Technical Memorandum

THE NUMERICAL ANALYSIS OF AIR COMBAT ENGAGEMENTS DOMINATED BY MANEUVERING PERFORMANCE

by

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20 June 1977

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NAVAL AIR TEST CENTER
PATUXENT RIVER, MARYLAND
The numerical analysis of air combat engagements dominated by maneuvering performance.

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Air combat maneuvering  
ACM analysis  
Flight test

An analysis capability has been developed for use by the training and test and evaluation communities to quantify air combat maneuvering engagement outcomes. Details of this analysis capability in the form of computer programs for producing analytic engagement data are presented. Results from a sample test data base are presented to illustrate analysis and conclusion forming methods. The conclusions from the sample data set are not intended to represent actual strategic decisions but are exemplary only. These analytical programs have been implemented at NAVAIRTESTCEN (SA43), the Naval
20.

Weapons Center (Code 4072), the Air Combat Maneuvering Range (via COMITAEWNINGPAC), and the Center for Naval Analyses.
PREFACE

Recent emphasis on Air Combat Maneuvering (ACM), including the congressionally directed AIMVAL/ACEVAL trials, has created interest in developing methods of analysis to assess aircraft capabilities, pilot proficiency, force requirements, etc. Several methods are in use by industry, but many emphasize specific aircraft characteristics and are therefore limited in their application. This report describes an ACM analysis method developed by Mr. W. S. Stewart (Naval Weapons Center), Dr. R. A. Oberle (Center for Naval Analyses), and Mr. W. R. Simpson (NAVAIRTESTCEN). Several aspects of these analysis methods are being explored jointly by the Navy Fighter Weapons School, the Naval Weapons Center, the Center for Naval Analyses, and NAVAIRTESTCEN. These analysis techniques have been implemented at NAVAIRTESTCEN, the Naval Weapons Center, the Air Combat Maneuvering Range, and the Center for Naval Analyses. The NAVAIRTESTCEN participation was funded by the Joint Technical Coordinating Group/Munitions Effectiveness chaired by the Army Materiel Systems Analysis Agency, Aberdeen, Maryland. Assistance in the application of these techniques to specific problems of air combat is available through:

a. NAVAIRTESTCEN (SA43)
b. NAVWPNCEC (Code 4072)
c. Naval Air Combat Maneuvering Range (CNA Rep to COMFITAEC-WINGPAC)
d. Center for Naval Analyses
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INTRODUCTION

BACKGROUND

1. The development of adequate analysis techniques in the area of Air Combat Maneuvering (ACM) is vital to the definition of the mission effectiveness of fighter aircraft, performance devices installed on fighter aircraft, and aircraft weapon systems. For the most part, however, the development of ACM testing and analysis procedures has lagged other evaluation areas such as air-to-ground or aircraft performance and flying qualities testing. Beginning in late 1971, the Commander, Operational Test and Evaluation Force initiated development of stochastic ACM analysis techniques. This effort resulted in the finite state maneuver conversion model (reference 1) and its application to the ACM evaluation of a thrust vectored attack aircraft as part of CNO Project P/V-2 (reference 2). An additional application of the maneuver conversion model to an in-flight ACM evaluation was made at NAVAIRTESTCEN for the F-11A thrust vector control system (reference 3). Following these applications, the finite state maneuver conversion model was extended by the introduction of a continuous time/continuous state performance index (reference 4). The performance index scales the offensive value of the interaircraft dynamics via the product of angle, range, and energy penalty functions. Numerical analysis of the stochastic process resulting from the application of these two evaluation techniques to sample ACM engagements has been an ongoing effort at NAVAIRTESTCEN, NAVWPNCEN, COMFITAEW-WINGPAC and CNA. The goal of the exploitation has been the development of tactically meaningful readiness measures through further mathematical development of the ACM models for application in aircraft test and evaluation and pilot training.

PURPOSE

2. This memorandum is intended as a supplement to references 1 and 4 to discuss the implementation of ACM analysis methods at several facilities, to present further developments, and to illustrate the use of the analytical methods via application to an example data set selected from a family of flight tests conducted on the Air Combat Maneuvering Range (ACMR). The data base and the numerical techniques described are also being used to guide further investigations into stochastic models useful for evaluating air combat maneuvering engagements.


METHOD OF TESTS

3. Test methods for ACM evaluation are detailed in reference 4. This memorandum addresses the form of numerical techniques applied to quantitative ACM data.

ANALYSIS PARAMETERS

4. The primary ACM parameters to be used in this memorandum are given in table I. A complete listing of general technical terms is presented at the end of this report.

Table I

<table>
<thead>
<tr>
<th>Aircraft Parameters</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Angle of Attack (AOA)</td>
<td>Angle between the free stream flow and the airplane reference line</td>
</tr>
<tr>
<td>Normal Acceleration (N_z)</td>
<td>The load factor taken perpendicular to the flight path</td>
</tr>
<tr>
<td>Altitude (ALT)</td>
<td>Geometric altitude above ground level</td>
</tr>
<tr>
<td>Indicated Airspeed (IAS)</td>
<td>Airspeed measured by AIS uncorrected for position error</td>
</tr>
<tr>
<td>Specific Energy (E_s)</td>
<td>Sum of the weight specific kinetic and potential energies</td>
</tr>
<tr>
<td>Target Mach Number (MT)</td>
<td>Mach number of the target airplane</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Interairplane Parameters</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Range (R)</td>
<td>Line of sight distance between the c.g. of two airplanes</td>
</tr>
<tr>
<td>Closing Velocity (VC)</td>
<td>Time rate of change of range</td>
</tr>
<tr>
<td>Antenna Train Angle (ATA)</td>
<td>The angle between the aircraft reference line forward of the c.g. and any sight line</td>
</tr>
<tr>
<td>Angle Off Tail (AOT)</td>
<td>The angle between the aircraft reference line aft of the c.g. and any sight line</td>
</tr>
</tbody>
</table>
Table I (Cont'd)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Performance Index</td>
<td>A time variant figure-of-merit based on angular, range and energy penalty functions (detailed in reference 4)</td>
</tr>
<tr>
<td>Conversion Coefficient</td>
<td>An ACM state adaptation of the performance index (detailed in this memorandum)</td>
</tr>
<tr>
<td>ACM State</td>
<td>Maneuver conversion model state (detailed in reference 1)</td>
</tr>
</tbody>
</table>

ANALYSIS METHODS

5. The primary analysis methods employed in this report are the maneuver conversion model (detailed in reference 1) and the performance index model (reference 4). The maneuver conversion model characterizes an ACM engagement as a realization of a semi-Markov process with state conversion probabilities and time in state distributions. The performance index model is a continuous state continuous time stochastic process. A secondary analysis method, the conversion coefficient, combines the continuously varying measurement of the performance index and the state definitions of the maneuver conversion model to yield a third continuous time process. This third model, although suffering from discontinuities at state boundaries, is also being investigated for applicability to ACM evaluation. These models are used in combination because of their complimentary nature and the fact that the same conclusions follow from the three methodologies. Even though the maneuver conversion model includes a no-history Markov assumption and the performance index and conversion coefficient models assume a continuous time dependence, no conflict between results has yet been observed, nor is any expected. It is anticipated that for field application the analysts can select any of the methodologies for planning and evaluating a group of ACM flight tests. The methodology will primarily be chosen on the basis of off-line computational capability as well as the mathematical sophistication of the intended data usage.
ANALYSIS PROGRAMS

GENERAL

6. An analysis capability has been developed to define pertinent information and identify significant conclusions for air combat maneuvering engagements up to four fighter aircraft versus four target aircraft. Computer programs are available which calculate analysis data for specific aircraft pairs, fighter or bogie section analysis data for two-on-one engagements, and a stochastic analysis program for two-on-one engagements which is extendable to many versus many. The primary modes of analysis in these programs are the characterization of the semi-Markov parameters of the maneuver conversion model and a one dimensional evaluation of the stochastic process during the performance index model, together with stochastic data for the conversion coefficient and an expression of the expected paths for a statistical sample. The resulting numerical techniques are being used by the authors to support further theoretical development. For example, in reference 4, a feedback sequence leading to the development of a predictor model is discussed. Achievement of this predictor model requires a theoretical characterization of the underlying probability space for which the performance index and conversion coefficient are natural realizations. Identification of this underlying probabilistic structure is the goal of the ongoing investigations.

PAIRED ANALYSIS

7. The first step in the analysis is the computation of analysis parameters for fighter-to-adversary pairs in the engagement. The NAVAIRTESTCEN implementation of the paired analysis computer program is given in appendix A. Input is taken as the aircraft and interaircraft data of table I. These data are directly available from tests conducted at the ACMR in Yuma, Arizona, but can also be computed from use of radar data and onboard tape. Required inputs to the program are given in table II. These inputs are assumed to be at 1 second intervals from initialization. The beginning of the engagement can be taken analytically (such as at first visual contact) or mathematically (such as a fixed interaircraft range). Because of the inconsistency of results initialized at first visual contact, the latter is recommended.
Table II
Input Required for Paired Analysis Program

<table>
<thead>
<tr>
<th>Input</th>
<th>Definition</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>TITLE</td>
<td>A 50-character identifier of the engagement</td>
<td></td>
</tr>
<tr>
<td>ES1</td>
<td>Fighter aircraft specific energy</td>
<td>(1)</td>
</tr>
<tr>
<td>ES2</td>
<td>Target aircraft specific energy</td>
<td></td>
</tr>
<tr>
<td>AOT</td>
<td>Fighter-to-target angle off tail</td>
<td></td>
</tr>
<tr>
<td>ATA</td>
<td>Fighter-to-target antenna train angle</td>
<td></td>
</tr>
<tr>
<td>R</td>
<td>Fighter-to-target interaircraft range</td>
<td></td>
</tr>
<tr>
<td>RMAX1</td>
<td>Fighter offensive maximum range</td>
<td>(2)</td>
</tr>
<tr>
<td>RMAX2</td>
<td>Fighter defensive maximum range</td>
<td></td>
</tr>
<tr>
<td>ROPT1</td>
<td>Fighter optimum missile launch range</td>
<td></td>
</tr>
<tr>
<td>ROPT2</td>
<td>Target optimum missile launch range</td>
<td></td>
</tr>
<tr>
<td>RO1</td>
<td>Target zero penalty range</td>
<td></td>
</tr>
<tr>
<td>RO2</td>
<td>Fighter zero penalty range</td>
<td></td>
</tr>
<tr>
<td>RG1</td>
<td>Fighter range at which guns tactics begin to dominate fight</td>
<td></td>
</tr>
<tr>
<td>RG2</td>
<td>Target range at which guns tactics begin to dominate fight</td>
<td></td>
</tr>
<tr>
<td>EDEV1</td>
<td>Fighter energy relevance term</td>
<td></td>
</tr>
<tr>
<td>EDEV2</td>
<td>Target energy relevance term</td>
<td></td>
</tr>
<tr>
<td>FG1</td>
<td>Fighter interenvelope gun penalty</td>
<td></td>
</tr>
<tr>
<td>FG2</td>
<td>Target interenvelope gun penalty</td>
<td></td>
</tr>
<tr>
<td>ATAOF</td>
<td>Antenna train angle for offensive state</td>
<td>(3)</td>
</tr>
<tr>
<td>AOTOF</td>
<td>Angle off tail for offensive state</td>
<td></td>
</tr>
<tr>
<td>ATAWEP</td>
<td>Antenna train angle for weapons envelope</td>
<td></td>
</tr>
<tr>
<td>AOTWEP</td>
<td>Angle off tail for weapons envelope</td>
<td></td>
</tr>
<tr>
<td>R1WEP</td>
<td>Weapons envelope minimum range</td>
<td></td>
</tr>
<tr>
<td>R2WEP</td>
<td>Weapons envelope maximum range</td>
<td></td>
</tr>
<tr>
<td>RNUT</td>
<td>Range beyond which the fight is considered neutral for the maneuver conversion model</td>
<td></td>
</tr>
<tr>
<td>NFILES</td>
<td>The number of data files to be input</td>
<td></td>
</tr>
<tr>
<td>IPRINT</td>
<td>Print Option 1 for terminal output 5 for printer output</td>
<td></td>
</tr>
<tr>
<td>IGRAF</td>
<td>Graph Option 1 for terminal output</td>
<td></td>
</tr>
</tbody>
</table>

NOTES: (1) As a function of time
(2) Defined in reference 4
(3) Defined in reference 1
8. The program computes and graphs the paired analysis data. An example data run is given in appendix B. Data output is defined in table III, and output data are placed on disk file for further use.

Table III
Output From Paired Analysis Program

<table>
<thead>
<tr>
<th>Output</th>
<th>Definition</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>TIME</td>
<td>Assumed 1 second interval beginning at 1</td>
<td></td>
</tr>
<tr>
<td>RANGE</td>
<td>Interaircraft range from table II</td>
<td>(1)</td>
</tr>
<tr>
<td>AOT</td>
<td>Angle off tail from table II</td>
<td></td>
</tr>
<tr>
<td>ATA</td>
<td>Antenna Train Angle from table II</td>
<td></td>
</tr>
<tr>
<td>NRG #1</td>
<td>Fighter aircraft ES1 from table II</td>
<td></td>
</tr>
<tr>
<td>NRG #2</td>
<td>Target aircraft ES2 from table II</td>
<td></td>
</tr>
<tr>
<td>DIR ANG</td>
<td>Normalized Directional Angle</td>
<td>(2)</td>
</tr>
<tr>
<td>NRG FN</td>
<td>Energy function for performance index calculation</td>
<td></td>
</tr>
<tr>
<td>RNG FN</td>
<td>Range function for performance index calculation</td>
<td></td>
</tr>
<tr>
<td>PERF INDEX</td>
<td>Performance Index</td>
<td></td>
</tr>
<tr>
<td>STATE</td>
<td>ACM State</td>
<td>(3)</td>
</tr>
</tbody>
</table>

NOTES: (1) Output only on printer (print option 5). Not included in appendix B output. (2) Defined in reference 4. (3) Defined in reference 1.

SECTION ANALYSIS

9. The section coefficient data are computed by a second program as given in appendix C. The program was written for two versus one engagements and requires two output files generated by the previous program. These output files are for the two fighter-to-target pairs. The program computes the section performance index, section coordination, coordination consistency, the conversion coefficient, and the ACM state by the two-on-one state definitions of reference 1.
Section Performance Indices

10. The section performance indices are computed by the magnitude sum method (the vector sum method of reference 4). Section coordination and coordination consistency are computed as per reference 4.

Conversion Coefficient

11. The conversion coefficient was introduced to compensate for difficulties arising in the tactical interpretation of the section performance index. Specifically, as more aircraft are introduced, the section performance index becomes less responsive to tactical extremes because of mathematical "washout." That is, alternate signs in the performance index cancel to yield a numerically neutral fight which is often not representative of the tactical situation. For example, a precise interpretation of the "daisy chain" shown in figure 1 cannot be realized mathematically. The individual fighter-to-target performance indices cancel mathematically, yet tactically the fighter section is advantaged.

![Figure 1: Air Combat "Daisy Chain" for Two-On-One Engagements](image)

12. The situation as shown in figure 1 favors the fighter section if none of the aircraft are in a weapons envelope because of two very important reasons:

   a. The forward fighter has a friendly observer looking over his rear quarter (the rear fighter).

   b. In an attempt to close to the weapons envelope, the target aircraft in the middle will be flying a flight path which is in a large part determined by the first aircraft whose maneuvers can be made known to the rear aircraft. The situation will last only a short time with a smart pilot in the center aircraft and will quickly lead to "bogie switching" (a term applied to the situation) where the target (center) aircraft switches his offensive press to the other fighter.
13. The extension of the maneuver conversion model given in Table IV covers this point adequately. (Rule 2 applies to the "daisy chain" of figure 1.)

Table IV(1)

Rules for State Evaluation of a Two-On-One Engagement

<table>
<thead>
<tr>
<th>Rule</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>The section is OFFENSIVE WEAPON when at least one member is in offensive weapon state and the other is higher than a fatal defensive state.</td>
</tr>
<tr>
<td>2.</td>
<td>The section is OFFENSIVE when at least one member has an offensive position and the other is higher than a fatal defensive state.</td>
</tr>
<tr>
<td>3.</td>
<td>The section is NEUTRAL when both members are in neutral state.</td>
</tr>
<tr>
<td>4.</td>
<td>The section is DEFENSIVE when at least one member is in defensive state and the other is either neutral or defensive.</td>
</tr>
<tr>
<td>5.</td>
<td>The section is FATAL DEFENSIVE when at least one member is in fatal defensive state and the other has less than offensive weapon state.</td>
</tr>
<tr>
<td>6.</td>
<td>The section is in a TRADE OFF state when one member of the section is in offensive weapon state and the other is in a fatal defensive state.</td>
</tr>
</tbody>
</table>

NOTE: (1) Taken from reference 1.

14. The conversion coefficient introduced in this memorandum is an attempt to modify the performance index to cover the "daisy chain" situation and increase responsiveness. It is computed along the lines of Table IV as follows:

   a. The conversion coefficient is equal to the section performance index when both of the paired performance indices are less than 30 in absolute value (corresponding to conditions 3 and 4 of Table IV).

   b. The conversion coefficient is equal to the section performance index when both paired performance indices have the same sign (corresponding in part to conditions, 2, 3, and 4 of Table IV).

   c. The conversion coefficient is equal to the section performance index when the paired performance indices are both greater than 75 in absolute value and opposite in sign (corresponding to condition 6 of Table IV). These are flagged as a trade-off situation.
d. The conversion coefficient is not equal to the section performance index when the paired performance indices are opposite in sign and one is greater than 30 but less than 75. In this case, the conversion coefficient is computed as follows:

\[
\text{CONCO} = P_{11}^2 \left(1 - \frac{|P_{12}|}{75}\right)
\]  

(1)

where \( P_{11} \) is the positive value of the paired performance indices. This weights the positive (offensive factor) but degrades to a neutral value as a defensive fatal situation evolves (corresponding to condition 2 of table IV).

e. The conversion coefficient is not equal to the section performance index when the paired performance indices are opposite in sign with one greater than 75 in absolute value and both greater than 30 in absolute value. In this case, it is computed as follows:

\[
\text{CONCO} = P_{11}^2 \left(1 - \frac{|P_{12}|}{400}\right) \left(\frac{|P_{12}|}{P_{11}}\right)
\]  

(2)

where \( P_{11} \) is the paired performance index greater than 75 in absolute value and \( P_{12} \) is the other paired performance index. This weights the offensive weapons and defensive fatal states (corresponding to conditions 1 and 5 of table IV).

15. The conversion coefficient combines the best features of the maneuver conversion model with the performance index model but suffers in discontinuities due to equation changes at specified points. Care must be taken in further extensions of the conversion coefficient to include not only the case of the "daisy chain" (figure 2 shows a two versus two "daisy chain") but also other potential situations which cannot readily be described functionally such as the "floating diamond" in figure 3.
Maneuver Conversion Model

16. The computation of the two-on-one ACM state is taken directly from table IV as obtained from reference 1.

Output of Section Analysis Program

17. An example output of the section analysis program is given in appendix D. The data are self-explanatory. These data are additionally output onto disk for use in the stochastic analysis program.

STOCHASTIC ANALYSIS

18. The stochastic analysis program takes the output data from both previous programs for a large sample of data. Because of the number of data points and calculations required, the program requires segmentation to fit most computers (the program given in appendix E takes in excess of 250K storage). Pertinent features of the program are:

a. A file of data management options which allows the user to selectively compute and output data as documented in appendix E.

b. A frequency distribution recovery subroutine using the techniques developed by Ultrasystems (reference 5).

5) Dr. R. Curry and Dr. R. Egbert, Investigation of Distribution Recovery Techniques, Operations Research and Economic Analysis Development Department, Ultrasystems, Incorporated, Newport Beach, California, 11 Feb 1974.
c. A moment generating routine calculating the classical moments of distributed functions with a given frequency distribution (reference 6).

d. An integration routine for integration of equally spaced functions using a combination of Simpson's rule and Newton's three-eighths rule (reference 7).

e. A general plot routine for use of the line printer in plotting developed at the NAVAIRTESTCEN.

19. The purposes of the stochastic analysis program are to:

a. Compute the frequency distributions of the continuous variables in time for section data and paired data.

b. Compute the first 4 moments of these frequency distributions.

c. Compute the maneuver conversion/conversion probability matrix for aircraft sections and pairs.

d. Compute the time in state frequency distributions for the maneuver conversion model.

e. Compute the first 4 moments of these frequency distributions.

Stochastic Analysis Program Output

20. Full output of the stochastic analysis program is too voluminous to present here. Selected output for the test run and significant analysis information is, however, included for documentation. The test run, while representing actual engagement data, is for purposes of illustrating analysis methodology only. Separate reports are being written covering test data analysis and conclusions.

Continuous Variable Frequency Distributions and Moment Data

21. Frequency data output at 5 second intervals and for selected values of the performance index are shown in table V for a sample data set. The conclusions to be drawn from the data set are a function of the frequency value assumed to be significant. For example, the attainment of an optimal position (either best or worst) will come much less frequently than the neutral position. In table V, if a significance level of .001 is used, it can be seen that an optimal position will be attainable for the fighter section 20-30 seconds into the fight (a performance index of +100). This value does not occur until 80-90 seconds for the target (a performance index value of -100). This would indicate an early advantage to the fighter section and a recommended action to press and exploit the early advantage.


### Table V

**Performance Index Distribution for Two-On-One Example Data Set**

<table>
<thead>
<tr>
<th>Time (sec)</th>
<th>-100</th>
<th>-98</th>
<th>-90</th>
<th>-78</th>
<th>0</th>
<th>2</th>
<th>80</th>
<th>82</th>
<th>98</th>
<th>100</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency</td>
<td>0.00000</td>
<td>0.00000</td>
<td>0.00000</td>
<td>0.00000</td>
<td>0.03268</td>
<td>0.033643</td>
<td>0.00000</td>
<td>0.00000</td>
<td>0.00000</td>
<td>0.00000</td>
</tr>
<tr>
<td>Index</td>
<td>0.00000</td>
<td>0.00000</td>
<td>0.00000</td>
<td>0.00000</td>
<td>0.01432</td>
<td>0.01553</td>
<td>0.00004</td>
<td>0.00002</td>
<td>0.00000</td>
<td>0.00000</td>
</tr>
<tr>
<td>Frequency</td>
<td>0.00000</td>
<td>0.00000</td>
<td>0.00000</td>
<td>0.00000</td>
<td>0.02459</td>
<td>0.02579</td>
<td>0.00002</td>
<td>0.00001</td>
<td>0.00000</td>
<td>0.00000</td>
</tr>
<tr>
<td>Index</td>
<td>0.00000</td>
<td>0.00000</td>
<td>0.00000</td>
<td>0.00000</td>
<td>0.02738</td>
<td>0.02856</td>
<td>0.00005</td>
<td>0.00004</td>
<td>0.00000</td>
<td>0.00000</td>
</tr>
<tr>
<td>Frequency</td>
<td>0.00000</td>
<td>0.00000</td>
<td>0.00000</td>
<td>0.00000</td>
<td>0.03145</td>
<td>0.03264</td>
<td>0.00002</td>
<td>0.00001</td>
<td>0.00000</td>
<td>0.00000</td>
</tr>
<tr>
<td>Index</td>
<td>0.00000</td>
<td>0.00000</td>
<td>0.00000</td>
<td>0.00000</td>
<td>0.03484</td>
<td>0.03602</td>
<td>0.00006</td>
<td>0.00005</td>
<td>0.00000</td>
<td>0.00000</td>
</tr>
<tr>
<td>Frequency</td>
<td>0.00000</td>
<td>0.00000</td>
<td>0.00000</td>
<td>0.00000</td>
<td>0.03823</td>
<td>0.03941</td>
<td>0.00002</td>
<td>0.00001</td>
<td>0.00000</td>
<td>0.00000</td>
</tr>
<tr>
<td>Index</td>
<td>0.00000</td>
<td>0.00000</td>
<td>0.00000</td>
<td>0.00000</td>
<td>0.04164</td>
<td>0.04283</td>
<td>0.00002</td>
<td>0.00001</td>
<td>0.00000</td>
<td>0.00000</td>
</tr>
<tr>
<td>Frequency</td>
<td>0.00000</td>
<td>0.00000</td>
<td>0.00000</td>
<td>0.00000</td>
<td>0.04503</td>
<td>0.04621</td>
<td>0.00002</td>
<td>0.00001</td>
<td>0.00000</td>
<td>0.00000</td>
</tr>
<tr>
<td>Index</td>
<td>0.00000</td>
<td>0.00000</td>
<td>0.00000</td>
<td>0.00000</td>
<td>0.04842</td>
<td>0.04961</td>
<td>0.00002</td>
<td>0.00001</td>
<td>0.00000</td>
<td>0.00000</td>
</tr>
<tr>
<td>Frequency</td>
<td>0.00000</td>
<td>0.00000</td>
<td>0.00000</td>
<td>0.00000</td>
<td>0.05181</td>
<td>0.05300</td>
<td>0.00002</td>
<td>0.00001</td>
<td>0.00000</td>
<td>0.00000</td>
</tr>
<tr>
<td>Index</td>
<td>0.00000</td>
<td>0.00000</td>
<td>0.00000</td>
<td>0.00000</td>
<td>0.05520</td>
<td>0.05639</td>
<td>0.00002</td>
<td>0.00001</td>
<td>0.00000</td>
<td>0.00000</td>
</tr>
</tbody>
</table>
22. For the fringe of a weapons envelope (as shown in table V) at a value of +80 for the fighter or -80 for the target, a significance level of .003 may be chosen due to the higher incidence of occurrence. These values again occur at 20-30 seconds for the fighter section (+80 performance index) and much later, 80-90 seconds for the target (-80 performance index) with the same conclusions. Further, the data indicate a loss of this advantage in the later stages of the fight due to the higher frequency of occurrence of performance indices in the negative range after 90 seconds, suggesting it may be desirable for the fighters to stay engaged for only short periods (say up to 60 seconds). The defensive disengagement for the fighter section between 60 and 90 seconds is the tactical defense to the tide of battle shifting to the bogie. The neutral values (values of performance index near 0) are included for reference.

23. Table VI shows the statistical summary data for the data of table V. The variation of the mean as a function of time points again to an early advantage to the fighter section and loss of that advantage at around 90 seconds into the fight. The variance shows that events in the latter half of the engagement are more random in nature (larger relative values of variance). That is, events are less in control of either the fighter section or the target section, but not a significant difference. The value of the mean is indicative of the relative worth of the two sections and the engagements show to be predominantly neutral with a slight advantage to the fighter section initially and a slight advantage to the target section later in time. The overall conclusion is that the sections are fairly equally matched. The third and fourth moments were computed for later analysis and model building.

24. Figure 4 shows the output of the frequency of occurrence plot as a function of performance index for the start of the set of engagements. Figure 4(a) shows a tightly distributed data set in the region of -16 to +20 indicating a neutral start condition. One or more engagements are seen to start with the fighter section at a disadvantage as shown in the secondary peak between -30 and -16, and these engagements should probably be deleted from the engagement set for the neutral start analysis.
### Table VI
Summary Statistics for Section Performance Index Distribution

<table>
<thead>
<tr>
<th>Time (sec)</th>
<th>Number of Points</th>
<th>Mean Performance Index</th>
<th>Variance of Performance Index</th>
<th>Third Moment of Performance Index About Mean</th>
<th>Fourth Moment of Performance Index About Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>33</td>
<td>6.34</td>
<td>114.37</td>
<td>-636.67</td>
<td>56159.57</td>
</tr>
<tr>
<td>6</td>
<td>33</td>
<td>12.80</td>
<td>462.40</td>
<td>-4176.03</td>
<td>757210.59</td>
</tr>
<tr>
<td>11</td>
<td>33</td>
<td>14.57</td>
<td>1151.75</td>
<td>-12832.23</td>
<td>3800668.85</td>
</tr>
<tr>
<td>16</td>
<td>33</td>
<td>13.90</td>
<td>1570.17</td>
<td>-19020.63</td>
<td>6318563.84</td>
</tr>
<tr>
<td>21</td>
<td>33</td>
<td>10.42</td>
<td>1811.55</td>
<td>-17839.51</td>
<td>8065442.44</td>
</tr>
<tr>
<td>26</td>
<td>33</td>
<td>12.29</td>
<td>1782.15</td>
<td>-19620.96</td>
<td>7975665.77</td>
</tr>
<tr>
<td>31</td>
<td>33</td>
<td>8.27</td>
<td>1491.78</td>
<td>-1178.67</td>
<td>5558583.45</td>
</tr>
<tr>
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<td>33</td>
<td>8.14</td>
<td>1527.16</td>
<td>-5578.23</td>
<td>6023055.01</td>
</tr>
<tr>
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<td>13.02</td>
<td>1120.23</td>
<td>-4447.80</td>
<td>3593418.53</td>
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<tr>
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<td>1198.91</td>
<td>-5504.27</td>
<td>3974260.30</td>
</tr>
<tr>
<td>51</td>
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<td>5.99</td>
<td>807.96</td>
<td>-4006.78</td>
<td>1734312.40</td>
</tr>
<tr>
<td>56</td>
<td>32</td>
<td>3.55</td>
<td>847.04</td>
<td>380.94</td>
<td>1840745.63</td>
</tr>
<tr>
<td>61</td>
<td>32</td>
<td>4.27</td>
<td>1000.48</td>
<td>1595.19</td>
<td>2757920.97</td>
</tr>
<tr>
<td>66</td>
<td>32</td>
<td>4.97</td>
<td>1249.15</td>
<td>-201.43</td>
<td>4090099.35</td>
</tr>
<tr>
<td>71</td>
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<td>8.30</td>
<td>1702.58</td>
<td>-9678.55</td>
<td>7107357.44</td>
</tr>
<tr>
<td>76</td>
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<td>7.00</td>
<td>1850.01</td>
<td>-7680.61</td>
<td>8024471.00</td>
</tr>
<tr>
<td>81</td>
<td>30</td>
<td>4.25</td>
<td>1800.18</td>
<td>-994.28</td>
<td>7555697.28</td>
</tr>
<tr>
<td>86</td>
<td>30</td>
<td>2.31</td>
<td>2300.12</td>
<td>-5018.21</td>
<td>11336444.27</td>
</tr>
<tr>
<td>91</td>
<td>29</td>
<td>-0.77</td>
<td>2242.77</td>
<td>1069.86</td>
<td>11057838.18</td>
</tr>
<tr>
<td>96</td>
<td>28</td>
<td>-7.02</td>
<td>1766.26</td>
<td>12959.65</td>
<td>7677819.65</td>
</tr>
<tr>
<td>101</td>
<td>27</td>
<td>-8.54</td>
<td>1871.21</td>
<td>15561.02</td>
<td>8432997.65</td>
</tr>
<tr>
<td>106</td>
<td>27</td>
<td>-8.12</td>
<td>1624.86</td>
<td>14356.95</td>
<td>6497451.97</td>
</tr>
<tr>
<td>111</td>
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<td>-0.96</td>
<td>1797.02</td>
<td>-1663.24</td>
<td>7357124.42</td>
</tr>
<tr>
<td>116</td>
<td>27</td>
<td>-4.89</td>
<td>1983.82</td>
<td>8765.20</td>
<td>8980127.66</td>
</tr>
<tr>
<td>121</td>
<td>27</td>
<td>-11.43</td>
<td>1540.44</td>
<td>12607.21</td>
<td>7724302.77</td>
</tr>
<tr>
<td>126</td>
<td>25</td>
<td>-6.31</td>
<td>1789.32</td>
<td>9495.46</td>
<td>7541745.63</td>
</tr>
<tr>
<td>131</td>
<td>24</td>
<td>-2.79</td>
<td>1934.10</td>
<td>5310.66</td>
<td>8574531.13</td>
</tr>
<tr>
<td>136</td>
<td>24</td>
<td>-1.51</td>
<td>1957.46</td>
<td>3766.21</td>
<td>8824056.90</td>
</tr>
<tr>
<td>141</td>
<td>21</td>
<td>-1.93</td>
<td>1927.95</td>
<td>9173.04</td>
<td>8660194.07</td>
</tr>
<tr>
<td>146</td>
<td>19</td>
<td>-3.52</td>
<td>2064.53</td>
<td>9781.27</td>
<td>9692787.76</td>
</tr>
<tr>
<td>151</td>
<td>19</td>
<td>-6.13</td>
<td>1768.94</td>
<td>19825.28</td>
<td>7818620.14</td>
</tr>
<tr>
<td>156</td>
<td>18</td>
<td>-7.86</td>
<td>1930.58</td>
<td>21118.76</td>
<td>9156490.34</td>
</tr>
<tr>
<td>161</td>
<td>18</td>
<td>-9.46</td>
<td>1879.12</td>
<td>19982.05</td>
<td>8677585.29</td>
</tr>
<tr>
<td>166</td>
<td>16</td>
<td>-9.20</td>
<td>2209.72</td>
<td>27797.15</td>
<td>11175677.66</td>
</tr>
<tr>
<td>171</td>
<td>14</td>
<td>-10.19</td>
<td>2369.51</td>
<td>27960.52</td>
<td>12478168.37</td>
</tr>
<tr>
<td>176</td>
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<td>-13.59</td>
<td>2179.04</td>
<td>31991.96</td>
<td>11230738.18</td>
</tr>
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<td>2422.24</td>
<td>30528.05</td>
<td>12983093.75</td>
</tr>
<tr>
<td>186</td>
<td>10</td>
<td>-16.13</td>
<td>1456.25</td>
<td>18236.56</td>
<td>5761935.46</td>
</tr>
</tbody>
</table>
Figure 4
Performance Index Distribution Plots for
Two-On-One Example Data Set
25. Figure 4(b) shows the output of the frequency of occurrence plot as a function of performance index for a time 25 seconds into the engagements. As discussed in paragraphs 21 and 22, it can be seen that for a significance level of 0.003, the distribution of performance indices lies between -54 and +82 which contains the fringe weapon envelope case for the fighter section (+80), but not the target (-80), indicating a decided advantage for the fighter section in this time frame. Thus, the neutral starts have shifted to a fighter section advantage during the initial engagement period.

26. Figures 4(c) and 4(d) show the reversal of this trend later in the engagement. In figure 4(c), the frequency distribution at 87 seconds into the engagements shows that both the fighter section and the target section have weapon opportunities available. Figure 4(d), taken for 180 seconds into the engagements, shows a very skewed distribution which includes weapon opportunities for the target aircraft but none for the fighter section. This reflects the breakdown of the fighter section integrity as engagement time accumulates and the resulting dominance by the bogie. At this point, the fighters are essentially uncoordinated and the more maneuverable bogie is selectively engaging the most vulnerable fighter of the section.

27. Engagement dominance can be taken from the cumulative probability of occurrence of performance indices at various times during the engagements as shown in figure 5 for the times corresponding to figure 4. Mathematically, the fighter section will dominate if a positive value of performance index has a cumulative probability of greater than 50%. Practically, however, the split should be greater than 51/49 or more like 70/30. As shown in the figures, and taking the split in the value of cumulative probability at zero performance index, no tendency to dominate is present in either the fighter section or the target aircraft over the entire engagement time. There is, however, a mathematical tendency for the fighter section to dominate early in the fight and to lose this advantage to the target aircraft later in the fight. This is consistent with the trend isolated by the time history of expected values discussed in paragraph 23. While no combatant controlled the entire engagement, the initial engagement dominance by the fighter section is a decided advantage since the fighter section will incur the majority of early shot opportunities.
Figure 5
Cumulative Probability Plots for Performance Indices
of Two-On-One Example Data Set
Maneuver Conversion/Conversion Probability Matrix

28. Table VII shows the program output of the conversion probability matrix for the sample data set as computed by the methods described in reference 1. The table shows the probability of converting from the states listed down the left to the states listed across the top. For example, in the first line of the table, the probability of converting from offensive weapons to offensive state is 1.0 or all of the offensive weapons states in the engagement set reverted eventually to offensive state. The trade off state was not observed in the data set under investigation. That is, there was no simultaneous occurrence of one fighter being in the offensive weapons state and the other fighter being in the fatal defensive state.

Table VII

Conversion Probability Matrix for Two-On-One Example Data Set

<table>
<thead>
<tr>
<th>Section State</th>
<th>Offensive Weapons</th>
<th>Offensive</th>
<th>Neutral</th>
<th>Defensive</th>
<th>Fatal Defensive</th>
<th>Trade Off</th>
</tr>
</thead>
<tbody>
<tr>
<td>Offensive</td>
<td>*</td>
<td>1.0000</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.0000</td>
</tr>
<tr>
<td>Offensive</td>
<td>0.1293</td>
<td>*</td>
<td>0.5918</td>
<td>0.2517</td>
<td>0.0272</td>
<td>0.0000</td>
</tr>
<tr>
<td>Neutral</td>
<td>0.0000</td>
<td>0.5583</td>
<td>*</td>
<td>0.4417</td>
<td>0.0000</td>
<td>0.0000</td>
</tr>
<tr>
<td>Defensive</td>
<td>0.0000</td>
<td>0.3426</td>
<td>0.5556</td>
<td>*</td>
<td>0.1019</td>
<td>0.0000</td>
</tr>
<tr>
<td>Fatal</td>
<td>0.0000</td>
<td>0.4000</td>
<td>0.0000</td>
<td>0.6000</td>
<td>*</td>
<td>0.0000</td>
</tr>
<tr>
<td>Trade Off</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.0000</td>
<td>*</td>
</tr>
</tbody>
</table>

29. Several other points may be noted from table VII. From neutral, the fighter section had a higher probability of converting to the offensive state (56%) than to the defensive state (44%) indicating a slight advantage to the fighter section. Further, the conversion from offensive state to offensive weapons state occurred 13% of the time, while the conversion from defensive state to fatal defensive state occurred only 10% of the time. These numbers, while representing a slight advantage to the fighter section are nowhere near engagement dominance figures. Further, they must be modified by the time in state distributions as summarized in table VIII.
Table VIII

Time in State Summary for Two-On-One Example Data Set

<table>
<thead>
<tr>
<th>Section State</th>
<th>Number of Points</th>
<th>Mean Time in State (sec)</th>
<th>Variance of Mean Time in State (sec²)</th>
<th>Third Moment about Mean Time in State (sec³)</th>
<th>Fourth Moment about Mean Time in State (sec⁴)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Offensive Weapons</td>
<td>18</td>
<td>2.93</td>
<td>4.39</td>
<td>9.74</td>
<td>68.59</td>
</tr>
<tr>
<td>Offensive</td>
<td>142</td>
<td>14.52</td>
<td>141.52</td>
<td>2329.60</td>
<td>96707.36</td>
</tr>
<tr>
<td>Neutral</td>
<td>153</td>
<td>18.13</td>
<td>206.64</td>
<td>3876.30</td>
<td>197143.09</td>
</tr>
<tr>
<td>Defensive</td>
<td>97</td>
<td>15.30</td>
<td>136.32</td>
<td>1862.18</td>
<td>77235.03</td>
</tr>
<tr>
<td>Fatal Defensive</td>
<td>16</td>
<td>2.56</td>
<td>5.08</td>
<td>14.96</td>
<td>96.76</td>
</tr>
<tr>
<td>Trade Off</td>
<td>0</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
</tbody>
</table>

30. As shown in Table VIII, the mean time spent in the offensive state is somewhat less than the mean time spent in the defensive state for roughly the same variance (same degree of consistency), thus offsetting the partial advantage to the fighter section. The nonparametric frequency function fits for time in offensive, neutral, and defensive states displayed the log normal characteristic referred to in reference 2. Figure 6(a) shows the time in state distribution for the offensive state.

31. Time in state distributions for the offensive weapons and defensive fatal states are multimodal and means do not compare directly. Figure 6(b), the time in state distribution of the offensive weapons state for the fighter section, is characterized as a bimodal distribution which approximates the log normal form. Figure 6(c), the time in state distribution of the fatal defensive state for the fighter section, is characterized by a trimodal distribution which approximates the log normal form. The primary difference in the two states is probably characterized by the pilot tactics employed in two-on-one engagements. The first peak in figure 6(b) probably represents a transient or "flash through" computation in the neighborhood of one second, while the second peak (at 8.5 to 9 seconds) represents the tracking solution. The fatal defensive state (figure 6(c)) shows both these peaks, together with an intermediate peak which is probably due to 'bogie switching' as discussed in paragraph 12. The target aircraft, being threatened, in some instances would not complete the tracking solution, but hold the state for some finite time (around 5 seconds), fire a missile, and then switch. No such pressures to switch states are incumbent upon the fighter section in a two-on-one engagement. This intermediate short duration peak could be termed the 'survival sting' peak. This logic would lead to the supposition that a trimodal distribution for offensive weapons and defensive fatal states would be present in all engagements with multiple bogies and multiple fighters. The above observations are based upon a small data base and must be verified by further data samples.
32. The above discussion exhausts the conclusions that can be drawn directly from the estimated values of the maneuver conversion parameters. Further analysis, for example, the complete characterization of the underlying probability space and the estimation of the expected trade off ratio (the ratio of the probability of a win to the probability of a loss), requires the methodology described in reference 8. Since the techniques are adequately described in reference 8, they will not be repeated here.

33. At this point in the analysis, the semi-Markov process of the maneuver conversion model is defined, and when integrated with the weapon employment parameters, the full range of ACM measures of effectiveness including exchange ratios, survivability and dominance indices, etc., can be computed. These terms are treated in detail in references 1 and 8. The stochastic process of the performance index is only partially defined and is still in the developmental phase.

MODEL VALIDATION

34. The question of model validity may be addressed at two levels. The first level is consistency of conclusions drawn from the differing analytic techniques. The above discussions demonstrate this consistency for the data set under consideration. The authors believe that the two models are equally right or equally wrong. Thus, validation is reduced to determining if either model characterizes ACM correctly. An indication of this validity has already been obtained by noting the consistency of the common conclusion set with the intuitive evaluation of the participating aircrews. A formal mathematical validation may be obtained by comparing the tactical measures (listed in reference 1) as estimated from the computer solution of the semi-Markov process and as estimated directly from the data sample. Although this has not been done for this data sample, a valid comparison has been described in reference 8.

CURRENT RESEARCH

35. The above discussion summarizes some of the early research into the evaluation of test range ACM engagements. Work is continuing toward the development of a completely mathematical characterization of such engagements. Specifically, the investigations are directed toward a complete characterization of the underlying probability structure for which the performance index and conversion coefficient are natural realizations. The numerical techniques discussed above not only provide tactically significant data interpretation techniques but also serve as the initial technical tools to support the ongoing research. Further numerical techniques which are expected to be useful for data interpretation include a full nonparametric covariance and increment analysis along with selected distribution fitting analyses. The current research emphasis centers around a characterization of the performance index as a solution of a stochastic differential equation. It is expected that such a characterization will identify a few stochastic parameters that will serve to replace the mass of numerical calculations currently necessary as well as identify the theoretical connection between the maneuver conversion and the performance index models.
REFERENCES


5. Dr. R. Curry and Dr. R. Egbert, Investigation of Distribution Recovery Techniques, Operations Research and Economic Analysis Development Department, Ultrasystems, Incorporated, Newport Beach, California, of 11 Feb 1974.


L PRINDX
FILE:PRINDX  -03/13/76  10:22 AM.
100  !ERRMES
200  !FILE  5=PANDY,UNIT=PRINTER BACKUP DISK
200  !FILE  4=PFF,UNIT=DISK
400  !FILE  2=ACM,UNIT=DISK
500  !FILE  3=CNST,UNIT=DISK
500  !FILE  1=TRMNL,UNIT=REMOTE
700  !INTEGER  X
900  !REAL  K
900  !DIMENSION TITLE(50)
910  !DIMENSION ISTAT(500)
1000  !DIMENSION BE(500),AA(500)
1200  !DATA  BLANK:DOT:STAR:XXX"",",","","X"/
1300  !DATA  PLUS:*
1400  !DATA  OFWEPS:OFF,DEFINITION:DEFAT:"W","D","D","N","F"/
1410  C-
1420  C-  DATA FOR ACM STATE CALCULATION  W=OFFENSIVE WEAPON STATE
1430  C-  D=OFFENSIVE STATE
1440  C-  N=NEUTRAL STATE
1450  C-  D=DEFENSIVE STATE
1460  C-  F=DEFENSIVE FATAL STATE
1470  C-
1480  C-
1500  !DIMENSION R(500),K(500),FNG(500),DA(500),PI(500)
1520  !DIMENSION ES1(500)
1700  !DIMENSION ES2(500)
1800  !DIMENSION ADT(500)
1900  !DIMENSION STA(500)
1950  IF(1=.1)
3360  PRINT 433
1970  433 FORMAT(5x,"HOW MANY FILES AM I LOOKING AT")
1990  READ(1,/) NFILS
2000  KOUNT=1
2100  READ(3,/) RMAX1,RMAX2,ROPT1,ROPT2,RO1,RO2,PG1,PG2,EDE1,EDE2,
2110  C-
2115  =FG1,FG2,ATADF,ATADF,R1WEP,R2WEP,RMUT,ATAMEP,ATAMEP
2120  C-  SEE TEXT FOR EXPLANATION OF THESE NUMBERS
2130  C-
3290  PRINT 434
2900  434 FORMAT(5x,"WHERE DO YOU WANT DATA OUT, 1=HERE, 5=PRINTER",
2900  "OTHERS=NONE")
3100  READ(1,/) IPRINT
3200  PRINT 435
3300  435 FORMAT(5x,"WHERE DO YOU WANT A GRAPH, 1=HERE, 5=PRINTER",
3400  "OTHERS=NONE")
3500  READ(1,/) IGRAF
3510  96 CONTINUE
3512  KOUNT=1
3515  READ(2,/) N(R(I,i)=1,N),ES1(I),I=1,N),ES2(I),I=1,N),
3520  (ADT(I),I=1,N),ATA(I),I=1,N)
3530  READ(2,111) (TITLE(I),I=1,50)
3540  111 FORMAT(50A1)
3550  191 CONTINUE
3560  WRITE(1,111) (TITLE(I),I=1,50)
3560  IF(IPRINT.EQ.1.OR.IPRINT.EQ.5) GO TO 387
3700  50 TO 100
5200 CONTINUE
5300 WRITE(IPRINT,1003) TITLE(I),I=1,50
4000 1003 FORMAT(1H1,10X,50X)
4100 WRITE(IPRINT,444) RM4X,RAK2,ROPT1,ROPT2,RO1,RO2,RS1,RS2
4110 EDEV1,EDEV2,FG1,FG2,ATAOF,AOTOF,AOTWEP,R2WEP,R1WEP,RNUT
4200 444 FORMAT(10X,"INPUT CONSTANTS FOR THIS RUN")
4300 -10X,"FIGHTER OFFENSIVE MAX RANGE",F10.1," TARGET =",F10.1,
4500 -10X,"FIGHTER OPT MISSLE RANGE",F10.1," TARGET =",F10.1,
4600 -10X,"FIGHTER MINIMUM RANGE (Gun)",F10.1," TARGET =",F10.1,
4700 -10X,"FIGHTER SUN ENVELOPE MAX",F10.1," TARGET =",F10.1,
4800 -10X,"FIGHTER ENERGY RELEVENCE",F10.4," TARGET =",F10.4,
4900 -10X,"FIGHTER INTER-ENVELOPE PENAL",F10.4," TARGET =",F10.4,
4910 -10X,"OFFENSIVE ATA",F10.1," AOT",F10.1,
4920 -10X,"OFF WEP ATA",F10.1," AOT",F10.1,
4925 -10X,"OFF WEP MAX",F10.1," AOT",F10.1,
4930 -10X,"FIGHTER NEUTRAL BEYOND",F10.1," RANGE")
5000 IF(IPRINT.EQ.1) WRITE(1,30)
5010 30 FORMAT(5X,"TIME RANGE AOT ATA MGR=1 MGR=2 DIR ANG")
5020 "NRG FN RNG FN PERF INDEX STATE")
5100 30 FORMAT(5X,"TIME DIR ANG MGR FN RNG FN",4X,
5200 "PERF INDEX"," STATE")
5210 C-
5220 C- COMPUTE ACM STATE
5230 C-
5300 100 DD 10 I=1,N
5400 STATE(I)=NUT
5500 IF(ATA(I),LE,ATAOF.AND.AOT(I),LE,AOTOF) STATE(I)=OFF
5500 IF(ATA(I),LE,ATAWEP.AND.AOT(I),LE,AOTWEP.AND.R(I),LE,RWEP.AND.
5700 R(I),LE,REWEP) STATE(I)=OFFWEP
5800 IF(ATA(I),GE,(180,-AOTOF).A ND.AOT(I),GE,(180,-ATAOF)) STATE(I)=DEF
5800 IF(ATA(I),GE,(180,-AOTWEP).A ND.AOT(I),GE,(180,-ATAWEP).A ND.
6000 R(I),GE,RWEP.A ND.R(I),LE,REWEP) STATE(I)=DEFAT
6050 IF(R(I),GT, RNUT) STATE(I)=NUT
6060 C-
6070 C- COMPUTE NORMALIZED DIRECTIONAL ANGLE
6080 C-
6100 DA(I)=180.*((180.-AOT(I)+ATA(I))/180.).
6200 IF(DF(I),EQ,0.) 15,25,25
6210 15
6220 C- BRANCH ON DIRECTIONAL ANGLE PLUS FOR OFFENSIVE FIGHTER
6220 C- MINUS FOR DEFENSIVE FIGHTER
6240 C-
6300 15 CONTINUE
6400 RM4X=RM4X
6500 ROPT=ROPT2
6420 RN=RO2
6430 RG=RS2
6440 EDEV=EDEV2
6450 FG=FG2
6500 GO TO 45
6550 25 RM4X=RM4X
6610 ROPT=ROPT1
6620 R0=RO1
6630 RS=RS1
6640 EDEV=EDEV1
6650 FG=FG1
6700 45 IF(RG.EQ.ROPT.OR.RG.EQ.R0,OR.FG.EQ.0.) GO TO 35
BEGIN COMPUTATION OF PERFORMANCE INDEX

C

FSTR = F/G * (RG/FRMAX) + (RG/FFOPT) * FRMAX * (RG/RMAX) ** 2

GO TO 35

35 FSTR = 0.

55 H = R(I)

E = (H-ROPT) / RMAX

D = EXP(-2. ** (H - R/G) / ROPT) ** 2

FRNG(I) = E + 1. / (1. + 500. * EXP(-12. * B))

EID = ES1(I) - ES2(I)

ESE = ES1(I) + ES2(I) / B.

DES = EID / ESB

GEE = E - (RMAX-ROPT) / (RMAX-ROPT)

EFF = DEV*EXP(-4. * GEE ** 2)

ECH = 1. / (1. + EDEV*EXP(-6. * R(I) / R0))

K(I) = 1. + (ECH * EFF - 1.) * DES

IF (DA(I) + 1718) GO TO 986

17 K(I) = 1. / K(I)

18 CONTINUE

19 IF (IPRINT.E0.1) WRITE(I,100) (TITLE(I),1=1,50)

20 IF (IPRINT.E0.1) WRITE(5,301)

30 IF (IPRINT.E0.1) WRITE(1,30)

31 IF (IPRINT.E0.1) WRITE(S,20)

32 IF (IPRINT.E0.1) WRITE(5,27$)

33 CONTINUE

9900 CONTINUE

9910 IF (KOUNT.EQ.45) WRITE(IPRINT,1003) (TITLE(I),1=1,50)

9920 IF (KOUNT.EQ.45) WRITE(5,301)

9930 IF (KOUNT.EQ.45) WRITE(I,30)

9940 IF (KOUNT.EQ.45) KOUNT = 0

9950 KOUNT = KOUNT + 1

9960 IF (IPRINT.E0.1) WRITE(5,301)

9970 IF (IPRINT.E0.1) WRITE(1,30)

9980 IF (IPRINT.E0.1) WRITE(5,27$)

9990 IF (IPRINT.E0.1) WRITE(5,27$)

1000 CONTINUE

10000 IF (IGRAF.E0.1) WRITE(I,1003) (TITLE(I),1=1,50)

10100 GO TO 99

10200 KOUNT = KOUNT + 1

10300 IF (IPRINT.E0.1) WRITE(5,301)

10400 IF (IPRINT.E0.1) WRITE(1,30)

10500 IF (IPRINT.E0.1) WRITE(5,27$)

10600 IF (IPRINT.E0.1) WRITE(5,27$)

10700 IF (IPRINT.E0.1) WRITE(I,30)

10800 IF (IPRINT.E0.1) WRITE(5,27$)

10900 IF (IPRINT.E0.1) WRITE(5,27$)

11000 IF (IPRINT.E0.1) WRITE(5,27$)

11100 CONTINUE

11200 IF (IPRINT.E0.1) WRITE(5,27$)

11300 IF (IPRINT.E0.1) WRITE(5,27$)

11400 CONTINUE

11500 IF (IPRINT.E0.1) WRITE(5,27$)

11600 IF (IPRINT.E0.1) WRITE(5,27$)

11700 IF (IPRINT.E0.1) WRITE(5,27$)

11800 IF (IPRINT.E0.1) WRITE(5,27$)

11900 IF (IPRINT.E0.1) WRITE(5,27$)

12000 IF (IPRINT.E0.1) WRITE(5,27$)

12100 IF (IPRINT.E0.1) WRITE(5,27$)

12200 IF (IPRINT.E0.1) WRITE(5,27$)

12300 IF (IPRINT.E0.1) WRITE(5,27$)

12400 IF (IPRINT.E0.1) WRITE(5,27$)

12500 IF (IPRINT.E0.1) WRITE(5,27$)

12600 IF (IPRINT.E0.1) WRITE(5,27$)

12700 IF (IPRINT.E0.1) WRITE(5,27$)

12800 IF (IPRINT.E0.1) WRITE(5,27$)

12900 IF (IPRINT.E0.1) WRITE(5,27$)

13000 IF (IPRINT.E0.1) WRITE(5,27$)

13100 IF (IPRINT.E0.1) WRITE(5,27$)

13200 IF (IPRINT.E0.1) WRITE(5,27$)

13300 IF (IPRINT.E0.1) WRITE(5,27$)

13400 IF (IPRINT.E0.1) WRITE(5,27$)

13500 IF (IPRINT.E0.1) WRITE(5,27$)
11400  DD  66, J=10,  60
11700  BE(J) = DOT
11900  66 CONTINUE
12000  DD  66, J=10,  60,  5
12060  BE(J) = PLUS
12100  666 CONTINUE
12200  WRITE (IGRAF, 77) (BE(J), J=10, 60)
12300  77 FORMAT (1X, 'E', 1X, 'C', 5X, 51A1)
12400  DO  88 I=1, N
12500  DD  99, J=10,  60
12600  BE(J) = BLANK
12700  99 CONTINUE
12800  BE(35) = DOT
12900  BE(60) = STATE(1)
13000  BE(10) = STATE(1)
13100  IF (DA(I).GT.99.9 OR DA(I).LT.-99.9) GO TO 4123
13200  IK = .25*DA(I)+35.5
13300  BE(IK) = PLUS
13400  GO TO 4133
13500  4123 BE(35) = XXX
13600  4133 CONTINUE
13700  IF (AA(I).GT.99.9 OR AA(I).LT.-99.9) GO TO 9876
13800  J = .25*AA(I)+35.5
13900  BE(J) = STAR
14000  GO TO 7654
14100  9876 BE(35) = XXX
14200  7654 CONTINUE
14300  IF (KOUNT.EQ.45) WRITE (IGRAF, 1003) (TITLE(JK), JK=1, 50)
14400  1003 IF (KOUNT.EQ.45) WRITE (IGRAF, 1114)
14500  1114 IF (KOUNT.EQ.45) WRITE (IGRAF, 90)
14600  90 IF (KOUNT.EQ.45) KOUNT = 0
14700  14800 KOUNT = KOUNT + 1
14900  WRITE (IGRAF, 11) MT, (BE(J), J=10, 60)
15000  11 FORMAT (14, 5X, 51A1)
15100  MT = MT + 1
15200  98 CONTINUE
15210  PRINT 411, IFIL
15220  411 FORMAT (5X, "ANOTHER FILE DONE ", I4)
15230  WRITE(4, 786) N
15240  786 FORMAT (2X, I4)
15250  WRITE(4, 785) (TITLE(JK), JK=1, 50)
15260  785 FORMAT (2X, 50A1)
15270  DO  42 I=1, N
15280  IF (ABS(P1(I)).GT.99.9) P1(I)=0.
15290  42 CONTINUE
15300  WRITE(4, 789) (P1(I), I=1, N)
15310  789 FORMAT (50(2X, 9(F6.2," ",F6.2))
15410  DO  1141 J=1, N
15420  1141 IF (STATE(J).EQ.DFWEF) ISTAT(J)=1
15430  1142 IF (STATE(J).EQ.OFF) ISTAT(J)=2
15440  1143 IF (STATE(J).EQ.OFF) ISTAT(J)=3
15450  1144 IF (STATE(J).EQ.OFF) ISTAT(J)=4
15460  1145 IF (STATE(J).EQ.DEF) ISTAT(J)=5
15470  1146 IF (STATE(J).EQ.DEF) ISTAT(J)=5
15480  1147 IF (STATE(J).EQ.DEF) ISTAT(J)=5
15490  1148 IF (STATE(J).EQ.DEF) ISTAT(J)=5
15500  WRITE(4, 790) (ISTAT(J), J=1, N)
15510  790 FORMAT (50(2X, 9(I1," ",I1))
15600  9
15625 IFIL=IFIL+1
15650 IF(IFIL.LE.MFILE) GO TO 36
15700 PRINT 8111
15800 8111 FORMAT(/'REQUIRED FILE KEEPING TO SAVE DATA\'"
\"IS-'/
15900 -"LOAD YOUR DATA FILE"/"ADD REF"/"SAVE"/"REMOVE REF, ACM"/
16000 -"MAKE ACM AND REF"/"SAVE"/"TH-TH-THATS ALL FOLKS")/
16100 8765 CALL EXIT
16200 END

END QUICKLIST 4.2 SEC.
PAIRED ANALYSIS PROGRAM OUTPUT

FOR EXAMPLE DATA SET
R PFINDX
RUNNING

HOW MANY FILES AM I LOOKING AT
?1-
WHERE DO YOU WANT DATA OUT, 1=HERE, 5=PRINTER, OTHERS=NONE
?1-
WHERE DO YOU WANT A GRAPH, 1=HERE, 5=PRINTER, OTHERS=NONE
### AIM553Y A/C1 F4 TO A/C3 A4 ONE-ON-ONE

#### AIM553Y A/C1 F4 TO A/C3 A4 ONE-ON-ONE

**INPUT CONSTANTS FOR THIS RUN**

- **Fighter Offensive Max Range**: 24000.0 Target = 30000.0
- **Fighter Opt Missile Range**: 6000.0 Target = 7500.0
- **Fighter Minimum Range (Gun)**: 500.0 Target = 300.0
- **Fighter Gun Envelope Rmax**: 3000.0 Target = 3500.0
- **Fighter Energy Relevance**: 0.5000 Target = 0.7500
- **Fighter Inter-Envelope Fnal**: 0.0250 Target = 0.0500

#### Offensive ATA = 60.0, ADT = 90.0

---

#### OFF WEP ATA = 5.0

---

#### OFF WEP Rmax = 9000.0, Rmin = 3000.0

#### FIGHT NUETRAL BEYOND 18000.0 RANGE

<table>
<thead>
<tr>
<th>TIME</th>
<th>DIR ANG</th>
<th>HRG FN</th>
<th>RNG FN</th>
<th>PERF INDEX</th>
<th>STATE</th>
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<td>1.0360</td>
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<td>37.64 D</td>
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36
APPENDIX B
A1MS3Y 9/01 4 TO 9/03 4 ONE-ON-ONE

PERFORMANCE INDEX

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ANOTHER FILE DONE

REQUIRED FILE KEEPING TO SAVE DATA IS-
LOAD YOUR DATA FILE
ADD REF
SAVE
REMOVE REF, ACM
MAKE ACM AND REF
SAVE

TH-TH-THAT'S ALL FOLKS

END PENSIX 14.9 SEC.
SECTION ANALYSIS PROGRAM
TM 77-2 SA

APPENDIX C

FILE: SECT 2  03/16/76 10:01 AM.

100 REMOTES
200 FILE 1=REMOTE, UNIT=REMOTE
300 FILE 2=REMOTE, UNIT=REMOTE
400 FILE 3=REMOTE, UNIT=REMOTE
500 FILE 4=REMOTE, UNIT=REMOTE
600 FILE 5=REMOTE, UNIT=REMOTE

610 REM
620 C- REFERENCES  ************** REFERENCES  ************** REFERENCES
630 C- 1--- NAVFAC RPT SA-CR-76 OF 26 JAN 1976
640 C- 2--- NAVFAC RPT TM-76-15A OF 16 JUL 1976
650 C- 3--- CENTER FOR NAVAL ANALYSES RPT CRC 274 OF NOV 1974

700 DIMENSION R1(500), R2(500), ES11(500), ES12(500), ES21(500),
800 -ES22(500), AOT1(500), AOT2(500), AOTA(500), AOTA2(500),
900 -TITLE(500), TITLE2(500), PI1(500), PI2(500), ISTAT1(500),
1000 -ISTAT2(500), PI3(500), PHI(500), STATE(500),
1100 DIMENSION HA(500), BE(500),
1200 DIMENSION CONCO(500),
1300 DIMENSION ISTAT(500),
1400 DATA BLANK, DOT, STAR, XXX, PLUS, ",", ".", ".", "X", "+", "/
1500 DATA DOLLAR, DOLLARS, DEF, DEFAT, TRADE, "W", "O", "D", "N", "F", "T"

1601 C-
1602 C- MANEUVER CONVERSION DATA L=OFFENSIVE WEAPONS
1603 C- L=OFFENSIVE
1604 C- N=NEUTRAL
1605 C- D=DEFENSIVE
1606 C- F=FATAL DEFENSIVE
1607 C- T=TRADEOFF
1608 C-
1610 PRINT 433
1620 433 FORMAT(5X,"HOW MANY FILES AM I LOOKING AT")
1630 READ(1,1) NFILES
1640 IF L=1 THEN GOTO 1700
1650 PRINT 434
1660 434 FORMAT(5X,"WHERE DO YOU WANT DATA OUT, 1=HERE, 5=PRINTER")
1670 READ(1,5) WHERE
1680 IF WHERE=1 THEN GOTO 2000
1690 "OTHERS=NONE"
1700 PRINT 435
1710 435 FORMAT(5X,"WHERE DO YOU WANT A GRAPH, 1=HERE, 5=PRINTER")
1720 READ(1,5) GRAPH
1730 IF GRAPH=1 THEN GOTO 2400
1740 WRITE(1,775)
1750 775 FORMAT(2X,"GO TO SLEEP, I WILL CALL WHEN I AM READY")
1760 C-
1770 "BEGIN INPUT FROM PERFORMANCE INDEX PROGRAM"
1780 C- PAIR 1 DATA IS LOCATED IN DISK FILE ACM
1790 C- PAIR 2 DATA IS LOCATED IN DISK FILE BCM
1800 C-
1810 READ(2,5) N1
1820 READ(2,123) TITLE1(I), I=1,50
1830 123 FORMAT(50A1)

1840 C-
C  BEGIN COMPUTATION OF SECTION PERFORMANCE INDEX BY MAGNITUDE SUM METHOD OF REFERENCE 2

C  BEGIN COMPUTATION OF CONVERSION COEFFICIENT AS OUTLINED IN THE TEXT

IF(ABS(P11(I)) .GT. 0.1) CONCO(I) = 0.

IF(ABS(P12(I)) .GT. 0.1) CONCO(I) = 0.

IF(ABS(P11(I)) .GT. 0.1 AND. ABS(P12(I)) .GT. 0.1) GO TO 9.

IF(P11(I) .LT. 30. AND. P12(I) .LT. 30. AND. P12(I) .GT. 30.) GO TO 5.

IF(ABS(P11(I)) .GT. 0.1 AND. ABS(P12(I)) .GT. 0.1) GO TO 9.

IF(P11(I) .LT. 75.) AND. ABS(P12(I)) .LT. 75.) GO TO 6.

IF(ABS(P11(I)) .LT. 0.1) P11(I) = 0.1.

IF(ABS(P12(I)) .LT. 0.1) P12(I) = 0.1.

IF(ABS(P11(I)) .GT. 0.1 AND. ABS(P12(I)) .GT. 0.1) CONCO(I) = 0.

IF(ABS(P11(I)) .GT. 0.1 AND. ABS(P12(I)) .GT. 0.1) GO TO 9.

IF(ABS(P11(I)) .GT. 0.1 AND. ABS(P12(I)) .GT. 0.1) GO TO 6.

IF(P11(I) .LT. 75.) AND. ABS(P12(I)) .LT. 75.) CONCO(I) = P11(I).

GO TO 9.

IF(P11(I) .LT. P12(I)) CONCO(I) = P11(I).

IF(P12(I) .LT. P11(I)) CONCO(I) = P12(I).

IF(P11(I) .LT. P12(I)) CONCO(I) = P11(I).

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IF(P11(I) .LT. P12(I)) CONCO(I) = P11(I).

IF(P12(I) .LT. P11(I)) CONCO(I) = P12(I).

DEN = X2.

X2 = X1.

X1 = X2.

X2 = X1.

IF(DEN .LT. 0.1) PHI(I) = 0.

IF(DEN .LT. 0.1) GO TO 10.

PHI(I) = X1.

10 PHIT = PHI(I).

PHIT = PHI/I.
7310 C-
7320 C- COMPUTE ACM STATE FOR TWO ON ONE PER REFERENCE 3
7330 C-
7400 DO 20 I=1,N
7500 STATE(I)=DEF
7600 IF(I STAT1(I).EQ.1.AND.I STAT2(I).NE.5) STATE(I)=DFWEP
7700 IF(I STAT1(I).EQ.1.AND.I STAT1(I).NE.5) STATE(I)=DFWEP
7800 IF(I STAT1(I).EQ.0.AND.I STAT2(I).EQ.0) STATE(I)=TRADE
7900 IF(I STAT1(I).EQ.0.AND.I STAT1(I).EQ.0) STATE(I)=TRADE
8000 IF(I STAT1(I).EQ.0.AND.I STAT1(I).EQ.0) STATE(I)=DEFAT
8100 IF(I STAT1(I).EQ.0.AND.I STAT2(I).EQ.0) STATE(I)=NUT
8200 IF(I STAT1(I).EQ.0.AND.I STAT2(I).EQ.0) STATE(I)=DEFAT
8300 IF(I STAT1(I).EQ.0.AND.I STAT1(I).EQ.0) STATE(I)=DEFAT
8400 CONTINUE
8500 SUM=0.
8600 DO 30 J=1,N
8700 SUM=SUM+PHI(J)**2
8800 COORD(I)=1.-SORT(SUM/N)
8900 C-
9020 C- BEGIN PRINT OF OUTPUT
9030 C-
9090 IF(PRINT.NE.1.AND.PRINT.NE.5) GO TO 40
9100 WRITE(1),TITLE1(I),I=1,50,TITLE2(I),I=1,50
9110 1003 FORMAT(1H1,10X,50A1-10X,50A1)
9120 WRITE(1),PRINT,301
9130 301 FORMAT(5X,"TIME PERF PERF PERF PERF CONVERSION \"
9140 \" STATE/"
9150 \" 5X," INDEX INDEX INDEX INDEX COEFFICIENT \"
9160 \" 5X," PAIR1 PAIR2 SECTN")
9170 400 KOUNT=1
9180 C-
9250 C- BEGIN GRAPHICAL COMPUTATIONS FOR OUTPUT GRAPH
9260 C-
9370 DO 40 J=1,N
9400 IF(KOUNT.EQ.45.) WRITE(1),TITLE1(I),I=1,50,
9410 TITLE2(I),I=1,50
9420 1003 FORMAT(1H1,10X,50A1-10X,50A1)
9430 WRITE(1),PRINT,301
9440 301 FORMAT(5X,"TIME PERF PERF PERF PERF CONVERSION \"
9450 \" STATE/"
9460 \" 5X," INDEX INDEX INDEX INDEX COEFFICIENT \"
9470 \" 5X," PAIR1 PAIR2 SECTN")
9480 500 KOUNT=KOUNT+1
9490 10300 WRITE(1),PAIR1(J),PAIR2(J),PAIR3(J),COORD(J),STATE(J)
9500 10400 278 FORMAT(5X,13.4,3X,F6.2,9X,A1)
9510 10500 40 CONTINUE
9560 IF(PRINT.EQ.0.OR.PRINT.EQ.5) WRITE(1),PRINT,909
9570 909 FORMAT(10X,"SECTION COORD = ",F6.4,5X,"CONSISTENCY = ",F6.4)
9580 MT=1
9590 10900 DO 44 I=1,N
9600 44 A(I)=PAIR(I)
9610 IF(IGRAF.NE.1.AND.IGRAF.NE.5) GO TO 50
9620 KOUNT=1
9630 11200 WRITE(IGRAF,1003) TITLE1(KK),KK=1,50,TITLE2(KK),KK=1,50
9640 11400 WRITE(IGRAF,1114)
9650 11500 1114 FORMAT(25X,"SECTION INDEX + FOR TRADE-OFF",+25X)
9660 11400 -I CONVERSION COEFFICIENT "+/1X"T")
9670 11700 WRITE(IGRAF,50)
9680 11800 50 FORMAT(1X,"I","1",","5","1","M","1","E","3",
9690 -100","2","-80","2","-60","2","-40","2","-20",
9700 -100","2","-80","2","-60","2","-40","2","-20",
9710 -100","2","-80","2","-60","2","-40","2","-20")
TM 77-2 SA

12000 +3.0, 3x^2 + 30x^2 + 2x^4 + 40x^2 + 2x^6 + 80x^2 + 2x^8 + 100
12100 DD 65 J=10*60
12200 BE END
12300 55 CONTINUE
12400 DD 56 J=10*60+5
12500 BE J=PLUS
12600 D55 CONTINUE
12700 WRITE (IGRAF,77) (BE(J),J=10*60)
12900 DD 85 I=1-N
13000 DD 99 J=10*60
13100 BE J=ERASE
13200 74 CONTINUE
13300 BE K=DOT
13400 BE J=STATE(1)
13500 BE J=STATE(1)
13600 IF CONC(1).GT.99.9 OR CONC(1).LT.-99.9 GO TO 4123
13700 K = 25*CONC(1)+35.5
13800 BE K=DOLL
13900 GO TO 4123
14000 4123 BE (35)=XXX
14100 4123 CONTINUE
14200 IF (AA(1).GT.99.9 OR AA(1).LT.-99.9) GO TO 9876
14300 J = 25*AA(1)+35.5
14400 BE J=STAR
14500 IF (PI1(1).GT.75. AND PI2(1).LT.-75.) OR (PI1(1).LT.-75. AND PI2(1).GT.75.) BE J=PLUS
14600 GO TO 7654
14700 7654 BE (35)=XXX
14800 7654 CONTINUE
15000 IF (KOUNT.EQ.45) WRITE (IGRAF,1003) (TITLE(XX),XX=1,50)
15100 -(TITLE2(XX),XX=1,50)
15200 IF (KOUNT.EQ.45) WRITE (IGRAF,1114)
15300 IF (KOUNT.EQ.45) WRITE (IGRAF,90)
15400 IF (KOUNT.EQ.45) KOUNT-0
15500 KOUNT=KOUNT+1
15600 WRITE (IGRAF,11) MT,(BE(J),J=10*60)
15700 11 FORMAT (14,5X,51A1)
15800 MT=MT+1
15900 33 CONTINUE
16000 50 CONTINUE
16100 WRITE (1,275)
16200 275 FORMAT (2X,"WAKE UP; I HAVE DONE ANOTHER FILE")
16300 WRITE (1,123) (TITLE(1),I=1,50)
16400 123 C-
16500 CREATE AN OUTPUT FILE ON DISK (REF) FOR FURTHER ANALYSIS
16600 C-
16700 WRITE (4,777) N
16800 777 FORMAT (2X,14)
16900 WRITE (4,789) (PI(1),I=1,N)
17100 WRITE (4,787) (TITLE1(1),I=1,50),(TITLE2(1),I=1,50)
17200 787 FORMAT (2X,50A1,2X,50A1)
17300 789 FORMAT (50X,9,F6.2,";",F6.2)
17400 DO 1141 J=1,N
17500 IF (STATE(J).EQ.DFMEP) ISTAT(J)=1
17600 IF (STATE(J).EQ.DFMEP) ISTAT(J)=2

APPENDIX C
16600 IF (STATE(J'.ED).NE.0) ISTAT(J)=3
16700 IF (STATE(J'.ED).EQ.0) ISTAT(J)=4
16800 IF (STATE(J'.ED).EQ.EDJ) ISTAT(J)=5
16900 IF (STATE(J'.ED).EQ.EDJ) ISTAT(J)=6
17000 1141 CONTINUE
17100 WRITE(4,790) (ISTAT(I), I=1,N)
17200 790 FORMAT(50X,9(I1,'",',I1))
17300 WRITE(4,789) (CONC(I), I=1,N)
17350 IFIL=IFIL+1
17360 IF (IFIL.LE.NFILES) GO TO 85
17400 8785 CALL EXIT
17500 END

END QUICKST 3.1 SEC.
SECTION ANALYSIS PROGRAM OUTPUT
FOR EXAMPLE DATA SET
R SECTION
RUNNING

HOW MANY FILES AM I LOOKING AT
? 1.
WHERE DO YOU WANT DATA OUT, 1=HERE, 5=PRINTEROTHERS=NONE
? 1.
WHERE DO YOU WANT A GRAPH, 1=HERE, 5=PRINTEROTHERS=NONE
? 1.
GO TO SLEEP. I WILL CALL WHEN I AM READY
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ACM5641 1 TO 3 2 ON 1 TEST 5/40, 3-9K, 60/90, 13K
BCM564 2 ON 1, 2 TO 3 TEST 5/40, 3-9K, 60/90, 13K

+ SECTION INDEX + FOR TRADE-OFF

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WAKE UP, I HAVE DONE ANOTHER FILE

ACM5641 1 TO 3 2 ON 1 TEST 5/40, 3-9K, 60/90, 13K

END SECT17 17.4 SEC.
STOCHASTIC ANALYSIS PROGRAM
FILE:STACM6  09/23/76 10:33 AM.

100  $ERRMES
200  FILE 1=TMML,UNIT=REMOTE
300  FILE 2=ACM,UNIT=DISK
400  FILE 3=BCM,UNIT=DISK
500  FILE 4=PEF,UNIT=DISK
500  FILE 5=RANDY,UNIT=PRINTER BACKUP DISK
600  FILE 6=CCM,UNIT=DISK
700  FILE 7=OPT,UNIT=DISK
800  INTEGER GRAFOP
900  DATA PLUS/"*"
1000 DATA BLANK/""
1100 DATA DOT/:"/
1200 DATA STAR/"*"
1300 DATA DOLL/"$
1400 DATA AT/"#"
1500 DATA AT/"*"
1600 DIMENSION TPCALE(5,51)
1700 DIMENSION N(40),PI(40,300),SECTIT(40,140),ISTATS(40,300),
1800 -CONC(40,300),HAIR(30),PARTIT(80,70),PIPAIR(80,300),
1900 -ISTATP(80,300),A(300),B(300),KPIS(300),FPIS(250,120),
2000 -FREO(300),CUPIS(250,120),CUMP(300),PISMSN(300),PISDEV(300),
2100 -PIS3(300),PIS4(300),ANS(4),FCC(250,120),CUMPCC(250,120)
2200 DIMENSION CCMN(300),CCDEV(300),CCM3(300),CCM4(300),KIPAIR(300),
2300 -FP1P(250,120),CUP1P(250,120),P1PMN(300),P1PDEV(300),P1P3M(300),
2400 -P1P4M(300),NCS(6,6),CPS(6,6),TC(6),NXX(300),NAME1(40),NAME2(40)
2500 FILE :ENSION IFI(6),ITII(6,300),TSCALE(6,51),TREO(6,51),TCTM(6,51),
2600 -TMEAN(6),TDEV(6),TMOM3(6),TMOM4(6),CP(5,5),CP2(5,5),ITIP(5,300),
2700 -TPEPEO(5,51),TPCUMP(5,51),TPMEAN(5),TPDEV(5),TPMOM3(5),TPMOM4(5)
2800 DIMENSION NAME3(40),NAME4(40)
2900 DIMENSION IFM(6)
3000 C— READ IN REQUIRED CONSTANTS FOR DATA MANAGEMENT
3100 C—
3200 READ(7,/) HFILIE,IPRINT,ICALC,DELTA,ICOMP
3300 GRAFOP=IGRAF/ABS(IGRAF)
3400 IGRAPH=ABS(IGRAF)
3500 MCK=IGRAF/ICOMP
3600 MKC=IGRAF/ICOMP+0.999
3700 IF (MCK,ME,NMK) IGRAPH=ICOMP
3800 101 FORMAT(40A1)
3900 READ(7,101) (NAME1(I),I=1,40)
4000 READ(7,101) (NAME2(I),I=1,40)
4100 READ(7,101) (NAME3(I),I=1,40)
4200 READ(7,101) (NAME4(I),I=1,40)
4300 READ(7,101) (NAME5(I),I=1,40)
4400 C—
4500 C—
4600 C— HFILIE IS THE NUMBER OF DATA FILES TO BE REDUCED
4700 C—
4800 C—
4900 C— IPRINT IS OUTPUT OPTION, 1 FOR TERMINAL 5 FOR PRINTER
5000 C—
5100 C—
5200 C— IGRAPH IS PLOTTING TIME INTERVAL + FOR FREQUENCY DATA — FOR FEO 8
5300 C— CUMULATIVE PROBABILITY
5400 C—
TM 77-2 SA

5500 C- 
5600 C- ICALC IS CALCULATION OPTION 1 FOR CONVERSION COEFF / SECTION PI
5700 C- 2 FOR PAIRED PI IN ADDITION
5800 C- 3 FOR MANEUVER CONVERSION OF SECTION
5900 C- IN ADDITION TO 1/2
6000 C- 4 FOR ALL ABOVE PLUS IND
6100 C- PAIRED MAN CONV
6200 C- 5 FOR SECTION DATA ONLY (ALL COMPUTATIONS)
6300 C- DELTA IS GRID SIZE FOR CONTINUOUS COMPUTATIONS IN RANGE OF
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6400 C- 
6500 C- ICMP IS THE FREQUENCY OF DATA COMPUTATION IN INTEGER SECONDS
6600 C- NAME1 IS THE TITLE FOR FREQUENCY DATA GRAPH
6700 C- NAME2 IS THE TITLE FOR PERFORMANCE INDEX GRAPH
6800 C- NAME3 IS THE TITLE FOR CUMULATIVE PROBABILITY GRAPH
6900 C- NAME4 IS THE TITLE FOR CONVERSION COEFFICIENT GRAPHS
7000 C- NAMES IS THE TITLE FOR TIME IN STATE GRAPHS
7100 C- NPAIR IS THE NUMBER OF POINTS IN PAIRED FILES IT HAS
7200 C- FOR A V 1 ENGAGEMENT
7300 C- PIS ARE THE SECTION PERFORMANCE INDICES IT HAS N(I) VALUES
7400 C- PER DATA FILE
7500 C- ISTATS ARE THE MANEUVER CONVERSION STATES--N(I) VALUES PER FILE
7600 C- 1=OFF WEAPONS
7700 C- 2=OFFENSIVE
7800 C- 3=NEUTRAL
7900 C- 4=DEFENSIVE
8000 C- 5=DEF FATAL
8100 C- 6=TRADEOFF
8200 C- CONCO ARE THE CONVERSION COEFFICIENTS N(I) VALUES PER FILE
8300 C- PIPAIR ARE THE PAIRED PERF INDEX VALUES NPAIR(I) VALES PER PAIR
8400 C- PER FILE
8500 C- ISTATP ARE THE PAIRED STATE DATA SAME AS ISTATS BUT NO 6
8600 C- SECTIT A TITLE FOR SECTION+PARTIT-A TITLE FOR PAIRS
8700 DO 200 I=1,NFILES
8800 READ(2,10) N(I)
8900 JK=K(I)/10
9000 KJ=K(I)
9100 READ(2,10) (PIS(I,J),J=1,N(I))
9200 IF(KJ.EQ.N(I)) READ(2,300) BLANK
9300 READ(2,300) (SECTIT(I,J),J=1,70)
9400 READ(2,300) (SECTIT(I,J),J=71,140)
9500 READ(2,10) (ISTATP(I,J),J=1,NPAIR(I))
9600 READ(2,10) (CONCO(I,J),J=1,N(I))
9700 200 CONTINUE
9800 WRITE(1,310)
9900 310 FORMAT("I JUST READ ALL THE SECTION DATA")
10000 IF(ICALC.EQ.0.OR.ICALC.EQ.5) GO TO 500
10100 DO 400 I=1,NFILES
10200 READ(3,10) NPAIR(I)
10300 READ(3,300) (PARTIT(I,J),J=1,70)
10400 READ(3,10) (PIPAIR(I,J),J=1,NPAIR(I))
10500 READ(3,10) (ISTATP(I,J),J=1,NPAIR(I))
10600 400 CONTINUE
10700 WRITE(1,320)
10800 320 FORMAT("I JUST READ PAIR A DATA")
10900 DO 500 I=1,NFILES
11000 K=I+NFILES
11100 READ(6,/) NPAIR(K)
11200 READ(6,3000) (PARTIT(K, J), J=1, 70)
11300 READ(6,/) (PIPAIR(K, J), J=1, NPAIR(K))
11400 READ(6,/) (ISTATP(K, J), J=1, NPAIR(K))
11500 500 CONTINUE
11600 WRITE(1,330)
11700 330 FORMAT("I JUST READ PAIR B DATA")
11800 500 FORMAT(70A1)
11900 WRITE(1,332)
12000 332 FORMAT("DATA ARE IN")
12100 WRITE(1,410)
12200 410 FORMAT(141,23, "THE FOLLOWING DATA IS USED IN THIS RUN")
12300 WRITE(1,3000) (SECTIT(I, J), J=1, 140), I=1, NFILES
12400 NBIG=0
12500 NPAIR=B
12600 DO 501 I=1,NFILES
12700 IF(NPAIR(I), GT, NBIG) NBIG=4(I)
12800 NPAIR=NBIG=MPAIR(I)
12900 501 CONTINUE
13000 NPTS=200, DELTA+1
13100 C-
13200 C-
13300 C- SECTION INDEX FREQUENCY DISTRIBUTIONS IN TIME
13400 C-
13500 C-
13600 DO 600 I=1,NBIG,ICOMP
13700 KSET=I
13800 K=0.
13900 DO 550 J=1,NFILES
14000 IF(NPAIR(I), LT, I) GO TO 550
14100 K=K+1
14200 R(K)=PIS(J, I)
14300 KPI(J)=K
14400 B(K)=-COS(Q(J, I))
14500 550 CONTINUE
14600 IF(K.LT.10) GO TO 610
14700 CALL FREDIS(-100., 100., DELTAA + K, FP0 + CUMP + ANS)
14800 DO 570 J=1,NPTS
14900 FP0(J) = FREDI(J)
15000 570 CUMP(J) = CUMP + J
15100 PISMIN(J) = ANS(1)
15200 PISMAX(J) = ANS(2)
15300 PISC(J) = ANS(3)
15400 PISMA(J) = ANS(4)
15500 CALL FREDIS(-100., 100., DELTAK + K, FP0 + CUMP + ANS)
15600 DO 580 J=1,NPTS
15700 FCE(J) = FREDI(J)
15800 580 CUMPCC(J) = CUMPCC(J)
15900 COMN(J) = ANS(1)
16000 COMC(J) = ANS(2)
16100 COMS(J) = ANS(3)
16200 COMA(J) = ANS(4)
16300 600 CONTINUE
16400 GO TO 620
16500 610 KSET=I-ICOMP
16600 620 CONTINUE
16700 WRITE(1,332) KSET
16800 333 FORMAT("1 JUST FINISHED SECTION FP0 DATA FOR" + I3, " PTS")
16900 IF(I<CALC.E0.1 OR. ICALC.E0.5) GO TO 320

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17000 C-
17100 C-
17200 C- CALCULATE PAIRED INFORMATION FREQUENCY DATA
17300 C-
17400 C-
17500 DO 300 I=1,NPBIG,ICOMP
17600 KPAIRS=I
17700 K=0
17800 K=NFILES+2
17900 DO 550 J=1,KD
18000 IF(NPAIR(J).LT.I) GO TO 550
18100 K=K+1
18200 A(K)=PIPAIR(J,1)
18300 KPAIR(I)=K
18400 550 CONTINUE
18500 IF(K.LT.10) GO TO 310
18600 CALL FREQB(-100.,100.,DELTR,A,K,FREQ,CUMP,ANS)
18700 DO 770 J=1,NPTS
18800 FPII(J)=FREQ(J)
18900 770 CONTINUE
19000 WRITE(I,334) KPAPLS.
19100 C-
19200 C- CALCULATE SECTION MANEUVER CONVERSION DATA
19300 C-
19400 IF(ICALC.LT.3) GO TO 1201
19500 DO 350 I=1,6
19600 DO 950 J=1,6
19700 CPS(I,J)=0.
19800 950 CONTINUE
19900 WRITE(1,334) KPAIRS
20000 334 FORMAT("I JUST FINISHED PAIRED FREQ DATA FOR",13," PTS")
20100 C-
20200 C- CALCULATE SECTION MANEUVER CONVERSION DATA
20300 C-
20400 C-
20500 IF(ICALC.LT.3) GO TO 1201
20600 DO 950 I=1,6
20700 DO 950 J=1,6
20800 CPS(I,J)=0.
20900 950 CONTINUE
21000 WRITE(I,334) KPAIRS
21100 334 FORMAT("I JUST FINISHED PAIRED FREQ DATA FOR",13," PTS")
21200 C-
21300 IF(ISTAT(I,J).LE.0.OR.ISTAT(I,J+1).LE.0) GO TO 900
21400 IF(ISTAT(I,J).EQ.ISTAT(I,J+1)) GO TO 900
21500 IDEX=ISTATS(I,J)+1
21600 DOEX=ISTATS(I,J+1)
21700 NCS(I,J)=NCS(I,J)+1
21800 900 CONTINUE
21900 DO 1000 I=1,5
22000 TC(I)=0.
22100 DO 1000 J=1,5
22200 1000 TC(I)=MC(I,J)+TC(I)
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22300 DO 1200 I=1,6
22400 DO 1200 J=1,6
22500 IF(I.EQ.J) GO TO 1200
22600 IF(I.GT.J) GO TO 2050
22700 IF(J.GT.I) GO TO 2050
22800 CONTINUE
22900 CONTINUE
23000 CONTINUE
23100 WRITE(1,*335)
23200 335 FORMAT("I JUST FINISHED SECTION MANEUVER CONV DATA")
23300 C-
23400 C-
23500 C- CALCULATE TIME IN STATE DISTRIBUTION
23600 C-
23700 C-
23800 IF(ICALC.LT.3) GO TO 2702
23900 DO 1600 I=1,6
24000 IFL(I)=1
24100 DO 1600 J=1,300
24200 1500 ISTAT(I,J)=0.
24300 DO 1800 I=1,NFILES
24400 MM=/stats(I,J)-1
24500 DO 1200 J=1,MM
24600 M=STATE(S(I,J))
24700 L=IFL(M)
24800 ITIS(I,J)=IFL(I)+1
24900 IFL(I)=IFL(I)+1
25000 1750 ITIS(M,L)=ITIS(M,L)+1
25100 IF(J.EQ.MM AND ISTAT(I,J).EQ.1) ITIS(M,L)=0.
25200 IF(ITIS(M,L).EQ.0) IFL(M)=IFL(M)-1
25300 1800 CONTINUE
25400 TMP=0.
25500 DO 2000 I=1,6
25600 NN=IFL(I)
25700 TMP=0.
25800 DO 1950 J=1,NN
25900 R(J)=ITIS(I,J)
25910 1950 IF(ITIS(I,J).GT.TMAX) TMAX=ITIS(I,J)
26000 DO 2050 IF(J.TM.LT.0.5) GO TO 2050
26100 DEL=TMAX/50.
26200 DO 1950 K=1,51
26300 1900 TSCALE(I,J)=K*DEL
26400 1900 TSCALE(I,J)=K*DEL
26500 IF(NN.LT.3) GO TO 2050
26400 CALL FREDIS(0.,TMAX,DEL,NN,FREQ,CUMP,ANS)
26500 DO 1950 K=1,51
26600 TFR Fritz(I,J)=FREQ(I,J)
26700 1950 TCUMP(I,J)=CUMP(I,J)
26800 TMEAN(I,J)=ANS(1)
26900 TDV(I,J)=ANS(2)
27000 TDM(I,J)=ANS(3)
27100 TDM(I,J)=ANS(4)
27200 GO TO 2000
27300 2050 CONTINUE
27400 DD 2060 K=1,51
27500 TSCALECK)=0.
27600 TFRED(I,K)=0.
27700 2050 TCMPIK,K)=0.
27800 TMEAN(I)=0.
27900 TDEV(I)=0.
28000 TMOM(I)=0.
28100 TMOM4(I)=0.
28200 2000 CONTINUE
28300 WRITE(1,2001)
28400 2001 FORMAT('I JUST FINISHED SECTION TIME IN STATE')
28500 C-
28600 C-
28700 C- CALCULATE PAIRED MANEUVER CONVERSION DATA
28800 C-
28900 C-
29000 IF (ICALC.NE.4) GO TO 2702
29100 DD 2100 I=1,5
29200 DD 2100 J=1,5
29300 CPP(I,J)=0.
29400 2100 NCP(I,J)=0
29500 MX=2.0*NFILES
29600 DD 2200 I=1,MX
29700 NMPAIR(I):-1
29800 DD 2200 J=1,MX
29900 IF (ISTATP(I,J).LE.0.OR.ISTATP(I,J+1),LE.0) GO TO 2200
30000 IF (ISTATP(I,J).EQ.ISTATP(I,J+1)) GO TO 2200
30100 IDEX=ISTATP(I,J)
30200 JDEX=ISTATP(I,J+1)
30300 NCP(IDEX,JDEX)=NCP(IDEX,JDEX)+1
30400 2200 CONTINUE
30500 DD 2200 I=1,MX
30600 TC(I)=0.
30700 DD 2300 J=1,5
30800 2300 TC(I)=TC(I)+NCP(I,J)
30900 DD 2400 I=1,5
31000 DD 2400 J=1,5
31100 IF(I.EQ.J) GO TO 2400
31200 IF(TC(I).LT.0.5) CPP(I,J)=0.
31300 IF(TC(I).LT.0.5) GO TO 2400
31400 CPP(I,J)=NCP(I,J)/TC(I)
31500 2400 CONTINUE
31600 WRITE(1,2401)
31700 2401 FORMAT('I JUST FINISHED PAIRED MAN CONV')
31800 C-
31900 C-
32000 C- CALCULATE TIME IN STATE FOR PAIRS
32100 C-
32200 C-
32300 DD 2500 I=1,5
32400 IFM(I)=1
32500 DD 2500 J=1,300
32600 2500 ITI(I,J)=0
32700 DD 2600 I=1,MX
32800 NH=NPAIR(I)-1

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32400 DO 2600 J=1,NN
32600 M=ISTATP(I,J)
33100 L=IFM(M)
33200 IF (ISTATP(I,J),EO,ISTATP(I,J+1)) GO TO 2550
33300 IFM(M)=IFM(M)+1
33400 2550 ITIP(M,L)=ITIP(M,L)+1
33500 IF(J,EO,MH,ANB,ISTATP(I,J),EO,ISTATP(I,J+1)) ITIP(M,L)=0
33600 IF(ITIP(M,L),EO,0) IFM(M)=IFM(M)-1
33700 2600 CONTINUE
33800 TMAX=0.
33900 DO 2700 J=1,N
34000 TMM=IFM(I)
34100 TMAX=0.
34200 DO 2610 J=1,NN
34300 A(J)=ITIP(I,J)
34400 2610 IF(ITIP(I,J).GT.TMAX) TMX=ITIP(I,J)
34500 IF(TMAX.LT.0.5) GO TO 2655
34600 DEL=TMAX/5.
34700 DO 2620 K=1,51
34800 2620 TPCALE(I,K)=(K-1)*DEL
34900 IF(NN.LT.3) GO TO 2655
35000 CALL FRED(IS,NN,NN,NN,FREQ,FREQ,FREQ,FREQ,ANS
35100 2655 DO 2650 K=1,51
35200 TPFREQ(I,K)=FREQ(K)
35300 2650 TPCUMP(I,K)=CUMP(K)
35400 TPMEAN(I)=ANS(1)
35400 TPDEV(I)=ANS(2)
35500 TPMOM3(I)=ANS(3)
35600 TPMOM4(I)=ANS(4)
35700 GO TO 2700
35800 2700 CONTINUE
35900 DO 2656 K=1,51
36000 TPFREQ(I,K)=0.
36100 TPCUMP(I,K)=0.
36200 2656 TPCALE(I,K)=0.
36300 TPMEAN(I)=0.
36400 TPDEV(I)=0.
36500 TPMOM3(I)=0.
36600 TPMOM4(I)=0.
36700 2700 CONTINUE
36800 2700 CONTINUE
36900 WRITE(1,2701)
37000 2701 FORMAT("I JUST FINISHED PAIRED TIME IN STATE-OUTPUT BEGINS")
37010 C-
37020 C- BEGIN OUTPUT OF THE COMPUTED DATA
37030 C-
37040 C- THE COMPUTED DISTRIBUTION OF THE SECTION PERF INDICES
37050 C-
42000 DO 3100 J=1,KSET*ICOMP
42100 WRITE(IPRINT,8950) J, (FCC(J,K), K=K0,K09)
42200 3100 CONTINUE
42300 WRITE(IPRINT,8950) (MX(I), I=NR,NPTS)
42400 DO 3101 J=1,KSET*ICOMP
42500 WRITE(IPRINT,8950) J, (FCC(J,K), K=NR,NPTS)
42600 3101 CONTINUE
42700 WRITE(IPRINT,3120)
42800 3120 FORMAT(1H1*20,'SUMMARY STATISTICS FOR CONVERSION COEFF')
42900 WRITE(IPRINT,9002)
43000 DO 3300 J=1,KSET*ICOMP
43100 WRITE(IPRINT,9002) J,KPIS(I)+CCMN(I)+CCDEV(I)+CCM3(I), CCN4(I)
43200 3300 CONTINUE
43300 DO 3200 J=1,KSET*1GRAF
43400 WRITE(4,9200) J
43500 BACKSPACE 4
43600 READ(4,9205) (NAME4(I), I=31,40)
43700 DO 3150 K=1,NPTS
43800 B(K)=CUMPC(J,K)
43900 3150 CONTINUE
44000 CALL PLOT(MXX,A,NPTS,IPRINT,NAME4,NAME1)
44100 IF(GRAFOP.EQ.-1) CALL PLOT(MXX,B,NPTS,IPRINT,NAME4,NAME3)
44200 3200 CONTINUE
44300 WRITE(1,3201)
44400 3201 FORMAT('CONV COEFF IS OUT')
44500 IF(ICALC.NE.1.AND.ICALC.NE.4) GO TO 3603
44510 C-
44520 C- THE COMPUTED DISTRIBUTION OF THE PAIRED PERFORMANCE INDICES
44530 C-
44540 WRITE(IPRINT,3300)
44600 3300 FORMAT(1H1*20,'PAIRED PERFORMANCE INDICES DISTRIBUTION')
44650 DO 3400 K0=1,NMPT,10
44700 K09=K0+9
44800 WRITE(IPRINT,8001) (MX(I), I=K0,K09)
44900 DO 3400 J=1,KPARLS*ICOMP
45000 WRITE(IPRINT,8950) J, (FPJP(J,K), K=K0,K09)
45100 3400 CONTINUE
45200 WRITE(IPRINT,8001) (MX(I), I=NR,NPTS)
45300 3400 CONTINUE
45400 WRITE(IPRINT,8001) (FPJP(I), I=NR,NPTS)
45500 3401 CONTINUE
45600 WRITE(IPRINT,9002)
45700 DO 3402 I=1,KPARLS*ICOMP
45800 WRITE(IPRINT,9003) I, KIPAIR(I), PIPMN(I), PIPDEV(I), PIP3(I),
45900 -PIM4(I)
4600 3402 CONTINUE
46100 WRITE(I4,9200) J
46200 BACKSPACE 4
46300 READ(4,9205) (NAME2(I), I=31,40)
46400 DO 3550 K=1,NPTS
46500 B(K)=CUMIP(J,K)
46600 WRITE(3550,4) FPJP(J,K)
46700 3550 CONTINUE
CALL PLOT(MXX,4,NPTS,IPRINT,NAME2,NAME1)
IF(GRAF0P.EQ.,1) CALL PLOT(MXX,4,NPTS,IPRINT,NAME2,NAME1)
3600 CONTINUE
3603 CONTINUE
3604 WRITE(*,3601)
3601 FORMAT("PI PAIR IS OUT")
IF(ICALC.LT.3) GO TO 3633
WRITE(*,IPRINT,3604)
3604 FORMAT(1H1,3X,"SECTION MANEUVER CONVERSION/CONVERSION",
            "PROBABILITY MATRIX")
WRITE(*,IPRINT,3603)
3603 FORMAT(1H1,3X,"OFF WEP OFFENSIVE  NEUTRAL  DEFENSIVE ",
            "DEF FAT TRADEOFF")
WRITE(*,IPRINT,3610) (CPS(1,J),J=1,6)
3610 FORMAT(2X,"OFF WEP *",5X,5F10.4)
WRITE(*,IPRINT,3612) (CPS(2,J),J=1,6)
3612 FORMAT(2X,"OFFENSIVE "*F10.4,4X,"*",5X,4F10.4)
WRITE(*,IPRINT,3614) (CPS(3,J),J=1,6)
3614 FORMAT(2X,"NEUTRAL "+F10.4,4X,"="*,5X,3F10.4)
WRITE(*,IPRINT,3616) (CPS(4,J),J=1,6)
3616 FORMAT(2X,"DEFENSIVE "+F10.4,4X,"="*,5X,2F10.4)
WRITE(*,IPRINT,3618) (CPS(5,J),J=1,6)
3618 FORMAT(2X,"DEF FAT "*F10.4,4X,"*",5X,F10.4)
WRITE(*,IPRINT,3620) (CPS(6,J),J=1,5)
3620 FORMAT(2X,"TRADEOFF "+F10.4,4X,"*")
WRITE(*,IPRINT,3622)
3622 FORMAT(1H1,2X,"SECTION TIME IN STATE DISTRIBUTION")
WRITE(*,IPRINT,3624)
3624 FORMAT(2X,"TIME FREQ(OFFWEP) TIME FREQ(OFFNSV)"
            " TIME FREQ(NEUTR) TIME FREQ(DEFNSV) TIME FREQ(DEF2FAT)",
            50000 ", TIME FREQ(TRADE )"
            ",")
DO 3650 J=1,51
3650 WRITE(*,3626) (TS(CSCALE(I,J),TFREO(I,J)),I=1,6)
3626 FORMAT(2X,6F10.2,F10.4)
3650 CONTINUE
DO 3650 J=1,6
3650 WRITE(*,IPRINT,3628)
3628 FORMAT(1H1,4X,"SUMMARY STATISTICS FOR SECTION MANEUVER"
            " CONV")
WRITE(*,IPRINT,3630)
3630 FORMAT(2X,"STATE MEAN VARIANCE"
            50000 "+", 3PMOM
            4THMOM NPTS)
WRITE(*,IPRINT,3655)
3655 FORMAT("OFF WEP/"OFFENSIVE/"NEUTRAL/"DEFENSIVE/"DEF"
            " FAT")
DO 3650 J=1,6
3650 WRITE(*,3657) ANAKING
3657 FORMAT(3A5)
WRITE(*,IPRINT,3662) ANAKING,TMEAN(J),TDEV(J),TMOM3(J),TMOM4(J)
WRITE(*,IPRINT,3663) ANAKING,TMEAN(J),TDEV(J),TMOM3(J),TMOM4(J)
DO 3665 J=1,6
3665 WRITE(*,IPRINT,3667)
3667 FORMAT(2X,2A5,4F10.2,17)
3660 CONTINUE
DO 3665 J=1,6
3665 WRITE(*,IPRINT,3667)
3667 FORMAT(2X,2A5,4F10.2,17)
3660 CONTINUE
DO 3665 J=1,6
3665 WRITE(*,IPRINT,3667)
3667 FORMAT(2X,2A5,4F10.2,17)
5200  DO 3680 I=1,6
5210  DO 3670 J=1,51
5220  A(J)=TPRIO(I,J)
5230  3670 B(J)=TSCALE(I,J)
5240  READ(4,3556) (NAMES(I),K=31,40)
5250  3556 FORMAT(10A1)
5260  CALL PLOT(E,A,51,1,PRINT,NAMES,NAMES1)
5270  IF(GRAPOP,NE,-1) GO TO 3680
5280  DO 3675 J=1,51
5290  CALL PLOT(B,A,51,PRINT,NAMES,NAMES3)
5300  3680 CONTINUE
5310  3683 CONTINUE
5320  WRITE(1,3681)
5330  3681 FORMAT("SECT MN CHV IS OUT")
5340  IF(ICALC,NE,4) GO TO 3800
5350  WRITE(1,PRINT,3692)
5360  3692 FORMAT(1H1,2X,"PAIRED MANEUVER CONVERSION PROBABILITY",1H4 " MATRIX")
5370  WRITE(1,PRINT,3693)
5380  WRITE(1,PRINT,3694) (CPP(I,J),J=1,51)
5390  WRITE(1,PRINT,3695) (CPP(I,J),J=1,51)
5400  WRITE(1,PRINT,3696) (CPP(I,J),J=1,51)
5410  WRITE(1,PRINT,3697) (CPP(I,J),J=1,51)
5420  WRITE(1,PRINT,3698) (CPP(I,J),J=1,51)
5430  WRITE(1,PRINT,3699) (CPP(I,J),J=1,51)
5440  WRITE(1,PRINT,3690) (CPP(I,J),J=1,51)
5450  WRITE(1,PRINT,3691) (CPP(I,J),J=1,51)
5460  WRITE(1,PRINT,3692) (CPP(I,J),J=1,51)
5470  WRITE(1,PRINT,3693) (CPP(I,J),J=1,51)
5480  3684 FORMAT(1H1,2X,"PAIRED TIME IN STATE DISTRIBUTIONS")
5490  WRITE(1,PRINT,3624)
5500  DO 3686 J=1,51
5510  WRITE(1,PRINT,3625) (TPCALE(I,J),TPFREQ(I,J),I=1,5)
5520  3686 CONTINUE
5530  WRITE(1,PRINT,3630)
5540  3630 FORMAT(1H4,3655)
5550  DO 3689 J=1,6
5560  3689 BACKSPACE 4
5570  3687 FORMAT(1H1,2X,"SUMMARY STATISTICS FOR PAIRED TIME IN STATE")
5580  DO 3690 J=1,5
5590  READ(4,3567) ANMA,KING
5600  WRITE(1,PRINT,3610) ANMA,KING,TPMEAN(J),TPDEV(J),TPMOM3(J)
5610  WRITE(1,PRINT,3615) ANMA,KING,TPMEAN(J),TPDEV(J),TPMOM3(J)
5620  WRITE(1,PRINT,3620) ANMA,KING,TPMEAN(J),TPDEV(J),TPMOM3(J)
5630  READ(4,3568) ANMA,KING
5640  3690 CONTINUE
5650  DO 3691 J=1,5
5660  3691 BACKSPACE 4
BEGIN

55700 DO 3698 I=1,5
55800 DO 3692 J=1,51
55900 A(J)=TPFRED(I,J)
57000 3692 E(J)=TPCALE(I,J)
57100 READ(1,3696) (NAME5(K),K=31,40)
57200 CALL PLOT(B+A,51,IPRINT,NAMES,NAMES1)
57300 IF(GRAFOF.NE.-1) GO TO 3698
57400 DD 3694 J=1,51
57500 3694 A(J)=TPCMPP(I,J)
57600 CALL PLOT(B+A,51,IPRINT,NAMES,NAMES3)
57700 3698 CONTINUE
57800 3690 CONTINUE
57900 WRITE(1,3699)
58000 3699 FORMAT(ALL DATA ARE OUT)
58100 C-
58200 C- START OUTPUT OF EXPECTED PATHS
58300 C-
58400 DD 4005 I=1,101
58500 4005 A(I)=BLANK
58600 4005 B(I)=BLANK
58700 DO 4000 J=1,101,10
58800 4000 B(J)=PLUS
58900 A(J)=DOT
59000 WRITE(4001)
59100 4001 FORMAT(1H1,2X,"EXPECTED PATHS FOR CONTINUOUS DATA"/
59200 "PERFORMANCE INDEX SECTION"/
59300 "PERFORMANCE INDEX PAIRS"/
59400 "CONVERSION COEFFICIENT SECTION"/
59500 -10X,"TIME","SECS",-10X,
59600 -20 +20 +40 +60 +90 +100")
59700 WRITE(4002) (B(J),J=1,101), (A(J),J=1,101)
59900 DO 4100 J=1,101
60000 4100 B(J)=PLUS
60100 WRITE(4101) (B(J),J=1,101)
60200 4101 FORMAT(10X,101A1)
60300 IF(ICALC.EQ.1.OR.ICALC.EQ.5) KPARLS=KSET
60400 DO 5000 J=1,KPARLS,ICOMP
60500 5000 A(J)=DOT
60600 5005 A(J)=PLUS
60700 5000 IF(J.GT.KSET) GO TO 4004
60800 K=0.50*CPMN(J)+50.5
60900 IF(K.GE.1.AND.K.LE.101) A(K)=DOLL
61000 L=0.50*CPMN(J)+50.5
61100 IF(L.GE.1.AND.L.LE.101) A(L)=STAR
61200 4004 M=0.50*CPMN(J)+50.5
61300 IF(M.GE.1.AND.M.LE.101) A(M)=PLUS
61400 WRITE(4006) J, (A(KK),KK=1,101)
61500 DD 4006 CONTINUE
61600 CALL EXIT
61700 END

END

APPENDIX E
SUBROUTINE PREDICT(ALPHA, BETA, DELTA, X, NDATA, FREQ, CUMP, ANS)

THIS SUBROUTINE USES FREQUENCY DISTRIBUTION RECOVERY TECHNIQUE -- PER ULTRASYSTEMS RPT

IT CALLS AN INTEGRATION SUBROUTINE (OSF) AND A MOMENT\CALCULATION

SUBROUTINE (MOMENT)

THE DISTRIBUTION FUNCTION OF THE X STRING VECTOR IS COMPUTED AND PLACED IN FREQ AFTER IT IS NORMALIZED

X HAS NDATA VALUES WITH A MAXIMUM OF BETA (RANGE VALUE)
A MINIMUM OF ALPHA (RANGE VALUE) TO BE COMPUTED OVER A GRID VALUE OF DELTA

THE PROGRAM ALSO RETURNS THE NORMALIZED CUMULATIVE PROBABILITY OF OCCURRENCE (CUMP) AND THE FIRST FOUR MOMENTS (ANS)

DIMENSION (500, 500), FREQ(500), CUMP(500), Y(500), X(500),

DO 10 I=1, NDATA
    DO 10 J=1, NDATA
10 SUMAI = X(I) - X(J)

SUM = SUM + SUMAI

MINT = (BETA - ALPHA) / DELTA

DO 10 J=1, NDATA
    DO 10 K=1, NDATA
10 F = ABS(XMU) / (XMU / (DATA - 1))

IF (K <= 1.0) RHO = 0.

IF (ABS(XMU) .LT. 1.0) Go To 22

IF (XMU .GT. 1.0) DELTA1 = 0.010

IF (XMU .LT. 1.0) RHO = DELTA1 * ALOG(NDATA) + ALOG(XMU) / XMU

IF (XMU .LE. 1.0) DELTA1 = 0.250

IF (XMU .LE. 1.0) XMU = DELTA1 * ALOG(NDATA) / XMU

CONTINUE

BIN = 0.0

IF (ABS(BINV) <= 1.0) BIN = 1.0

END
65400 DO 40 I=1,NPTS
65500 40 Y(I)= ALPHA+(I-1)*DELTA
65600 DO 50 I=1,NPTS
65700 FHAT(I)=0.
65800 DO 50 J=1,NDATA
65900 STEP1=Y(I)-X(J)
66000 STEP2=EXP(-1*(B*STEP1)**2/2.)
66100 50 FHAT(I)=FHAT(I)+B/NDATA*STEP2
66200 CALL OSF(Delta,FHAT,XI,NPTS)
66300 DO 500 J=1,NPTS
66400 IF(ABS(XI(NPTS))=.GE.1.E-08) GO TO 490
66500 FREQ(J)=0.
66600 CUMP(J)=0.
66700 GO TO 500
66800 490 FREQ(J)=FHAT(J)/XI(NPTS)
66900 CUMP(J)=XI(J)/XI(NPTS)
67000 500 CONTINUE
67100 CALL MOMEN(FREQ,UCO,NPTS,ANS)
67200 RETURN
67300 END
SUBROUTINE ODF(H,Y,Z,NDIM):
C- THIS IS A GENERAL INTEGRATION ROUTINE FOR EQUALLY SPACED
FUNCTIONS (Y)
C- THE SPACING OF Y IS H---- THE NUMBER OF POINTS IS NDIM
C- THE INTEGRAL OF Y IS 2
C- THE SUBROUTINE USES A COMBINATION OF SIMPSON'S RULE
C- AND NEWTON'S THREE-EIGHTHS RULE
C- DIMENSION Y(1),Z(1)
C- HT=H/1.3,
C- SUM1=Y(2)+Y(2)
C- SUM1=SUM1+SUM1
C- SUM1=HT*Y(1)+SUM1+Y(3)
C- AUX1=Y(4)+Y(4)
C- AUX1=AUX1+AUX1
C- AUX1=SUM1+HT*Y(3)+AUX1*Y(5)
C- AUX2=HT*Y(1)+3.875*(Y(2)+Y(5))+2.625*(Y(3)+Y(4))+Y(6)
C- SUM2=Y(5)+Y(5)
C- SUM2=SUM2+SUM2
C- SUM2=AUX2+HT*Y(4)+SUM2+Y(6)
C- Z(1)=0.
C- AUX=AUX+Y(3)+Y(3)
C- AUX=AUX+AUX
C- SUM2=HT*Y(2)+AUX*Y(4)
C- Z(3)=SUM2
C- Z(4)=SUM2
C- IF (NDIM=6) 5,5,2
C- Z(1)=0.
C- AUX=AUX+Y(3)+Y(3)
C- AUX=AUX+AUX
C- AUX=AUX+Y(3)+Y(I-1)
C- AUX=AUX+AUX
C- AUX=AUX+Y(I-1)+AUX1+Y(I)
C- Z(1-2)=SUM1
C- IF (I-NDIM)=3,6,6
C- AUX=AUX+Y(1)+Y(1)
C- AUX=AUX+AUX2
C- AUX=AUX+Y(1)+Y(I)
C- AUX=AUX+AUX2
C- AUX=AUX+Y(1)+Y(I-1)+AUX2+Y(I+1)
C- Z(I-1)=SUM2
C- Z(I-1)=SUM2
C- Z(I-1)=AUX
C- Z(I-1)=AUX
C- RETURN
C- RETURN
C- RETURN
C- RETURN
C- END
SUBROUTINE MOMEN(F,UBO,NPTS,ANS)
C- THIS ROUTINE CALCULATES THE CLASSICAL MOMENTS OF A GIVEN
C- FREQUENCY FUNCTION (F) HAVING A MAX (UBO(2)) A MIN (UBO(1))
C- AND A GRID SIZE (UBO(3)) THE MOMENTS ARE PLACED IN ANS
C-
C- THE FIRST MOMENT (MEAN) IS ABOUT THE ORIGIN
C- ALL SUBSEQUENT MOMENTS ARE ABOUT THE MEAN
C-
DIMENSION F(1),ANS(1),XM(500),Y(500)
DIMENSION UBO(3)
DO 10 I=1,4
10 ANS(I)=0.
DO 20 I=1,NPTS
20 Y(I)=UBO(1)+(I-1)*UBO(3)
20 XM(I)=Y(I)*F(I)
CALL QSF(UBO(3),XM,XM,NPTS)
ANS(1)=XM(NPTS)
DO 30 I=1,NPTS
30 XM(I)=F(I)*Y(I)-ANS(1)**2
CALL QSF(UBO(3),XM,XM,NPTS)
ANS(2)=XM(NPTS)
DO 40 I=1,NPTS
40 XM(I)=F(I)*Y(I)-ANS(1)**3
CALL QSF(UBO(3),XM,XM,NPTS)
ANS(3)=XM(NPTS)
DO 50 I=1,NPTS
50 XM(I)=F(I)*Y(I)-ANS(1)**4
CALL QSF(UBO(3),XM,XM,NPTS)
ANS(4)=XM(NPTS)
RETURN
END
SUBROUTINE PLOT(X,Y,NDATA,IPRINT,NAMEX,NAMEY)
C-
C- THIS ROUTINE PLOTS A GENERAL VECTOR Y VERSUS A GENERAL
C- VECTOR X CONSISTING OF NDATA VALUES NOT NECESSARILY ORDERED
C-
C- NAMEX IS A 40 CHARACTER IDENTIFIER OF THE X VECTOR
C- NAMEY IS A 40 CHARACTER IDENTIFIER OF THE Y VARIABLE
C-
C- IPRINT IS THE OUTPUT LOGICAL UNIT NUMBER
C-
C- THE ROUTINE COMPUTES ITS OWN SCALE VALUES AND DEVELOPES
C- ITS OWN OUTPUT---IT RETURNS NOTHING TO THE MAIN PROGRAM
C-
DIMENSION NAMEX(16),NAMEY(16)
DIMENSION X(51),Y(51),PLOTS(51,51)
DATA BLANK*:STAR:XXX,PLUS/" "," "," "," "," "/
DATA DOT/* "/
DATA DASH/* "/
DO 10 J=1,51
DO 10 K=1,51
10 PLOTS(J,K)=BLANK
DO 11 K=1,51
11 PLOTS(51,K)=DOT
DO 12 K=1,51
12 PLOTS(K,51)=DOT
DO 13 K=1,51
13 IF(J.EQ.51.OR.K.EQ.51) GO TO 130
130 PLOTS(J,K) DASH
PLOTS(J,51) DASH
PLOTS(51,K) DASH
131 CONTINUE
XBIG=-9.9E06
XSMALL=9.9E06
YBIG=-9.9E06
YSMALL=9.9E06
DO 999 I=1,NDATA
IF(X(I).GT.XBIG.AND.Y(I).GT.(1.E-06)) XBIG=X(I)
IF(X(I).LT.XSMALL.AND.Y(I).GT.(1.E-06)) XSMALL=X(I)
IF(Y(I).GT.YBIG) YBIG=Y(I)
IF(Y(I).LT.YSMALL) YSMALL=Y(I)
999 CONTINUE
998 CONTINUE
APPENDIX E
77800 XAVG= (XBIG+XSMALL)/2.
77900 YAVG= (YBIG+YSMALL)/2.
78000 XM= XAVG-XDEL/2.
78100 XMAX= XAVG+XDEL/2.
78200 YMIN= YAVG-YDEL/2.
78300 YMAX= YAVG+YDEL/2.
78400 XINC= (XMAX-XMIN)/50.
78500 YINC= (YMAX-YMIN)/50.
78600 DO 20 I=1,NDATA
78700 IF (X(I),GT,XMAX) GO TO 12
78800 IF (X(I),LT,XMIN) GO TO 13
78900 IF (Y(I),GT,YMAX) GO TO 16
79000 IF (Y(I),LT,YMIN) GO TO 17
79100 K= (X(I)-XMIN)* (1./XINC)+1.
79200 L= (Y(I)-YMIN)* (1./YINC)+1.
79300 PLOTS(L,K)=STAR
79400 GO TO 20
79500 12 K=51
79600 IF (Y(I),LT,YMIN) L=1
79700 IF (Y(I),GT,YMAX) L=51
79800 IF (Y(I),LT,YMIN,OR,Y(I),GT,YMAX) GO TO 19
79900 L= (Y(I)-YMIN)* (1./YINC)+1.
80000 GO TO 19
80100 13 L=51
80200 IF (Y(I),LT,YMIN) L=1
80300 IF (Y(I),GT,YMAX) L=51
80400 IF (Y(I),LT,YMIN,OR,Y(I),GT,YMAX) GO TO 19
80500 L= (Y(I)-YMIN)* (1./YINC)+1.
80600 GO TO 19
80700 16 L=51
80800 K= (X(I)-XMIN)* (1./XINC)+1.
80900 GO TO 19
81000 17 L=1
81100 K= (X(I)-XMIN)* (1./XINC)+1.
81200 19 PLOTS(L,K)=XXX
81300 20 CONTINUE
81400 DO 22 I=1,51
81500 21(I)=XMIN+(I-1)*XINC
81600 22(I)=YMIN+(I-1)*YINC
81700 22 CONTINUE
81800 WRITE (IPRINT,25)
81900 25 FORMAT (1H1,/')
82000 DO 30 J=1,51
82100 I=52-K
82200 WRITE (IPRINT,26) 22(I), (PLOTS(I,J),J=1,51)
82300 26 FORMAT (2X,E10.4,' + ','5I1)
82400 30 CONTINUE

73  APPENDIX E
22500 WRITE (IPRINT, 40)
22600 40 FORMAT (15X, "\""++++++""")
22700 WRITE (IPRINT, 50)
22800 50 FORMAT (16X, "\""
22900 WRITE (IPRINT, 45) Z1(1), Z1(11), Z1(21), Z1(31), Z1(41), Z1(51)
23000 45 FORMAT (9X, 6F10.2)
23100 WRITE (IPRINT, 46) (NAMEX(I), I=1,40), (NAMEY(I), I=1,40)
23200 46 FORMAT (10X, "THE X VARIABLE IS ", 40AI/
23300 - 10X, "THE Y VARIABLE IS ", 40AI/
23400 RETURN
23500 END

END QUIKLST 14.0 SEC.
TM 77-2 SA

TERMINOLOGY

ACM - Acronym for Air Combat Maneuvering

ACM State - A descriptor of the ACM situation as offensive, defensive, etc.

AIS - Airborne Instrumentation Subsystem

Bimodal - Having two characteristic peaks.

Bogie - A term applied to the opposition aircraft in an engagement.

Bogie Switching - A maneuver wherein the opposition aircraft switches his offensive press to avoid being "predictable".

Conversion Coefficient - An analysis term computed by combining the performance index and maneuver conversion computations.

Conversion Probability - The probability of converting from one ACM state to another.

Coordination Consistency - The difference between unity and the standard deviation of the section coordination term.

Defensive - A mathematical state where the subject aircraft or section is being threatened.

Distributions - A mathematical term applied to the probable range of events and how test data covers that range.

Dominance - A term applied when one aircraft or section is in decisive control of the engagement.

Expected Path - The locus of expected values of a variable.

Fatal Defensive - A mathematical state where the subject aircraft or section is in a weapons opportunity of an opponent.

"Flash Through" - A mathematical term indicating a transient situation (extreme short duration).

Frequency Distribution - A distribution of the frequency of occurrence of a variable as a function of the variable.

Magnitude Sum - A method of combining paired data to yield section data.

Markov - A mathematical term referring to a time independence occurrence of events.
<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Multimodal</td>
<td>Having several characteristic peaks.</td>
</tr>
<tr>
<td>Maneuver Conversion Model</td>
<td>An ACM analysis model made up of ACM states.</td>
</tr>
<tr>
<td>Neutral</td>
<td>A mathematical state where the subject aircraft has neither an advantage nor disadvantage.</td>
</tr>
<tr>
<td>Offensive</td>
<td>A mathematical state where the subject aircraft is threatening an opponent.</td>
</tr>
<tr>
<td>Offensive Weapons</td>
<td>A mathematical state where the subject aircraft has a weapons opportunity on an opponent aircraft.</td>
</tr>
<tr>
<td>Paired Data</td>
<td>A term applied to data generated for a specific fighter-to-target pair.</td>
</tr>
<tr>
<td>Paired Coefficient</td>
<td>An analysis parameter generated for a specific fighter-to-target pair.</td>
</tr>
<tr>
<td>Performance Index</td>
<td>A time variant figure-of-merit which scales the offensive value of a fighter-to-target pair or aircraft section via the product of angle, range, and energy penalty functions.</td>
</tr>
<tr>
<td>Section Data</td>
<td>A term applied to data generated for a fighter or target section.</td>
</tr>
<tr>
<td>Section Coefficient</td>
<td>An analysis parameter for a fighter or target section.</td>
</tr>
<tr>
<td>Section Coordination</td>
<td>An analysis parameter which accounts for the relative contribution of each aircraft in the section.</td>
</tr>
<tr>
<td>Semi-Markov</td>
<td>A Markov process modified to include a time dependence only within a given state.</td>
</tr>
<tr>
<td>Significance Level</td>
<td>A mathematical term representing a minimum acceptable tactical advantage or maximum acceptable disadvantage.</td>
</tr>
<tr>
<td>State</td>
<td>See ACM State.</td>
</tr>
<tr>
<td>Stochastic</td>
<td>A mathematical term applied to a time dependent occurrence of events that are statistical in nature.</td>
</tr>
<tr>
<td>Survival Sting</td>
<td>A term applied to a shortened tracking solution due to the tactical press of an opponent.</td>
</tr>
<tr>
<td>Target Aircraft</td>
<td>An opponent aircraft; a bogie.</td>
</tr>
</tbody>
</table>
Trade Off - An ACM state where, in a section, the offensive weapons and defensive fatal states exist simultaneously.

Trade Off Ratio - The ratio of opponent aircraft shot down to friendly aircraft lost.

Trimodal - Having three characteristic peaks.

Vector Sum - A method of combining paired information.
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