARS service (A bit = 1). Consider the encounter conditions shown in figure 20. In this case, Active BCAS PWI messages were suppressed for aircraft A, even though Active BCAS was responsible for resolving this encounter. A more sophisticated procedure should be developed which permits the own aircraft to receive Active BCAS PWI messages, especially when Active BCAS has generated a command. Figure 21 presents the necessary modification to DISPWI logic that would provide Active BCAS PWI messages for the above cases.

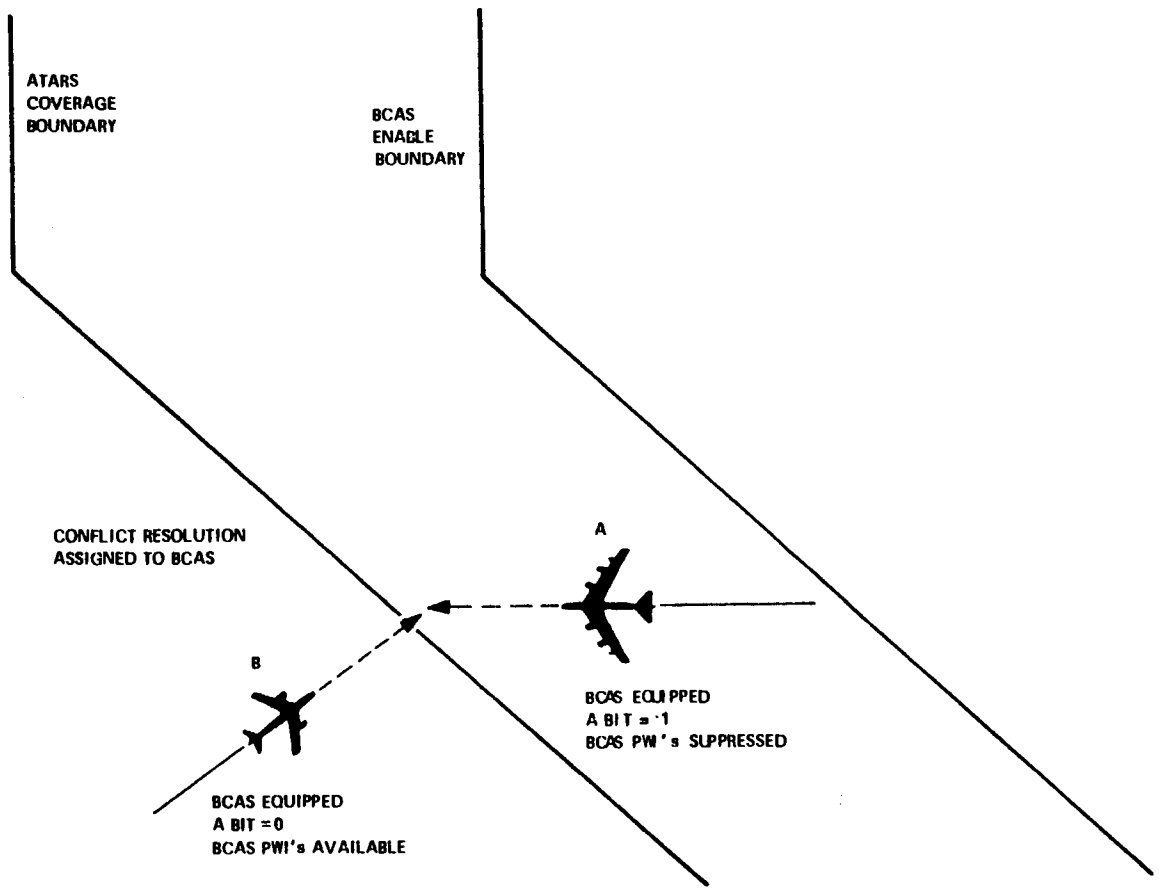
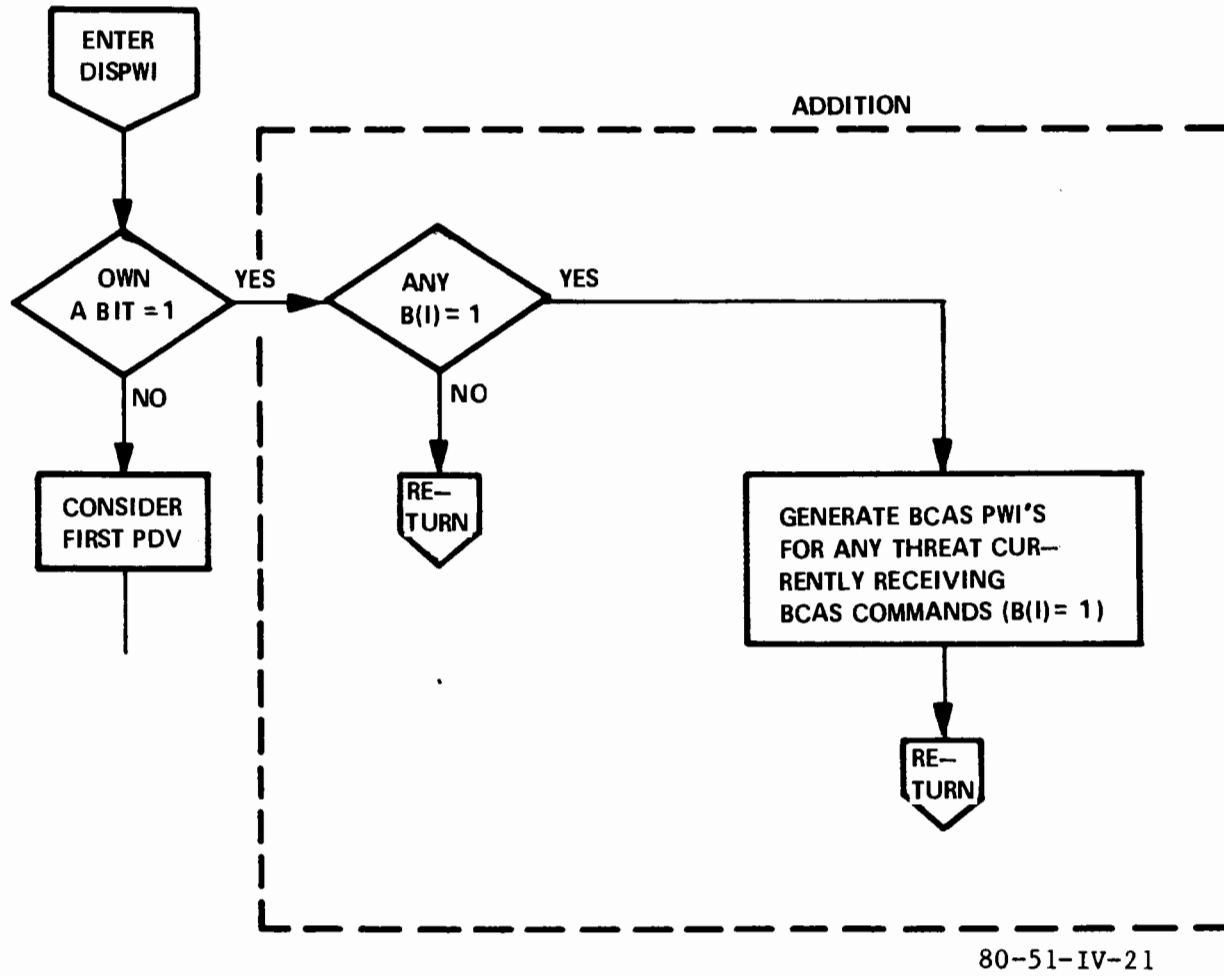


FIGURE 20. ENCOUNTER CONDITION WHICH CAUSED BCAS PWI SUPPRESSION



80-51-IV-21

FIGURE 21. MODIFIED DISPWI LOGIC

## CONCLUSIONS AND RECOMMENDATIONS

The current Conflict Indicator Register (CIR) coordination design and communications protocols required the exchange of all rows of the CIR. This is done despite the fact that Active Beacon Collision Avoidance System (BCAS) logic totally ignored all received CIR rows from a threat aircraft except for the row that contains data for own aircraft. In order to reduce the engineering complexity and improve coordination reliability, Active BCAS air-to-air coordination protocols should be developed so that only one CIR row need be exchanged.

Analysis of multiple aircraft encounters in the Automated Traffic and Advisory Service (ATARS)/BCAS seam area showed that the current CIR logic reference 3 provided proper coordination to generate sufficient separation. The logic provided the necessary checks to insure compatibility of new threat resolutions with resolutions for other threats which already existed in the CIR. The internal compatibility checks functioned properly regardless of the Collision Avoidance System (CAS) (ATARS or BCAS) which generated the new resolution. The external compatibility checks required before posting a resolution were always satisfied. These external coordination actions had been thoroughly evaluated in previous Active BCAS logic evaluations (reference 7).

The use of the A bit status of the BCAS equipped intruder properly prevented unnecessary BCAS alarms from being generated when sufficient horizontal miss distance (MD) existed and had been detected by ATARS. For ATARS/BCAS seam area ATCRBS threats, no method currently exists to suppress BCAS alarms for cases where ATARS would detect sufficient horizontal MD's and would not generate an alarm.

The lack of the setting of the A bit in the case of Discrete Address Beacon System (DABS) equipped threats permits BCAS to properly generate alarms for DABS equipped pop-up threats. Since ATCRBS threats do not provide A bit information to BCAS aircraft, Active BCAS is not suppressed and can adequately resolve ATCRBS pop-up threats.

The current ATCRBS threat correlation logic (TIC) does not guarantee unique identification of ATCRBS threats. The current logic does not use position projection techniques to correlate threat information during nonconstant data acquisition periods. This can prevent correlation during likely encounter situations. Bearing and bearing rate information is subject to large sequential changes which would prevent threat correlation when near the closest point of approach. More sophisticated airborne ATCRBS threat correlation logic, which utilizes positional projections based on data time differences, is recommended. The possibility of merging or splitting ATCRBS threat block data must be minimized.

The current coordinations logic (COORD) does not always reset the indicator for dropping BCAS commands. This can result in the erroneous setting of B bits in the CIR. The minor logic additions described in this report to handle this problem should be implemented.

Several operational deficiencies exist in the Active BCAS proximity warning indicator (PWI) logic described in reference 2. These deficiencies include the following:

1. The inability to generate PWI messages when operating in performance level 2 regions.
2. The freezing of the displayed PWI data for up to 20 seconds following deletion of the intruder state vector.
3. The setting of PWIDET threat threshold parameters.
4. The inability to display Active BCAS PWI messages for pop-up threats when the own aircraft is in ATARS coverage.

Logic designed to resolve these deficiencies was developed and tested. Implementation of the new PWI logic is recommended.

#### REFERENCES

1. McFarland, A., et al., Report of the FAA Task Force on Aircraft Separation Assurance, Federal Aviation Administration, FAA-EM-19, January 1979.
2. Spracklin, D. R., Program Design Specification for the Fast-Time Encounter Generator, Revision 1, Computer Sciences Corporation, ATCSF 80-005, February 1980.
3. Zeitlin, A. D., Active Beacon Collision Avoidance System — Collision Avoidance Algorithms, MTR 79-W00110, April 1979.
4. McFarland, A. L., Spencer, N. A., Active Beacon Collision Avoidance System — Collision Avoidance Algorithms, W46-06B, January 1980.
5. Adkins, A., Billman, B., Thomas, J., and Windle, J., Active Beacon Collision Avoidance Logic Evaluation: Volume II, Collision Avoidance (BCAS) Threat Phase, FAA Report Publication Pending.
6. Spracklin, D. R., Program Design Specifications for the Active BCAS ATARS/CIR Simulation, Computer Sciences Corporation, TM15-016 R01, May 1980.
7. Berry, T. and Morganstern, B., An Evaluation of Aircraft Separation Assurance Concepts Using Airline Flight Simulators, Aeronautical Radio, Incorporated, Report 1343-01-3-2058, November 1979.

## APPENDIX A

### CONFLICT INDICATOR REGISTER (CIR) DESCRIPTION

The CIR should (1) provide an orderly and unambiguous coordination of conflict resolution when Beacon Collision Avoidance System (BCAS) and Automated Traffic Advisory and Resolution Service (ATARS) coexist, (2) coordinate BCAS alarms and manage complete information exchange in multi-aircraft conflicts, and (3) assigns the conflict resolution responsibility to either ATARS or BCAS depending on the position of the protected aircraft and threat aircraft relative to a Discrete Address Beacon System (DABS) radar site. The structure and definitions of the CIR's constituent fields are shown in figure A-1.

When the aircraft was in ATARS coverage, its A bit was set to 1. There are four site bits in figure A-1 which identify the sites that provide ATARS service to the aircraft. Whenever, an aircraft was within coverage of an ATARS ground site, it sent (1) the indication that the aircraft was receiving ATARS service and (2) the identification of the ground site. Although four site bits are shown in the figure, in this simulation a single-site scenario was modeled. That is, the scenarios in which own aircraft received ATARS from more than one site were not simulated. Timer fields stored the time at which the last update from each site was received. As long as a site bit was set, the A bit was set to 1. During a conflict, if the B bit was set to 1, then BCAS was responsible for resolving that conflict. Likewise, if the C bit was set, ATARS was responsible for resolving the conflict. The B bit and C bit could be simultaneously set to 1 in the same row. This would indicate more than one system was responsible for resolving a particular paired conflict.

If the threat aircraft was DABS equipped, its DABS address would be found in the ID field. If the threat is (ATCRBS), the positional ATCRBS track block would be filled. Own aircraft's maneuver intent for each was stored in the D field. These entries were due to ATARS or BCAS conflict resolution. Bit E was set when BCAS-initiated air-to-air coordination was in progress. If the E bit was set, the B bit for that row would also be set. LTACS and LTBCS were fields that contained the last time that ATARS or BCAS, respectively, updated the CIR row. During coordination, the only elements of the CIR not exchanged with a DABS equipped threat were the site ID's site timers, E, LTACS, and LTBCS fields. For multi-threat (two or more intruders) scenarios, additional rows were created for each individual intruder.

Coordination procedures for conflicts detected by BCAS were done in the COORD logic. Whenever BCAS selected a command at the beginning of a conflict, changed the command, or dropped the command, it had to ascertain compatibility with the entries in its own CIR and the threat CIR (if the threat was equipped). Two types of compatibility checks were involved in this procedure.

The first type was the compatibility of a new command entering the CIR with entries already in the CIR; that is, ensuring that the commands already in the CIR could be simultaneously obeyed along with the new command. The second type was the compatibility of own aircraft's intent with the threat's intent. In the case of BCAS or ATARS equipped threats, this would avoid own aircraft and threat aircraft selecting maneuvers that negate each other's effect. This coordination logic was contained in the COMPATIBLE subroutine.

When a maneuver intent (due to a particular threat) was received, the BCAS coordination logic searched the own CIR for the row dedicated to that particular threat. The row was identified (1) by the DABS address in the ID field if the threat was equipped, or (2) by the correlation of positional track block data, if the threat was ATCRBS. The threat correlation logic routine performs this task. If no row existed for the particular threat, a new row would be created in the CIR. If a row already existed, its C bit was checked to see if ATARS has taken control of the conflict. In the ATARS/BCAS seam area, with ATARS in control and a DABS equipped threat, BCAS would still send coordination interrogations, but would do nothing more to resolve the conflict. When own aircraft received a coordination interrogation and maneuver sense complement from an equipped threat, the compatibility of the maneuver sense complement with own preferred maneuver was checked. If compatible, own intent was used, and the complementary sense was sent in the coordination interrogation to the threat. If a maneuver intent was found in the CIR which was not compatible with own preferred maneuver, then a credibility test (based on projected vertical separation) would determine whether to reverse own intent to become compatible with the intruder's established command.

A	SITE	TIMER 1	SITE	TIMER 2	SITE	TIMER 3	SITE	TIMER 4
	1		2		3		4	
B	C	ID	D	E	LTACS	LTBCS		
TRACK BLOCK (ATCRBS THREATS ONLY)								
R	RD	THETA	THDOT	Z	ZD			
B	C	ID	D	Z	LTACS	LTBCS		

ADDITIONAL ROWS AS REQUIRED FOR EACH THREAT

DEFINITIONS OF FIELDS

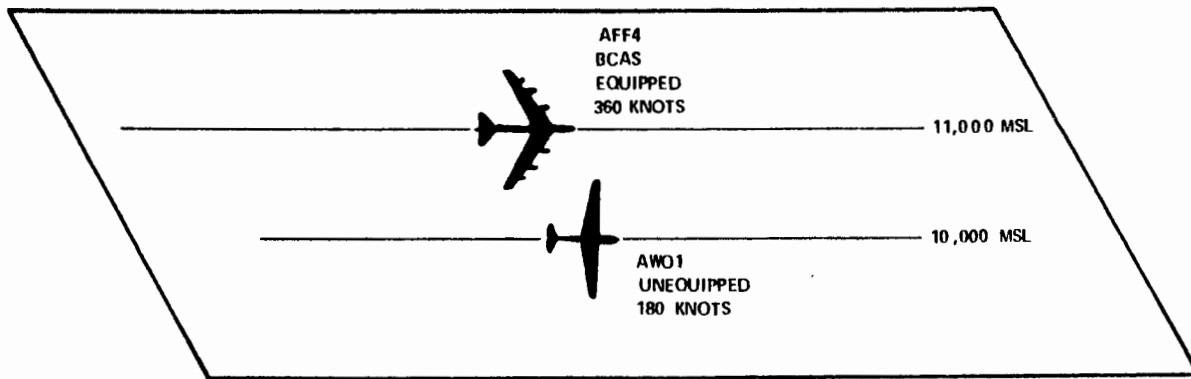
- A RECEIVING ATARS SERVICE. LOGICAL OR OF SITE ID'S 1...4
- SITE 1 - 4 RECEIVING ATARS SERVICE FROM INDIVIDUAL SITES
- TIMERS 1 - 4 LAST UPDATE FROM ATARS SITES 1...4
- B RESOLUTION COMMITTED TO BCAS
- C RESOLUTION COMMITTED TO ATARS
- ID DABS ID IF AVAILABLE
- D MANEUVER INTENT
- E BCAS COORDINATION IN PROGRESS
- LTACS TIME LAST ATARS COMMAND RECEIVED
- LTBCS TIME LAST BCAS COMMAND RECEIVED
- R RANGE TO ATCRBS THREAT
- RD RANGE RATE TO ATCRBS THREAT
- THETA BEARING TO ATCRBS THREAT
- THDOT BEARING RATE TO ATCRBS THREAT
- Z ALTITUDE OF ATCRBS THREAT
- ZD ALTITUDE RATE OF ATCRBS

FIGURE A-1. CIR STRUCTURE

APPENDIX B

RESULTS OF MODIFIED PROXIMITY WARNING INDICATOR (PWI) LOGIC

The modified PWIDET logic was tested using the encounter conditions shown in figure B-1. The sequenced Beacon Collision Avoidance System (BCAS) data that resulted is presented in table B-1. The receipt of an Active BCAS PWI is indicated when the letter P appears in the third column from the right in the table B-1 data. The displayed PWI altitude is found in column headed PWI ALT. The identity of the threat causing the PWI is found in the column headed ID. The displayed range is found in the column headed RANGE BCAS. On the 50th second, the initial PWI was displayed. This occurred because  $TAURP < 40$  and  $A < 1,800$  feet, the threshold for performance level 5 PWI's. Throughout the encounter period, the proper PWI data was displayed. The PWI display terminated properly.



80-51-IV-B-1

FIGURE B-1. ENCOUNTER CONDITIONS FOR TESTING THE MODIFIED PWIDET LOGIC