SP-1352-4

SHIP POINT DEFENSE WEAPON SCHEDULING

23 April 1981

Prepared for:

NAVAL SURFACE WEAPON CENTER/DAHLGREN LABORATORY
Department of the Navy
Dahlgren, Virginia

WEAPON SCHEDULING BRIEFING OVERVIEW

R-70925

- PROGRAM DESCRIPTION
- ASSUMED SHIP CAPABILITIES AND LIMITATIONS
- WEAPON SCHEDULING ALGORITHMS
- PERFORMANCE COMPARISONS FOR REALISTIC SCENARIOS
- CONCLUSIONS AND RECOMMENDATIONS

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PROGRAM DESCRIPTION

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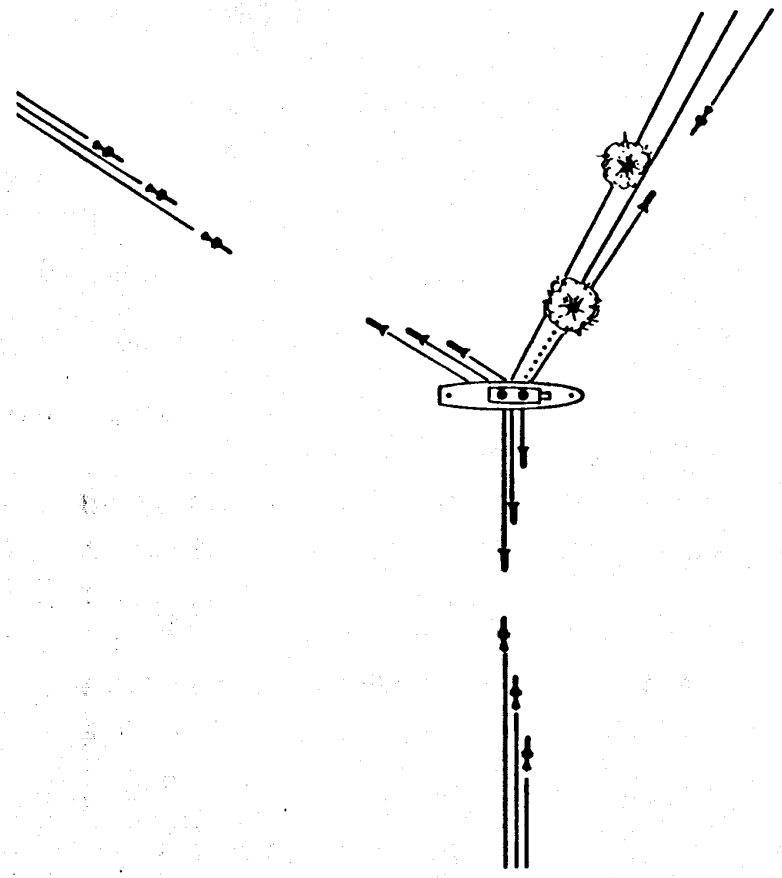
PROBLEM: DEFEND SHIP AGAINST ANTI-SHIP CRUISE MISSILE (ASCM) ATTACK

R-70929



- MULTIPLE SIMULTANEOUS ASCM ATTACKS ANTICIPATED
- SCHEDULE ASSETS FOR HARD KILL USING MISSILES AND GUNS

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PROGRAM OVERVIEW

R-70930

- GOAL: DEVELOP WEAPON SCHEDULING METHODS FOR SHIP POINT DEFENSE AGAINST

  ASCM THREATS
  ASCM LAUNCH PLATFORMS

- ACCOMPLISHMENTS

  DEVELOPED AND COMPARED THREE SCHEDULING ALGORITHMS, ONE BASED ON AN OPTIMIZATION TECHNIQUE.

  ASSESSED ALGORITHM PERFORMANCE AGAINST THREATS AND PLATFORMS IN REALISTIC SCENARIOS.

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GENERAL CONCLUSION

ALTHOUGH DIFFERENT SCHEDULING ALGORITHMS SOMETIMES GIVE IDENTICAL RESULTS, AN OPTIMIZED ALGORITHM CAN SIGNICANTLY ENHANCE SHIP SURVIVAL IN STRESSFUL SCENARIOS.

ASSUMED SHIP CAPABILITIES AND LIMITATIONS

POINT DEFENSE ASSETS

R-70932

- MODERN INTEGRATED SEARCH/TRACK RADAR
  - UNLIMITED TRACK CAPACITY
  - RANGE LIMITED TO 60,000 FT AGAINST SEASKIMMER ASCMs

- HARD KILL WEAPONS*
  - ANTI-AIR WARFARE (AAW) MISSILES
  - POINT DEFENSE GUNS (PDGs) FOR INNER DEFENSE
  - SURFACE-TO-SURFACE WARFARE (SSW) CRUISE MISSILES AGAINST SURFACE PLATFORMS

- WEAPON SYSTEM FEATURES
  - AAW MISSILES LAUNCHED WITH FIELD-OF-FIRE LIMITATIONS AND RELOAD/SLEW TIME DELAYS
  - INNER DEADZONE EXISTS INSIDE WHICH INTERCEPTS CANNOT OCCUR
  - AAW MISSILES REQUIRE ONE SHIPBOARD ILLUMINATOR PER ASCM UNTIL INTERCEPT (TWO MISSILES LAUNCHED AT EACH ASCM)
  - PDG IS A STAND-ALONE SYSTEM WITH DELAYS, FIELD-OF-FIRE AND SEQUENTIAL ASCM ENGAGEMENT LIMITATIONS
  - SSW MISSILES, CANISTER-LAUNCHED AND AUTONOMOUSLY-GUIDED, AVOID LAUNCHER/ILLUMINATION RESTRICTIONS

*NO (SOFT KILL) ELECTRONIC WARFARE ASSETS ARE CONSIDERED.

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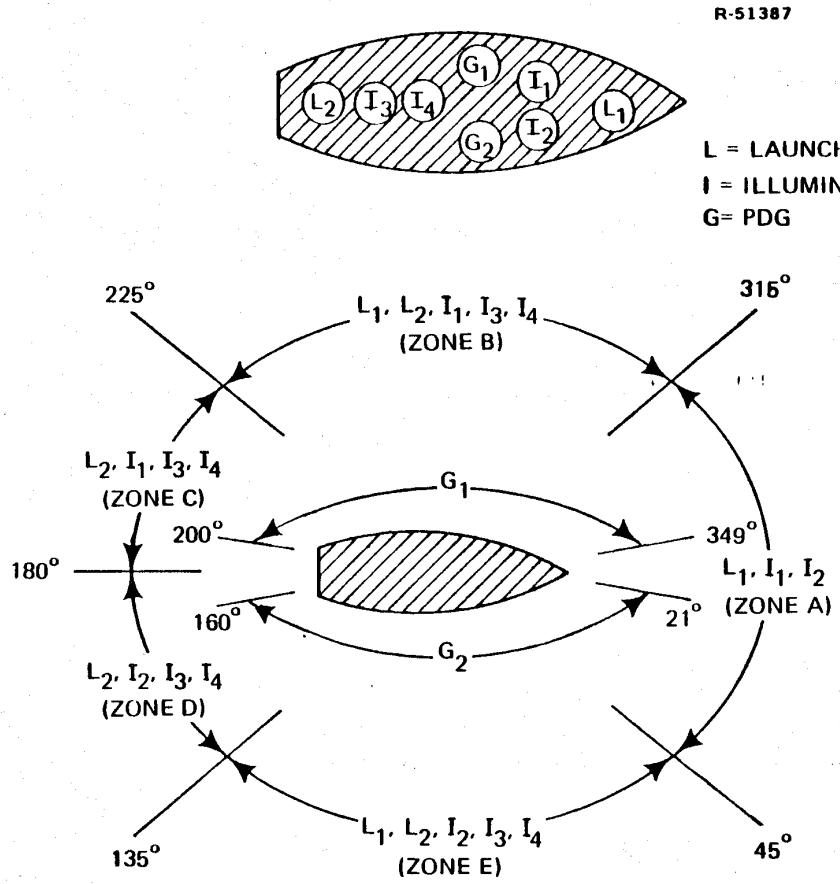
LAUNCHER, ILLUMINATOR, AND PDG FIELD-OF-FIRE ZONES



IN THIS AND ALL OTHER FIGURES DEPICTING THREAT ENGAGEMENTS, THE SHIP TRAVEL IS ALWAYS ASSUMED TO BE FROM LEFT TO RIGHT.

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CAPABILITY (LAUNCHER/ILLUMINATOR) PAIR SCHEDULING

- COVERAGE OFFERED BY (L/I) PAIRS FOR DDG-47

R-51472

ZONES COVERED

(L_i/I_j) PAIRS	A	B	C	D	E
L_1/I_1	X	X			
L_1/I_2	X				X
L_1/I_3		X			X
L_1/I_4		X			X
L_2/I_1		X	X		
L_2/I_2				X	X
L_2/I_3		X	X	X	X
L_2/I_4		X	X	X	X

- WHEN A PAIR BECOMES AVAILABLE, CONSIDER ASSIGNMENTS TO THREATS IN ZONES COVERED

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WEAPON SCHEDULING ALGORITHMS

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TASKS FOR ALL SCHEDULING ALGORITHMS

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- GIVE A PRIORITY TO EACH THREAT AS IT "APPEARS"*
- ASSESS RESOURCE AVAILABILITY
- ESTABLISH A SCHEDULE FOR RESOURCE USE
- REPEAT THIS PROCESS FOR EACH NEW THREAT, ATTEMPTING (THROUGH SOME POLICY OR OPTIMIZATION CRITERION) TO PROTECT THE SYSTEM AGAINST SATURATION DUE TO UNFORSEEN EVENTS

*i.e., IS DETECTED, TRACKED, AND ASSESSED AS A THREAT.

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SCHEDULING ALGORITHMS EVALUATED

R-70935

- SUBOPTIMAL ASSIGNMENT POLICIES

  HIGHEST-PRIORITY-BASED POLICY: FIRST-COME FIRST-SERVED
  USE-RESOURCES-WHEN-AVAILABLE POLICY: ACTIVE RESOURCE

- OPTIMIZING SEARCH OVER ALTERNATIVE SCHEDULES: BRANCH AND BOUND

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FIRST-COME FIRST-SERVED (FCFS)

R-70936

- RANK THREATS IN ORDER OF INCREASING ESTIMATED TIME-TO-GO FOR ARRIVAL AT SHIP

- FOR EACH THREAT PROCEEDING DOWN THE LIST, ASSIGN THE NEXT AVAILABLE LAUNCHER/ILLUMINATOR PAIR*

- RESCHEDULE WHENEVER A NEW THREAT APPEARS

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*PRIORITY IN (L/I) PAIR ASSIGNMENT GOES TO TARGETS WITH LESSER TIME-TO-GO, THOUGH OTHERS MAY BE ENGAGEABLE AT EARLIER TIMES.

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ACTIVE RESOURCE (AR)

R-70937

- AS WITH FCFS, RANK THREATS IN ORDER OF INCREASING TIME-TO-GO

- UNLIKE FCFS, ATTACK THE HIGHEST PRIORITY THREAT WHICH CAN BE ENGAGED BY ANY AVAILABLE (L/I) PAIR*

- RESCHEDULE FOR NEW THREATS

*E.G., DO NOT WAIT TO FIRE UNTIL THE TOP PRIORITY THREAT CAN BE ENGAGED.

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BRANCH AND BOUND (BAB) SCHEDULING

R-70926

- PERFORMANCE CRITERIA

  SEEK MINIMUM NUMBER OF ASCM LEAKERS IN PDG BLIND ZONES

  ATTEMPT TO TIME-SPACE LEAKERS NOT IN BLIND ZONES SO THAT PDG CAN ENGAGE THEM

  MAXIMIZE THE MINIMUM TIME-TO-GO ANY NON-LEAKER HAS BEFORE BEING DESTROYED

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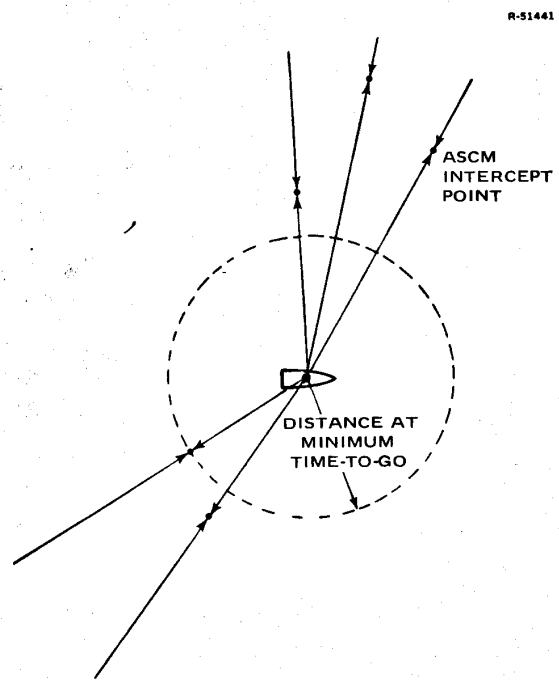
BRANCH AND BOUND (BAB) SCHEDULING (Cont.)

- MOTIVATION FOR MAXIMIN CRITERION

  TENDS TO MAXIMIZE THE TIME AVAILABLE FOR A SECOND ATTACK ON THE THREAT, IF NEEDED.

  PERMITS MORE TIME TO RESPOND TO NEW THREATS



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PERFORMANCE COMPARISONS FOR REALISTIC SCENARIOS

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PRINCIPAL THREAT/DEFENSE PARAMETERS ASSUMED

R-70941

PARAMETER	VALUE
Threat designation: speed	SSW/OW_1: 1000 f/sec
	SSW/OW_2: 2000 f/sec
	SSWW: 2000 f/sec
	HFD: 2000 f/sec
	DS: 1900 f/sec
	UAO: 1300 f/sec
	$FSSWW_1$: 2200 f/sec
	$FSSWW_2$: 2800 f/sec
	FHFD: 2600 f/sec
AAW missile speed	2000 f/sec
" " boost lag	1 sec
" " launcher reload time	8 sec
PDG threat engagement interval	12 sec

ALL MOTIONS ARE VIEWED AS HORIZONTAL PLANE PROJECTIONS

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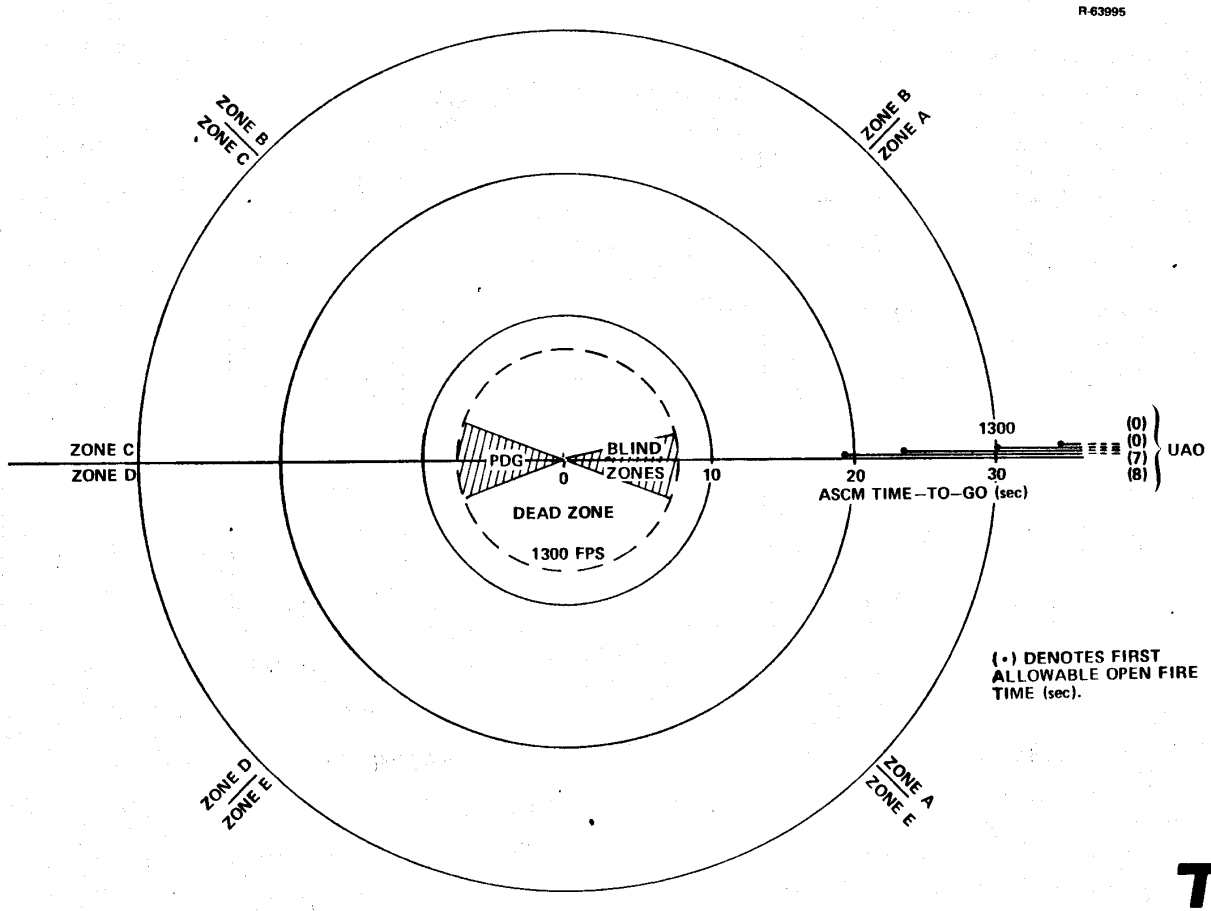
SIMPLE ATTACK: ALL THREATS FROM SAME DIRECTION

- SCENARIO B - SECOND ATTACK (ALL ALGORITHMS)
- ALL ALGORITHMS GIVE SAME RESULTS



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PERFORMANCE AGAINST UP TO TWO SIMULTANEOUS THREATS FOR ONE LAUNCHER

R-70942

THREAT NAME	SPEED (ft/sec)	OPEN FIRE RANGE (thousands of feet)	TIME-TO-GO/RANGE-TO-GO (sec) 1ST THREAT	TIME-TO-GO/RANGE-TO-GO (thousands of feet) 2ND THREAT
SSW/OW_1	1000	48	31.3/31.3	26/26
SSW/OW_2	2000	36	8.5/17	4.5/9*
SSWW	2000	36	8.5/17	4.5/9*
HFD	2000	65	15.8/31.5	11.8/23.5
DS	1900	37.2	9.5/18.1	5.4/10.3
UAO	1300	77	35.3/45.9	30.4/39.6
$FSSWW_1$	2200	33.6	6.8/15.0	3.0/6.6*
$FFSSWW_2$	2800	26.4	3.5/9.8*	0.2/0.5*
FHFD	2600	83.1	13.5/35	10.0/26.0

*Inside dead zone.

- IDENTICAL PERFORMANCE FOR ALL SCHEDULING ALGORITHMS
- LAUNCHER DELAY IS CRITICAL AGAINST HIGH SPEED ASCMs
- $FSSWW_2$ ALWAYS ELUDES AAW MISSILE DEFENSE

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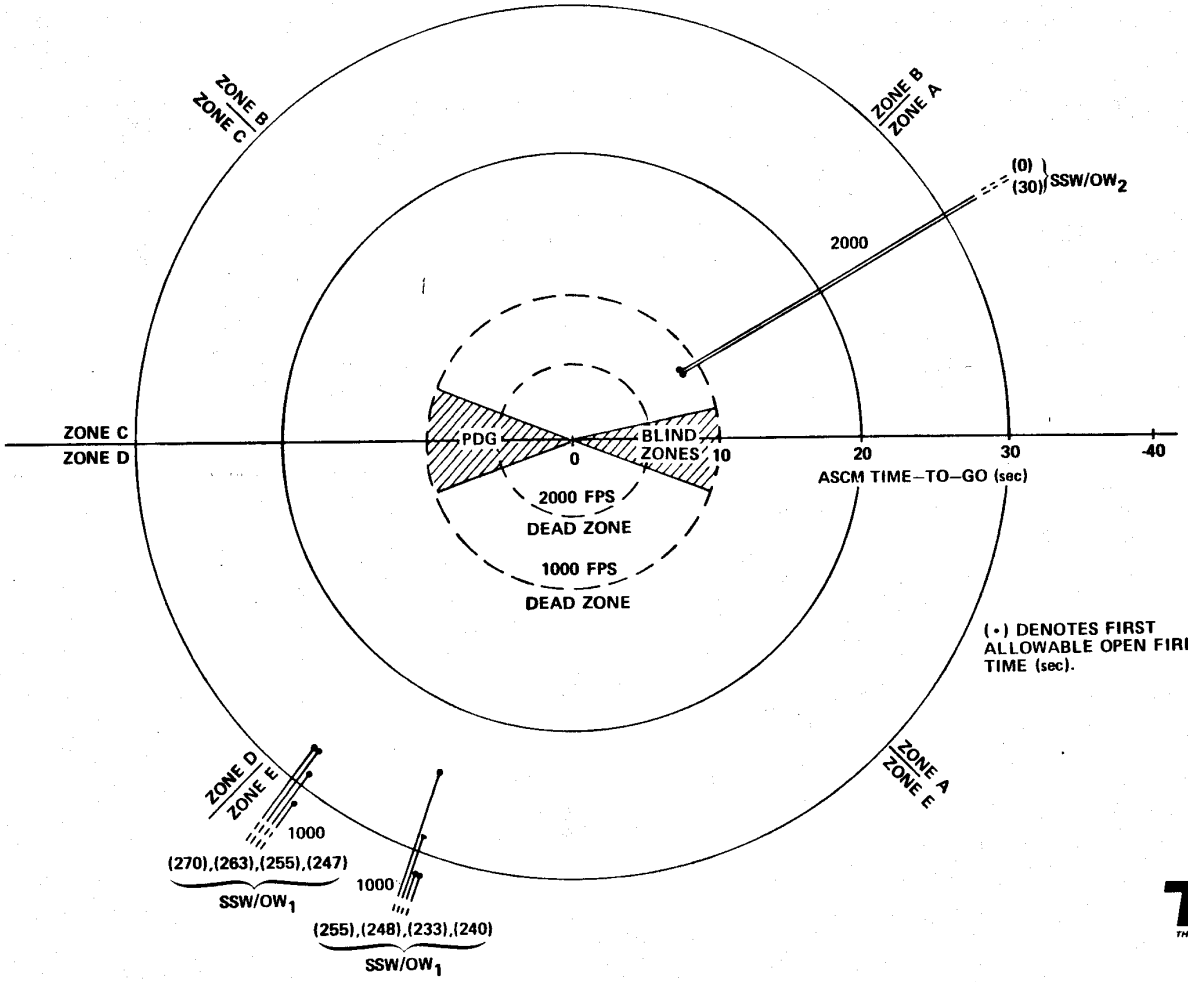
MORE COMPLEX CASE: THREATS TIME-CLUSTERED IN DIFFERENT ZONES

- SCENARIO D (ALL ALGORITHMS)
- ALL ALGORITHMS GIVE SAME RESULTS

R-63997



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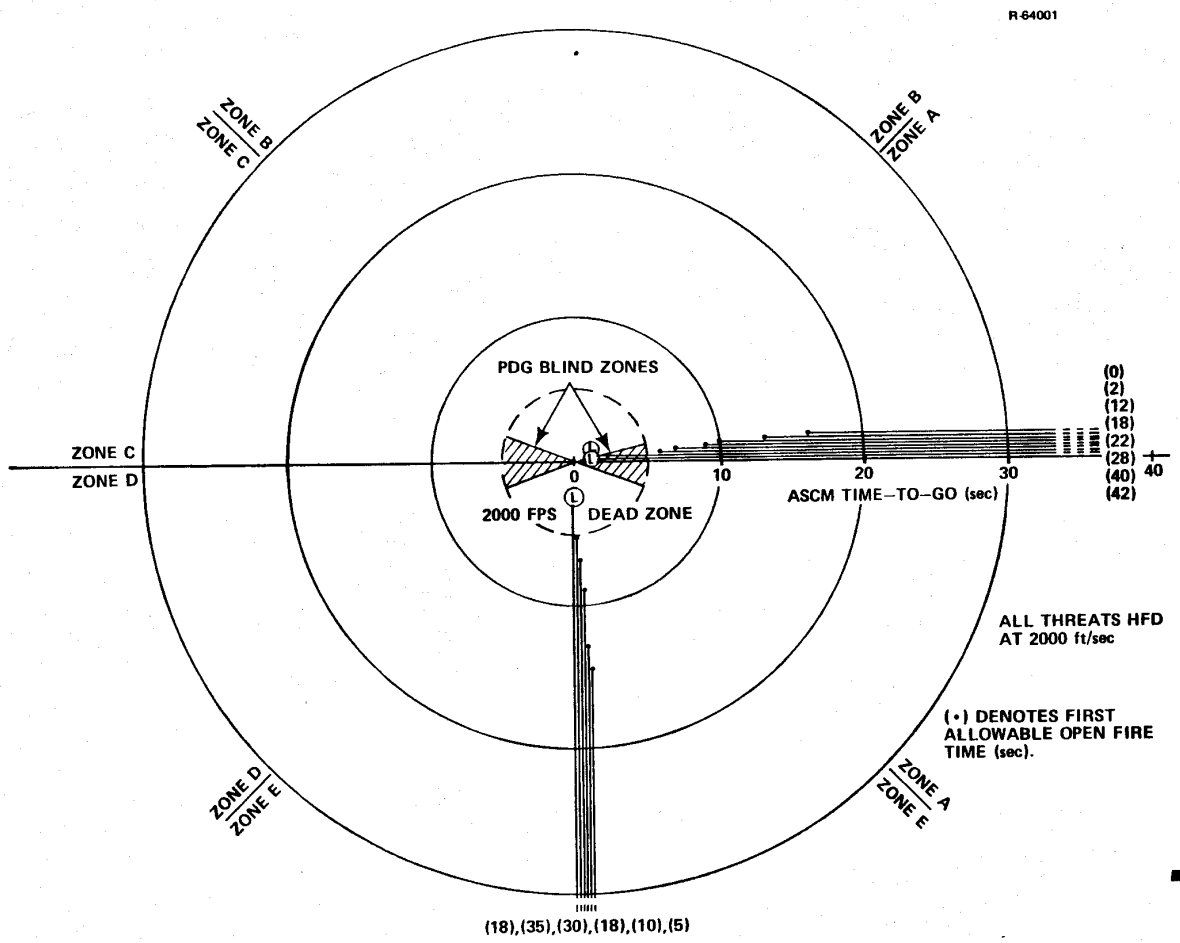
SIMULTANEOUSLY ACTIVE ZONES GIVE DIFFERING PERFORMANCE

- ENGAGEMENT MODEL I (FCFS ALGORITHM)
- THREE LEAKERS



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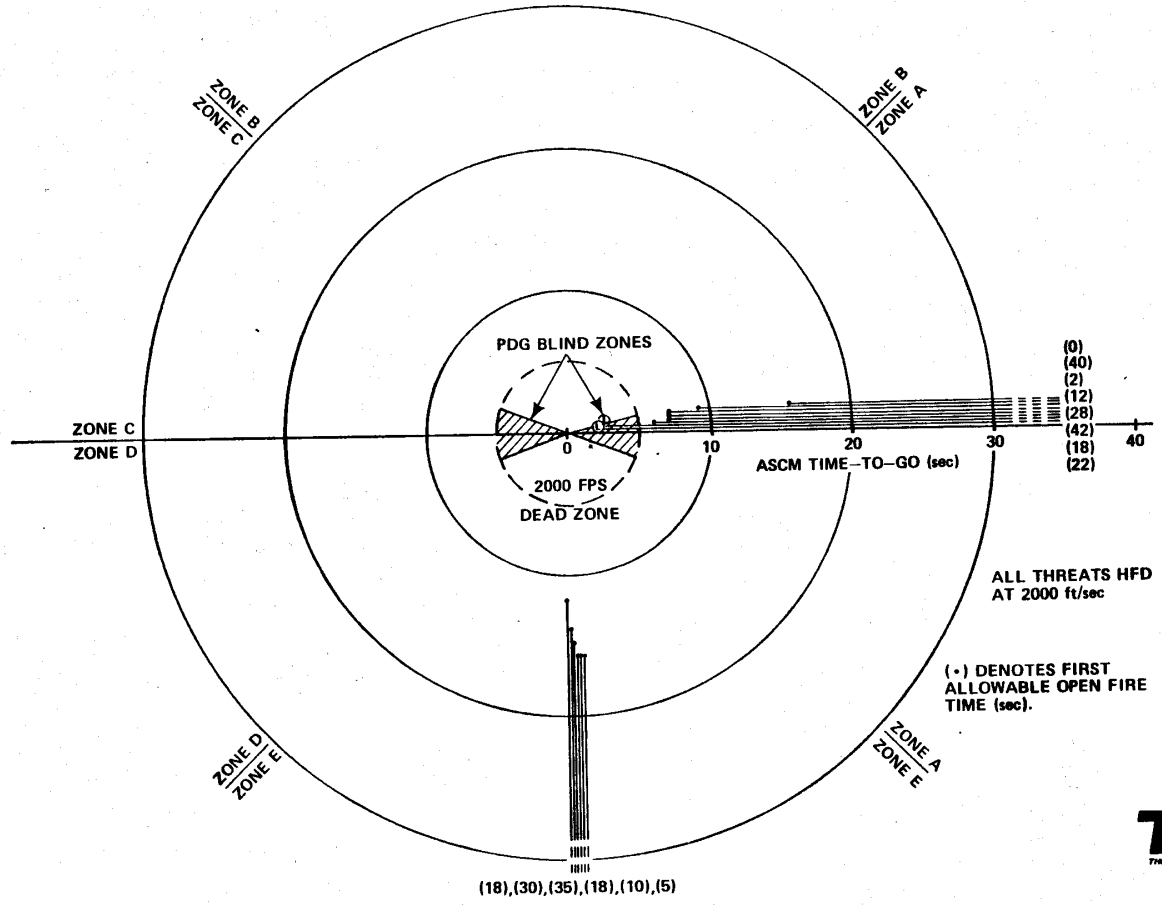
SIMULTANEOUSLY ACTIVE ZONES GIVE DIFFERING PERFORMANCE (Cont.)

R-84002

- ENGAGEMENT MODEL I (AR ALGORITHM)
- TWO LEAKERS



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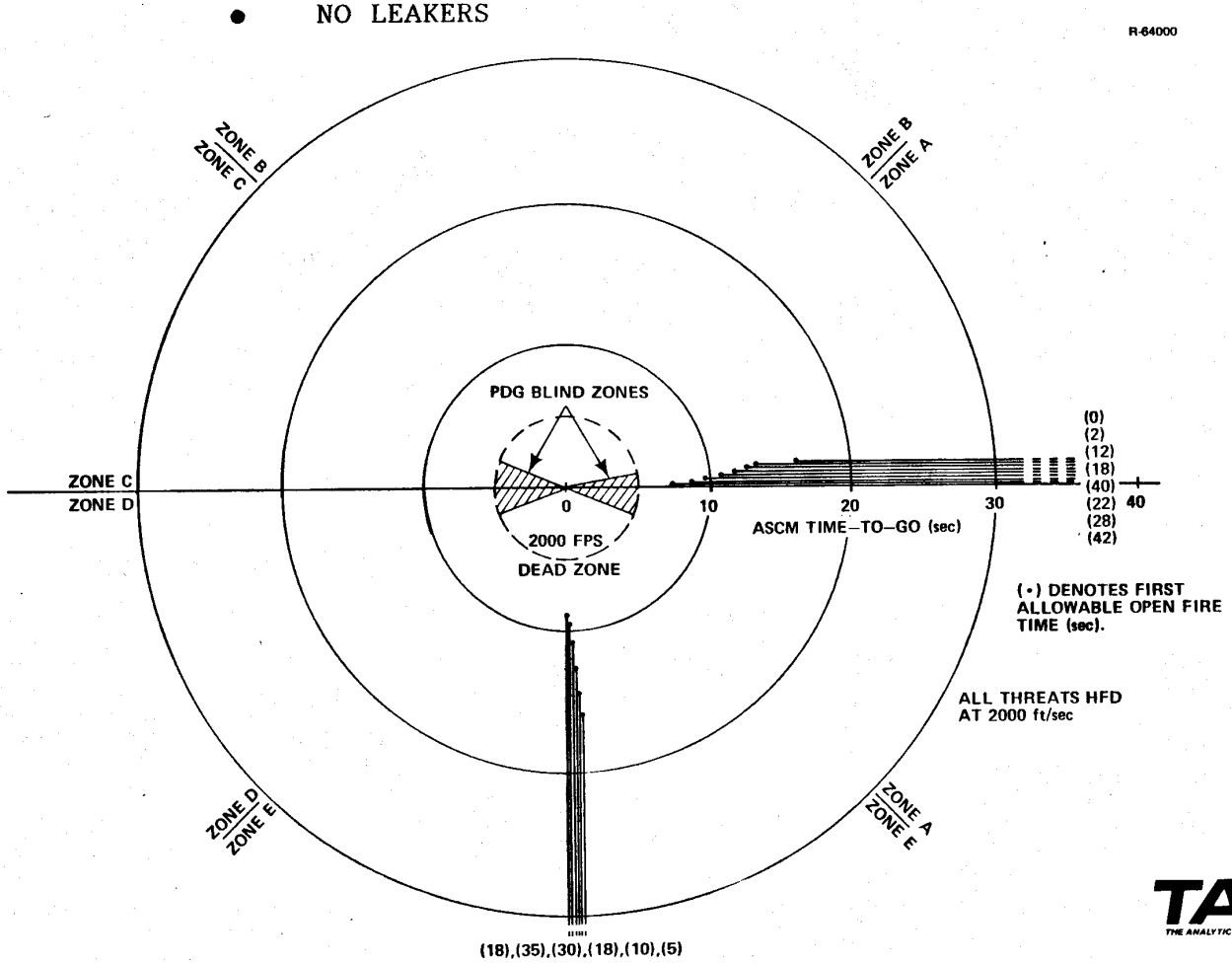
SIMULTANEOUSLY ACTIVE ZONES GIVE DIFFERING PERFORMANCE (Cont.)

- ENGAGEMENT MODEL I (BAB ALGORITHM)
- NO LEAKERS



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COMPARISON SUMMARY FOR TWO SIMULTANEOUSLY ACTIVE ZONES

R-70943

ALGORITHM	NO. LEAKERS	NO. PDG LEAKERS*	"CLOSEST" NON LEAKER	NO. NON-LEAKERS INSIDE TWO DEAD-ZONE RADII
FCFS	3	2	5 sec	7
AR	2	2	6 sec	5
BAB	0	0	7 sec	5

- OBSERVATIONS

  ONLY BAB PREVENTS ALL LEAKERS

  PDG LEAKERS FOR FCFS AND AR ARRIVE IN A PDG BLIND ZONE

*PDG LEAKERS ELUDE THE PDG INNER DEFENSE AND HIT THE SHIP.

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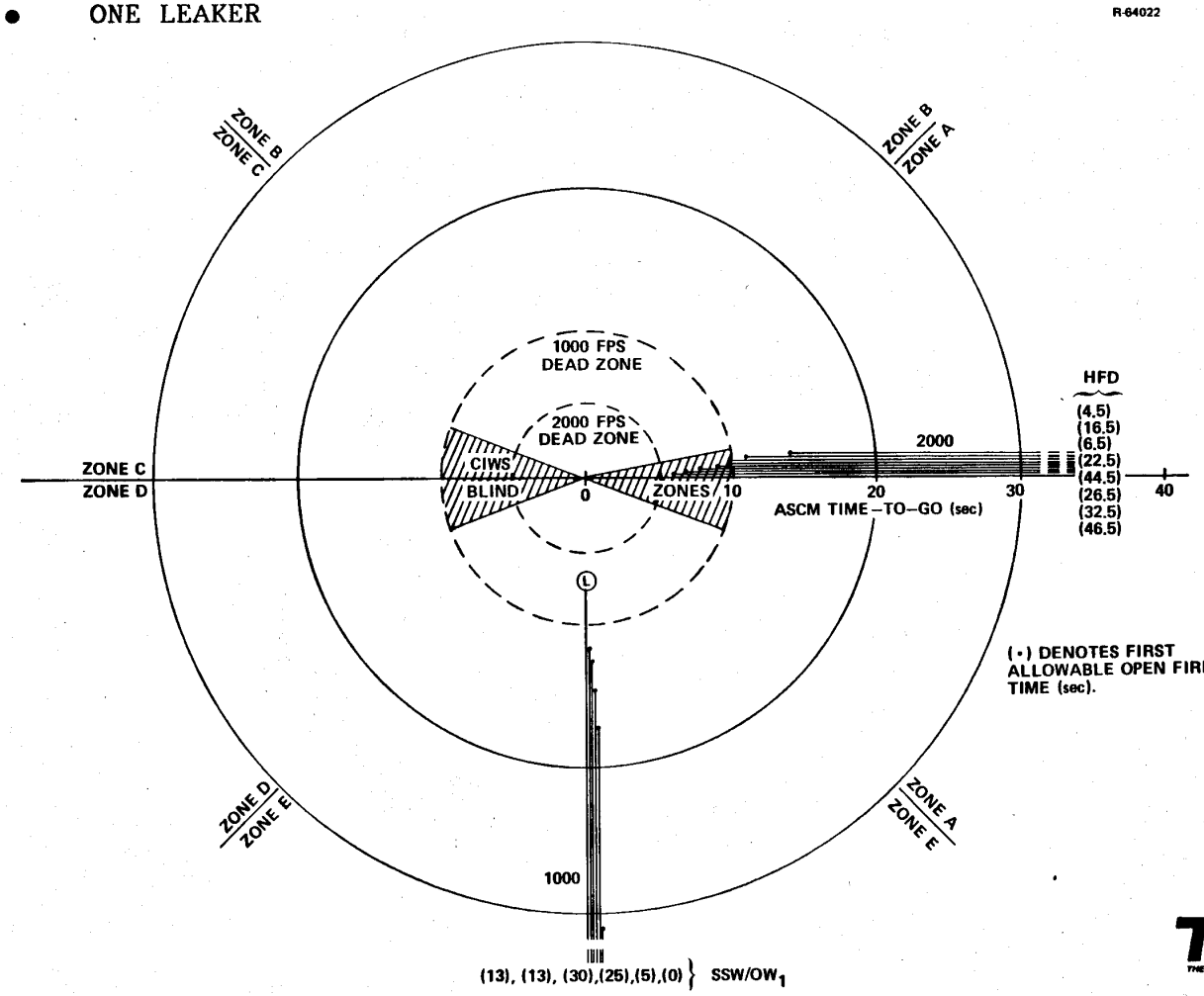
SECOND CASE OF TWO SIMULTANEOUSLY ACTIVE ZONES

- REWORK OF ENGAGEMENT MODEL I FOR TWO THREAT TYPES (FCFS ALGORITHM)
- ONE LEAKER



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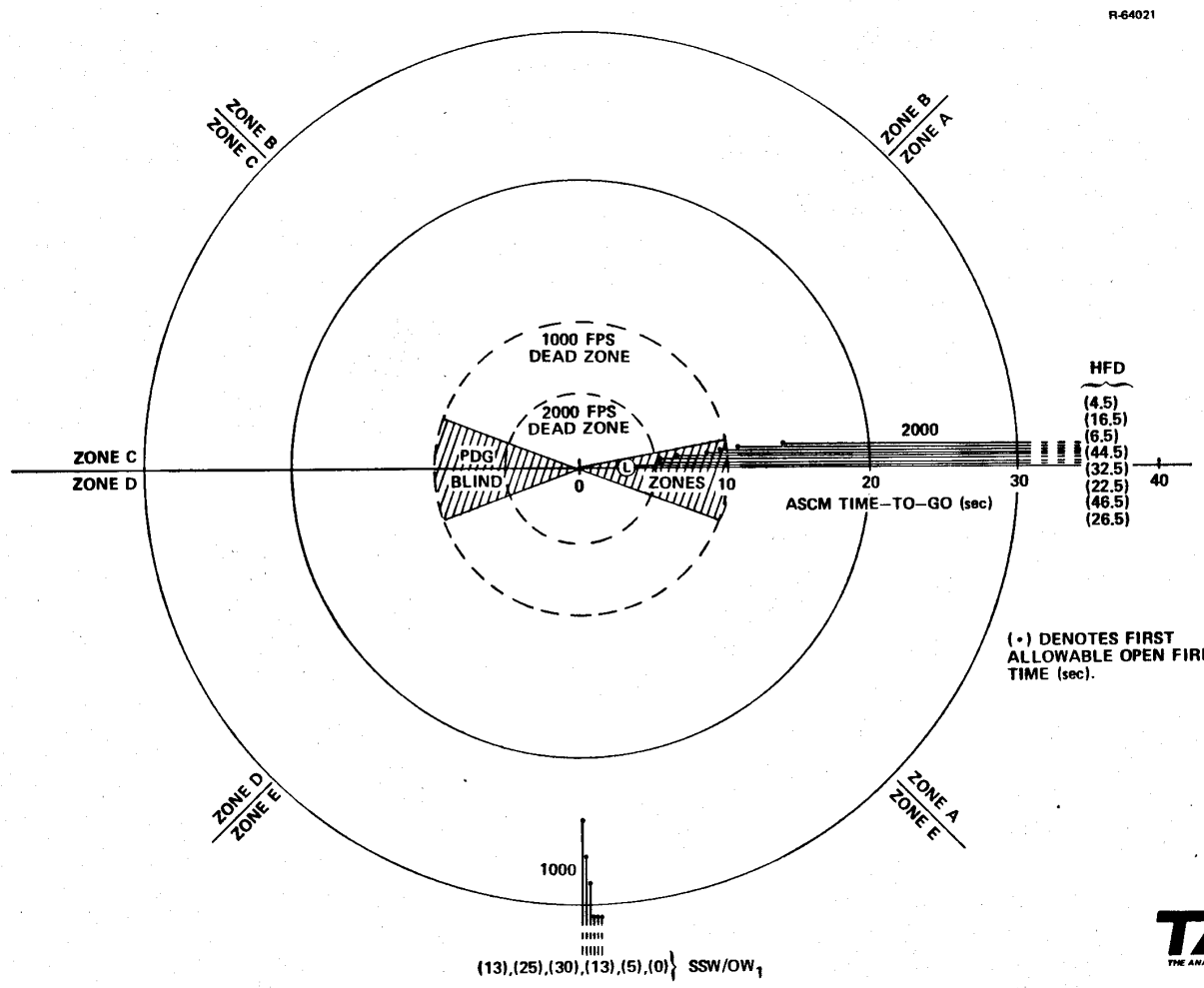
SECOND CASE OF TWO SIMULTANEOUSLY ACTIVE ZONES (Cont.)

- REWORK OF ENGAGEMENT MODEL I FOR TWO THREAT TYPES (AR ALGORITHM)



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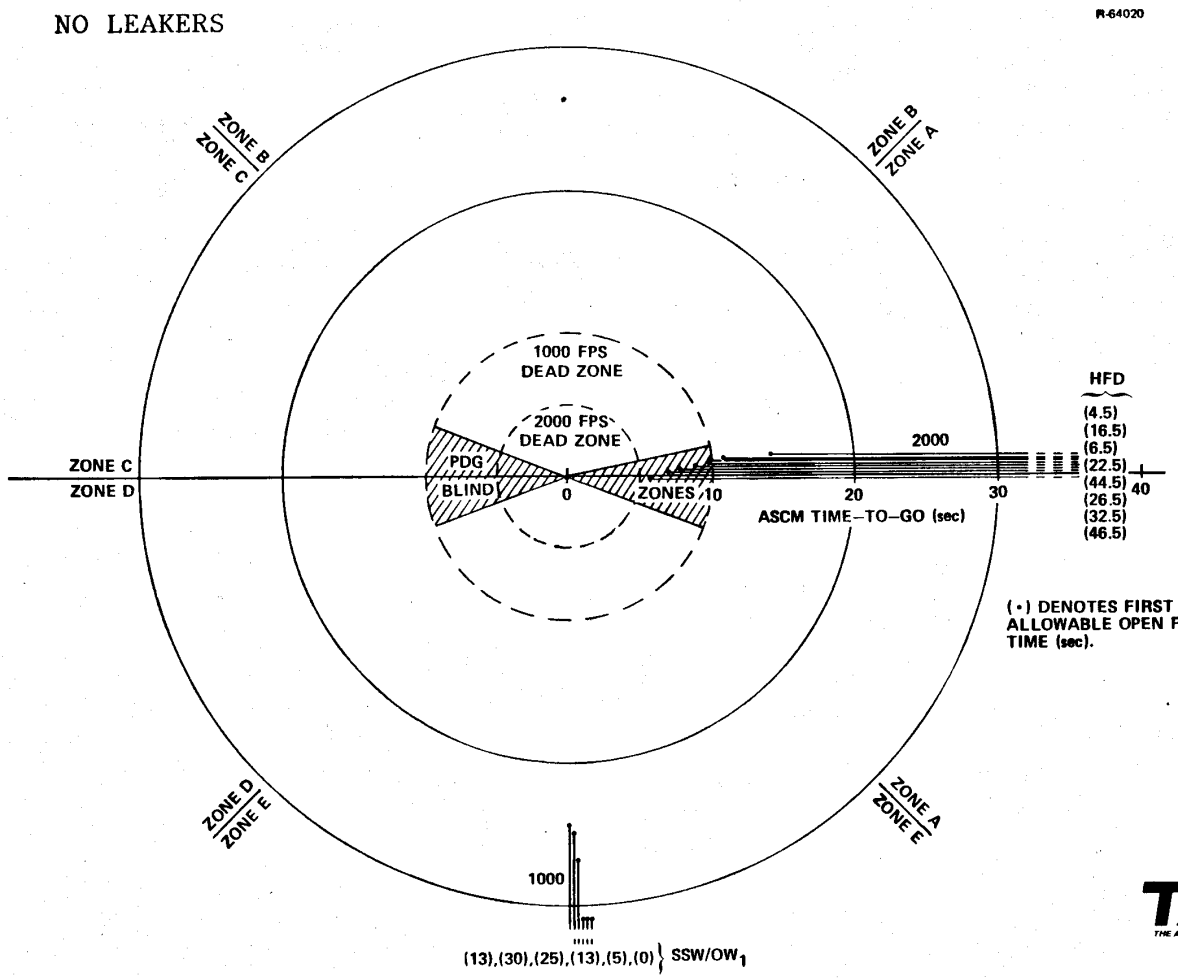
SECOND CASE OF TWO SIMULTANEOUSLY ACTIVE ZONES (Cont.)

- REWORK OF ENGAGEMENT MODEL I FOR TWO THREAT TYPES (BAB ALGORITHM)
- NO LEAKERS



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SECOND COMPARISON SUMMARY FOR TWO SIMULTANEOUSLY ACTIVE ZONES

R-70944

ALGORITHM	NO. LEAKERS	NO. PDG LEAKERS	"CLOSEST" NON LEAKER	NO. NON-LEAKERS INSIDE TWO DEAD-ZONE RADII
FCFS	1	0	6 sec	10
AR	1	1	5 sec	5
BAB	0	0	6 sec	5

- OBSERVATIONS

  AGAIN, BAB PREVENTS ALL LEAKERS

  AR PERMITS A PDG LEAKER; FCFS DOES NOT

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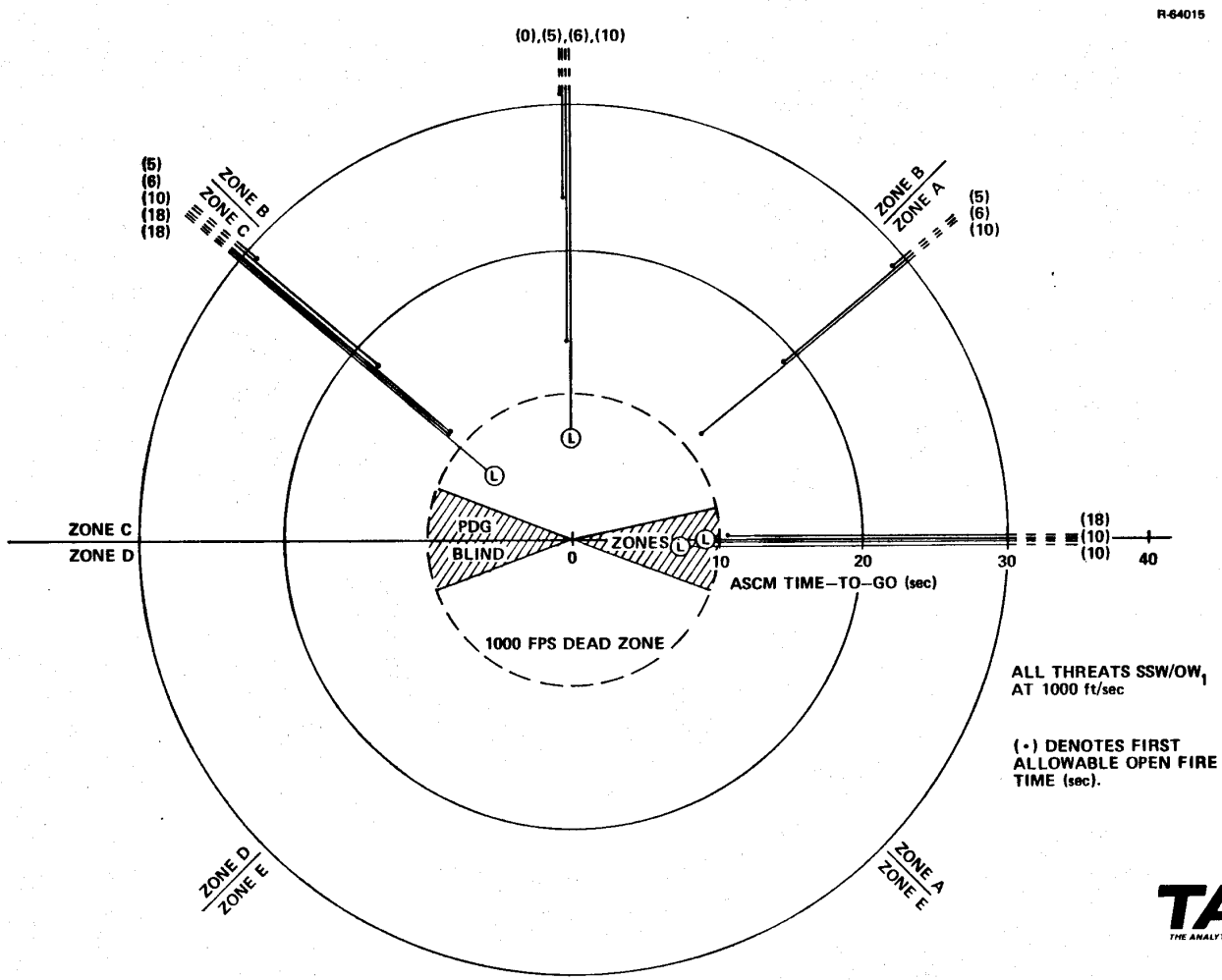
THREE SIMULTANEOUSLY ACTIVE ZONES

- TASC MODEL I (FCFS ALGORITHM)
- FOUR LEAKERS



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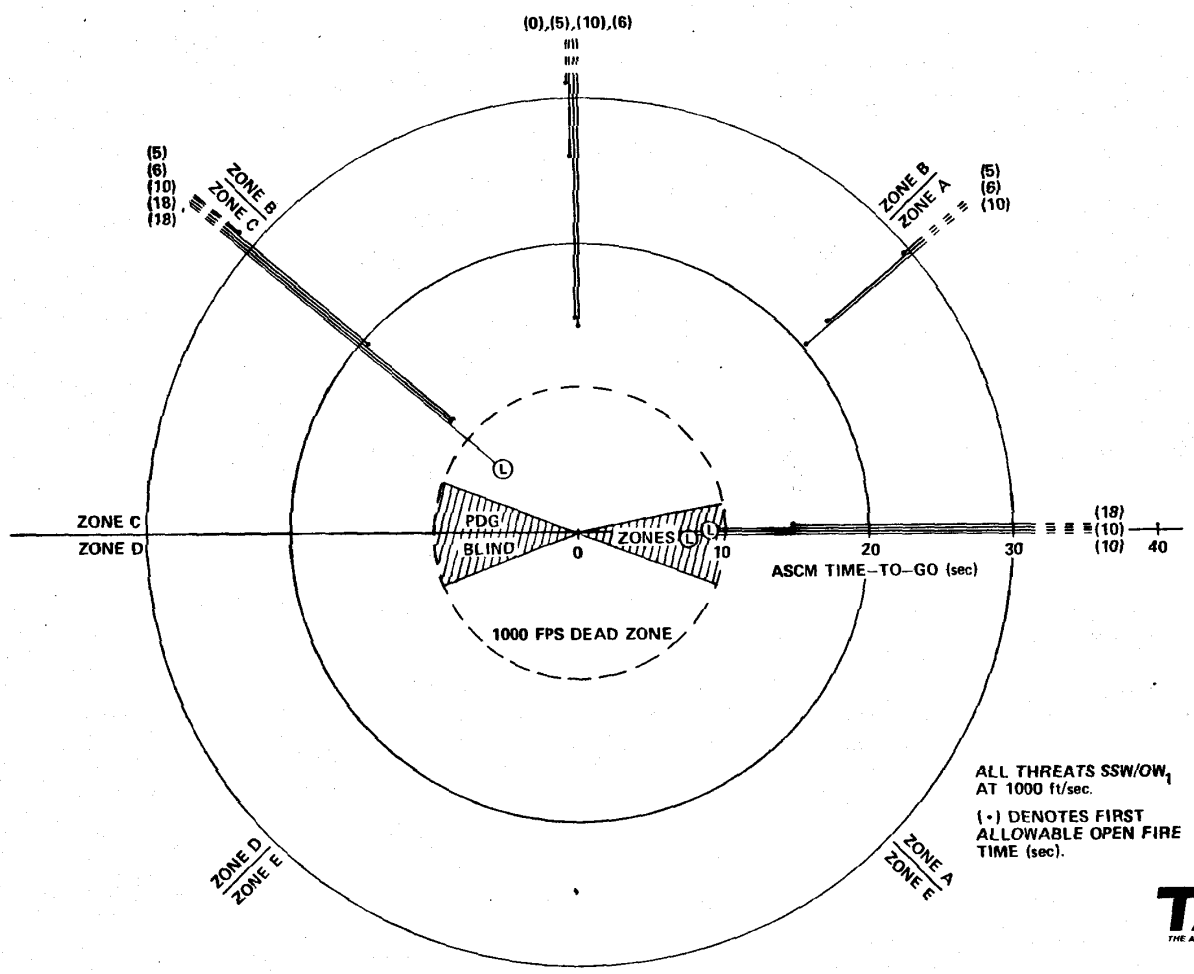
THREE SIMULTANEOUSLY ACTIVE ZONES (Cont.)

- TASC MODEL I (AR ALGORITHM)
- THREE LEAKERS



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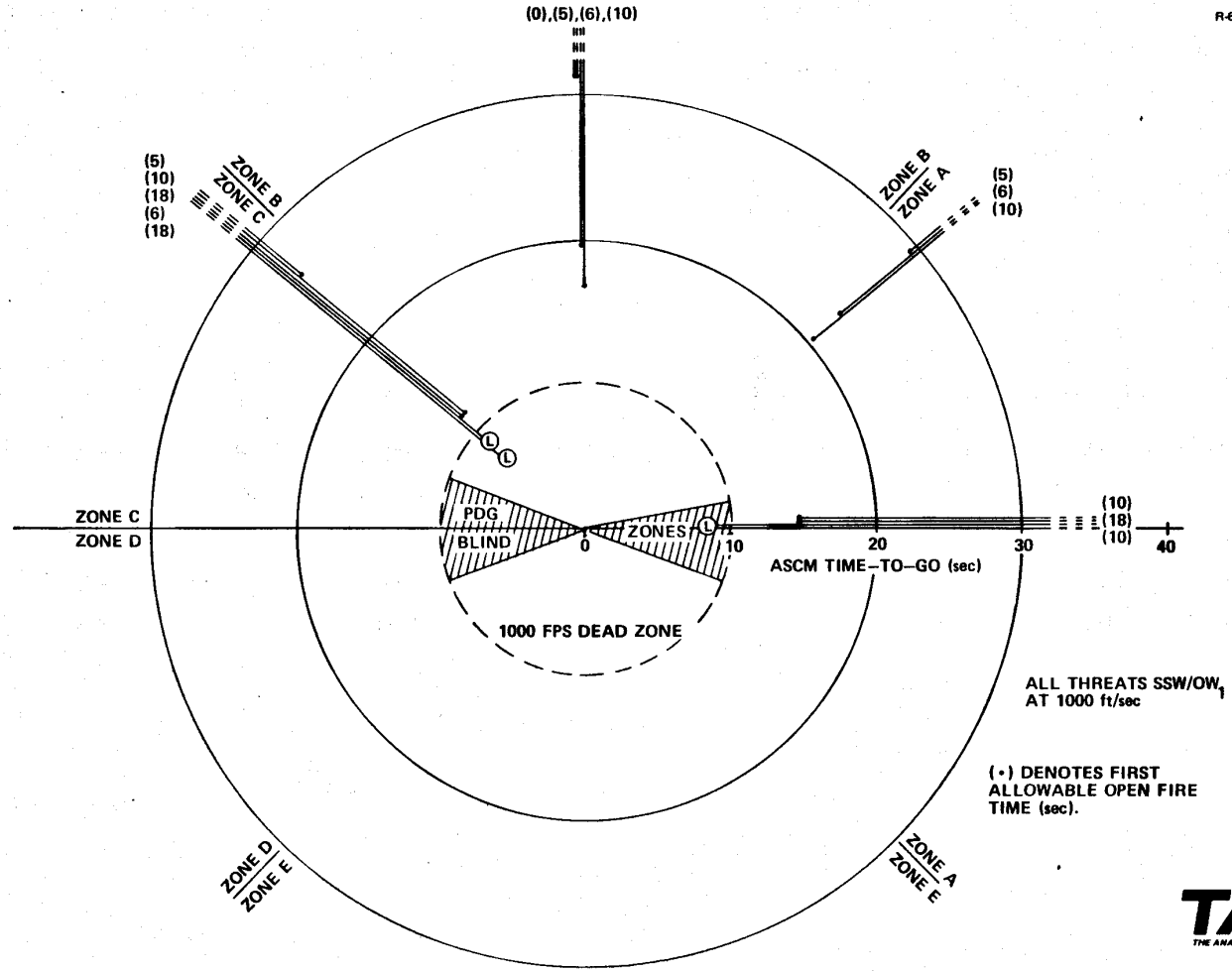
THREE SIMULTANEOUSLY ACTIVE ZONES (Cont.)

- TASC MODEL I (BAB ALGORITHM)
- THREE LEAKERS



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COMPARISON SUMMARY FOR THREE SIMULTANEOUSLY ACTIVE ZONES

R-70945

ALGORITHM	NO. LEAKERS	NO. PDG LEAKERS	"CLOSEST" NON LEAKER	NO. NON-LEAKERS INSIDE TWO DEAD-ZONE RADII
FCFS	4	3	11 sec	7
AR	3	2	12 sec	6
BAB	3	1	12 sec	6

- OBSERVATIONS

  BAB ALLOWS ONLY ONE PDG LEAKER; TWO OTHER LEAKERS ARE SEPARATED IN TIME SO THAT PDG CAN ENGAGE THEM

  OTHER ALGORITHMS ALLOW MORE PDG LEAKERS; FCFS PERMITS TWO LEAKERS OUTSIDE THE PDG BLIND ZONES BUT THE SECOND ONE IS TOO CLOSE IN TIME FOR ENGAGEMENT

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SURFACE PLATFORM KILL WITH AAW MISSILES

R-70946

- SCENARIO

  THREE EQUIDISTANT PLATFORMS APPEAR AT 54,000 FEET RANGE AND APPROACH AT 54 F/SEC* TO LAUNCH ASCMs

  ALL PLATFORMS MUST BE KILLED WITHIN 90 SEC FROM THEIR APPEARANCE, CORRESPONDING TO 910 SEC PLATFORM TIME-TO-GO

- DEFENSE MUST KILL EACH PLATFORM WITH SIX AAW MISSILES BEFORE THREAT ASCMs CAN BE LAUNCHED

*RANGE OF 54,000 FEET AND 54 F/SEC CLOSING SPEED IMPLIES 1000 SEC PLATFORM TIME-TO-GO

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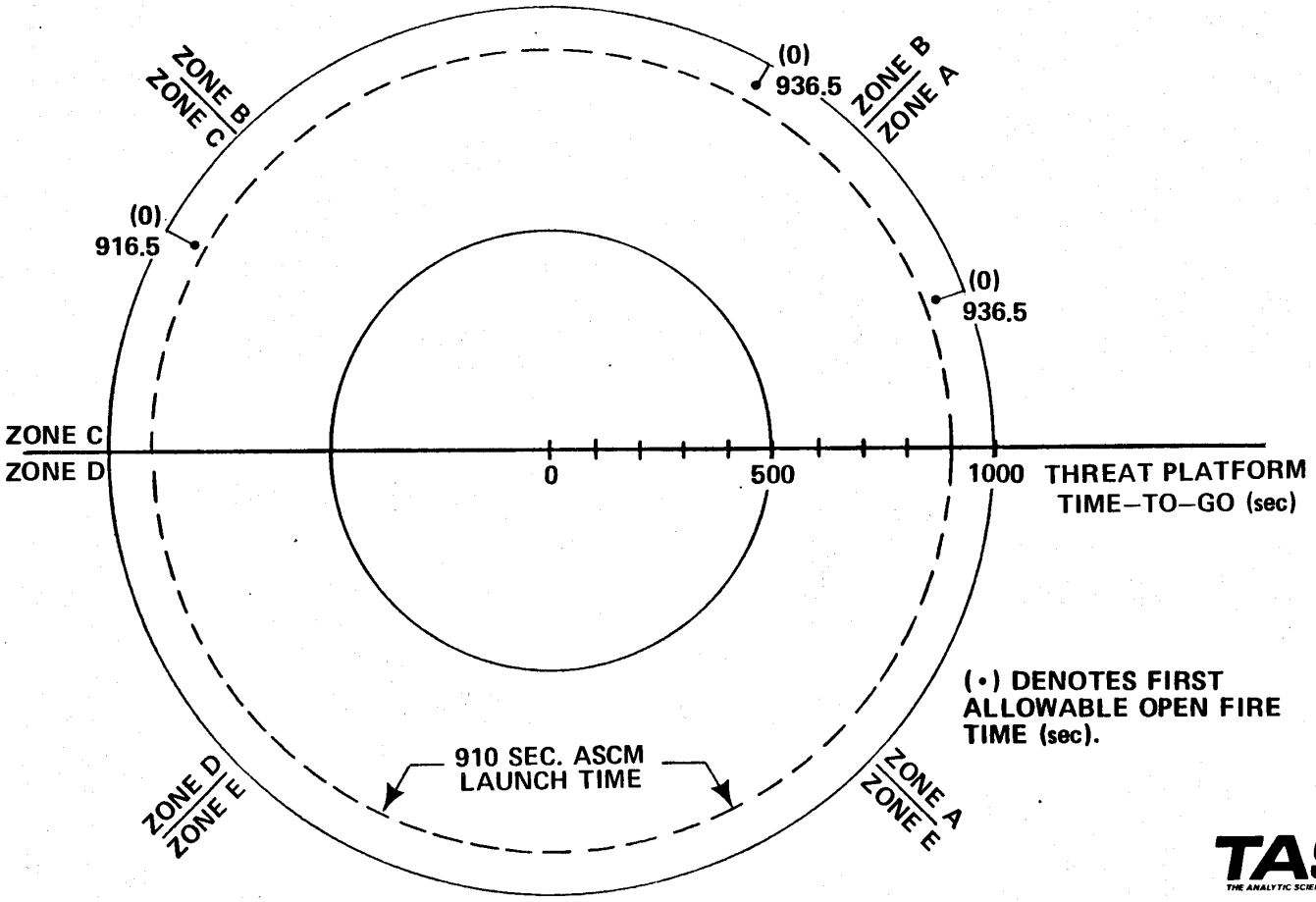
SURFACE PLATFORM KILL WITH AAW MISSILES (Cont.)

- ATTEMPT TO DESTROY THREAT PLATFORMS BEFORE ASCM LAUNCH (FCFS AND AR ALGORITHMS)
- USE AAW MISSILES IN SSW MODE

R-63999



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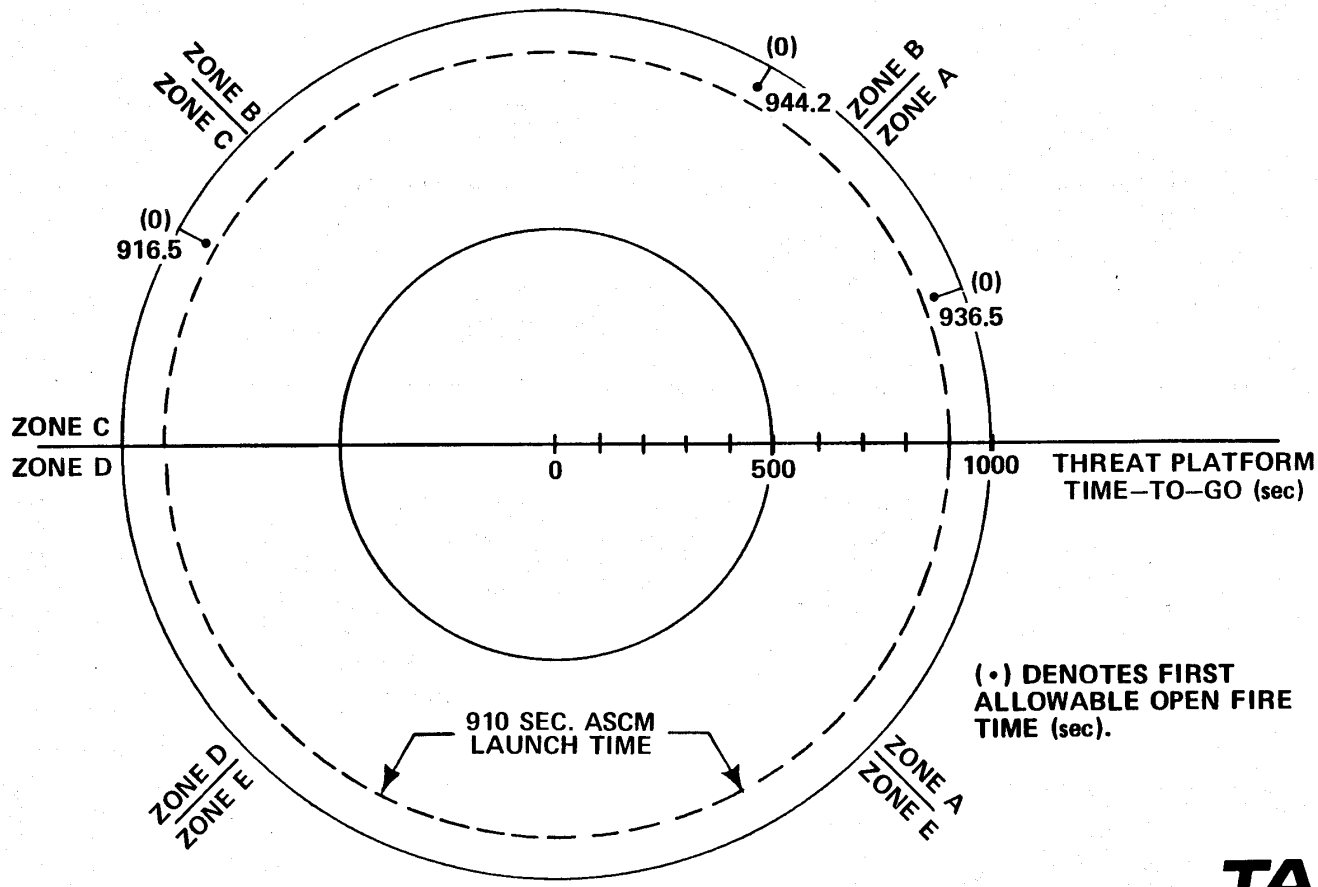
SURFACE PLATFORM KILL WITH AAW MISSILES (Cont.)

- ATTEMPT TO DESTROY THREAT PLATFORMS BEFORE ASCM LAUNCH (BAB ALGORITHM)

R-63998



(•) DENOTES FIRST ALLOWABLE OPEN FIRE TIME (sec).

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COMPARISON SUMMARY FOR SURFACE PLATFORM KILL

R-70947

- EACH ALGORITHM KILLS ALL THREATS BEFORE ASCMs CAN BE LAUNCHED

- BAB OFFERS A SLIGHT IMPROVEMENT OVER THE OTHERS (MIDDLE PLATFORM IS KILLED 7.7 SEC EARLIER)

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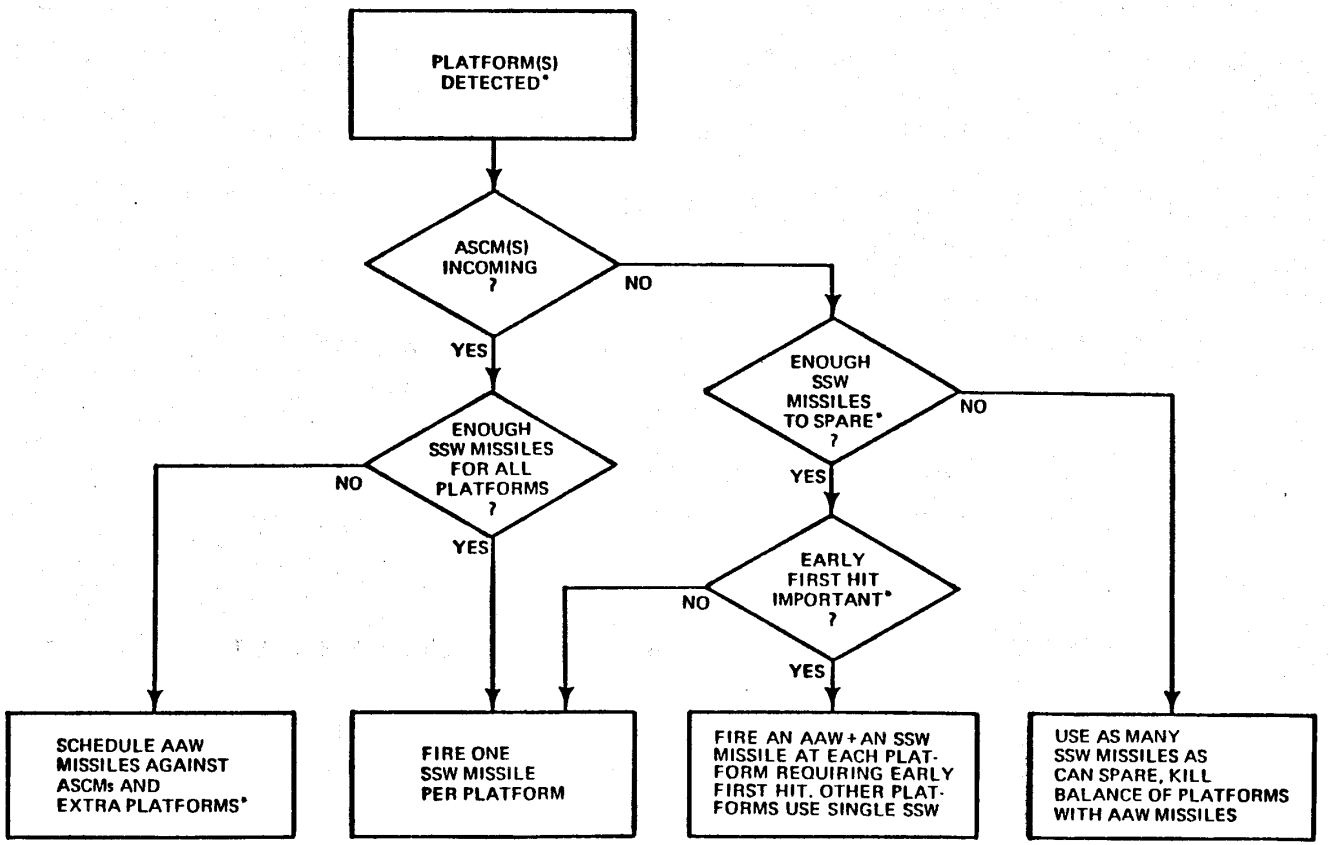
AN APPROACH TO THE GENERAL ANTI-PLATFORM PROBLEM (USING AAW AND SSW ASSETS)

R-61825



* FUTURE WORK SHOULD BE DIRECTED TOWARDS THESE TYPES OF ISSUES.

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PRELIMINARY COMPUTATION LOAD ASSESSMENT

R-70948

- PROCESSOR USED

  IBM SYSTEM 370 COMPUTER

  PROGRAMMED IN APL LANGUAGE (SLOW, WITH MUCH OVERHEAD)

- CURRENT RESULTS

  FCFS AND AR ASSIGNMENT POLICIES REQUIRE 0.025 SEC PER SCHEDULE

  BAB OPTIMAL SEARCH TYPICALLY REQUIRES 0.1 - 1.0 SEC PER SCHEDULE, WITH AN EXTREME CASE OF 30 SEC

- FUTURE OPPORTUNITIES TO REDUCE BAB COMPUTATION LOAD

  SPECIAL-PURPOSE COMPUTER/SOFTWARE COULD CUT TIMES BY 100:1

  RESTRICTING SEARCH SCOPE AND DEPTH RADICALLY REDUCES SIZE OF TREE TO BE SEARCHED, PERHAPS WITH SMALL PERFORMANCE PENALTY

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CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

R-70950

- THREE ALGORITHMS WERE DEVELOPED AND STUDIED UNDER REALISTIC SCENARIOS

- HARDWARE RESTRICTIONS (LAUNCHER DELAYS, ILLUMINATOR AVAILABILITY, ETC.) ARE CRUCIAL FACTORS, LIMITING ALL ALGORITHM PERFORMANCES, PARTICULARLY AGAINST SOME ASCMs

- IN RELATIVELY BENIGN SCENARIOS ALL ALGORITHMS BEHAVE THE SAME

- IN STRESSFUL SCENARIOS BAB CAN SIGNIFICANTLY ENHANCE SHIP SURVIVAL

  PROTECTS SHIP AGAINST PDG CIRCUMVENTION BY LEAKERS TOO CLOSELY SPACED IN TIME OR APPROACHING IN PDG BLIND ZONES

  LEAKERS ARE REDUCED 32% COMPARED TO FCFS AND 25% COMPARED TO AR ALGORITHMS

- SCHEDULING ALGORITHMS CAN BE SUCCESSFULLY APPLIED AGAINST SURFACE PLATFORMS

- DEDICATED PROCESSORS/SOFTWARE SHOULD PERMIT REAL-TIME COMPUTATION FOR BAB ALGORITHM IN SHIPBOARD APPLICATION

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RECOMMENDATIONS

R-70951

- SCHEDULE OPTIMIZATION STUDIES SHOULD BE EXPANDED:

  INCREASE BAB OPTIMIZATION EFFECTIVENESS

  SCHEDULE WITH VARIABLE THREAT WEIGHTS

  INTERFACE WITH NTDS FOR EARLIER THREAT WARNING

  CONSIDER SCHEDULING PROBLEMS OF LOWER-DEFENSE-CAPABILITY SHIPS (SUCH AS THE O.H. PERRY CLASS OF FRIGATES)

  ADDRESS AREA DEFENSE

- COMPUTATION CONTROL VIA DEDICATED COMPUTER HARDWARE/SOFTWARE SHOULD BE PURSUED

- ANTI-PLATFORM MISSION MERITS FURTHER STUDY (REDUCE THE NUMBER OF THREAT ASCMs LAUNCHED)

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