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TRAINING IMPROVEMENTS FOR THE TACTICAL AIRCREW TRAINING SYSTEM (TACTS): PROJECT SUMMARY REPORT

A. P. Ciavarelli
A. M. Williams
*G. R. Stoffer

Dunlap and Associates, Inc.
Western Division
La Jolla, California 92037

*Naval Training Equipment Center
Orlando, Florida 32813

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A. M. Williams
G. R. Stoffer

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This report presents summarized information related to the Tactical Aircrew Combat Training System (TACTS) training improvements program. The two major sections of the report are addressed to: (1) a description of a computer based TACTS debrief system, referred to as the Performance Assessment and Appraisal System (PAAS), and (2) a problem definition study of air intercept missile (AIM) envelope recognition training. The preliminary design of a computer based system has been completed and a single design module, Performance Assessment and Combat Effectiveness (PACE), is ready for operational (cont.)

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test and evaluation.

Summarized information from a more comprehensive study of U.S. Navy air-to-air missile envelope training problems is included. Recommendations for improving fleet envelope recognition training are reviewed.

PREFACE

This report summarizes research performed for the Naval Training Equipment Center, Orlando, Florida, under contract N61339-78-C-0136. Two primary research tasks were completed under the general rubric of a "Training Improvements Program" for the Navy's Tactical Aircrew Combat Training System (TACTS). A summary of work completed on two major task areas, (1) Development of a Computer Based TACTS Debrief System, and (2) A Problem Definition Study of Navy Missile Envelope Recognition Training, is presented herein. It should be noted that two more technically detailed reports, covering the same research and development tasks, have already been published. Individuals requiring greater detail on research background, empirical findings, and technical discussion, should consult these earlier studies which are referenced in this summary report.

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INTRODUCTION

BACKGROUND

This report reviews research and development efforts related to a Training Improvements Program for the Navy's Tactical Aircrew Combat Training System (TACTS). The research reported traces its origins to previous studies of air combat performance measurement for TACTS.[1,2,3]

The TACTS, formerly called the Air Combat Maneuvering Range (ACMR), is an instrumented system used primarily to train Navy aircrews in air-to-air combat. Briefly, TACTS provides a capability for real-time tracking of aircraft engaged in air combat. The system has a replay capability which provides a rich source of quantitative information, including inter-aircraft position data and computer generated weapon launch outcomes.

The availability of TACTS data has provided a rare opportunity for researchers to obtain operational measures of aircrew performance. These measures have potential application across a variety of ongoing aviator selection and training research efforts.

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[1] Ciavarelli, A.P., Brictson, C.A., and Young, P.A. Development and Application of Performance Criteria and Aircrew Assessment Methods for the Air Combat Maneuvering Range (ACMR) (U). Pensacola, Florida: Naval Aerospace Medical Research Laboratory, Special Report 79-5, September 1979. (CONFIDENTIAL)

[2] Brictson, C.A., Ciavarelli, A.P., Pettigrew, K.W. and Young, P.A. Performance Assessment Methods and Criteria for the Air Combat Maneuvering Range (ACMR): Missile Envelope Recognition (U). Pensacola, Florida: Naval Aerospace Medical Research Laboratory, Special Report No. 78-4, July 1978. (CONFIDENTIAL)

[3] Brictson, C.A., Ciavarelli, A.P. and Jones, T.N. Development of Aircrew Performance Measures for the Air Combat Maneuvering Range (ACMR) (U). Pensacola, Florida: Naval Aerospace Medical Research Laboratory, Report No. L53001, June 1977. (CONFIDENTIAL)

The Naval Aerospace Medical Research Laboratory, realizing the value of having available operational measurement of aircrew performance, sponsored a program designed to develop performance criteria and assessment methods for TACTS. During the course of this measurement research program, two significant fleet training deficiencies were identified:[4]

1. Need for training debrief aid -- TACTS training was conducted in an unsystematic manner, with no standardized training procedures or structured debrief aids, and no means to provide performance based training feedback.
2. Need for improved envelope recognition training -- measures of missile envelope recognition performance for Navy aircrews, taken on TACTS, showed consistent deficiencies when compared to recommended fleet standards.

On the basis of numerous on-site observations, backed by empirical findings, it was concluded that "...the TACTS represents a significant technological advance in instrumentation and computing, but it has not had the benefit of an organized training and performance assessment program."

TRAINING IMPROVEMENTS

The primary aim of the original measurement research program sponsored by the Naval Aerospace Medical Research Laboratory was, and continues to be, the development of reliable air combat performance criteria for use in validating aviator selection variables. With the identification of TACTS training deficiencies, however, the more immediate benefits of applying these performance criteria directly to operational ACM training was recognized.

A TACTS Training Improvements Program, therefore, was initiated and sponsored by the Naval Training Equipment Center in order to focus some of the research results thus far obtained on immediate operational training problems. The training improvements program has concentrated in two areas:

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[4] See footnotes 2 and 3, page 5

1) development of a computer based TACTS debrief system, and 2) a problem definition study of Navy missile envelope recognition training.

Research related to these two areas has already been extensively discussed in earlier technical reports.[5,6] This summary report presents highlights of this prior research, and in addition, includes some work completed subsequent to these earlier studies.

This summary report has two major sections, each covering one of the principal research task areas. Section II, The Performance Assessment and Appraisal System (PAAS), summarizes work completed to date on a computer based debrief system for TACTS. Section III, Review of Air-to-Air Missile Envelope Recognition Training Problems, summarizes the unclassified portion of a more comprehensive study.[7] The reader interested in greater technical detail than reported here should consult these earlier reports (referenced below).

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[5]Ciavarelli, A.P., Pettigrew, K.W., and Brictson, C.A. Development of a Computer Based Air Combat Maneuvering Range Debrief System: Interim Report (Volume I). La Jolla, California: Dunlap and Associates, Inc., January 1980.

[6]Ciavarelli, A.P., Narsete, E.M., and Brictson, C.A. A Problem Definition Study of U.S. Navy Air-to-Air Missile Envelope Recognition Training (U). Interim Report (Volume II). La Jolla, California: Dunlap and Associates, Inc., April 1980. (CONFIDENTIAL)

[7]Ibid.

SECTION II
PERFORMANCE ASSESSMENT AND APPRAISAL SYSTEM (PAAS)

OVERVIEW

For the past five years, scientists at Dunlap and Associates, Inc., Western Division, have been intimately involved in the study of air combat training and performance measurement on the Navy's TACTS operated out of Miramar Naval Air Station, San Diego, California. On-site observations made during this time and verified by data collected from over 300 engagements reveal that TACTS training missions and their associated debriefs vary considerably in training emphasis, content, and quality. Additionally, cumulative data are not routinely collected, so that performance review of more than one mission at a time is not readily available. Determining Air Combat Maneuvering (ACM) training progress on TACTS is, therefore, a time consuming and expensive process in which data from many missions must be hand-compiled. On the basis of our observations and research, and in response to requests by ACM training personnel, we proposed the development of a computerized system, PAAS, to aid in immediate aircrew debrief and to facilitate longer term evaluation of training progress.[8]

Thus far, we have completed a single software module, or subsystem of PAAS. This initial module represents a preliminary, or baseline, TACTS debrief system which was first introduced at the 1980 TACTS User Conference.[9,10] This baseline debrief was developed after several years of research using a system approach to air combat training and performance measurement.

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[8] See footnote 5, page 7.

[9] Ciavarelli, A.P. Development and application of aircrew performance criteria and assessment methods for TACTS. Proceedings of the Seventh TACTS/ACMI Users Seminar. San Diego, California: COMNAVAIRSYSCOM, May 20-21, 1980.

[10] Williams, A.M. Performance assessment and combat effectiveness (PACE). Proceedings of the Seventh TACTS/ACMI Users Seminar. San Diego, California: COMNAVAIRSYSCOM, May 20-21, 1980.

Using this approach, an air combat engagement was considered to be a system composed of several mission phases, and measures associated with successful completion of these phases were found to be statistically related to successful engagement outcomes.[11] Thus, the air combat sequence is a highly structured event, and overall ACM success depends on success at several critical points. With the identification of these phases and empirical results from ongoing measurement studies, Dunlap and Associates was ready to move from the research arena into applications, and the computer based aircrew debrief program was introduced. The purpose of the PAAS is two-fold. First, it aids in structuring and therefore standardizing the aircrew debrief by providing feedback for only the critical ACM phases identified by our earlier research. And second, training progress can be observed because the system stores data from past missions, building a cumulative data base. In addition, PAAS allows aircrews to review training results off-line to TACTS in a timely manner and in a summarized graphic format.

The currently completed module, Performance Assessment and Combat Effectiveness (PACE), is a fully operational, stand-alone system designed to provide performance review at the squadron level. The system has been developed, however, with an eye toward adding three more modules to complete the proposed PAAS system, one module to review individual pilot performance (TAD: Training Appraisal and Diagnostics), another to review fleet normative data (NORM: Numerical Operational Readiness Measurement), and a third to provide a complete set of operating procedures (SOP: Standard Operating Procedures). Figure 1 shows the conceptual design configuration of PAAS, with the now completed PACE module highlighted.

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[11] See footnote 1, page 5

PERFORMANCE ASSESSMENT AND APPRAISAL SYSTEM (PAAS)

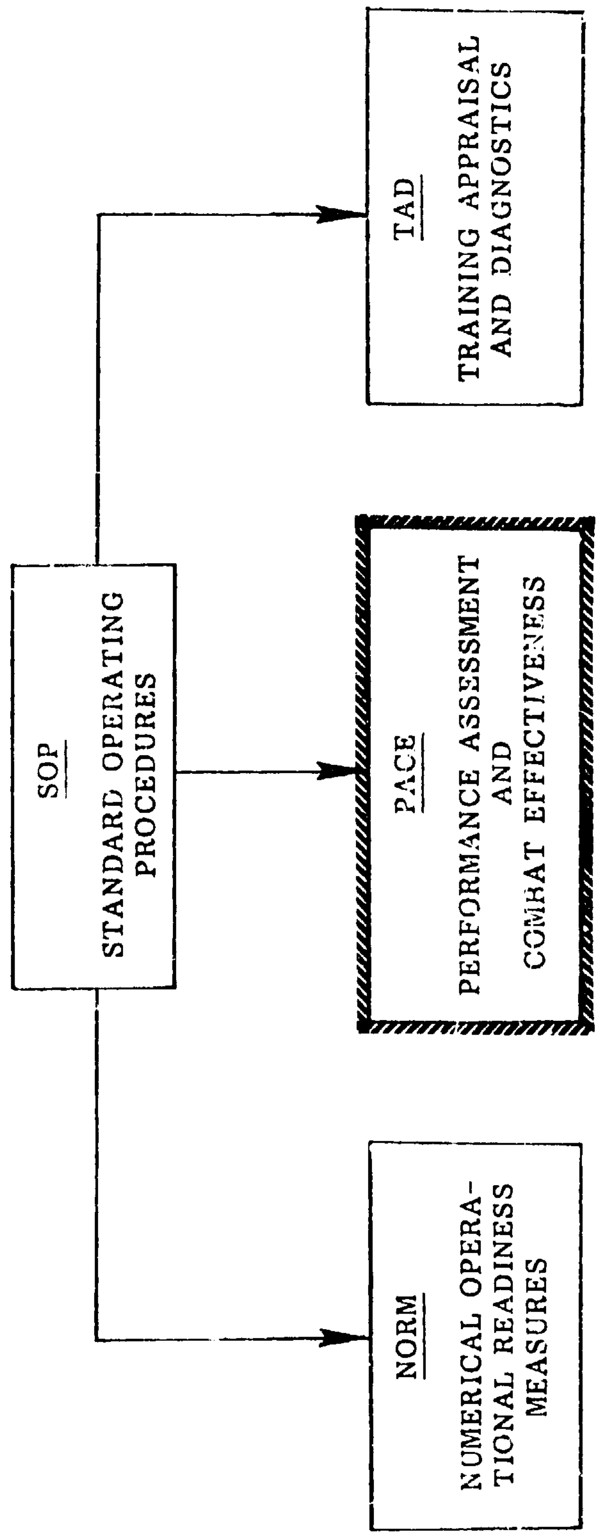

Figure 1. Conceptual Design of Performance Assessment and Appraisal System (PAAS)

PACE has been enthusiastically accepted by operational personnel at Miramar Naval Air Station. A letter of operational support, for example, stated:

> "...Because it is so difficult to give the Commanding Officer readily available and easily understood factual information on which to base his assessment of aircrew readiness, I have been very favorably impressed with the PAAS capability to provide empirical data in a meaningful display. There is a great requirement for this type of system, and I strongly recommend continuance of the development of the PAAS system..."

The letter has been forwarded to Naval Air Systems Command, Washington, D.C. and NAVTRAEQUIPCEN, Orlando from Commander Fighter Airborne Early Warning Wing, U.S. Pacific Fleet (June 27, 1980, letter 50/HRK:pw, 3500, Ser 1079).

GENERAL DESCRIPTION OF PACE.

Application. PACE has been designed primarily for use by the squadron training officer to review performance of a squadron, as a whole, for key ACM tasks. Missions to be reviewed are selected by entering squadron, mission type, adversary aircraft type, and two inclusive dates in response to prompts by the computer. Performance can be reviewed either on a daily basis by entering the same date twice, or over a more extended period of time by entering both start and finish dates. Thus, PACE could be used to review daily training missions flown by the members of a squadron to look for improvements in training on a day-to-day basis, or it could be used to compare performance among several squadrons. Performance of squadrons for entire, week-long detachments can also be reviewed and compared.

Computer Graphics. Feedback is provided by PACE for several selected training objectives: 1) radar procedures, 2) look-out procedures, 3) tactics and maneuvers, and 4) envelope recognition. In our previous research,[12] we have defined these training objectives and have demonstrated their importance to air combat success. Our empirical evidence has shown, for example, that obtaining an early radar contact and Tally Ho, results in a greater likelihood of winning an air combat engagement.[13] Figure 2 shows the typical air combat mission sequence and identifies the key events in the mission, i.e., radar contact, Tally Ho, etc., for which performance information is required. We have, therefore, structured the PACE module to provide graphic performance feedback addressed to the above four training objectives and related to most of the key air combat events depicted in Figure 2. Available graphics for the PACE module are itemized and discussed in the following subsections of this report. All data used in graphic displays presented here are hypothetical, but in actual application PACE uses data collected during TACTS missions.

Radar Procedures. Performance feedback on radar procedures is provided in terms of what percent of the total number of missions the fighter aircrews obtained a radar contact on the adversary. This percentage is further broken down into what percent of the missions obtained early and late contact. (See Figure 3)

Look-Out Procedures. Feedback on look-out procedures is provided in the same graphical format as for radar procedures. The percent of total missions obtaining a visual contact (Tally Ho) and a breakdown in terms of early and late are provided. (See Figure 4)

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[12]See footnotes 1 and 3, page 5

[13]See footnote 5, page 7

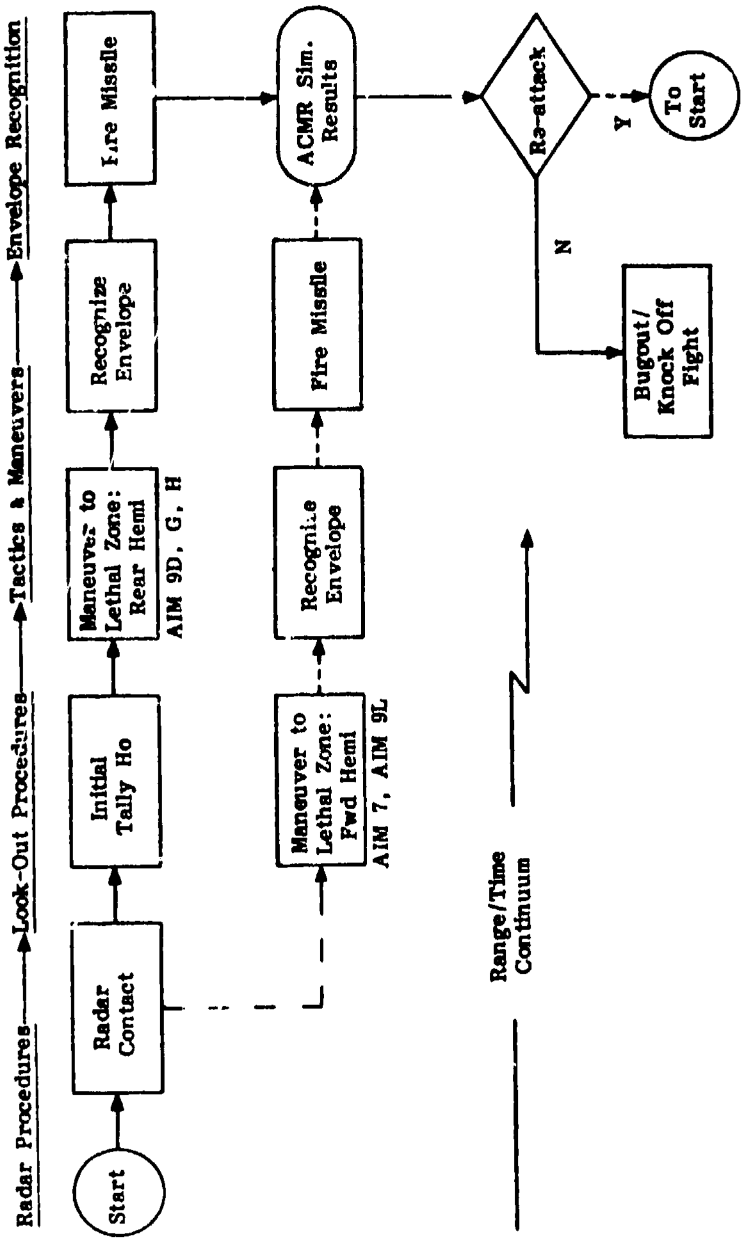

Figure 2. ACM mission sequence

SQUADRON: ALL FROM 01MAY78

MISSION TYPE: 2V2 TO 14MAY78

ADV. A C: ALL

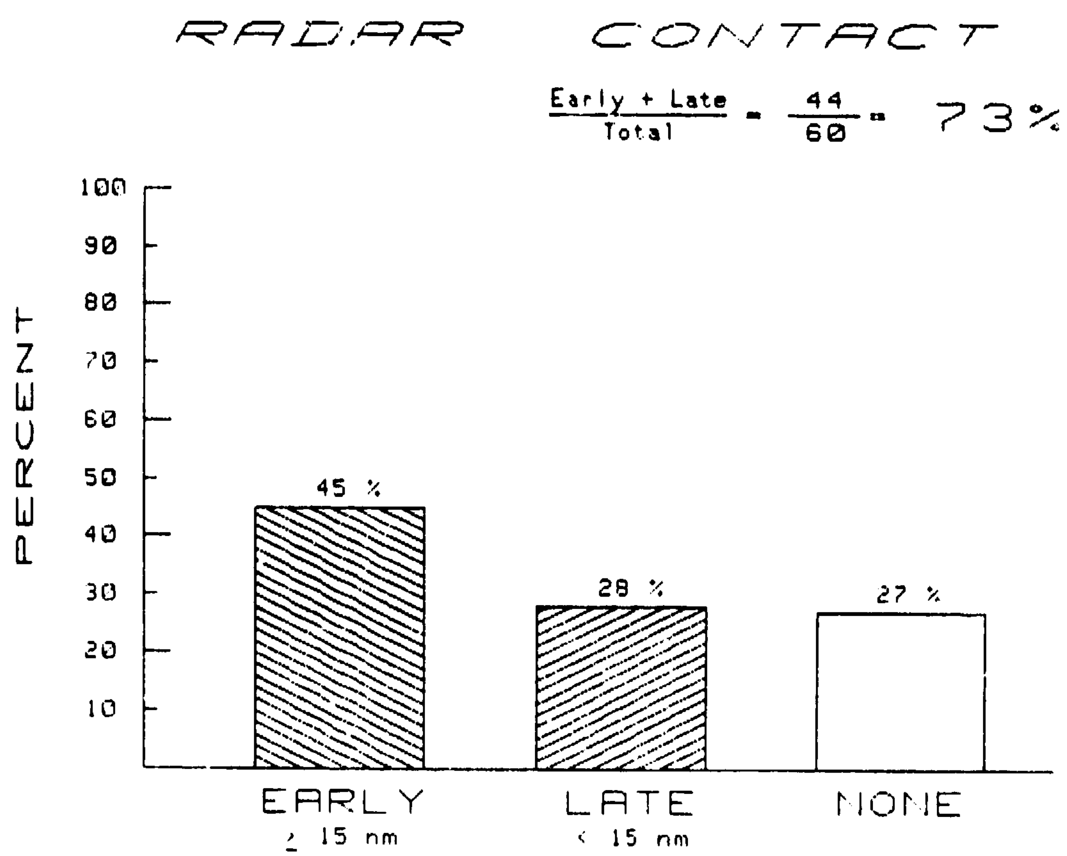

Figure 3. Sample display format for Radar Contact: percent of engagements with early, late and no radar contact

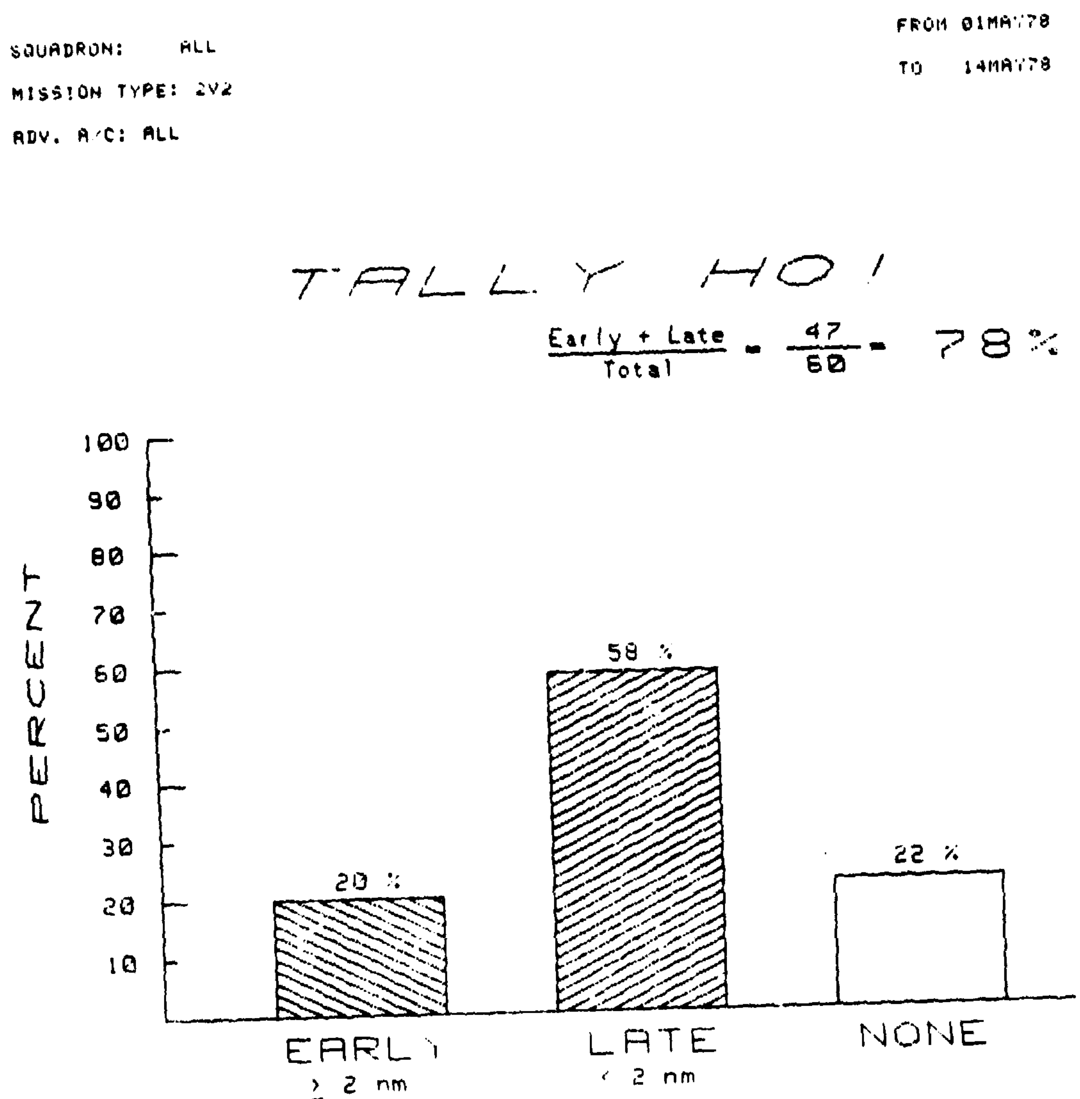

Figure 4. Sample display format for Radar Contact: percent of engagements with early, late, and no Tally Ho

Tactics. Tactical feedback provided by PACE includes the percent of missions on which a first shot, and independently, a first kill were obtained by the fighter aircraft. (See Figure 5)

Envelope Recognition (Kill/No Kill). Missile fire envelope boundaries are defined in terms of AOT (angle off adversary's tailpipe) and range (distance from adversary) at the time of missile launch. The firing envelope defines the boundary values for these parameters. To maximize changes of a successful launch, a missile should be fired within these boundaries. PACE displays graphical feedback of AOT and range at the time of each missile shot. The fighter's position is plotted as a star or a circle (hit or miss, respectively, according to preselected rules for scoring) on a polar plot with the adversary's tailpipe at 0°, 0 ft. Missile shot fire points are plotted on the so called "hot" and "cold" sides of the hypothetical missile envelope. These terms are extensively defined in earlier technical publications[14] and are roughly equivalent to shots fired on the cockpit side (hot) and bellyside (cold) of the target aircraft. Separate displays are presented for three missile types, AIM 9G, AIM 7F, and AIM 9L. To score shots according to rule-of-thumb envelopes, the computer overlays an outline of the missile fire envelope on the polar plot.* (See Figures 6, 7 and 8.) Missile fire positions in Figures 6-8 are hypothetical and used for illustrative purposes only.

Engagement Outcomes. A final display to indicate win/loss statistics (i.e., exchange rate) has been included in the program. The total exchange rate is indicated in terms of total fighter hits to total adversary hits. Missile fire success rate in terms of percent hits is displayed for four missile types, three fighter missiles (AIM 7F, AIM 9L, and AIM 9G) and one type of adversary missile (ATOLL). (See Figure 9)

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[14]See footnotes 2 and 3, page 5

*Actual missile envelopes are classified and can not be shown here (examples are provided in Reference 5).

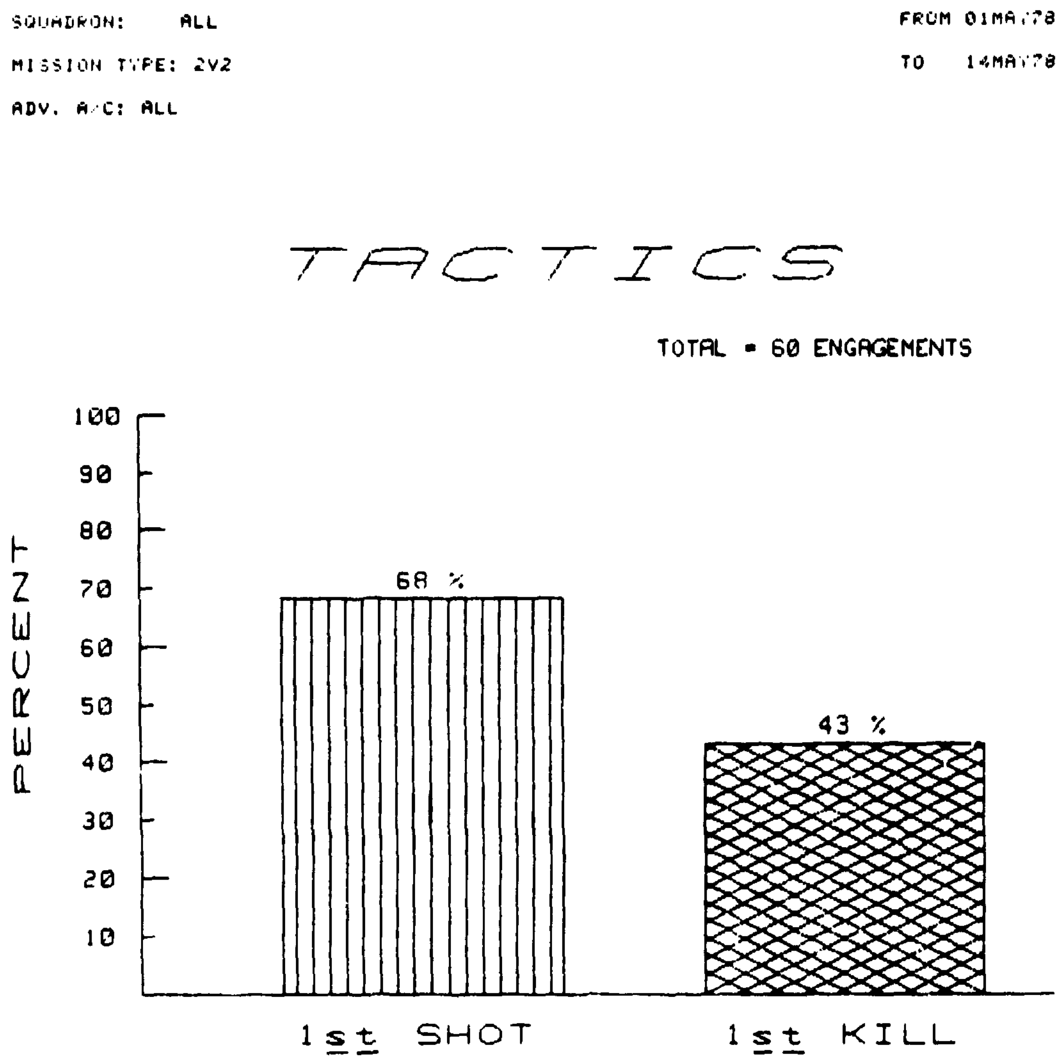

Figure 5. Sample display format for Tactics: percent first fighter shot and percent first fighter kill out of total engagements

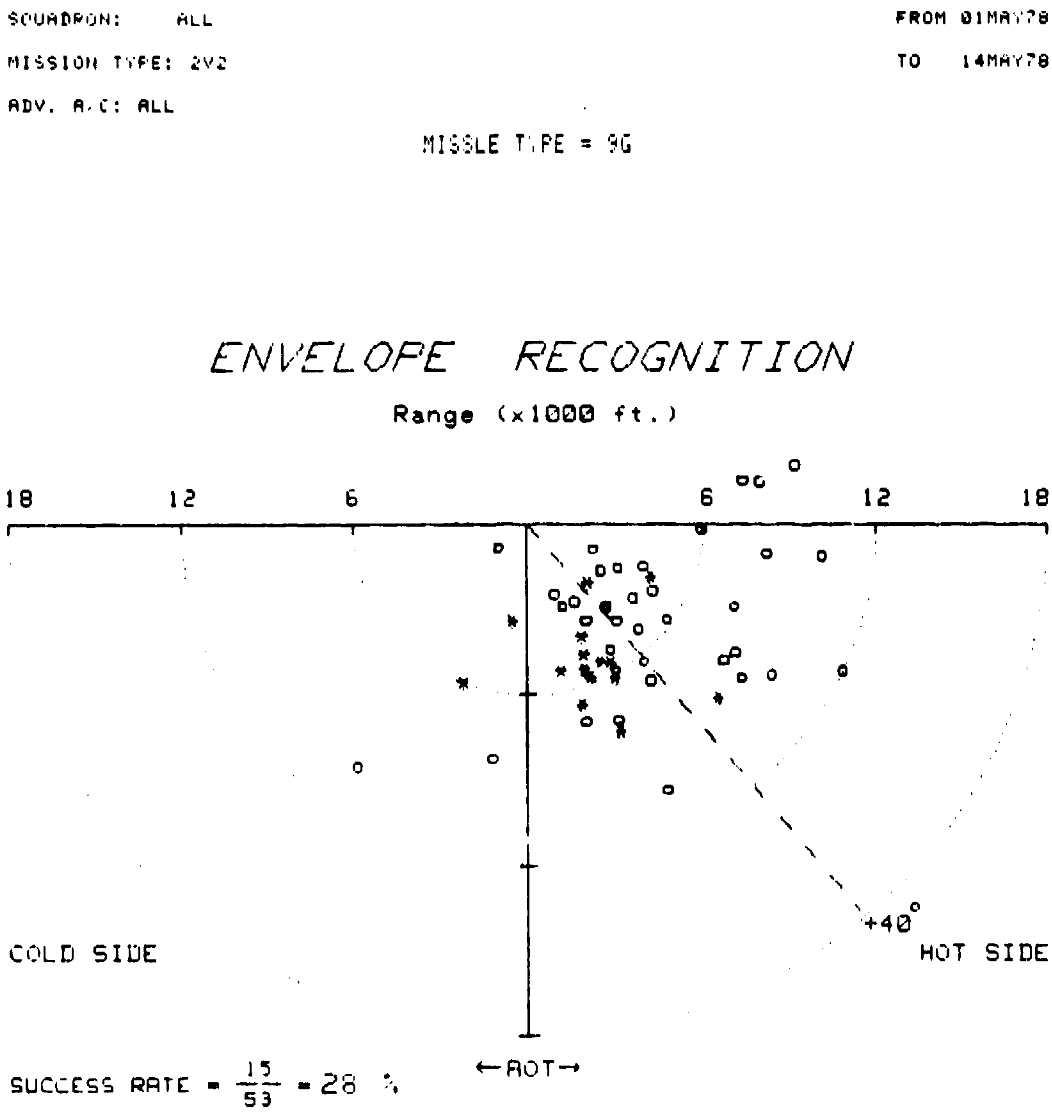

Figure 6. Sample display format for Envelope Recognition: Sidewinder AIM 9G -- shows fighter aircraft position at missile fire in terms of range (x1000 ft.) and angle off tail (AOT in degrees) from target. Circles and stars indicate hits and misses, respectively, according to preselected rules for scoring.

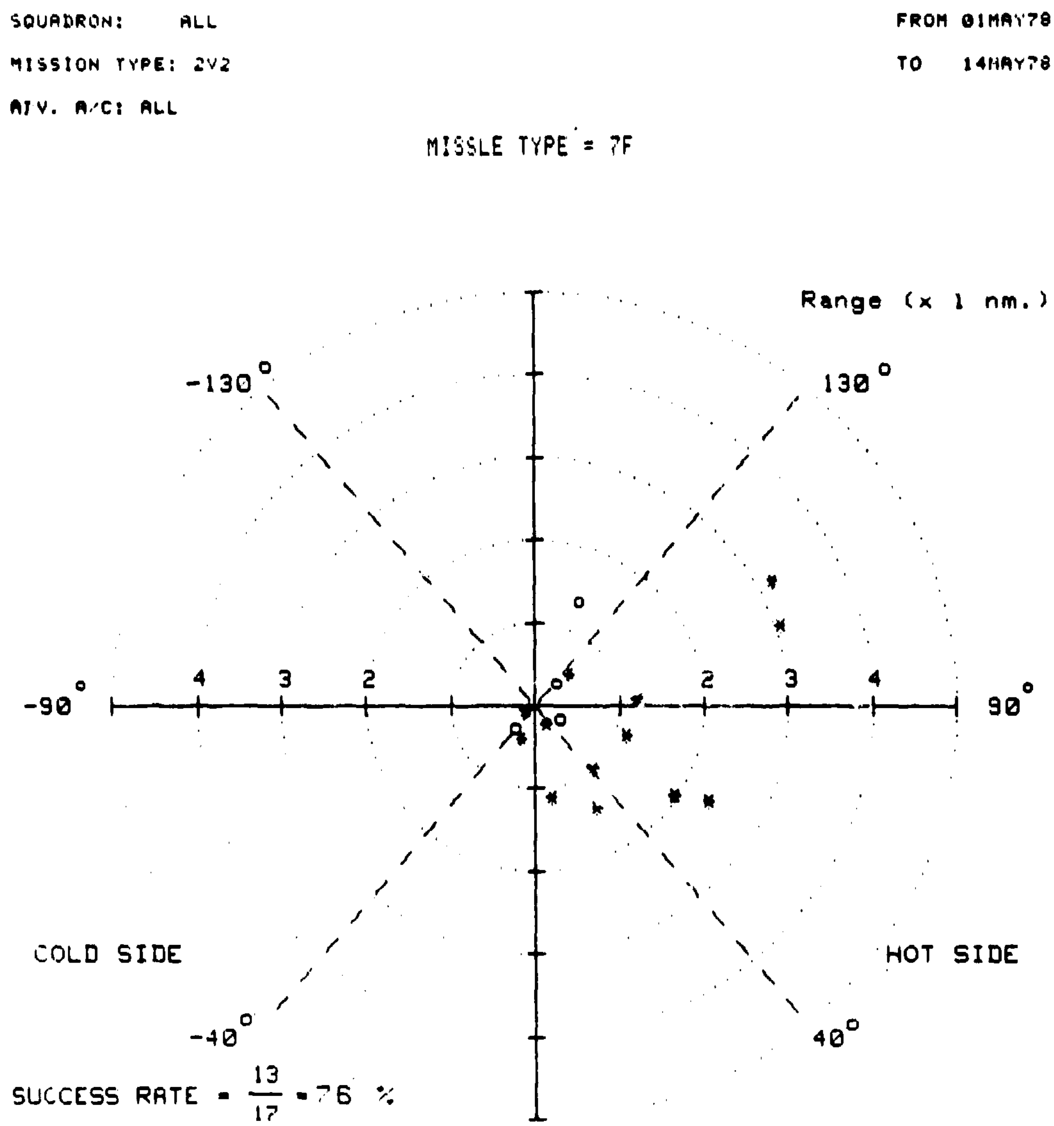

Figure 7. Sample display format for Envelope Recognition: Sparrow AIM 7F -- shows fighter aircraft position at missile fire in terms of range (n.m.) and angle off tail (AOT in degrees) from target. Circles and stars indicate hits and misses, respectively, according to preselected rules for scoring.

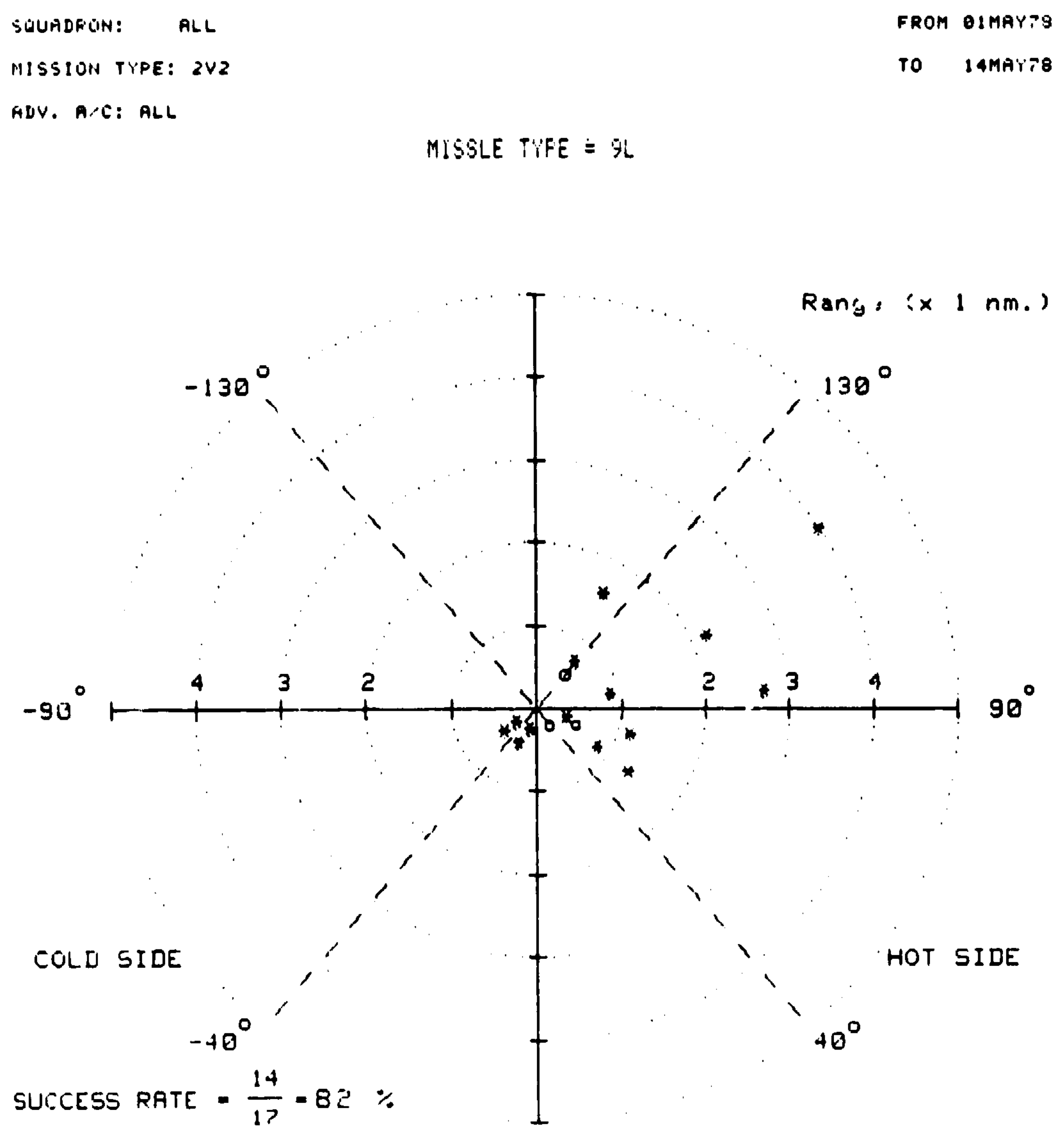

Figure 8. Sample display format for Envelope Recognition: Sidewinder AIM 9L -- shows fighter aircraft position at missile fire in terms of range (n.m.) and angle off tail (AOT in degrees) from target. Circles and stars indicate hits and misses, respectively, according to preselected rules for scoring.

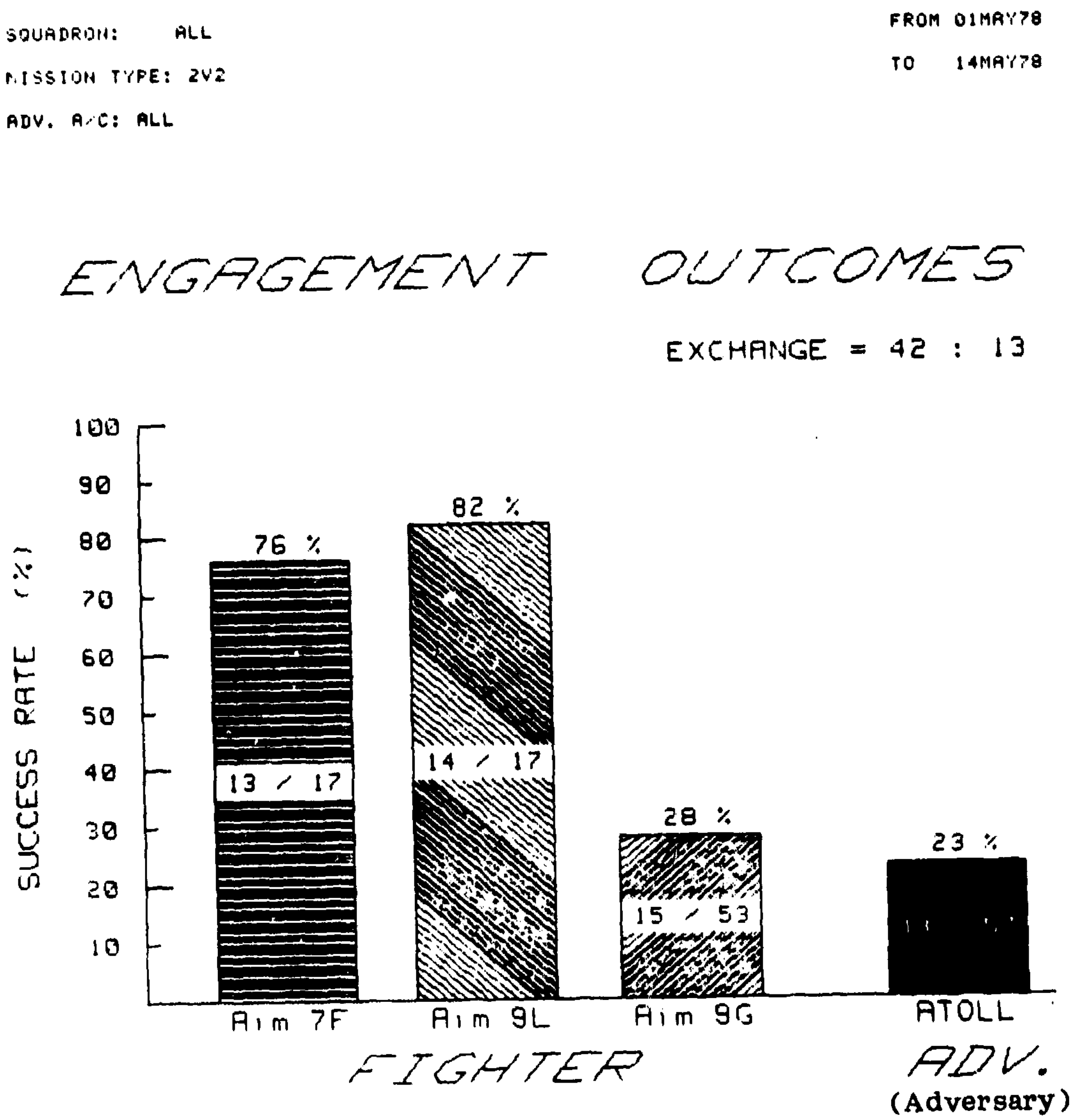

Figure 9. Sample display format for Engagement Outcomes: shows hypothetical missile fire success rate (percent) by missile type and overall exchange rate (fighter to adversary (ADV) kills)

Graphics Use. Graphic displays can be requested individually, or they can be presented as part of an automated sequence and used to structure and standardize the aircrew debriefing procedure. Hardcopy printout of each display is also available for permanent records, to make comparisons among squadrons, and to make comparisons over time to determine training progress.

Envelope Recognition (by engagement). One final graphics display is available and is used for more detailed training data analysis. This display allows the squadron training officer to identify shots by engagement. The format of this display is the same as the format of Envelope Recognition (kill/no kill). It is a polar plot with the adversary's tailpipe at 0°, 0 ft. Missile fire positions, however, are indicated by numbers rather than stars and circles. These numbers refer to the engagement number of each shot. Use of this display along with a data listing feature incorporated into PACE allows the squadron training officer to call up the data associated with a particular shot. (See Figures 10 and 11.) This display has an additional feature. It can be used to examine training progress on a longitudinal basis. Engagements are entered into the data base chronologically; low numbers indicate missile shots taking place during earlier engagements. Hence, comparisons of the plotted numbers from low to high reveal whether or not training improvement is occurring in terms of shot accuracy.

Data Listing. This feature of PACE, which allows access to all of the engagements selected for debriefing, displays all data related to one record in the data base. One record is stored in the data base for each engagement flown by each pilot. The data are listed on the CRT display only. To preserve individual confidentiality and for security purposes, a hardcopy of these data is not available. A sample of a single data record is included as Figure 12. Using the information on the record, such other shot parameters as closing velocity, pointing angle, and shooter-indicated-airspeed are also available for debriefing if required.

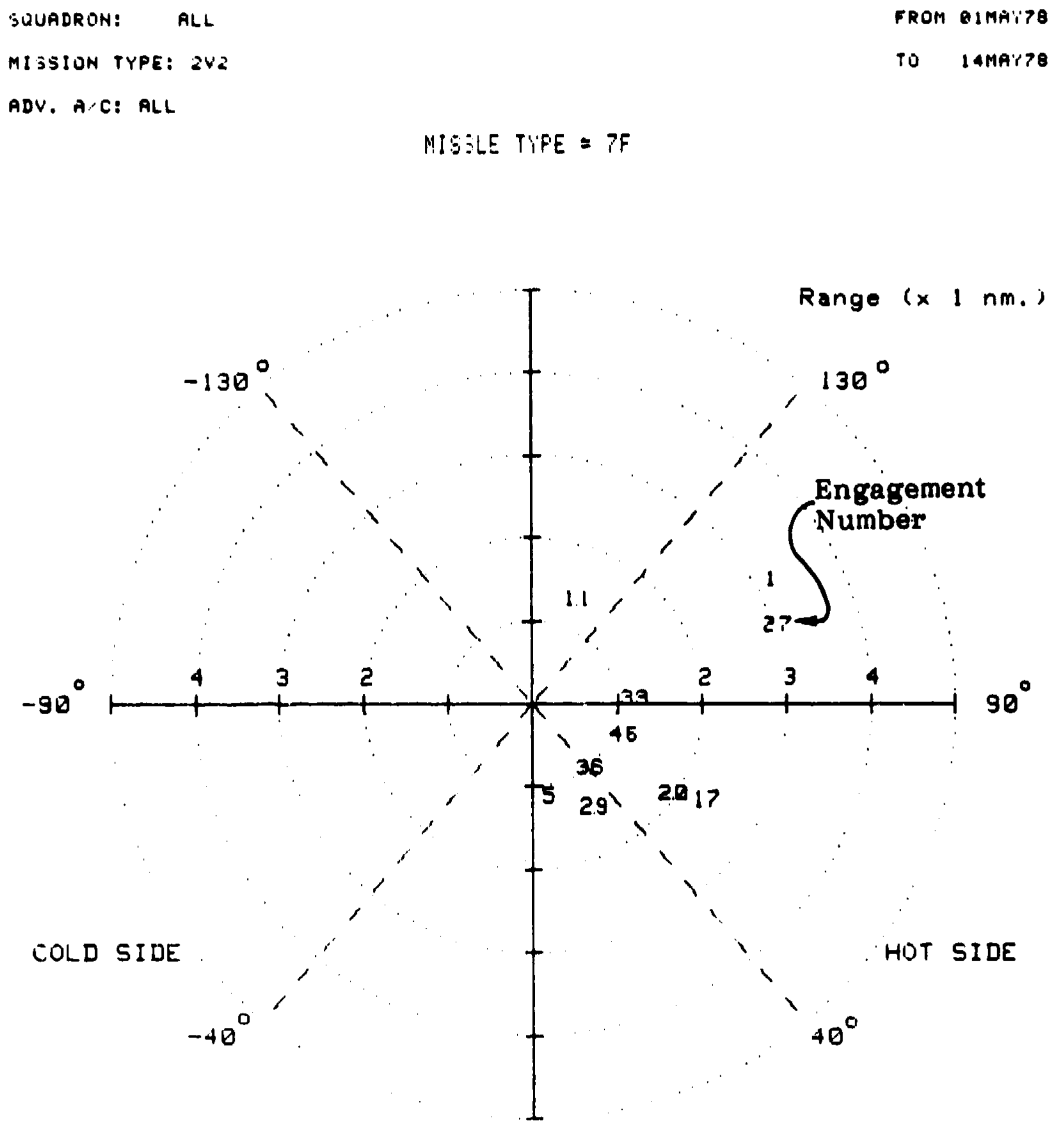

Figure 10. Sample display format for Envelope Recognition (by engagement) for selected missile: shows fighter aircraft fire position in terms of range (n.m.) and angle off tail (AOT in degrees) from target. Numbers refer to engagement number of each shot.

ENVELOPE RECOGNITION

	AOT	RANGE(ft.)
RECORD # 1	117	18896
RECORD # 5	9	7170
RECORD # 11	156	7838
RECORD # 17	59	14279
RECORD # 20	55	12091
RECORD # 27	107	18167
RECORD # 29	29	8992
RECORD # 36	39	6441
RECORD # 39	90	7230
RECORD # 46	68	6987

Figure 11. Information printed out concurrently with Envelope Recognition (by engagement). The record numbers listed here allow access to the data base by the Data Listing feature of the PACE program. AOT is presented in degrees; Range is presented in feet (6076 ft. = 1 n.m.)

PILOT	SQUAD	A/C	RIO	DATE	TAPE	ENG
Keycode*	VF	F4	Keycode*	05|03|78	585	1

ADV SQ	A/C	MISSION	WINGMAN	T START	MODE
	TA4	2V2	Keycode*	10:30:00	2

1ST-RADAR-R	1ST-RADAR-T	2ND-RADAR-R	2ND-RADAR-T	FORM
1.21	10:36:28	.	: :	

1ST-TALLY-R	1ST-TALLY-T	1ST-PILOT/RIO
10992	10:37:04	

2ND-TALLY-R	2ND-TALLY-T	2ND-PILOT/RIO
	: :	

PMI OFF	PMI NTRL	PMI DEF

FIGHTER SHOTS:

MISSLE	TIME	AOT	RANGE	IAS	Vc	ATA	RES
9G	10:37:48	100	8024	270	367	1	N
9G	10:39:46	20	5600	410	292	2	K
	: :						
	: :						
	: :						
	: :						

ADVERSARY SHOTS:

TIME	RES
10:38:23	N
: :	
: :	
: :	
: :	
: :	

* Note: Operator keycode will be required to protect identity of aircrew members.

Figure 12. Example of a single data record representing information from a TACTS ACM engagement

PACE Summary. The PACE program has been designed to provide squadron level performance review to the squadron training officer. Engagements are selected by squadron, adversary aircraft, mission type and dates. Performance review occurs for several critical mission phases, including Radar Contact, Tally Ho, Tactics, and Envelope Recognition. Win/loss statistics are provided by an additional display, Engagement Outcomes. An automated debrief capability, or feature, aids in structuring and standardizing the debrief process. Hardcopy printout is available for these review phases. An additional feature, Envelope Recognition (by engagement), enables review of additional parameters for an individual shot, and the Data Listing feature of the PACE program allows access to any single engagement.

DATA MANAGEMENT

DATA BASE. The data base is a file of sequential records. One record of information is added to the data base for each engagement a pilot flies on TACTS. A list of the information stored in each record is shown in Table 1, and a formatted computer printout of one record from the data base is shown in Figure 12. Using a special pointer system incorporated into PACE, access to the data base is allowed on the four data fields mentioned earlier: squadron, mission type, adversary aircraft, and date. The data base is in final form; all the data fields needed by PACE are included in this current data base system. When other modules are added, i.e., SOP, TAD, NORM, programming changes to the data base or to the data management program may be necessary.

DATA MANAGEMENT PROGRAM. "Entry" is the name of the data management program. Entry is not considered to be a module in the PAAS program, but is a separate program which operates independently of the PAAS. For security purposes Entry is to be used only by personnel assigned the task of keeping the data base current and not by typical users of PAAS like squadron training officers, or later on, pilots. Entry is the only program that can be used to change the data base. Its most important function is to add new data, although it can also be used to look at records of specific engagements, to list the data base, and to change data that have been added incorrectly.

Data for the PAAS data base is transcribed manually onto data sheets and then entered into a desktop HP 45-T computer using Entry. Entry is an easy-to-use, interactive program which facilitates efficient data entry. Our long-range plan is to completely automate data transfer from the TACTS computer to the desktop computer now located at Dunlap and Associates, Inc., Western Division. However, the present mode of data transfer is highly efficient and minimally time consuming, enabling the squadron training officer to review performance on the same day an engagement takes place.

TABLE 1. TACTS DEBRIEF DATA BASE ELEMENTS

- ACM MISSION DATA
  - Pilot's Name
  - Squadron
  - Aircraft Type
  - RIO's Name
  - Date
  - TACTS Tape No.
  - Engagement No.
  - Adversary Squadron
  - Adversary Aircraft
  - Mission Type (e.g., 2v2)
  - Wingman's Name
  - Engagement Start Time
  - TACTS Mode
- RADAR PROCEDURES
  - Contact Range - 1st Bogey
  - Contact Time - 1st Bogey
  - Contact Range - 2nd Bogey
  - Contact Time - 2nd Bogey
  - Determine Formation (Y or N)
- LOOKOUT PROCEDURES
  - Contact Range - 1st Bogey
  - Contact Time - 1st Bogey
  - Contact Range - 2nd Bogey
  - Contact Time - 2nd Bogey
- MANEUVERING INFORMATION
  - Offensive
  - Neutral
  - Defensive
- MISSILE FIRE INFORMATION
  - Missile Type
  - Time of Shot
  - AOT
  - Range
  - Shooter IAS
  - Closing Velocity
  - ATA
  - Result (K or N)
- ADVERSARY MISSILE FIRE INFORMATION
  - Time of Shot
  - Result (K or N)

SUMMARY

In order to improve the training effectiveness of the Tactical Aircrew Combat Training System (TACTS), a computer based debrief system has been proposed. The Performance Assessment and Appraisal System (PAAS) has been designed and a single software module, Performance Assessment and Combat Effectiveness (PACE) has been developed thus far. PACE is a stand-alone and independent system used for review of squadron level performance for a single training detachment. Performance data collected during TACTS training can be entered in PACE, and this data base can be used by the PACE programs to generate statistical summary data in computer graphic displays. A series of display formats for selected training objectives has been designed and was described earlier.

Future development of PAAS calls for three additional software modules, Normative Operational Readiness Measures (NORM), Training Appraisal and Diagnostics (TAD), and Standard Operating Procedures (SOP). These new modules will serve respectively to: 1) review Navy group or fleet normative data, 2) provide training diagnostic data, and 3) help operational training personnel to use PAAS in the most effective way. The availability of programs like PACE, or better yet, the total integrated PAAS with <u>all</u> its modules, will serve to structure air combat debriefs, while providing performance based feedback to enhance training.

It is important to note that the availability of performance feedback may help aircrews to see "out of tolerance" missile shots and to this extent our debrief has been directly beneficial to envelope recognition training. Other envelope training difficulties, however, may require additional research and/or supplementary training aids as outlined in the next report section.

SECTION III
MISSILE ENVELOPE RECOGNITION
PROBLEM DEFINITION SUMMARY

INTRODUCTION

BACKGROUND. In spite of some striking advances in airborne avionics, and the growing sophistication of weapon delivery systems, no in-flight fire control system has evolved to provide automatic fire solutions for current Navy missiles. The determination of where to shoot, in terms of an aircraft's position relative to a target, is still primarily a visual tracking task. Selection of correct missile delivery boundaries, referred to as envelope recognition, is fundamentally a perceptual task in which a pilot must estimate the position of his aircraft with respect to an adversary aircraft. The pilot must then decide whether his relative position is within the limits of a prescribed launch cone, or envelope.

The Navy's TACTS was developed in response to lessons learned in Vietnam which showed that U.S. pilots had low success rates in air combat partly because they fired their weapons outside of recommended envelopes. TACTS was designed to improve weapon envelope recognition training, as well as to safely train and evaluate aircrews in all aspects of ACM.

Research conducted on TACTS over the past five years[15] has consistently shown that pilots are highly variable in their ability to fire missiles within launch envelopes specified by tactical doctrine. More recent evidence[16] has shown that missile shots are most frequently fired <u>outside</u> of

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[15]See footnotes 1, 2 and 3, page 5

[16]See footnote 6, page 7

recommended boundaries. Additionally, this finding is consistent across weapon types and aircrew experience levels.

Performance data collected on TACTS have demonstrated that the fleet's most experienced aircrews, many with extensive combat exposure in Vietnam, frequently fire out of thumbrule training envelopes--even when told that the thumbrule envelope would be used to score results of a competitive exercise. The evidence, provided by a considerable body of data from the previously cited research, suggests that the majority of aircrews still have difficulty launching weapons within prescribed envelope boundaries.

The Navy is now introducing new all-aspect weapons to the fleet, such as the radar guided AIM 7F and the heat-seeking AIM 9L. If these particular missiles meet their advertised capabilities, they will greatly increase weapon effectiveness in the fleet by expanding acceptable launch zones from a target's rear hemisphere to an all-aspect application.

Actual use of the all-aspect weapons, however, will still require pilots to fly to, recognize, and fire within prescribed weapon envelopes which maximize kill probability. Furthermore, pilots will now have a wider variety of weapons in their inventory and onboard their aircraft from which to choose. The net result is that pilots will not only have to determine where to shoot but also which weapon to shoot during the course of an air combat engagement. Knowledge of various missile envelopes (9G/H, 9L, 7F), and skill in firing these weapons, will continue to be essential to a pilot's effective use of available weapons.

The recent advances in weapon systems reflect a prevailing philosophy that the application of high technology may eliminate or substantially diminish problems associated with fleet training. Evidence provided in our problem definition study[17] suggests that the mere application of technological

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[17] See footnote 6, page 7

innovation, exemplified by TACTS and new weapon advances, has not been sufficient to eliminate the need for improved fleet training practices. In spite of a six-year availability of TACTS, and improvements in weapon system capabilities, fleet performance in envelope recognition remains below standards set by Navy doctrinal recommendations. The effective use of all weapons in the fleet inventory ultimately rests with the pilot, given his understanding of weapon capabilities and their proper application. The requirement for pilots to learn several missile envelopes and to gain experience firing new weapon types, in actuality, may have further complicated the training process.

PURPOSE AND SCOPE. In view of the potential difficulties associated with missile envelope recognition training, the Naval Training Equipment Center, Orlando, Florida sponsored a problem definition study in order to identify any training deficiencies which could be corrected through improved instructional methods.

This problem definition study is now complete and recommendations for improving envelope recognition training have been proposed.[18] The summary, presented here, delineates some of the more salient envelope recognition training deficiencies identified in the problem definition study and reviews our research conclusions and recommendations. It should be noted that much technical detail of our findings must be left out of this unclassified summary of the original study. The reader interested in these details is urged to consult the more comprehensive problem definition study previously referenced.

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[18] See footnote 6, page 7

PROBLEM DEFINITION SUMMARY

Major problems associated with U.S. Navy missile envelope recognition training fall into four broad categories as follows:

1. Missile envelope derivation and application,
2. TACTS utilization and training feedback,
3. Envelope concepts and instructional methods, and
4. Training impact of new weapons.

MISSILE ENVELOPES. Missile envelopes are derived from mathematical models which simulate missile launch and guidance characteristics. On the west coast TACTS, missile launch results (kill, no-kill) are based on kinematic mathematical models which do not consider such factors as warhead lethality and target vulnerability. Thumbrule boundaries, which represent the heart-of-the-envelope (i.e., most effective launch zones) are also derived from kinematic mathematical models.

There is considerable controversy in the operational community concerning the credibility of the kinematic simulations, and the incorporation ot . eir resulting launch boundary data in the TACTS. Scoring results from TACTS are notoriously liberal in awarding kills and this issue raises questions regarding the true capabilities of fleet weapons, and their appropriate application.

To further complicate the issue, the use of various thumbrule training envelopes vis a vis TACTS scoring methods results in highly disparate missile fire success rates. Aircrews vary widely in their viewpoints concerning the thumbrule limits and their use during TACTS training. Some aircrews prefer to capitalize on the full missile envelope, represented by TACTS Mode 5,* while others train to various thumbrule standards to emphasize heart-of-envelope boundaries.

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*TACTS can operate in five different modes. Modes 1-3 provide thumbrule missile boundaries and are designed primarily for envelope recognition training. Modes 4 and 5 provide dynamic missile launch simulation with full envelope boundaries. (See references for more detail.)

TACTS UTILIZATION. Extensive experience (over the past five years) on TACTS indicates that pilots seldom use early TACTS modes (1-3) which are designed to teach missile envelope boundaries. Most aircrews prefer to train in Mode 5 because they believe that this training configuration is more realistic for full spectrum air combat training, i.e., Mode 5 is more realistic in terms of missile capability and its allowance for target evasive maneuvers. As a result, aircrews do not focus their training specifically on teaching missile launch zones. Digital information (e.g., range, angle-off-tail, etc.) is available to aircrews during the TACTS replay, but the digital data format may not be the most suitable way to represent missile envelopes. Graphic methods that depict an envelope trailing a target may be more appropriate for debrief training feedback, and would visually illustrate shots <u>in</u> and <u>out</u> of envelope.

TACTS training, as currently practiced, does not provide aircrews with many repeated missile fire opportunities. Based on data taken over 300 engagements, fighters fire an average of three shots per engagement. Usually, the three or so shots are distributed across several participating aircraft. Exposure to repeated missile fire opportunities, and appropriately formatted knowledge of results, are considered by operational aircrews to be essential requirements for acquiring envelope recognition skills. TACTS resource restrictions, i.e., fuel considerations and TACTS time limits, may preclude the use of the range specifically to train envelope recognition. Aircrews are probably correct in their decision to maximize the time on range for full spectrum ACM.

INSTRUCTIONAL METHODS. There are considerable difficulties related to the conceptualization of missile envelopes and the methods used to instruct pilots in proper launch boundaries. Missile launch boundaries, in reality, vary widely over the dynamic range of air combat engagement conditions. The actual envelope may expand, contract, warp and distort at various engagement speeds and target maneuvering situations. Simplified representations, such as thumbrule envelopes, are designed to meet the most frequently encountered engagement conditions, but at best are static, imprecise estimates of the true weapon capabilities. TACTS provides simulations based on the dynamic aspects of an engagement (i.e., target-shooter relationship) but the information related to the pilot as a simulation output is a simplified kill/no-kill indication. A pilot does not see a representation of how a missile envelope changes under dynamic conditions of the engagement. In brief, a pilot must estimate launch boundaries based on static thumbrule restrictions, which depict an imaginary launch cone, or TACTS, which gives no visual representation of the envelope whatsoever.

Furthermore, the idea of a launch cone is not readily transferred to the actual judgement of launch conditions in the air, during which a pilot estimates his aircraft position based on a maneuvering target (i.e., by seeing target element details such as apparent size and wing and fuselage exposed to view).

TRAINING IMPACT OF NEW WEAPONS. New weapon development, such as the radar guided AIM 7F and the heat-seeking AIM 9L were designed to simplify the weapon launch process by providing expanded zones of missile effectiveness. On the surface, these technological innovations appear to eliminate problems related to envelope recognition training. In the words of some of the operational aircrews, these new weapons have been dubbed magic missiles. But are they?

The highly touted advances of the AIM 7F and AIM 9L are as yet only advertised capabilities which have not stood the test of operational application. The history of advertised weapon capabilities was shown to be wrong in the past, with the notorious failure of the old version Sparrow (AIM 7E) as a case in point. A question of highest priority in the minds of the authors and operational aircrews is, can we afford to be wrong in the future?

Evidence presented in the problem definition study[19] suggests that even with the application of high technology, which includes a six-year availability of TACTS and improvements in weapon capabilities, fleet performance remains below standards set by Navy doctrinal recommendations.

The effective use of all weapons in the fleet inventory ultimately rests with the pilot, given his understanding of weapon capability and their proper application. A requirement for pilots to learn several missile envelopes and to gain experience firing new weapon types has complicated the training process.

Finally, attaining the full potential in applying state-of-the-art missile improvements (AIM 7F, AIM 9L) may not be possible because of an operational requirement to positively identify unfriendly aircraft (i.e., pilots may not be able to identify enemy aircraft at maximum ranges). By the time positive visual identification of an adversary is made, the friendly aircraft is approaching minimum range limits of the weapon system.

CONCLUSIONS AND RECOMMENDATIONS

All of the problem areas discussed in the previous section are considered to be contributing factors to the envelope recognition performance variation observed in the fleet today. Unless steps are taken to rectify some or all of these difficulties, envelope recognition training effectiveness (and perhaps future operational weapon employment) may be seriously compromised.

The following training improvements are recommended:

1. Define more realistic and credible missile envelope thumbrules.
2. Provide structured debrief data which visually illustrate launch envelopes to aircrews.

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[19] See footnote 6, page 7

3. Develop training aids to teach dynamic missile envelope boundaries to aircrews, instead of static thumbrule representations.
4. Study the use of existing ACM simulators, or develop a special purpose part task envelope trainer, so that pilots can practice envelope recognition over repeated trials (including missile fire with knowledge of results presented in a visually enriched format).
5. Evaluate the use of earlier TACTS training modes (1-3) with the inclusion of more realistic rule-of-thumb envelopes.

Each of these recommendations should be viewed in the light of their likely cost and technical feasibility, in order to arrive at the most cost effective solution(s) to the envelope recognition training problem.

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