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TRAINING EFFECTIVENESS EVALUATION IN FLIGHT TRAINING

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Interim Report June 1980 - June 1981

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This report reviews training effectiveness issues as they relate to the Navy's 2E6 Air Combat Maneuvering (ACM) simulator. Discussions concerning ACM performance measurement considerations are also included.

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SUMMARY

It is imperative that the United States reverse its declining military trends of recent years. One relatively quick method for doing this would be to substantially increase proficiency levels of tactical combat readiness through enhanced training.

This report addresses Navy Air Combat Maneuvering (ACM) training, particularly as it relates to the Navy's 2E6 ACM simulator. A Training Effectiveness Evaluation (TEE) is being conducted by the Naval Training Equipment Center (NAVTRAEQUIPCEN) to quantify the training value of instructional systems such as exemplified by the 2E6. Quantitative measures of performance are being improved for both the 2E6 and the Tactical Aircrew Combat Training Simulator (TACTS) range. The TACTS range will be used as a setting in which to examine 2E6 performance. The end objective of this Training Effectiveness Evaluation effort is to assist in significantly increasing the Navy's ACM combat readiness. Several endeavors conducted to accomplish this objective are covered in the report.

An interservice review of ACM training relating to the use of simulators was undertaken; major conclusions and findings as they impact Navy ACM training are presented. A qualitative review of the 2E6 simulator was also performed. Discussions of selected issues impacting the training effectiveness of the simulator have been included.

A synopsis of progress to date for incorporating an ACM performance measurement system in the 2E6 is outlined. In addition, a detailed discussion of the current developmental status of an All-Aspect Maneuvering Index (AAMI) for assessing ACM proficiencies involving all-aspect weaponry is provided.

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[1]We wish to thank LCDR C. Bateman, United States Navy, for his invaluable inputs to the development of this technical effort.

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SECTION I

INTRODUCTION

Military flight simulators have been developed to simulate aircraft that consume costly quantities of fuel. Some claim that these new simulators provide flight hour substitution capabilities which will result in substantial fuel and cost savings; they often cite commercial airline use of simulators for flight hour substitution as examples. Others state that current simulators, though excellent complements to flight training, do not possess the fidelity to serve as actual flight hour substitutes. Reducing flight hours for training the extremely complex tactical combat environment cannot be achieved without sacrificing some degree of combat readiness. This latter position is difficult to defend because of the paucity of quantifiable data available in the field. In view of the reduced military posture of the United States in comparison to the USSR, the training effectiveness of these military simulators involves serious implications.

Any arbitrary reduction in military flight time which might detract from aircrew ACM readiness requires cautious examination. It is vital that objective, quantifiable data be obtained which can provide managers, leaders and type commanders with information necessary to make knowledgeable decisions in light of the dire consequences of arriving at, or being pressured into, making wrong ones. The need for reliable data to use as a training tool becomes more critical upon anlaysis of the military strengths and trends of the two superpowers.

"Technological and qualitative superiority is what the U.S. has depended on, and will continue to depend on, given the numerical superiority of the Soviets in several areas. But we cannot take our present technological pre-eminence for granted because the Soviets are working hard to catch up . . ."[1] The Soviet Union is utilizing their defense

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[1] Hayward, Thomas B. , Admiral, "CNO Speaks Out," Naval Aviation News, pp. 22-25, August 1980.

budget to correct two deficiencies: a Soviet lack of confidence, and a Soviet lack of capabilities. They have built a navy that "outnumbers the U.S. Navy and the navies of its Allies . . . Soviet naval ship construction is continuing at an alarming rate. They are building a nuclear submarine every six weeks."[2] The Soviets have launched a modern 50,000-ton nuclear powered carrier building program.

However, Soviet advances are not limited to ship construction; they are making advances in many areas. In recent years, the Soviets have

- o doubled the weapons load of their aircraft
- o nearly tripled their combat radius of action
- o produced and deployed a virtual explosion in ground-based fixed and mobile air defense weapons.

Technologically, the Soviets are making advances in air, surface and subsurface areas. Evidence indicates that the Soviets

- o are prototyping aircraft similar to the F-18 and F-14.
- o deployed supersonic Backfire bombers in an anti-carrier role.

Our attempt at maintaining capability and technology advantages should not be solely dependent on research and development activities for new and better equipment. Capabilities can be improved rather quickly by increasing proficiency levels; however,

> ". . . there is concern about the pilot's ability to master air-to-air combat in sophisticated high performance air superiority aircraft, particularly when flying time is so limited . . . . an equipment-training gap almost always exists . . . . it is a matter of degree, time, and circumstance . . . . during peacetime, we seldom, if ever, have properly . . . . trained pilots to win air battles, and in past wars, much training has been done in actual combat."[3]

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[2] Peterson, F.S., Vice Admiral, "Perspective," <u>Naval Aviation News,</u> pp. 8-15, July 1980.

[3] Blanch, Claude C., "Air Superiority Today and Tomorrow," Professional Study No. 5847, Air War College, pp. 42-44, April 1976.

Strong reactions to ineffective training have been registered as early as pre-World War II. Claire Chennault voiced his concerns about inferior training in the United States Air Force (USAF). The performance of the "Flying Tigers," a Chinese fighter force developed by Chennault, clearly indicates the value of intensive training. Richard Bong stated that his lack of training and skill in air-to-air tactics and gunnery prevented him from having twice as many kills. Our adversaries stated they were aware of our training deficiencies and were able to escape almost certain death because Americans had not been taught the basics of air-to-air gunnery and air combat maneuvering.

The Korean War came close on the heels of World War II and considerable air-to-air combat expertise was retained. The American pilots' kill ratio was about ten-to-one (792 MIG-15's shot down to 78 American aircraft lost). Statistical data indicates that 38 pilots became jet aces in Korea, collectively averaging 2,000 hours flying time in fighters and having had extensive experience (80 combat missions) during World War II. This group of pilots destroyed almost one-half of all the MIG's shot down in the Korean War. It became apparent that "pilot aggressiveness, the amount of jet flying time, and time in the type aircraft were . . . strong factors influencing combat effectiveness."[5]

With the technical advances made in aircraft after the Korean War, pilots in the Viet Nam War were required to maintain proficiency in diverse skills. "Early in the Viet Nam War it was apparent that the USAF had an aerial combat proficiency problem . . . USAF crews were not familiar in air combat tactics and were not proficient in maximum performance maneuvering . . . . It was found that the entire air combat tactics area had been sadly neglected."[6] A proficiency problem was apparent in the Naval aircrews as well at this time.

[4]Ibid, pp. 44-45.

[5]Ibid, pp. 45-46.

[6]Ibid, p. 47.

Historical combat data indicates that increases in training are necessary for improved combat performance:

o Viet Nam Conflict

(a) 1965 - 1968 Exchange Ratios USAF 2.25:1 - US Navy 2.42:1

(b) Advanced Air-to-Air Combat Training Program instituted by the Navy (Top Gun) and dissimilar ACM training in the FRS

(c) 1971 - 1973 Exchange Ratios USAF 2.25:1 - US Navy 12.5:1

O Israeli Conflict, October 1973

(a) Exchange Ratio of the Israeli Air Force 60:1

(b) Israelis provide aircrews with approximately seven times the amount of ACM flight hours that a Navy fighter aircrew receives before being permitted in combat

Two major trends must be addressed by the U.S. military: (1) Soviet military increases in numbers, capabilities and technology; and (2) aircrew proficiency problems. Aircrew proficiency will be the backbone of maintaining our capabilities advantage over Soviet advances for the near term. Opinions and conclusions of increased proficiency include the following:

o One stop gap measure to counter these alarming trends lies in major upgrading of our training programs to create orders of magnitude differences in training superiority over the Soviets. This can serve as a "force multiplier."

o Although large increases in simulator time have occurred in both the Training Command and Fleet Replacement Squadrons, simulator time alone cannot meet the reversing trends in military strength.

o The increasing complexity of today's warfare demands increases in flight hours, not reductions.

o Actual equipment and aircraft flight hour utilization are necessary to attempt to duplicate the combat environment.

- o Simulators and training devices should be designed to prepare aircrews to more effectively and efficiently use actual flight hours and equipment in training for combat readiness.

- o Any continuing pressure to reduce flight hours in aircrew training rather than reprogram them must be examined carefully for any potential reduction in combat readiness.

- o Previous examination of these issues concluded in April 1980 that:

  "Increases in both additional flight time as well as in simulators and training device acquisition will most probably be required to counter current (Soviet) numerical superiority."[7]

- o We must upgrade our current training programs substantially to achieve the order of magnitude increases in combat readiness dictated by the rapidly shifting military balance. For instance, every deployed Navy fighter crew should receive at least the equivalent of Top Gun training; Maritime Air Superiority emphasis also needs to be significantly increased. The dual-roled F/A-18 aircraft requires additional Fleet Replacement Squadron (FRS) hours to train its increased mission capabilities. Simulators alone will not be sufficient to accommodate the additional training requirements. Simulators must be included in a system that is well designed, maintained and carefully implemented. Delivery of a simulator does not ensure that combat readiness will result from ACM simulator training.

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[7] McGuinness, J., et al., "Applied Training Effectiveness Evaluation Methodology," (NAVTRAEQUIPCEN 79-C-0016-1), Naval Training Equipment Center, Orlando, Florida, November 1978.

SECTION II

INTERSERVICE REVIEW

During July 1980, a field trip to Luke, Williams and Nellis Air Force Bases was conducted to assess the latest USAF efforts involving performance measurement in ACM and USAF TEE efforts. The trip was extremely beneficial in promoting an exchange of interservice ideas and technology. The trip was instrumental in establishing liaison and ties between Naval Air Station (NAS) Oceana fleet personnel and Luke AFB Simulator for Air-to-Air Combat (SAAC) instructors. These efforts have assisted NAS Oceana endeavors to improve the operational utilization of the 2E6. Further communications along these lines are anticipated. Brief summaries of the interviews held are included as Appendix A.

Conclusions and Findings from the Interservice Review

The "Readiness Estimation System-Readiness Index Factor 'RES-RIF' concept" has been examined by the USAF as a means to provide an objective, quantitative indication of aircrew/aircraft ACM maneuvering effectiveness.

The USAF has attempted to measure the training effectiveness of the Luke SAAC through a classic transfer-of-training (TOT) experiment. That is, crews have been split into two groups: one group received simulator training; the other group went straight to the range at Nellis. Their Instructor Pilot (IP) scores were compared. The data indicated that simulator trained aircrews achieved a higher percentage of valid shots than those not receiving simulator training. These preliminary measures indicated greater kill efficiency for the simulator-trained aircrews. This effort, although preliminary in nature, has ramifications for Navy ACM training.

The Luke SAAC method of operation and basic utilization and instructional strategies are fundamentally different from those envisioned on the Navy's 2E6. Valuable "lessons learned" may be obtained from the USAF SAAC effort.

For example, the USAF has had a fairly large contingent of SAAC simulator personnel. The Navy's plans for eventual 2E6 utilization are more extensive and will require a substantially funded and integrated support effort. For instance, the Navy's 2E6 will train two separate aircraft types and communities, vice one; will be integrated into flight operations; will train a broader population group including FRS formal syllabuses, fleet formal syllabuses and fleet concurrency training; will involve at least five to six separate syllabuses; will train Radar Intercept Officers (RIOs) as well as pilots; will be capable of more extensive multi-plane engagement training than is possible on the SAAC; and, will provide a number of additional dissimilar aircraft types. The utilization and instructional strategies, which must be developed to create an optimally functioning 2E6 instructional system, have never before been attempted on such a large scale involving such a complex tactical mission area. As such, the degree to which it succeeds, in large measure, will depend upon effective planning and implementation.

A dearth of field research data exists upon which to formulate utilization and instructional strategies for high technology visual ACM simulators. Human factors and training research required to support the Navy's urgent needs in this area will have to be almost totally developed at on-site operational facilities in cooperation with the fleet user communities.

The Luke SAAC has required several years of on-site research support to develop its operational usefulness and the system is still evolving and improving. It appears as if the 2E6 will require at least this much support effort (if not more), because of its substantially increased training capabilities.

SECTION III

2E6 QUALITATIVE REVIEW

During the course of this contractual period a thorough qualitative review of the 2E6 was undertaken. The review, was conducted with two perspectives in mind: first, the current training effectiveness of the 2E6 and, second, its potential for enhanced training effectiveness. Areas analyzed included: system and subsystem operation, maintainability, facility management requirements, capacity for flight hour substitution, efficiency of the instructional design features, scheduling, reporting and documentation, syllabus development, and human factors considerations. Cognizant Navy commands, offices and organizations have been verbally apprised of the findings, opinions and conclusions of this review.

The 2E6 represents a complex high technology training device. As such, various interrelated factors have tended to impact the training potential of the device. The user commands, realizing the existence of these complexities, have effected positive measures to optimize daily operations within the constraints of the system design limitations. For instance, a scheduling system has been developed which accommodates the user needs and timetable requirements; a number of tailored syllabuses are being designed to address the variations in fighter type and aircrew experience levels, and many procedural improvements to the instructor/operator routines have been incorporated which significantly enhance device utilization and effectiveness. System design limitations, however, constrain the user commands from fully realizing benefits from the 2E6 training potential. A partial listing of the types of limiting system design characteristics are provided below. Approaches and courses of action to ameliorate these limiting factors have been passed to the responsible organizations during the course of the appraisal.

Instructional Design Features and Fidelity Considerations

- Required parameters are missing from pre-set Initial Condition selection (i.e., aircraft attitude)
- G, Buffet, Visual and G Dimming cues vary from day-to-day depending upon calibration and operator attention to mission.
- Aircrews sometimes inadvertently deselect cues in the cockpit.
- Adaptive Maneuvering Logic (Programmed Target) varies in performance depending upon equipment readiness.
- Instructor controlled target has limited application due to design deficiencies
- Different software flight characteristic models are not linked to corresponding cockpit control calibration settings.

Operation of Demo and Debrief Modes

- Demo storage tapes are not loaded to disc causing loss of demos.
- Demo create process is lengthy and difficult to perform.
- No audio is available on demos.
- Debrief tapes sometimes will not transfer to debrief disc causing loss of mission data.
- Debrief printouts (hard data) are very difficult to understand and are of limited usefulness.

Maintenance of the Device

- Failed components affect system operation (i.e., aircraft handling characteristics).
- Calibration routines are lengthy and difficult to perform.
- Calibration routines are often found in error after system malfunction is noted.
- Stick forces are often out of tolerance.
- No method is available to monitor system performance.
- Programmed Target response varies from day-to-day.

Utilization Documentation

- o Present documentation outmoded and not designed for this type of device.
- o System performance is unknown.
- o Catalog of historical events not available.

The following categories represent Research Development Test and Evaluation (RDT&E) issues which could assist in improving the training effectiveness of the 2E6. Specific examples are provided for each category.

- o Formulate short-, mid- and long-range utilization and instructional strategies.
  Example: To report utilization, two systems are presently used: Individual Flight Activity Reporting System (IFARS) (designed for aircraft) and NAVTRADEV P-4305 (TDU-2 and TDU-3 - designed primarily for maintenance and custodial utilization and availability reporting). The IFARS forms do not lend themselves for simulator utilization reporting and the Utilization Purpose Codes (UPC) used in conjunction with the TDU-2 and TDU-3 are outdated and do not accurately reflect current utilization reporting requirements. A method and procedure for accurately documenting device utilization needs to be developed.

- o Apply state-of-the-art Instructional Design Features (IDFs) within ACMS/TACTS systems.
  Example: The 2E6 contains a dedicated debrief console run by an independent SEL computer. Currently it is seldom used for debriefing aircrews. The training value of this instructional design feature needs to be determined. If it has little training value and/or is so complex and time consuming to operate that it limits training usefulness, then this should be documented and other IDF purchases of this nature eliminated from follow-on ACMS buys. On the other hand, if an examination indicates that it could be beneficial to training, then this subsystem should be redesigned and employed as as an integrated element of the 2E6 ACM instructional strategies.

- o Establish priorities for design and implementation of software and hardware modifications.

- o Ensure "lessons learned" flow to cognizant organizations responsible for developing and/or implementing follow-on equipment and systems such as the 2E7, the AV-8B and VTXTS ACMSs and future TACTS derivatives.
  Examples: Inadequacies exist in 2E6 instructor/operator functions such as: initialization (can only be set up with aircraft in level

flight); creating demonstrations (unable to correct a demonstration "flaw" without reflying the entire run); and inability to create a demo tape and a debrief tape from the same engagement at the same time. These types of inadequacies need to be documented and priorities established in order to:

- implement design changes in the 2E6, and
- ensure these design inadequacies are not incorporated into follow-on acquisitions.

SECTION IV

ACM PERFORMANCE MEASUREMENT

The ACM engagement model as portrayed in Figure 1 presents the states which a fighter aircraft might encounter from the moment of engagement to either disengagement or kill. A composite picture of a fighter crew's success over an engagement or series of engagments can be derived once measures of effectiveness are developed for each of these states.

A thorough review of means for measuring each state was completed. Attention was first devoted to developing a method of assessing every aspect of maneuvering depicted in the top three states of Figure 1 -- offensive, defensive, and neutral. Previous work demonstrated that the Rear Hemisphere Performance Index developed by the Center for Naval Analysis was an extremely effective means for assessing classical offensive, neutral and defensive maneuvering. That is, maneuvering in which the primary objective was to fly to the opponent's rear hemisphere in order to achieve a position to employ guns or heat seeking missiles. With the advent of all-aspect weaponry, however, it is now possible to employ weapons without necessarily maneuvering to the opponent's rear. The need for an all-aspect measure of maneuvering effectiveness in addition to the Rear Hemisphere Performance Index became obvious. A generic all-aspect equation was developed and is currently in the process of refinement into an All-Aspect Maneuvering Index (AAMI) which will be discussed in more detail in Section V. These two measures, it is felt, will accurately depict the full range of ACM offensive, defensive and neutral maneuvering.

However, other states of an ACM engagement remain in which these indicators do not discriminate well, such as, entering specific weapon's envelopes and fighter aircrew capabilities to outmaneuver enemy fired missiles. A thorough analysis was conducted to determine the best means for achieving the capabilities to assess degrees of effectiveness for envelope related ACM engagement states. Five different approaches were felt feasible within today's state-of-the-art technology to provide a demarcation of weapon

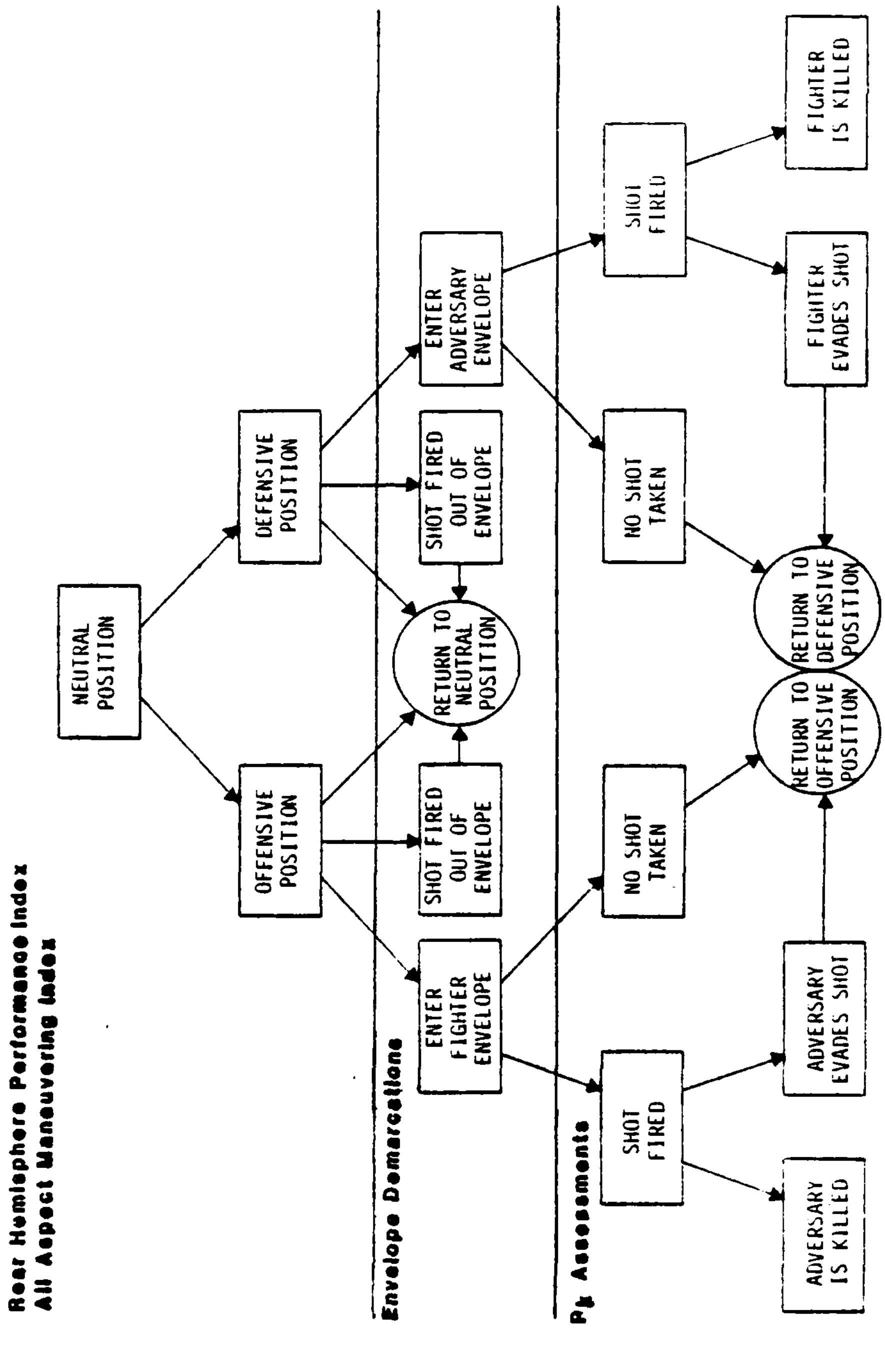

Figure 1. Model of an ACM Engagement

envelope penetration. A trade-off study was performed to determine which of the approaches offered the best prospects for accomplishing the goals of a TEE effort. The conclusions of the various approaches are presented in Table 1. The trade-off examined considerations such as degree of real-world fidelity, ease of inserting into the 2E6, and amount of commonality between the 2E6 and TACTS.

The most promising means for approximating weapons envelope demarcations appears to be the dynamic missile simulations currently in use on the TACTS ranges. Not only do these simulations possess the highest degree of fidelity of any of the measures but it appears as if they may be the simplest to incorporate into the 2E6. Efforts are currently underway to explore further the conceptual feasibility of inserting the Mode 3 missile simulations into the 2E6. If the Mode 3 measure cannot be incorporated into the 2E6, other approaches listed in Table 1 will be selectively reviewed for their potential application.

To date, training aircrews to outmaneuver enemy-fired missiles has been largely remiss. Two reasons account for this deficiency. First, until the advent of ACM simulators, it has been virtually impossible to visually simulate incoming enemy-fired missiles. This fact severely limited an aircrew's capability to develop counter moves. Second, no adequate method for measurement currently exists in which to assess the P_k of the missile at the instant of firing with end-game P_k in which the missile closes the target for a kill. Exploring avenues to adapt P_k assessments in this manner might permit significant increases in combat readiness to occur virtually overnight. It appears as if dynamic missile simulation software may be amenable to this P_k approach. This concept will be closely analyzed for feasibility.

Table 1. Envelope Trade-off Considerations

Approaches to Envelope Assessment	Advantages	Disadvantages
Dynamic missile envelopes from the TACTS range.	1) Available USN- and USAF-wide on TACTS now. 2) Provides common measurement base between 2E6 and TACTS. 3) Can readily be incorporated as USN/USAF standard. 4) Appears to be relatively straight-forward to install in the 2E6. 5) Can serve to validate and/or calibrate internally designed ACM simulator missile simulations against the TACTS range standard. 6) Provides the best available approximation of the entire dynamic missile envelope. 7) Appears easily adaptable to accommodating P_k assessments.	1) No gun measures available.
Launch Acceptability Regions (LARS) (LARS Curve)	1) Provides a good approximation of the dynamic missile envelope. 2) May be available in the 2E6 software.	1) No gun measures available. 2) Not used in the TACTS. 3) May be difficult to incorporate as a service-wide standard. 4) 2E6 LARS indicates approximately only 85 percent of the full-missile envelope. 5) Appears to take more man-hours to incorporate in the 2E6 than TACTS dynamic missile envelopes. 6) May not be feasible to develop the capability to validate and/or calibrate internally designed ACM simulator missile simulations.

Table 1. Envelope Trade-off Considerations (cont'd)

Approaches to Envelope Assessment	Advantages	Disadvantages
		7) P_k assessments may not match those used on the TACTS range.
Generically developed envelope equations.	1) Might be possible to accommodate gun envelope.	1) Not as good an approximation as dynamic missile simulations or LARS. 2) No P_k assessment available. 3) Might require extensive work to develop equations. 4) Possibly more work to validate the curves. 5) Not possible to serve as a validation and/or calibration scale for internally designed ACM simulator missile simulations. 6) Might be difficult to get approved as a USN/USAF standard. 7) Not used in the TACTS.
Dynamic Rule-of-thumb envelopes	1) Available USN-and USAF-wide on TACTS now. 2) Fairly easily incorporated in 2E6.	1) No gun measures available. 2) Found to not correlate well with shots taken on TACTS validation runs. 3) Cannot accommodate P_k assessments. 4) May be difficult to get approved as a USN/USAF standard. 5) Not possible to serve as a validation and/or calibration scale for internally designed ACM simulator missile simulations.

Approaches to Envelope Assessment	Advantages	Disadvantages
Internal 2E6 missile simulation envelopes.	1) Currently installed in the 2E6. 2) May be relatively easily obtainable. 3) Might be useful for guns.	1) Accuracy currently unknown. 2) Less accurate than TACTS missile simulations. 3) Could most probably not be used in the TACTS. 4) Capability to serve as a USN/USAF standard very questionable. 5) Feasibility for incorporating P_k assessments currently unknown. 6) Not possible to validate and/or calibrate with itself.

SECTION V

ALL-ASPECT MANEUVERING INDEX (AAMI)

Today the state-of-the-art in missile development has permitted a fundamental departure from historical ACM maneuvering doctrine. It is now possible to merely point the nose of the fighter aircraft in the direction of the adversary from any adversary aspect angle and launch a missile (within range) to achieve a kill. It is not necessary to achieve a (rear-hemisphere) position behind the adversary before launching a missile as required previously. The Center for Naval Analysis (CNA) developed a Rear-Hemisphere Performance Index (RHPI)[1] which was validated in a 1979 Navy in-house effort during a series of validity tests at NAS Oceana. The RHPI was judged to accurately depict historic ACM maneuvering doctrine. The content validity testing, however, demonstrated a need for an all-aspect maneuvering index (AAMI) to account for variance resulting from forward-hemisphere fired shots. This section provides a general overview of all-aspect maneuvering considerations while Appendix B furnishes a more detailed description of the steps taken in the development process.

There are many variables which impact the offensive and defensive maneuvering relationships in an ACM engagement. Variables such as radar gimbal limits, missile seeker-head tracking rates, sun angle, ground clutter, closing velocities, altitude and variations in G will all influence to a greater or lesser extent ACM maneuvering offensiveness and defensiveness. The steps to develop the AAMI are to formulate variables which have the greatest influence upon the spatial relationship; that is, the offensiveness and defensiveness between aircraft during a timed engagement.

The work is an expansion of the RHPI concepts which were previously validated for rear-hemishpere ACM maneuvering. The primary variable used in the formulation process is antennae-train-angle (ATA) which provides a

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[1]Simpson, W.R., Development of a Time-Variant Figure-of-Merit for Use in Analysis of Air Combat Maneuvering Engagements, Naval Air Test Center, MD: Strike Aircraft Test Directorate, July 1976.

measure of how close the fighter's nose points to the adversary aircraft (measured in degrees). This variable is currently being shaped by two other variables: (1) range (R) as influenced by (2) angle-off-the-tail (AOT).

Once ATA, R and AOT have been tailored to accurately depict offensive and defensive ACM maneuvering, other variables will be systematically reviewed for their degree of impact. Those variables found to influence regions of ACM maneuvering performance sufficient enough to warrant inclusion in the AAMI formulation will be tested and incorporated as required. The results of this testing will be documented in the next phase of this TEE effort.

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APPENDIX A

SUMMARY OF INTERVIEWS

Synopsis of Field Trip Interviews:

Place: Luke AFB (SAAC)
Date: 17-18 July 1980

Received an overview of Air Force Programs involving ACM performance measurement. This included approaches by Canyon Research, the Vought Good Stick Index (GSI) and in-house efforts including TACSPACE and the Navy developed Readiness Estimation System (RES). The briefing included future Air Force plans and major thrusts, including the achievement of a capability to predict aircrew performance.

Provided a more extensive update on Luke's current efforts relating to ACM performance measurement. Directed through a tour of the Luke Simulator for Air-to-Air Combat (SAAC) in which Person-System Integration (PSI) and Naval Training Equipment Center (NAVTRAEQUIPCEN) personnel were able to operate and "fly" the simulator. This provided valuable insight for comparing the potential effectiveness of the 2E6 in relation to the mature SAAC operation. Instructional features and SAAC modes of operation were examined in view of possible introduction or impact on the 2E6.

Extensive interviews conducted proved invaluable from a "lessons learned" perspective. Topics covered included the instructional knowledge gained from several years experience controlling the SAAC training program, professional opinions concerning empirically derived SAAC utilization patterns which tend to optimize simulator use, and personal methods and techniques used for assessing aircrew experience levels in the operational environment. Other subjects involved a detailed breakdown of their current syllabus with supporting rationale and discussions concerning their efforts to develop objective ACM performance predictors including their current transfer-of-training (TOT) experiment in conjunction with the F-4 Fighter Weapons School at Nellis AFB. There is a real interest in building dialogue and establishing formal as well as informal lines of communication with the Navy - NAS Oceana, in particular - in Navy ACM simulation efforts. Field trip members agreed to assist in hosting a tour of the 2E6 facility in the future.

A resident psychologist with prior F-4 flight experience briefed TEE members on Luke's current ACM performance measurement efforts. They are exploring the Navy RES concept. It was mentioned that the RES was the only system Luke has found so far which "works." Discussed was Luke's approach to integrating the RES into a "performance predictor system" for the USAF. It involves measuring increases and decreases in the 1v1 ACM states step function and Performance Index (PI) portions of the RES system.

Place: Williams AFB (AFHRL)
Date: 18 July 1980

Presented anticipated USAF reorganization plans and their impact upon Air Force aircrew performance measurement and training effectiveness programs. Described the projected F-16 Advanced Simulator for Undergraduate Pilot Training (ASUPT) simulator research goals in relationship to ACM missions. Reviewed previous USAF projects in relationship to operation "lessons learned" which might influence the Navy's goals and objectives. Opinions were expressed concerning the potential relevance of ongoing USAF projects to the Navy's TEE effort, with associated points of contact regarding the future investigative endeavors.

Place: Nellis AFB (Red Flag)
Date: 23 July 1980

Received extensive breakdown of the Red Flag concepts of training to combat readiness and a series of "lessons learned" to date. Discussed the severe data collection problems confronting McDonnell Douglas personnel in their endeavors to analyze operational results from numerous aircraft sorties in a realistic threat scenario. Provided with copies of Red Flag's data debrief forms. Reviewed performance measurement criteria considered pertinent for Fed Flag type of operations. The interview proved valuable in relating

ACM performance measurement in context with a more complex threat training environment. Discussed potential uses of simulation to assess Red Flag exercises.

Place: Nellis AFB (57th FWS)
Date: 23 July 1980

Given an overview of the Nellis Fighter Weapons School structure and directed to pertinent personnel concerning our areas of interest. Discussed curriculum breakdown for the various tactical aircraft. Received opinions concerning current USAF views toward Instructional System Development (ISD) and ground syllabus instructional philosophies. Discussed the differences in training concepts between Red Flag and the Fighter Weapons School at Nellis.

Place: Nellis AFB (414th FWS)
Date: 24 July 1980

Received in-depth review of the F-4 training syllabus with 414th officers. Analyzed the USAF methods and procedures for analyzing missile and gun kills through gun camera tracking techniques. Discussed the TOT experiment from the instructor's perspective. Agreed to maintain close USAF-USN liaison in the future. Received copies of the ACM portion of the 414th curriculum and a copy of the kill criteria agreed upon within the Air Force.

Place: Nellis AFB
Date: 24 July 1980

Very pertinent discussions were conducted concerning the current USAF effort to demonstrate transfer-of-training from the Luke SAAC to the 414th F-4 Fighter Weapons School at Nellis AFB. Stimulating discussions transpired concerning the relevance of the preliminary findings to increase combat readiness among USAF aircrews. The Air Force has collected both subjective and objective measures from their initial efforts. Although the sample sizes are too small to affirm or deny TOT, the preliminary data offer promising prospects. The current Navy TEE effort should follow these developments closely as they may directly impact the scope and direction of ongoing research.

APPENDIX B

AAMI DEVELOPMENT OVERVIEW

Appendix B discusses the derivation of the general All-Aspect Maneuvering Index (AAMI). The purpose for the development of the AAMI was to construct a measure which could accurately reflect the spatial relationships among aircraft in an ACM environment.[1]

The general All-Aspect Maneuvering Index (AAMI) is mathematically defined as follows:

$$AAMI = F_{OFF}\ f(R_{AOT}) \qquad \text{Where:}$$

$$F_{OFF} \text{ is either } F_{OFF_1} = 100\left(\frac{90-ATA}{90}\right), \text{ or}$$

$$F_{OFF_2} = 100\left(\frac{180-ATA}{180}\right),$$

and, $F(R_{AOT})$ is an empirically derived function which shapes the value of AAMI as range and AOT vary.

The primary variable required for developing an AAMI depends upon antenna-train-angle (ATA). The closer a fighter points toward the adversary, the more offensive it becomes. Building upon a scale of zero to 100, this concept can be expressed mathematically in several ways. One way is to state that the closer an adversary advances in front of the wing-line of the fighter (ATA = 90 degrees at the wing-line), the more offensive the fighter becomes. Mathematically, this can be expressed as fighter offensiveness:

$$F_{OFF_1} = 100\left(\frac{90-ATA}{90}\right)$$

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[1]The AAMI is an empirically derived function based upon changing values of antennae-train-angle (ATA) as shaped by variations in Range (R) and angle-off-the-tail (AOT). The offensive posture of the fighter is measured on a scale of zero to 100; zero representing no offensiveness and 100 being the highest state of offensiveness. The adversary's offensiveness is measured in the same manner as the fighter's. The extent to which the adversary is offensive against the fighter will determine the fighter's defensiveness. (It should be noted that, with all-aspect weapons, two opponents approaching each other head-on can be both offensive and defensive at the same time since each participant is capable of launching a missile against the other.)

Another means of expressing this concept is to state the further the adversary is displaced from the fighter's six-o'clock position (ATA equals 180 degrees at the six-o'clock position), the more offensive the fighter becomes. Mathematically this can be expressed as offensiveness:

$$F_{OFF_2} = 100\left(\frac{180-ATA}{180}\right)$$

Both mathematical expressions are basically the same with a few subtle differences. The first expression provides a better graphical resolution for ATA 90 degrees and assumes any adversary position from the fighter of ATA 90 degrees is of no offensive consequence and sets the equation equal to zero for these values. The latter expression delivers less resolution for $ATA < 90$ degrees, but provides a graphical representation for all values of ATA ($0 \leq ATA \leq 180$). Both of these mathematical expressions are undergoing evaluation to determine which one best defines the all-aspect posture. These primary mathematical expressions for describing all-aspect weapons maneuvering efficiency were compared to a 300-second trial engagement to test for content validity.

A 300-second test engagement was selected as the preliminary standard from which to analyze the feasibility of the concept formula. In the test engagement, the programmed target (PT) and the fighter initially were placed in an abeam (90^{o} of the nose) position. The PT flew a straight-line path for the first 100 seconds; the fighter was maneuvered from the abeam position to a position behind and pointing at the PT ($ATA < 10^{o}$) for the first 52 seconds. The fighter's nose was pulled away to one side of the PT (55-65 seconds) until the fighter's ATA was greater than 90^{o}. The fighter was then returned to a position behind and pointing at the PT (5^{o}-10^{o} ATA) for the remainder of the 100-second interval. At 100 seconds, the PT was allowed to maneuver at Level 3 (70 percent proficiency) of the Adaptive Maneuvering Logic (AML). The fighter's nose was held as close to the PT as possible ($ATA < 10^{o}$); however, a rather large excursion occurred between 150 and 160 seconds. At approximately 200 seconds into the test engagement, the fighter closed the range to enable a "slashing" gun attack in which the fighter subsequently overshot (flew in front of) the PT. The remainder of the 300-second test run consisted of three scissor (criss-cross) maneuvers with the fighter gradually achieving an offensive position on the PT (i.e., working the fighter to the rear position of the PT). The test engagement was terminated at 300 seconds. This test engagement was chosen because of its clear and concise changes in offensive-defensive maneuvering which should be clearly depicted by any Performance Measurement System (PMS).

Data runs for both F_{OFF_1} and F_{OFF_2} have been compared for this 300-second test engagement and are depicted in Figure B-1 (the top two curves). The upper portions of the curves are congruent; the curve for F_{OFF_1} is basically a truncated version of F_{OFF_2} from 50 on the ordinate axis and magnified by a factor of two. Either curve can be used to represent successfully all-aspect maneuvering. There are minor advantages for each curve: F_{OFF_1} provides an expanded view of the offensive position; F_{OFF_2} displays the entire range of ATA values for the fighter which permits analysis of maneuvering for ATA values 90°, but provides less discrimination of curve variances at the higher F_{OFF} values. Future experience gained through working with the two curves and comparing their advantages and disadvantages will permit selection of one as a standard, which selection will be based upon the greatest utilitarian value.

The bottom curve of Figure B-1 displays the relative range between fighter and adversary for the 300-second test engagement. Region B graphically demonstrates the requirement for a range function to refine the basic AAMI formula. The range between aircraft for this region approaches the minimum distances for effective weapons release and, as such, represents less of an offensive capability than the preceding Region A in which the range is closer to the heart of the weapons envelope. Both F_{OFF_1} and F_{OFF_2}, however, indicate the same relative values of offensiveness for each region. A function to correlate range with F_{OFF} $(f(R_{AOT}))$, therefore, is necessary. Efforts are currently underway to accomplish this requirement. An outline of the methodology used in this developmental process follows:

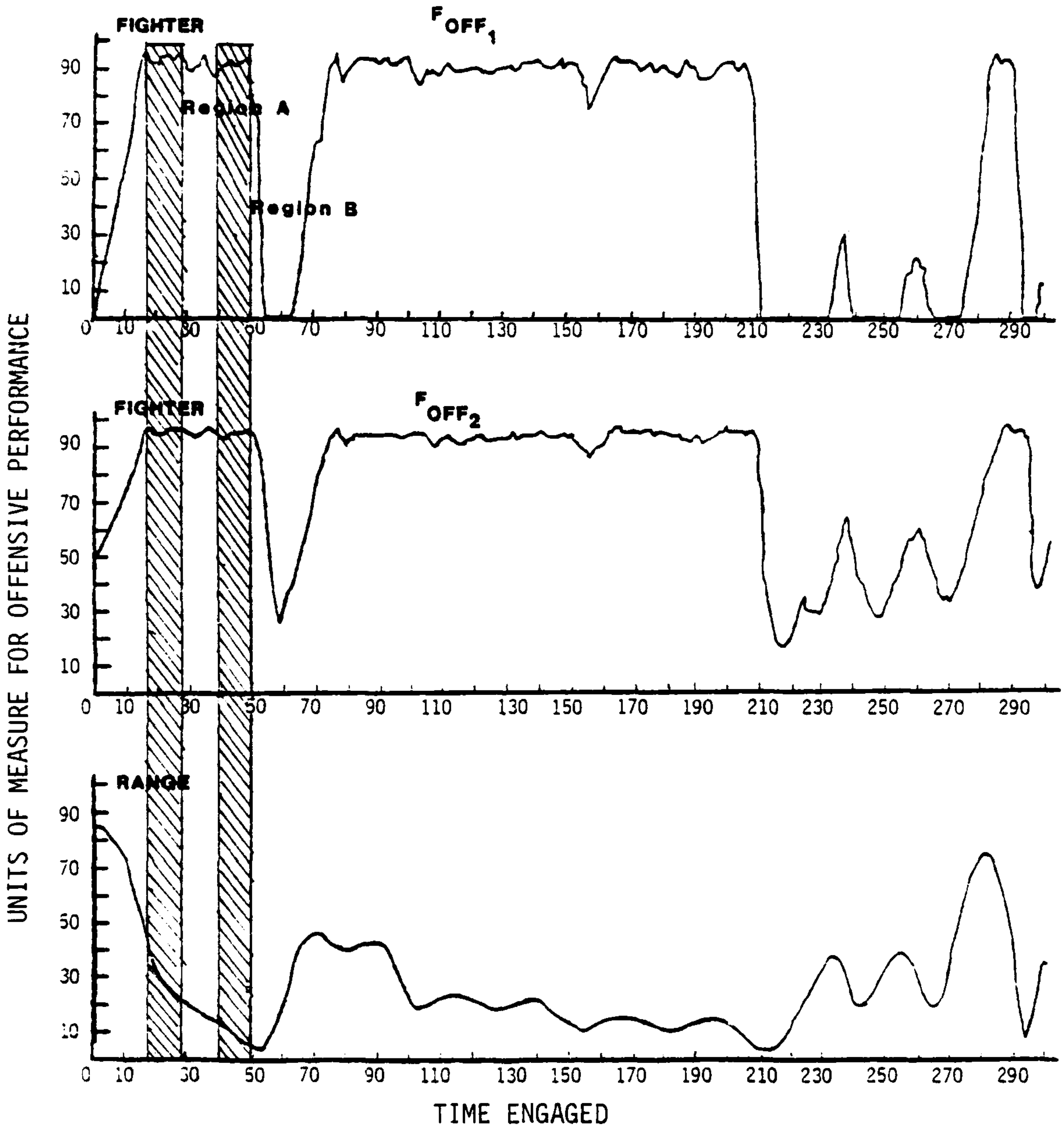


Figure B-1. 300 Second Test Engagement For F_{OFF}

$f(R_{AOT})$ Development

Initially LARS tables, as discussed in Section V, were reviewed, and generalized maximum (R_{MAX}), minimum (R_{MIN}), and optimum (R_{OPT}) missile ranges selected for three AOT sectors, 0^{o}-45^{o}; 45^{o}-135^{o}; and 135^{o}-180^{o}. A constant range value was selected for maximum visual sighting (R_{VIS}). Weighting values were assigned for each of the ranges:

Within R_{OPT} band width	= 1.0
From the outer boundaries of R_{OPT} to the R_{MIN} or R_{MAX} boundaries	= 0.6
From the R_{MAX} boundaries to the R_{VIS} limits	= 0.2
Beyond R_{VIS}	= 0.0

A representative example of the step function for AOT sector 135^{o}-180^{o} is included as Figure B-2. A preliminary analysis of this approach indicated a qualitative improvement over F_{OFF} alone; however, large curve gradients resulted as the range values crossed the established range boundaries which necessitated a smoothing of the $f(R_{AOT})$.

The next phase of the development effort expanded the number of AOT sectors from three to seven (0^{o}-30^{o}, 30^{o}-60^{o}, 60^{o}-90^{o}, 90^{o}-120^{o}, 120^{o}-150^{o}, 150^{o}-165^{o}, and 165^{o}-180^{o}) which permitted a finer discrimination of the range variations. In addition, the range function was modified from a "step" increase in range boundaries to a linear progression as depicted in Figure B-3. This modification has resulted in a much improved "smoothing" of the AAMI curve as demonstrated by Figure B-4.

Validity testing is currently in progress using a testing procedure in which AOT and ATA are held constant and a fictitious fighter, driven from outside R_{MAX} to inside R_{MIN}, and the calculations are run for 1000-foot segments. Seven AOT run-in lines are being used, as depicted in Figure B-5. Subject matter experts are analyzing the resultant peaks, valleys and slopes of the curves for content validity.

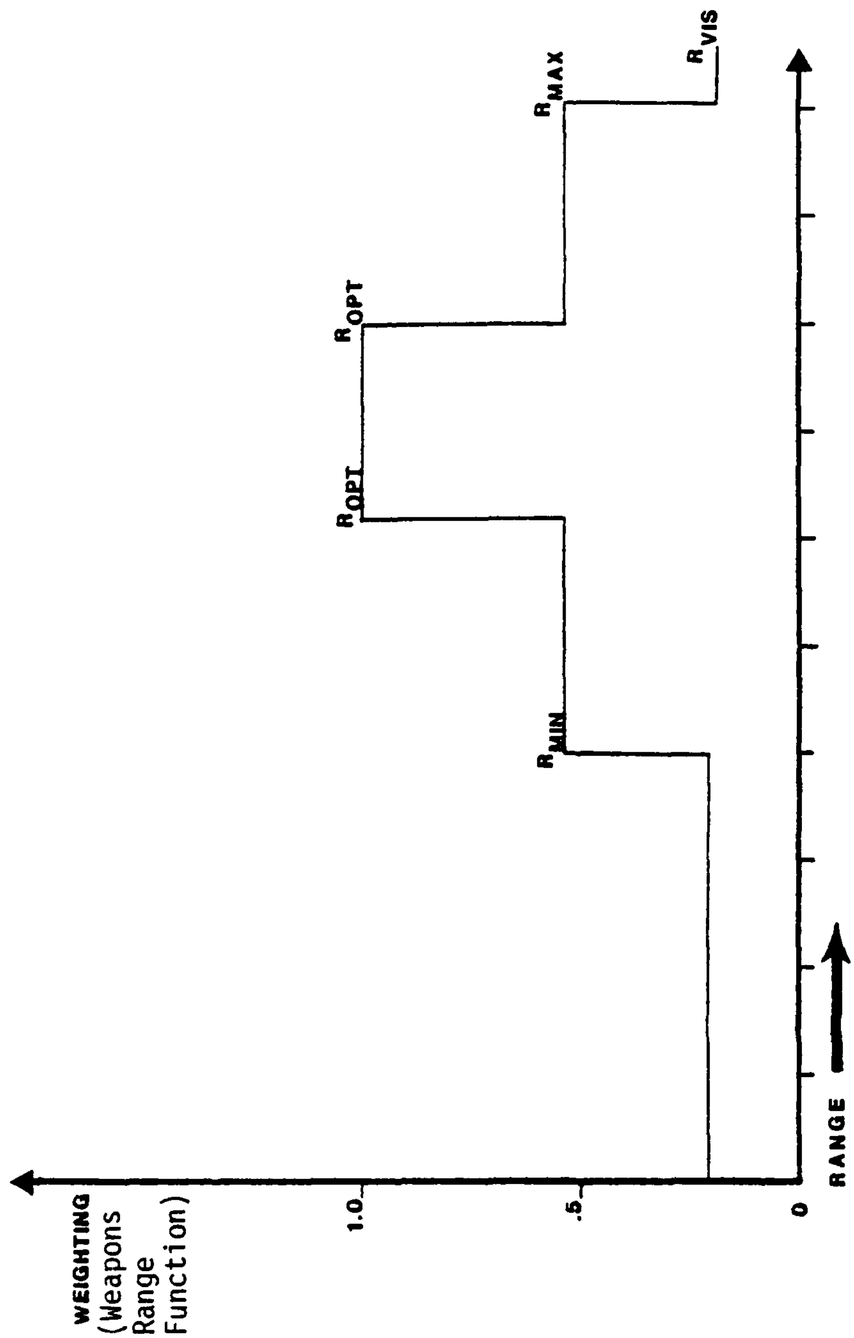


Figure B-2. Range Function For Fighter AOT 135 - 180 Degrees

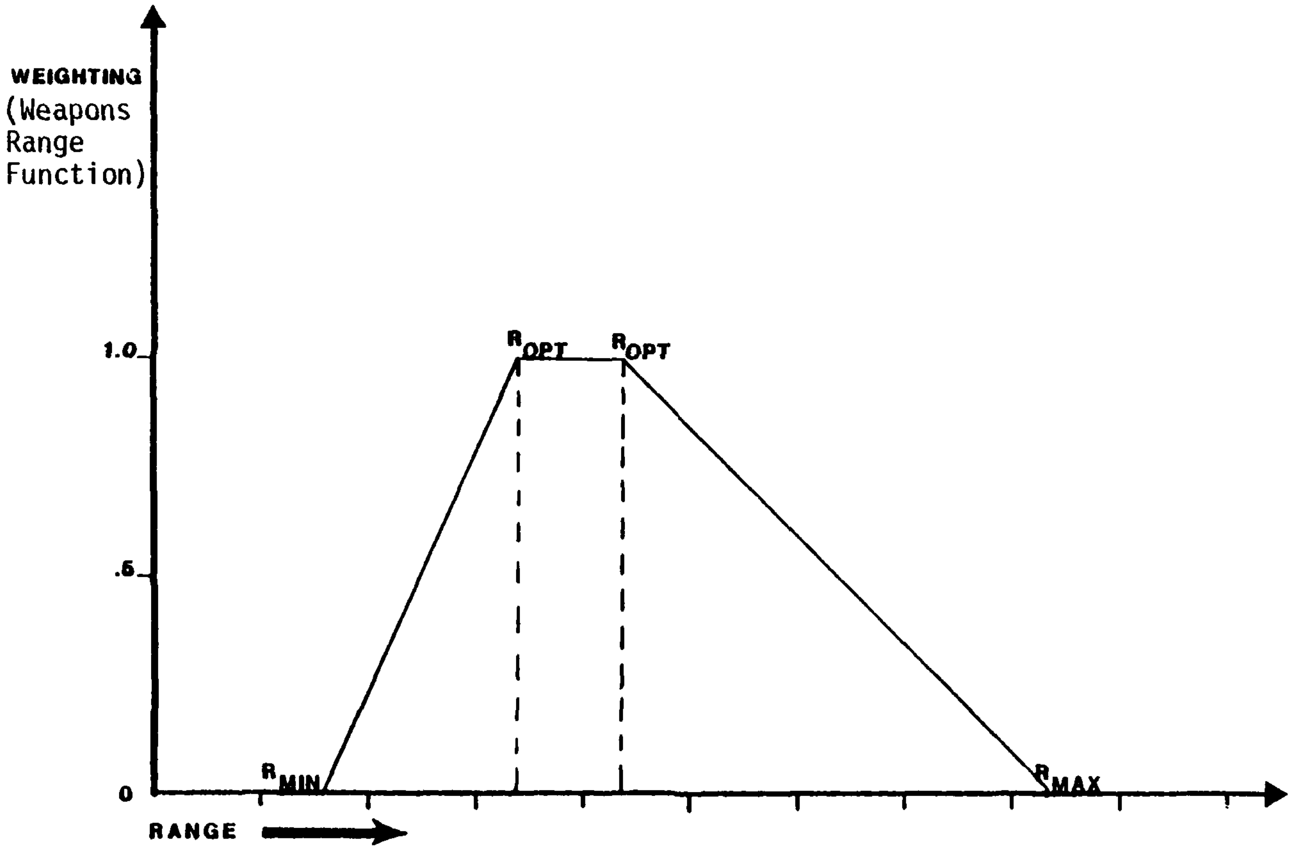


Figure B-3. Range Function For Fighter AOT 150 - 165 Degrees

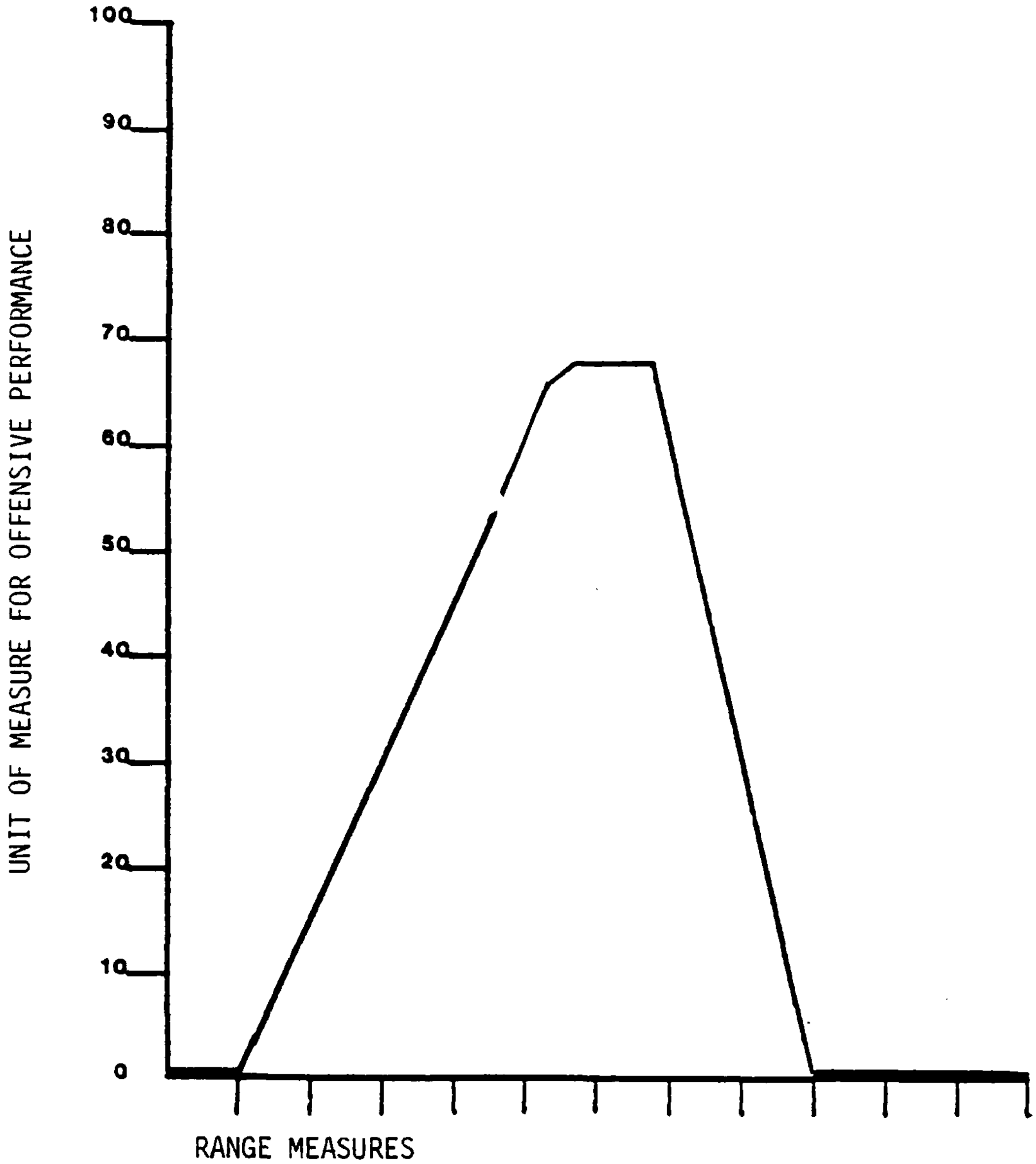
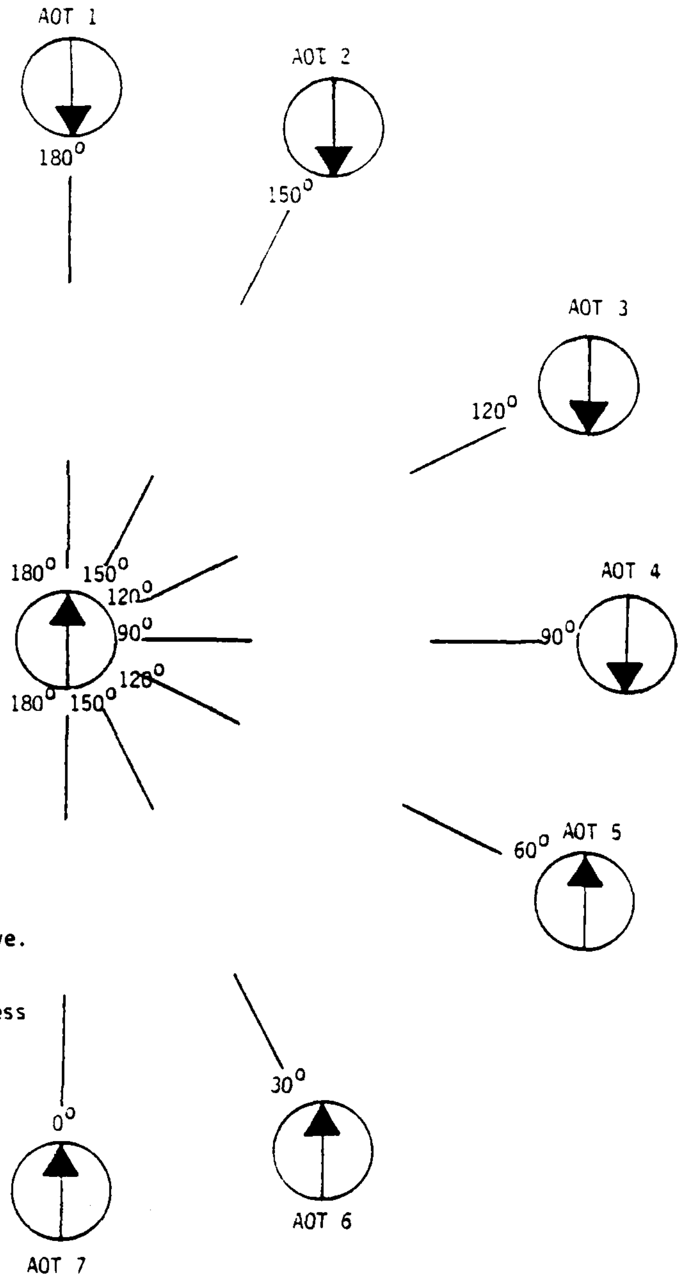


Figure B-4. Modified AAMI Curve

(The effect of Weapons Range Model on AOT Function)



NOTE: AOT, or Angle-Off-The Bogey's-Tail, is calculated irrespective of Fighter/Bogey heading depending upon perspective. I.e., ^{F}AOT = Fighter's position in degrees off the Bogey's tail regardless of Fighter heading.

FIGURE B-5 POLAR CHART OF AOT TEST SAMPLES

Other variables, in addition to AOT, ATA and range, impact offensive-defensive maneuvering. These include altitude, airspeed, closing velocity, G and lead/lag. These variables will be systematically evaluated for their impact upon the AAMI measures. Those variables significantly influencing maneuvering conditions will be incorporated into the AAMI equation providing an enhanced refinement to the $f(R_{AOT})$ function.

LIST OF ABBREVIATIONS, ACRONYMS AND SYMBOLS

AAMI	All-Aspect Maneuvering Index
ACM	Air Combat Maneuvering
AFB	Air Force Base
AOT	Angle-Off-The-Tail
ASUPT	Advanced Simulator for Undergraduate Pilot Training
ATA	Antennae-Train-Angle
CNA	Center for Naval Analysis
FRS	Fleet Replacement Squadron
FWS	Fighter Weapons School
GSI	Vought Good Stick Index
IDF	Instructional Design Feature
IFARS	Individual Flight Activity Reporting System
IP	Instructor Pilot
ISD	Instructional System Development
LARS	Launch Acceptability Regions
NAS	Naval Air Station
NAVTRAEQUIPCEN	Naval Training Equipment Center
PI	Performance Index
P_k	Probability of Kill
PMS	Performance Measurement System
PSI	Person-System Integration
PT	Programmed Target
R	Range
R_{MAX}	Maximum Range
R_{MIN}	Minimum Range
R_{OPT}	Optimum Range
RDT&E	Research Development Test and Evaluation
RES	Readiness Estimation System
RES-RIF	Readiness Estimation System-Readiness Index Factor
RHPI	Rear-Hemisphere Performance Index
RIO	Radar Intercept Officer
SAAC	Simulator for Air-to-Air Combat
TACTS	Tactical Aircrew Combat Training System
TDU	Training Device Utilization
TEE	Training Effectiveness Evaluation
TOT	Transfer-of-Training
USAF	United States Air Force
UPC	Utilization Purpose Codes