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DIFFERENTIAL MANEUVERING SIMULATOR DATA REDUCTION AND ANALYSIS SOFTWARE

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16. Abstract

A multielement data reduction and analysis software package has been developed for use with the Langley differential maneuvering simulator (DMS). This package, which has several independent elements, was developed to support all phases of DMS aircraft simulation studies with a variety of both graphical and tabular information. The overall software package is considered unique because of the number, diversity, and sophistication of the element programs available for use in a single study. The purpose of this paper is to discuss the overall DMS data reduction and analysis package by reviewing the development of the various elements of the software, showing typical results that can be obtained, and discussing how each element can be used.

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SUMMARY

A multielement data reduction and analysis software package has been developed for use with the Langley differential maneuvering simulator (DMS). This package, which has several independent elements, was developed to support all phases of DMS aircraft simulation studies with a variety of both graphical and tabular information. The overall software package is considered unique because of the number, diversity, and sophistication of the element programs available for use in a single study.

The initial use of the software package was in support of a joint NASA/Navy fighter study. The purpose of this paper is to discuss the overall DMS data reduction and analysis package, as used in the fighter study, by reviewing the various elements of the software, showing typical results obtained from the study, and discussing how each element was used to support the study.

INTRODUCTION

Langley Research Center (LRC) has in operation the six-degree-of-freedom differential maneuvering simulator (DMS) (refs. 1 and 2). This simulator was designed to be used to evaluate the differential performance of current and proposed aircraft. In order to effectively use information being obtained from the DMS, it was necessary to develop a data reduction and analysis capability. To aid in determining what should be included in this capability, a number of areas of interest were reviewed and a number of groups were consulted. Those consulted included National Aeronautics and Space Administration (NASA) design teams, military and NASA pilots, energy management and weapons systems experts, and various other military and civilian groups. The data reduction and analysis requirements resulting from this consultation and review were developed by NASA and used as a guideline in the development of the necessary software elements.

Prior to the development of a satisfactory data reduction and analysis package, a joint NASA/Navy study was initiated. In order to have the complete DMS data reduction

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and analysis software available for this study in the shortest possible time, personnel from the Naval Ship Research and Development Center (NSRDC) were consulted and utilized. The NSRDC group had had considerable programing experience along the lines of the DMS requirements. This group prepared new programs and modified existing NASA programs to meet the extensive DMS data reduction and analysis requirements. Some additional modifications and software development were performed by LRC and Naval Air Development Center (NADC) personnel. All the programs were designed to utilize as input either DMS input data used to define the aircraft simulated or DMS data resulting from simulation.

The initial use of the software package was in the joint NASA/Navy simulation study started in July 1971. The main purpose of the study was to evaluate the differential maneuvering performance of several fighter-type aircraft using air combat maneuvering (ACM) as the prime task. The airplane definitions were provided by the Navy and the Defense Intelligence Agency (DIA) and were programed on one of the Control Data 6600 computer systems by LRC personnel. The simulated aircraft were flown by current Navy fighter pilots experienced in ACM.

Included in this paper are a discussion of the various elements of the DMS data reduction and analysis software package, a presentation of typical output provided by the different elements, and a brief review of how each element can be used. The information presented in this paper is not intended to be a user's guide but is an introduction to each program.

SYMBOLS

C_D	drag coefficient
C_L	lift coefficient
E_s	specific energy
g	acceleration due to earth gravity
h	altitude ($h = -Z$)
M	Mach number
n	load factor
P_k	probability of kill

P_s	specific excess power
p,q,r	roll, pitch, and yaw angular velocity, respectively
R	range between aircraft
t	time into run
V	total aircraft velocity
X,Y,Z	coordinates of inertial axis system
$\Delta X, \Delta Y, \Delta Z$	difference in inertial coordinates, respectively, of two aircraft
x,y,z	coordinates of body axis system
α	angle of attack
β	sideslip angle
ϵ	deviation angle, $\cos^{-1} \dfrac{\dot{X}\Delta X + \dot{Y}\Delta Y + \dot{Z}\Delta Z}{\lvert R \rvert \lvert V \rvert}$
λ	off-boresight angle ($\cos^{-1}(x/R)$) measured in body axis system, $\sqrt{\lambda_a^2 + \lambda_e^2} = \sqrt{\lambda_{u/D}^2 + \lambda_W^2}$
λ_a	component of λ in x-y plane, $\tan^{-1}(y/x)$
λ_e	component of λ with respect to x-y plane, $\sin^{-1} \dfrac{-z}{\sqrt{x^2 + y^2}}$
$\lambda_{u/D}$	component of λ in x-z plane, $\tan^{-1}(-z/x)$
λ_W	component of λ with respect to x-z plane, $\tan^{-1} \dfrac{-y}{\sqrt{z^2 + x^2}}$
$\dot{\sigma}_H$	angular rate of change of range vector in X-Y plane
$\dot{\sigma}_V$	angular rate of change of range vector with respect to X-Y plane

$\dot{\sigma}_T$ total angular rate of change of range vector in inertial coordinate system, $\sqrt{\dot{\sigma}_V^2 + \dot{\sigma}_H^2}$

ϕ,θ,ψ Euler roll, pitch, and yaw angle, respectively

Subscripts:

A,B aircraft located in DMS sphere A and B, respectively

x,y,z along x-, y-, and z-axis, respectively

max maximum

Dot over a symbol denotes derivative with respect to time.

STUDY BACKGROUND

The NASA/Navy simulation study used the Langley differential maneuvering simulator (DMS) shown in figure 1. The DMS has a representative instrumented cockpit in each sphere and each cockpit has its own throttle, control stick, buffet system, and other instruments. The pilot in his cockpit is presented a projected visual scene, which represents the sky, earth, and horizon, and a target which simulates the other aircraft. The projected target moves relative to the sky earth scene in response to each pilot's control inputs. In addition, the pilots are given instrument readings (attitude, altitude, airspeed, etc.) indicating his aircraft's status. Standard aircraft controls are used to provide inputs to one of the Langley CDC 6600 computer systems. The computer system performs all computations by using the aircraft descriptions programed and provides output which drives the DMS projectors and instrumentation. All of this is done in a real-time mode. More detailed discussions of the DMS are given in references 1 and 2. Figure 2 shows schematically the major elements involved in the simulation.

Figure 2 also indicates the data output channels used by the DMS during a simulation. The major output of the DMS during the NASA/Navy study was the DMS Data Tape. Fifty-six variables are sampled and stored on a disk at a preselected rate (every 0.5 sec during the NASA/Navy study) during each computer run. At the end of a series of runs, the information on the disk was transferred to magnetic tape which was used as a permanent record for further data reduction and analysis. The variables sampled and stored on the DMS Data Tape are shown in table I. Other output channels used during the study included eight channel strip chart recorders, which monitored selected variables during a run, and a cathode ray tube (CRT) display giving real-time three-dimensional trajectory plots of each aircraft.

SOFTWARE REQUIREMENTS

The data reduction and analysis requirements of the DMS can generally be assigned to one of three different categories. These categories include (1) pretest programs which provide information for pilot briefings (expected trends and areas of potential aircraft superiority or inferiority), (2) daily used data reduction programs which provide information on individual runs prior to the next day's runs, and (3) posttest programs which provide analysis of sets of runs for aircraft combinations as a function of pilots, initial condition (I.C.), and other parameters. The three types used in support of the DMS and the major elements of each are briefly reviewed in the following sections. The review consists of a discussion of the purpose and main components of the individual programs and a description of the data input required and the output generated with examples of typical output. The information presented is not intended to be a user's guide to the programs but is instead an introduction to each program. Detailed information on program operation must be obtained from program operators.

Pretest Programs

Two particular types of information are provided by pretest programs for use independently or in support of DMS studies. The first type includes programs which provide digital simulation of ACM to evaluate possible maneuvers and to establish trends in offensive and defensive times for different aircraft combinations. The second type considers specific excess power and provides a theoretical indication of relative energy rate advantages and disadvantages. Both types of programs are discussed in this paper.

Digital ACM simulation.- The two digital ACM programs which are available to support DMS studies were both designed to accomplish several main objectives. These programs were not used in the NASA/Navy study but can be used to conduct aircraft and weapons systems design trade-off studies and to investigate maneuvers for combinations of new aircraft-weapons systems.

Analytical simulation of tactical air combat (ASTAC).- Program ASTAC, which is a modified version of the TAC Avenger computer program (ref. 3), provides a comparison of two aircraft in hard ACM situations and indicates the outcome of the maneuvering for a given I.C. and aircraft combination. Maneuvers used in the program are based on fighter pilot comments of what they would do under specific ACM situations on the basis of the two aircraft's relative positions, rates, etc. The major input data required for the ASTAC program includes the same drag, lift, thrust, and other aerodynamic data used in the DMS aircraft definitions. The ASTAC input also contains conditions and limits for available maneuvers and various radar, gun, and missile characteristics for evaluating radar and weapons use and effectiveness during ACM.

The output currently being obtained from ASTAC is summarized in table II. As indicated in the table the output includes single run data which (1) gives a time history of specific aircraft information, (2) indicates what maneuvers are selected, and when, for each aircraft, and (3) prints gun bursts and probabilities of kill for each gun burst. At the end of a run, the program outputs the time on offense for each aircraft, information on the speed, load factors, and altitudes encountered during the run, and a summary of gunfire and missile probabilities of kill. In addition to the single run data, a multirun output is provided which summarizes the gun and missile information for all runs and provides average values of this information.

Adaptive maneuvering logic (AML).- Program AML was developed under contract to LRC by Decision Science, Incorporated (DSI). The primary objective of this program was to develop a method by which maneuvers for the various situations arising in air-to-air combat could be obtained without relying on pilot expertise or retrospective opinion; that is, the method would find suitable tactical maneuvers for any given situation of one's own and the opponent's aircraft by using only the basic capabilities of the two aircraft and weapons systems.

Two characteristics distinguish Program AML from most other air-to-air combat simulation programs including ASTAC. The first feature of the program is its capability to adapt its maneuvers to changing characteristics of one's own and/or the opponent's aircraft. The second feature of the program is that it is not based on long-term classical maneuvers, such as "high-speed yo-yo" or "scissors" which are normally used to describe air-to-air combat. In contrast, the basic AML program maneuvers are elemental and utilize the following capabilities:

(1) Change in bank angle

(2) Change in load factor

(3) Change in thrust

The major inputs to the AML program include the thrust, drag, lift, maximum and minimum Mach numbers as a function of altitude, and maximum allowable load factor as a function of altitude and Mach number for both aircraft. This information is again the same as that used in the DMS aircraft definition.

The operation of the AML program is as follows. The two aircraft start at a given initial condition and the maneuvers that follow are determined at decision points occurring at equal time intervals into the program. At each such decision point, the program maps the present physical situation of the two opposing aircraft into a given cell of a situation matrix. It then calculates a value associated with that particular cell. Next, it determines a number of elemental trial maneuvers which are likely candidates for successful maneuvers for that present situation. Then, by predicting the flight path of one aircraft for the trial maneuvers and by extrapolating the flight path of the opponent's aircraft for this time period, it determines the cells of the situation matrix in which the trial maneuvers would end and the value of each of these cells. That trial maneuver which obtains the highest cell value is then executed. The questions that are answered in order to determine the cell value of the situation matrix are given in table III. Each question is assigned a weighted score that is used to determine cell values.

The types of output provided by the AML program are shown in table IV. A more complete discussion of the AML program is presented in reference 4.

Specific excess power programs.- Specific excess power P_s of an aircraft is defined as the difference between the thrust available and the total drag multiplied by the aircraft velocity and divided by the aircraft weight. This gives a measure of the rate at which an aircraft is gaining or losing energy and the ability of an aircraft to change energy levels. This type of information, when used relative to another aircraft, indicates areas in which a maneuvering advantage exists. Specific excess power P_s data for the NASA/Navy study were used to brief pilots on potential areas of superiority and inferiority for a particular aircraft combination prior to the actual simulated ACM. A schematic illustrating the P_s type of programs available is included in figure 3. A brief description of each of these programs follows.

Aircraft maneuvering performance (AMP): Program AMP was developed to generate energy maneuverability data for a single aircraft by using the same lift, drag, thrust, and maximum and minimum altitude information as were used in the DMS. The data input to the program includes C_L as a function of Mach number M, angle of attack α, and altitude h; C_D as a function of M and C_L; thrust as a function of M and h; $C_{L,max}$ as a function of M; and maximum and minimum altitude as a function of M. This information is in the same format as that used in the DMS.

The program operates by first selecting values of n_z, M, and h as specified by the user. Angle of attack is iterated until the lift generated is equal to or greater than that necessary for the given n_z, M, and h. Once this condition is met, the specific excess power P_s for that M, n_z, and h is calculated. During the calculations, the program checks to determine whether $C_{L,max}$ or flight envelope limits have been exceeded.

The output of the program consists of line printer output which lists P_s and the iterated α at specified values of n_z, M, and h. In addition to the line printer output, a magnetic tape is generated which contains the same data. The magnetic tape is saved for a permanent record and is used as input for a number of other P_s programs as shown in figure 3.

Program CONTOUR: Program CONTOUR takes P_S, h, and M data for a single aircraft and arranges the information for the plotting of a series of constant P_S contours. The only input to the program is the tape generated by Program AMP which contains all the necessary information for a given aircraft.

Program CONTOUR operates by taking the AMP tape for a particular aircraft and placing P_S and α information into arrays according to Mach number and altitude. These arrays are then used to find a set of P_S contours for a specific load factor by selecting a Mach number and iterating altitude until a P_S corresponding to one of the desired contours is found. At this point the h, M, and P_S values are placed in arrays which are used to determine coordinates for plotting the contours or data for printout. This process is repeated for a series of Mach numbers. After a set of contours is obtained for a particular load factor, the data are stored on magnetic tape for later use, the load factor is changed, and a new set of contours is obtained. The number of load factors tested is a variable. The plot data stored on tape from CONTOUR are used as input to one of the Langley plotting systems. A typical plot resulting from CONTOUR is given in figure 4. This figure shows a set of P_S contours for a load factor of 1 plotted at various altitudes and Mach numbers.

Program NEMO: Program NEMO creates a plot file of P_S as a function of turn rate and turn radius at given altitudes and Mach numbers for two aircraft. This plot file can be processed to obtain plots on 30 or 16 inch (0.76 or 0.41 meter) paper.

Input to the program consists of two tapes and two data cards. The tapes, containing P_S data, are created by Program AMP and each tape represents a single aircraft. The two data cards contain alphanumeric identifiers including the names or codes of the aircraft whose P_S data are on the tapes. The program operates as follows. The data tapes created by Program AMP are searched for the P_S value corresponding to a given altitude, Mach number, and normal load factor. Next, the turn rate and turn radius for the specified Mach number and normal load factor are computed. The P_S values found on the data tape and the corresponding turn radii and turn rates are then used as coordinates for one of the Langley graphics routines.

In the current version of NEMO, nine plots are developed. These plots are the resulting combinations of three altitude levels and three Mach number levels. The altitude levels are 10 000 feet (3.05 kilometers), 20 000 feet (6.1 kilometers), and 30 000 feet (9.14 kilometers). The Mach levels are 0.6, 0.9, and 1.1. The foregoing values of altitude and Mach number are those used in the NASA/Navy study but they are variable and any Mach-altitude set can be developed. A typical plot resulting from NEMO is given in figure 5. As shown in the figure, the variations of P_S with turn rate for both aircraft are plotted on the same set of axes for comparative purposes. Symbols along these curves correspond to integer levels of normal load factor as indicated. Also plotted in this figure is the corresponding turn radius associated with the turn rate.

Program EXTRA: Program EXTRA takes the P_S data for two aircraft (furnished by two AMP tapes) and computes the difference in specific excess power ΔP_S between the two aircraft at various Mach numbers, altitudes, and normal load factor levels. These ΔP_S values are then used in various forms of output.

The input to the program consists of two AMP tapes and aircraft identification cards. The data are taken from the tape and placed in arrays as a function of Mach number and altitude. Values of ΔP_S are then computed by using these arrays. At this point, the ΔP_S data are used in an iteration process similar to that used in Program CONTOUR. This consists of varying Mach number and altitude for a given load factor to determine Mach number-altitude sets for a selected value of ΔP_S. This gives information necessary for ΔP_S contour plots.

Two types of output are provided with the ΔP_S contour information. One is a plot tape which can be used in one of the Langley plotting systems. This option has not been used. The other output consists of line printer listings of the ΔP_S data for selected Mach numbers, load factors, and altitudes, and a line printer plot of ΔP_S superiority regions for the aircraft combination being considered. Figure 6 illustrates the line printer type of plot. As shown, the plot lists the altitude and Mach number conditions where either aircraft has a ΔP_S advantage or superiority of 50, 100, or 150 feet per second (15.2, 30.5, or 45.7 meters per second). Separate plots are generated for a number of load factors. The ΔP_S map represented by figure 6 can be used to show areas where one aircraft has a potential advantage in energy and thus where the pilot should try to maneuver it during the ACM.

Program SUGMUG: Program SUGMUG takes the same DMS aerodynamic input data (for a single aircraft) that were used in Program AMP. The program determines numerical values for sustained and maximum load factors for various combinations of Mach number and altitude.

The program uses three loops: altitude, Mach number, and angle of attack. It operates by selecting an altitude and a Mach number and iterates angle of attack through a range of values. At each value of α, a value of lift coefficient, drag coefficient, and thrust is obtained. A check is performed to ascertain that the value of C_L does not exceed $C_{L,max}$. Computations are performed to determine n_z and P_S for this set of conditions. Angle of attack is iterated until P_S becomes zero or negative or maximum lift is exceeded. If it is zero, then the values of Mach number, angle of attack, normal load factor, and altitude are placed in a holding array for later use. If P_S is not zero, but is negative, then it is used with the previous positive value of P_S to interpolate and obtain values of angle of attack, normal load factor, Mach number, and altitude at $P_s = 0$ and the values are placed in the holding arrays. If P_s is positive, the iteration of angle of attack continues. With this technique, values of α and n_z are obtained when $P_s = 0$ for a specified set of altitudes and Mach numbers.

This same type of process is employed for the maximum load factor case. However, instead of doing all the calculations to obtain $P_s = 0$, the calculations are performed by using the maximum lift coefficient obtainable for each Mach number and altitude combination. From these calculations, values of n_z, α, and P_s are obtained at maximum load factor for a specified set of Mach numbers at a number of different altitudes.

Data for both sustained and maximum load factors are generated as line printer output and are also placed on a magnetic tape for use in Program UNICORN.

Program UNICORN: Program UNICORN takes up to three SUGMUG tapes and prepares load-factor and angle-of-attack data from the tapes for plotting.

The input to UNICORN is the SUGMUG tape, or tapes, and labeling information for resultant plots. The program takes the SUGMUG data and determines the locations on a plot and stores the vertical and horizontal locations on a plot tape. This operation is done for both n_z and α as a function of Mach number. The resultant plot tape is used in one of the Langley plotting systems to give plots of n_z and α as a function of M for each altitude and for sustained and maximum n_z. A typical output of UNICORN is given in figure 7 for two aircraft. This plot represents a sustained n_z case.

Program SVELTE: Program SVELTE creates a plot file of maximum specific excess power $P_{s,max}$ as a function of specific energy E_s at given levels of turn rate for a number of aircraft. When more than one aircraft is being considered, plots of differential maximum specific excess power $\Delta P_{s,max}$ are also developed.

The input to the program consists of the same DMS performance data packages used in AMP and SUGMUG and cards with alphanumeric identification. The program operates as follows. Values of turn rate and E_s are specified. Mach number starts at zero and is increased as altitude is decreased with E_s constant $\left(E_s = h + \frac{V^2}{2g}\right)$. At each turn rate, specific energy, and altitude, the velocity, Mach number, normal load factor, and P_s are calculated and the $P_{s,max}$ over the altitude range is updated. When the altitude decrementation is completed, the E_s value is placed in the abscissa array and the $P_{s,max}$ value is placed in the ordinate array, and these data are placed on a plot file. A new E_s value is then specified and the ordinate calculation is repeated. This process is continued until the desired number of turn rate values are examined.

The plot file is the primary output of Program SVELTE. This plot file is used to provide curves of $P_{s,max}$ as a function of E_s. An example of SVELTE output is given in figure 8.

A $P_{s,max}$ plot consists of a number of curves of $P_{s,max}$ as a function of E_s, each curve corresponding to a different turn rate for one aircraft. After a $P_{s,max}$ plot has been developed, plots of $\Delta P_{s,max}$ between the present aircraft and each one of the previously considered aircraft are developed. The entire process is repeated for each aircraft. In addition to the plot file, similar data are output on the line printer. This information includes the abscissa and ordinate (E_s and $P_{s,max}$ or $\Delta P_{s,max}$) of each point plotted, the value of turn rate at which each point is plotted, and the altitude, Mach number and normal load factor at which maximum specific excess power occurred.

Daily Use Programs

To meet requirements for daily single run data reduction, display, and analysis, one primary and several secondary data reduction and analysis programs have been generated. As mentioned previously, the daily output of these programs was used by pilots and test engineers in the NASA/NAVY study to evaluate the previous day's results. The results were evaluated to determine whether maneuvers used were successful or not and whether any unusual outcome was encountered. In addition, these data provided the basis for the final evaluation of the tests. The programs that were used and that are available are shown in figure 9. As can be seen in the figure, the primary input to all the programs is the DMS Data Tape which was discussed previously. Each of these programs and their elements are discussed herein.

A general comment related to all programs shown in figure 9 is the heading information present on all output. During the DMS runs, information was placed on the DMS Data Tape in the integer word KODE to facilitate record keeping and future use. KODE contains the date, run number, aircraft pair being flown, pilots in each aircraft, and the I.C. for a given run. In each of the following programs, KODE was used in identifying runs and as information for output headings.

Program HASTE.- Program HASTE was developed by Naval Ship Research and Development Center (NSRDC) personnel to perform the major data reduction and display functions required to support the NASA/Navy study. The primary operations of HASTE include reading the DMS Data Tape, computing variables of interest from the DMS variables, and calling and controlling data handling subroutines. Figure 10 shows the data handling subroutines that can be called by HASTE and the type of output they produce. As seen in the figure, the subroutines and the output they produce are as follows:

(1) Time history listings of 68 variables by subroutine TLIST

(2) Time history listing of 30 event markers by FLAGER

(3) Cumulative histograms of 10 variables from FASTON

(4) 24 two- and three-way histograms by TTHIS

(5) Time history graphical display of 21 variables for up to 900 seconds of flight time and two X,Y-type plots every 300 seconds by GRAFIC

(6) Gun fire and offensive position summary section by S1RUN

(7) The first, second, and third cumulative central moments of 10 variables at various times during a DMS run presented by M123S

The output indicated are discussed in the descriptions of the subroutines.

The input to HASTE consists of the DMS Data Tape and a HASTE Data Package. The HASTE Data Package includes the following information:

(1) Gun and aircraft vulnerability definition
   (a) Number and types of guns
   (b) Characteristics of each gun type
   (c) Vulnerability profile (target area at different ranges, altitudes, etc.)

(2) Number of runs to be processed

(3) Entry rates for subroutines (How often is each subroutine to be entered?)

(4) What subroutines are to be used (What type output is desired?)

(5) Frequency of histogram, data listing, etc., output

Program HASTE operates in the following manner. First, the HASTE Data Package is read and all variables used in HASTE are initialized. Next, each DMS Data Tape file (run) processed by HASTE is read one record at a time. This is followed by computation of the variables required for the subroutines. Then, a test of the indicators associated with each subroutine is executed and the necessary subroutines are called. After all the subroutine calls, another DMS record is read and the computation, testing, and calling cycle is repeated. This cycle is continued until a run is processed. When the run has been completed, every subroutine that has been used is called again for final disposition of its accumulated data. This process is continued until all runs have been completed. The output resulting from HASTE is dependent on which of the optional data handling subroutines shown in figure 10 are called for in the HASTE Data Package. The data subroutines are independent of each other and under programer control in that data in the input card deck prescribe the frequency of display of each display and the time between samples with which the displays receive data. The fact that these values are supplied by the programer provides, first of all, flexibility to process data tapes which have radically different sampling rates. Secondly, programer control over the displays provides the ability to tailor-make the output to analysis needs with regard to type, amounts, and accuracy of displays. A brief description of the subroutines and a typical output of each follows.

Subroutine TLIST: Subroutine TLIST accumulates data from the DMS Data Tape and HASTE and outputs time listings of 68 parameters. Three types of output are provided, with one page per aircraft for each type (six pages per specified interval of time). The first two pages contain time histories of aircraft relative positions and velocities. The parameters given include time into run t, range between aircraft R, the time rate of change of range $\dot{R}$, the difference between the inertial coordinates of the two aircraft ΔX, ΔY, ΔZ, the difference between the inertial velocity components of the two aircraft $\Delta\dot{X}$, $\Delta\dot{Y}$, $\Delta\dot{Z}$, and the angular rate of change of the range vector in the inertial coordinate system $\dot{\sigma}_T$ and its components in the vertical (X-Z plane) and horizontal (X-Y plane) directions $\dot{\sigma}_V$, $\dot{\sigma}_H$. The next two pages contain aircraft specific information. The information presented consists of each aircraft's altitude h; velocity V; Mach number M; Euler roll, pitch, and yaw angles ϕ, θ, ψ and angular velocities p, q, r; normal and lateral load factors n_z, n_y; angle of attack α; sideslip angle β; specific excess power P_s; and an AML cell score similar to that generated in the AML program previously discussed. The last two pages of the series contain time listings of angular relations between the two aircraft. This type of output includes the angular relations illustrated in figure 11. The relations indicated in this figure are the off-boresight angle λ which is the angle between the x-axis and the range vector $\vec{R}$, the deviation angle ϵ, which is the angle between the velocity vector $\vec{V}$ and range vector $\vec{R}$. The other angle given is angle-off. Angle-off of an attacker aircraft is defined as the difference between the target aircraft's deviation angle and 180°. In addition to these angles, various components of λ are also presented $\left(\lambda_{u/D}, \lambda_W, \lambda_e, \lambda_a\right)$.

Each type of information presented by TLIST is output for both aircraft at user specified time intervals. Examples of the three types of TLIST output are given in tables V to VII.

Subroutine FLAGER: Subroutine FLAGER takes the flag word (IFLAG) from the DMS Data Tape, decodes it, and uses values contained in it to generate a page of event markers as illustrated by table VIII. The flag word is an 8-digit integer, with each digit representing one event and its status. The events contained in IFLAG and shown in table VIII are as follows:

(1) Gun status – Is aircraft in gun envelope (E) and/or firing guns (F)?

(2) Missile A status – Is aircraft in missile A launch envelope (simplified launch cone defined by λ and R) (E)? Is missile A selected (S)? Is missile A launched (F)?

(3) Repeat for missile B.

(4) Repeat for missile C.

(5) Bingo marker – Has aircraft reached bingo fuel limit or not (bingo fuel is minimum fuel required to return to safe area)?

(6) Angle-of-attack marker – Indicates when angle of attack exceeds designated maximum value.

(7) High lift device activation marker – Indicates when high lift devices are used (flaps, slats, etc.).

(8) Ground impact marker – Indicates when aircraft reaches altitude less than zero.

These events are given for both aircraft. The run shown in table VIII indicates, for example, that sphere A had missile type A selected and was in the envelopes of both missile types A and B from 160 to 170 seconds. At 170 seconds, sphere A fired a missile type A and then went out of the missile envelope for the rest of this page. Sphere A also had an angle of attack exceeding 30° at 160 to 162 seconds and later at 186 to 188 seconds into the run. Sphere B had missile B selected from 160 seconds until 180 seconds. During that time sphere B fired a missile type B, while in envelope, at 178 seconds. At 184 seconds sphere B selected guns and fired them, while in envelope, for the period between 184 and 196 seconds. The time interval for printing the FLAGER page is an input parameter.

Subroutine TTHIS: Subroutine TTHIS accumulates data from the DMS Data Tape and from HASTE and uses them to compute and write values for time cumulative two- and three-way histograms. Table IX lists the 24 histograms provided by TTHIS. A representative three-way histogram is shown in table X. This table gives the percentage of the total run time within various interval sets of the off-boresight angle λ for aircraft A and B and the range between the two aircraft. Table X represents only part of this particular histogram since λ for aircraft A is shown only up to 60°. This particular histogram can be used to determine the percent of time one aircraft spends in the envelopes of various weapons. The histograms provided by TTHIS can be output at any interval desired by the user through HASTE Data Package input. An example of this option would be an output every 60 seconds up to the total run time, that is, at 60, 120, 180, and 240 seconds.

Subroutine FASTON: Subroutine FASTON computes and displays the percentage of time in which selected parameters, indicated in table XI, lie within chosen intervals. These percentages are cumulative with respect to time into flight and computed at equally spaced time values. An example of one of the displays is given in table XII. This table gives the percent of time spent in various intervals of altitude as a function of time into the run (every 25 seconds up to 225 seconds). These data are presented for both aircraft. The time into run intervals are varied through the input to the HASTE Data Package.

Subroutine GRAFIC: Subroutine GRAFIC takes 21 parameters from HASTE and prepares them for graphical display by one of the Langley graphics systems. When the data for a run are accumulated, these accumulated data are placed on a magnetic tape which is used to provide graphic output. The output provided by GRAFIC consists of nine frames of graphics per run.

The nine frames of an output set consist of two different types of plots; those which plot a parameter value against time and those which plot one parameter's value at a time against another's value at that same time.

The first seven frames plot 21 parameters against time. Frame 1 has two plots and is illustrated in figure 12. On the lower plot, range is plotted as a function of time; on the upper plot, off-boresight angle is plotted as a function of time for both aircraft A and B. Off-boresight angle for aircraft A is plotted with + signs and off-boresight angle for aircraft B, with dots. The other parameters, all plotted against time, are as follows:

Frame 2	$\dot{R}$, $\dot{\sigma}$
Frame 3	$h(1)$, $V(1)$, $h(2)$, $V(2)$
Frame 4	$n_z(1)$, $\alpha(1)$, $\phi(1)$, $P_s(1)$
Frame 5	$n_z(2)$, $\alpha(2)$, $\phi(2)$, $P_s(2)$
Frame 6	$\epsilon(1)$, Angle-off (1)
Frame 7	$\epsilon(2)$, Angle-off (2).

The frequency with which points are plotted along the time axis is controlled by user input data.

The last two frames of data output by GRAFIC plot altitude against Mach number. The plot gives Mach-altitude points for every 10 seconds into the run and indicates by symbol whether at that time the aircraft was on offense (A), defense (X), or in a neutral position (N) with respect to other aircraft. This output is illustrated by figure 13. A frame is provided for each aircraft. An aircraft was defined as on offense when its λ was less than 90° and the other aircraft's λ was greater than 90°. An aircraft was considered to be on defense when the other aircraft was on offense. A neutral position was indicated when neither aircraft was on offense.

Subroutine S1RUN: Subroutine S1RUN compiles statistics and histograms which summarize gun and missile zone and firing information and offensive position data. The output from S1RUN is presented on six different pages. One of the prime relations considered is the off-boresight angles λ and the range between the two aircraft. This set of information indicates the offensive status of each aircraft and whether they are within simplified weapon envelopes. The pages output and what they present are as follows.

The first page of output is illustrated by table XIII and includes the following information:

(1) Time of first entry into a given weapon envelope (guns and three missiles)

(2) Total time on offense (λ of attacker < 90^{o}) as a function of time into run

(3) Total time on offense with advantage (λ of attacker < 90^{o} and λ of target > 90^{o}) as a function of time into run

(4) Total time in gunfire envelope (100 feet < range < 3000 feet, target $\lambda > 120^{o}$ and attacker $\lambda < 1^{o}$, 2^{o}, 3^{o}, 5^{o}, and 10^{o}) as a function of time into run

(5) Same as (4) except that target $\lambda > 90^{o}$

(6) Total time guns were firing while in envelope for envelopes given in (4) and (5)

(7) Time in each of the three missile envelopes as a function of time

The second page of output is illustrated by table XIV and gives percent of gunfire time within one-way intervals of deviation angle, range, and angle-off. The third and fourth pages of S1RUN output are similar and are represented by table XV. These pages give percentage of offensive time and offensive time with advantage, respectively, within one-way intervals of range, range rate, altitude, deviation angle, Mach number, and normal load factor. The fifth page of output is illustrated by table XVI and gives a listing of each gunfire burst and missile launch initiated by a DMS pilot during a run. The gunfire output includes the start and stop times of the burst and the probability of kill (APK) of the gunfire burst. This page also has the total run time, the accumulative gun APK, and the average AML score for a run. The missile launch output, similar to gunfire output, gives an indication of each DMS trigger pull when a missile had been selected, the type of missile selected, the time of the trigger pull, whether or not the missile was launched in envelope, and the aircraft the missile was launched from. There is no evaluation of missile probability of kill P_k in HASTE, and no firing logic, weapons load considerations, etc., are indicated in these data.

The five pages of output given by S1RUN were used as the primary method of daily run review by the test pilots and were generated for all data runs. In addition to the line printer output from S1RUN, the first four pages are output on punched cards or magnetic tape for use in Program MULTI2.

Subroutine M123S: Subroutine M123S takes selected DMS data (R, $\dot{R}$, V, h, n_z, λ) and calculates and lists the cumulative first and second central moments at given times into the run. The first central moment corresponds to the means of the parameters over the specified time interval and the second moment corresponds to the standard deviations. Subroutine M123S also outputs the initial conditions of λ_a, V, h, ϕ, θ, ψ, and R for each run. Typical M123S output is given in tables XVII and XVIII.

NWC missile program.- The NWC missile program is one of two off-line missile programs used to evaluate weapons, weapon loads, and launch opportunities and success. It was developed by personnel of the Naval Weapons Center (NWC) and modified by NSRDC and LRC personnel for the DMS. The NWC missile program utilizes aerodynamic descriptions of current missiles. These descriptions are used by the program to compute missile trajectories after launch. The trajectories are continued until impact or miss, due to exceeding some missile limit, occurs. Various output options are available.

The input to the program includes the DMS Data Tape and a data package which describes missile aerodynamic characteristics, thrust profiles, sensor gimbal angles and rates, and various limits (launch envelopes, sensor tracking rates, miss distance criteria, etc.). Any number of missile types can be evaluated in the program although only two types were used in the NASA/Navy study.

The program operates by investigating the situation of one aircraft at a time, with only one type of missile being evaluated at a time. The program takes the DMS Data Tape and checks at each time interval on the tape whether the aircraft meets the launch criteria and if not what was the reason. The launch criteria consist of off-boresight angles, ranges, line-of-sight sweep rates, etc. If the criteria were met, a launch is initiated and the resulting trajectory is calculated. If an impact or a miss within a specified distance occurs, the program indicates an impact and various conditions at impact. If the missile exceeds a limit during its flight, the trajectory calculations are discontinued and the reason is indicated. If an aircraft does not satisfy the launch envelope criteria, the reason is indicated and no trajectory is calculated. This check occurs for each time interval on the tape or at an interval specified by user. The launch criteria checks and successful launches are counted during a run. All runs on a tape are evaluated for the particular missile and aircraft combination and then the DMS Data Tape is rewound and the run evaluated from the other aircraft's viewpoint. This process continues until all aircraft and missile combinations have been evaluated.

The output of the NWC missile program is illustrated in tables XIX and XX. Table XIX is one page of time listings for a run. Below the standard heading is a line of print which gives the code words for the missile and aircraft combination being evaluated. Next is a line indicating the launch criteria for the missile being evaluated. These criteria include the launch gimbal angle limit (missile sensor gimbal angle), the maximum and minimum range limits, the sensor track rate limit, and the maximum gimbal angle limit after launch. The rest of the data given in the table relate to launch attempts. The first section, labeled "Launch Conditions," gives the conditions at selected time intervals when a launch is attempted. This section includes the range, sensor gimbal angle, and the sensor tracking rates. If any of these values exceed the launch limits, then a launch cannot occur and a statement telling which envelope criteria were not met is printed. These statements are illustrated by the printouts for the time interval between 108.5 and 111.0 seconds. Next is given the values which indicate a stop after a launch. This section is labeled "Limit Stop." This section includes the time interval after launch a limit stop is exceeded (T2), the gimbal angle (GA2), the sensor tracking rate (TR2), and the stop limit range (SLRNG). If any of these conditions exceed the limit criteria, then the trajectory is stopped and the reason printed out. These reasons are illustrated by the printouts for the period between 104.0 and 108 seconds. Finally, if a launch continues on to impact, the final section, labeled "Intercept Data," is printed out. This section gives conditions at impact or closest approach and maximum values occurring during trajectory The values given include the maximum load factor (GN) and angle of attack (ALM) occurring during trajectory, time of missile flight (TOF), miss distance (MSD), closing velocity (CLOVEL), range at impact (RSTP), yaw, pitch, and roll angles (AANG, EANG, RANG), missile velocity (MVEL), cross angle (CANG), angle of attack (ALF), off-boresight angle (LANG), longitudinal acceleration (GAX) at impact, and time of impact (TIMP). This output is illustrated by the line printed at 111.5 seconds in table XIX. In addition to the programed attempts to launch a missile, any trigger pulls recorded during a DMS run, with the correct missile selected, will cause a special printout indicating the launch and its success or failure. Table XX is an example of the summary-type page presented after each run. This output tabulates the simulated and DMS launches and their successes. The first set of data indicates the number of simulated launches out of envelope, in envelope but missing because of a limit stop, and hits. The frequency of launch attempts is also indicated. A similar output is given for pilot initiated launches. The final set of data incorporates a time in envelope delay and counts only the launches meeting this additional constraint. This output presents the total number of launches with the delay and the number of impacts with gimbal angles at launch of less than or equal to 40° and 20°.

NADC missile program (LAUNCH).- The NADC missile program was developed for the Naval Air Development Center (NADC) to support the NASA/Navy DMS study. This missile program utilized launch acceptance region (LAR) tables, based on actual results in combat and in extensive simulations, to determine when a successful launch could be initiated. The LAR tables contain combinations of range, off-boresight angle, target aspect angle (angle between target x velocity axis and range vector), Mach number, and altitude which should provide a successful missile impact. A graphical representation of a part of the LAR table for one missile is given in figure 14. As shown, this table is for the Mach 0.9 region, an altitude of 15 000 feet (4.6 kilometers), heading angles of 0° and 30°, and an assumed target maximum acceleration of 6.5g. When conditions within these acceptable zones are met, a successful launch is assumed. Various inputs are provided to describe the results of a run.

Inputs to the program consist of the DMS Data Tape and the LAR table information for up to three weapon systems in the form of data cards. These cards include missile launch sequencing and logic and run information indicating runs to be processed and weapon systems on each aircraft.

The program operates in the following manner:

(1) Reads LAR table and weapon constraint input cards

(2) Reads run information cards

(3) Reads DMS Data Tape record for current run

(4) Initializes run variables and arrays

(5) Computes states of both aircraft for current record

(6) Computes launch zone conditions for all available weapons

(7) Tests launch criteria for all available weapons

(8) Determines impact conditions for all launched missiles

(9) Prints launch report data for current record

(10) Continues (1) to (9) until run completed

(11) Outputs run summary data

The output provided by LAUNCH is illustrated in tables XXI and XXII. Table XXI is one page of the launch report output for each time interval on the DMS Data Tape. Each page of the launch report has a heading describing all the run information including the code for the weapons on each aircraft. Below this heading, the launch data for both aircraft are listed. For each time interval each aircraft's altitude, Mach number, normal load factor, off-boresight angle, aspect angle, and range are given. In addition, for the missiles carried, indications of when the aircraft are in a missile launch zone are listed. The letter H indicates that an aircraft has a proper heading but is not in the launch zone with respect to aspect angle or range. The letter V indicates that an aircraft is in the launch zone with respect to all parameters. The other columns indicate simulated and pilot controlled launches with the letter V representing simulated launches when time in zone criteria are satisfied and dashes indicating impacts for both the simulated and piloted launches. In addition, if a pilot attempts a launch while out of the envelope, the letter T is used.

Table XXII shows the launch summary report and impact matrix output at the end of a run. The launch summary report gives the DMS Data Tape numbers, run numbers, date, pilot, aircraft codes, weapons codes, number of time intervals in launch zone, and simulated launches for each missile type for each aircraft. The impact matrix outputs the simulated and piloted launches, indicating the type launched and the time at which it occurs. The code for the type of missiles launched is also given. In addition to the line printer output, the impact matrix and launch summary report are output on punched cards for use in Program OUTCOME which is discussed in the section entitled "Posttest Programs."

Program 3-D.- Program 3-D takes data from the DMS Data Tape and generates plots which represent a ground trace (X-Y plane) and a perspective 3-D representation of the two aircraft and their trajectories as seen from a selected point in space. The only input to the program is the DMS Data Tape and some identification and scale factor cards. The program operates in the following manner:

(1) The inertial coordinates of the center of gravity and the attitude of each aircraft are read from the Data Tape.

(2) Each aircraft is assumed to be represented by a simple nine-point vector figure, defined in the body axes. The computer uses the aircraft attitudes to transform the nine points from the body axis system to the inertial coordinate system.

(3) By using a predefined eye position and point of regard, the coordinates of the points are transformed from the inertial system to a line-of-sight coordinate system having the X-axis alined with the line of sight.

(4) By assuming that the plane of the plot is scaled to a location at some distance along and perpendicular to the line of sight, each of the points is located on the 3-D plot.

(5) The nine points are connected to form the aircraft symbol

(6) The locations of the two points representing the wing tips are stored for use in succeeding plots to define the trajectory of the aircraft.

(7) The velocity, range, and time into the run of each aircraft are printed.

The only difference between the 3-D perspective plot and the ground trace plot is that it is assumed for the ground trace that the aircraft is at zero altitude ($Z = 0$). Figure 15 is representative of the output of Program 3-D. In the figure the solid lines represent one aircraft's trajectory and the dotted lines represent the other aircraft's trajectory. One pair of side-by-side dots represents the aircraft wing tips and these data are output at a specified time interval. In this figure the data are output every second with 20 seconds given on each frame. The aircraft symbols and alphanumerics are given for the last time on the frame.

Posttest Programs

After a series of runs were completed for an aircraft pair, it was a requirement of the NASA/Navy study to perform multirun analysis and data presentation. This type of information gave some statistical support to trends encountered in single runs and permitted more concise presentation of study results. Three programs were used as represented by the dashed boxes in figure 9. All the programs are generally concerned with the aircraft's weapons and offensive performance with two of them being concerned primarily with time in zones and the other one being concerned with weapons performance and probability of kill P_k. Two of the programs output single run data as well as cumulative or average values. A discussion of these three programs follows.

Program OUTCOME.- Program OUTCOME was developed for NADC and its purpose is to determine the probabilities of win, lose, or draw in a simulated combat between two aircraft. Program OUTCOME receives its primary input data from the punched output of the LAUNCH program. Program OUTCOME determines sets of win, lose, or draw probabilities based upon sequences of both simulated (i.e., possible) impacts and actual (pilot initiated) impacts coming from LAUNCH and missile probability of kill and weapon load limitation parameters input by the user. In general, the probabilities of outcome are reported in a matrix form which is the result of a parametric study.

Program OUTCOME accepts the probabilities of kill for the firing of a single missile from each weapon system. It then varies the probability of kill of one weapon system (e.g., missile type) in steps from 0 to 1 and observes the effect upon the probabilities of win, lose, or draw. The program next varies a second probability of kill (either another weapon system on the same aircraft or a weapon system on the other aircraft) against the first while holding the remaining probabilities of kill constant. The variation of one probability of kill with another creates the matrices of win, lose, or draw.

For each run the program computes and prints matrices of win, lose, or draw for both the "simulated" and the "piloted" cases. At the end of the program, matrices which are the averages of the individual run matrices are computed and printed. An example of the output from OUTCOME is given in table XXIII. This table presents an average probability of loss matrix for sphere A for a set of runs. The first set of information on the left side of the page indicates what weapons are to be considered on each aircraft and the number of each type. Below that is given the desired single shot probability of kill for each weapon. The missiles with $P_k = 1.0$ are those to be varied from 0 to 1.0 in the matrix while the other missile P_k values are to be held constant during computation. Other heading information given by this output includes the DMS Data Tape being processed, the run number, the time interval in the run to be evaluated, and the code for the weapons that are being evaluated in the probability matrix. The matrix size itself can be varied by the user.

Program MULTI2.- Program MULTI2 takes run data output by subroutine S1RUN of Program HASTE and combines it according to pilot, date, I.C., or aircraft as specified by input cards. These data are then used to determine means, standard deviations, and t-test results for a specified set of runs and two histograms.

Input to MULTI2 consists of the punched cards or magnetic tape representing single run results coming from HASTE, cards which identify parameters that will be considered and output, and cards that identify runs to be used in computations. One set of run cards, including an alphanumeric identifier, is necessary for each set of data to be analyzed.

Runs to be evaluated as a set are designated by user. For example, if it is desired to evaluate the performance of one pilot against all other pilots, the runs in which the selected pilot was involved is specified as a set according to run dates. Any other evaluation would require another set of cards with desired runs listed.

The program operates in the following manner. First, it reads the alpha-numeric title for the set of data being processed, determines the number of parameters to be evaluated, and uses the number of parameters to establish a set of holding arrays. Next, MULTI2 reads and stores in arrays dates and runs to be used in the evaluation. When the run and date arrays are established, the program reads the run data from HASTE and checks each run number on tape with those in array. When a date matches, the information on that run is stored in the proper parameter arrays. This process continues until all runs have been located. The parameter data are then sent to output subroutines which perform the various computations required to obtain the means, standard deviations, t-test parameters, and histogram information. These data are printed out, the arrays are initialized, the next set of runs is read in, and the process is repeated until all sets of runs are processed.

Typical MULTI2 output is shown in tables XXIV to XXVIII. Table XXIV is the same output as given in table XIII except that the numbers shown represent mean values for a set of runs instead of one run. The heading describes the particular set of runs being considered. Table XXV presents also the same parameters as discussed in table XIII except that the numbers represent standard deviations. Table XXVI contains the values of the t-test (ref. 5) and the number of degrees of freedom (D.F.) for use in testing the hypothesis that the mean values for the two aircraft (table XXIV) are equal. Table XXVII gives a three-way histogram similar to one output by TTHIS of Program HASTE which gives the mean percentages of time at various intervals of n_z, M, and h. Table XXVIII is a three-way histogram similar to that discussed in table X except that it too represents mean values for a set of runs.

Program BZONE.- Program BZONE was developed to evaluate a pilot's capability to establish and maintain position of one aircraft with respect to another. This evaluation is accomplished by establishing three target zones and five attacker off-boresight-angle zones. The three target zones are illustrated in figure 16. The three target zones correspond to a head-on, beam, or tail situation. The five attacker zones correspond to off-boresight angles of $\leqq 10^{\circ}$, $\leqq 20^{\circ}$, $\leqq 40^{\circ}$, $\leqq 60^{\circ}$, and $<90^{\circ}$. An additional restriction of range of <3000 feet (0.914 kilometer) is included for the $\leqq 10^{\circ}$ zone. The resulting 15 attacker-target zone combinations give general trends as to relative offensive superiority and weapons delivery opportunities.

The only input to BZONE is the DMS Data Tape. Program BZONE operates with these data by reading the inertial positions and Euler angles and determining both aircraft's off-boresight angles. The angles, in turn, are checked to determine into which one of the 15 combined zones they fall. When the zone for the current record has been determined, the program checks to see whether it is the first time the zone has been entered and updates a time in zone counter. This process continues until a run is completed. After a single run is processed, the results are output and the first entry times and total time in zones are transferred to a set of holding arrays which are used for multirun averaging. The rest of the runs are processed in a similar manner until all runs are completed. At this time the holding arrays are used to compute average values of all the single run parameters. A single page of average values are output for each I.C.

Typical output from BZONE is given in tables XXIX and XXX. Table XXIX is representative of a single run output. The headings across the page relate to the target aircraft's three orientations as shown in figure 16, and the vertical headings are the attacker's off-boresight-angle intervals. The first three columns show the times of first entry into each of the 15 zones. The next three columns show total time in each of the zones. The last three sets of three columns indicate the first time in which the attacker aircraft entered one of the zones and remained in it for 2, 4, and 6 seconds, respectively. Directly below these columns are corresponding columns which indicate the number of times during the run in which the 2, 4, or 6 seconds in zone occurs. The same type of data is also given with the attacker and target roles reversed.

Table XXX represents the multirun output for BZONE. The same type of headings are used for the multirun output with the numbers given representing average values instead of single run values. The averages given, however, are not determined by the total number of runs being considered but instead are based on the total number of runs in which a zone has a nonzero value; that is, if one run had no first entries into one of the zones, that run would not be counted in averaging the first entry times for a set of data. The number of runs with nonzero values for each zone and for each element of output is output directly below the element of interest. The number of runs also indicates the degree of reliance that can be placed on average values, when compared with total number of runs. The output is again given with both aircraft as attacker and defender.

CONCLUDING REMARKS

An extensive data reduction and analysis capability has been developed to support differential maneuvering simulator (DMS) aircraft simulation studies. This capability includes programs which provide (1) pretest information which can be used to show pilots' areas of aircraft superiority and possible maneuvers, (2) daily use information which presents individual run data in different forms, and (3) multirun data to show, concisely, results of a series of runs.

These programs use, in general, one of three types of input data depending on which one of the three types of program is involved. The pretest programs utilize as input the same aerodynamic data used in the DMS to describe the aircraft of interest. Daily use programs, as described, use output from the DMS simulation as the major input. Multirun programs, in general, use as input the output from the daily use programs. The major programs are designed to be flexible and are generally adaptable to any aircraft pair.

The discussion of each program included in this paper was not intended to be a user's guide but to be an introduction to each available program and major input and output data.

Langley Research Center,
National Aeronautics and Space Administration,
Hampton, Va., April 5, 1973.

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TABLE I.- DATA STORED ON DIFFERENTIAL MANEUVERING SIMULATOR DATA TAPE

Word	Variable	Description	Unit
1	KODE	Code number of date, run, pilot, and aircraft	- - -
2	T	Time from start of run	Seconds
3	RBA (R)	Range	Feet
4	RBADOT ($\dot{R}$)	Range rate	Feet/second
5	IFLAG(1)	Integer FLAG for gun/missile data for sphere A	- - -
6	IFLAG(2)	Integer FLAG for gun/missile data for sphere B	- - -
7	X(1)	X inertial position of sphere A	Feet
8	Y(1)	Y inertial position of sphere A	Feet
9	HAB(1) (h)	Altitude of sphere A	Feet
10	SXDOT(1) ($\dot{X}$)	X inertial velocity of sphere A	Feet/second
11	SYDOT(1) ($\dot{Y}$)	Y inertial velocity of sphere A	Feet/second
12	HDOT(1) ($\dot{h}$)	Time rate of change of altitude of sphere A	Feet/second
13	PSID(1) (ψ)	Euler yaw angle of sphere A	Degrees
14	THETAD(1) (θ)	Euler pitch angle of sphere A	Degrees
15	PHID(1) (ϕ)	Euler roll angle of sphere A	Degrees
16	NZ(1)	Normal load factor of sphere A	G's
17	NY(1)	Lateral load factor of sphere A	G's
18	ALPDEG(1) (α)	Angle of attack of sphere A	Degrees
19	BETADEG(1) (β)	Angle of sideslip of sphere A	Degrees
20	P(1)	Body roll rate of sphere A	Radians/second
21	Q(1)	Body pitch rate of sphere A	Radians/second
22	R(1)	Body yaw rate of sphere A	Radians/second
23	WEIGHT(1)	Weight of sphere A	Pounds
24	TT(1)	Thrust of sphere A	Pounds
25	PS(1)	Specific excess power of sphere A	Feet/second
26	DELTSP(1)	Fore/aft stick position of sphere A	- - -
27	DELTAP(1)	Right/left stick position of sphere A	- - -
28	DELTRP(1)	Rudder pedal position of sphere A	- - -
29	TPOSTOL(1)	Throttle position of sphere A	- - -
30	ETAL(1)	Dummy word	- - -
31	ZETAL(1)	Dummy word	- - -
32 to 56	- - -	Repeats words 7 to 31 for sphere B	- - -

TABLE II.- OUTPUT FROM ASTAC MODEL

Output during each engagement

1. Initial position and velocity of each aircraft
2. Position, velocity, thrust, drag, load factor, and attitude of each aircraft, and range and closure rate between aircraft, at preselected time intervals
3. Time each new tactical maneuver is selected, and type of maneuver selected

Output after each engagement (for each aircraft)

1. Percent of time at –
   load factor: less than 2.5, 2.5 to 5.0, over 5.0
   Mach: less than 0.8, 0.8 to 1.2, over 1.2
   altitude: less than 10 000, 10 000 to 20 000, 20 000 to 30 000, over 30 000 feet
2. Time in offensive position
3. Fuel remaining
4. Type and number of missiles carried and fired
5. Cumulative probability of kill for gun, IR missiles, and radar missiles
6. Time and distance of closest approach for each missile fired
7. Time opponent was detected

Summary for set of engagements (for each aircraft)

1. Mean probability of kill for gun fire, IR missiles, and radar missiles
2. Mean of altitude versus Mach versus load factor distribution, over all duels
3. Mean percent of total gunfire time at
   load factor: less than 2, 2 to 4, 4 to 6, over 6
   range: 0 to 1000, 1000 to 2000, over 2000 feet

TABLE III.- QUESTIONS TO DETERMINE CELL OF SITUATION MATRIX IN AML

(1) Is the opponent within a certain cone behind me?

(2) Am I within a certain cone behind my opponent?

(3) Is the opponent in an attitude and position so that he can fire at me?

(4) Am I in an attitude and position so that I can fire at my opponent?

(5) What is the rate of closure (closing fast, closing slowly, separating slowly, separating fast)?

(6) Is the line-of-sight angle (angle between the velocity vector and the line-of-sight vector) from the opponent to me less than 60°?

(7) Is the line-of-sight angle from me to the opponent greater than 90°?

(8) Is the rate of change of the line-of-sight angle from me to the opponent negative?

(9) Is my specific energy rate P_s greater than a given constant?

TABLE IV.- OUTPUT FROM AML PROGRAM

Output during each engagement

1. Position, velocity, lift, drag, thrust, load factor, angle of attack, specific excess power, throttle position, and attitude of each aircraft, and range and closure rate at selected time intervals
2. Currently accumulated offensive, defensive, and gun envelope time
3. Current AML cell state
4. Trial maneuver data including number of maneuvers tested, load (g units) pulled during maneuvers, P_s values for each maneuver, cell state for each maneuver

Output after engagement

1. Time on offense and defense for each aircraft
2. Time in gun envelope for both aircraft
3. Percent of run time on offense and in gun envelope
4. Percent of offensive time in gun envelope
5. Total run time
6. Plots of aircraft trajectories projected on X-Y plane
7. 3-D plots of each run (perspective and projected plots)

TABLE V.- TIME LISTINGS OF RELATIVE POSITIONS AND VELOCITIES OUTPUT BY TLIST (TYPE I OUTPUT)

	SPHERE A	SPHERE B		LANGLEY RESEARCH CENTER DMS DATA PROCESSING					PAGE	15	
PILOT	3	4			10 18 71						
AIRCRAFT	1	2			RUN NUMBER 2						
	FIGHTER A	TARGET B		PAGE A 3.1							
TIME	RANGE	RANGE D	DELTA X	DELTA Y	DELTA Z	DELT DX	DELT DY	DELT DZ	SIGVD	SIGHD	SIGTD
80.0	2917	99	1465	2493	350	-28	183	-365	7.45	2.32	7.80
82.0	3190	147	1402	2845	-124	-22	168	-139	2.39	1.69	2.93
84.0	3478	143	1375	3171	-325	-4	155	-84	1.16	1.08	1.59
86.0	3769	142	1378	3466	-504	24	131	-95	1.16	.40	1.23
88.0	4047	139	1465	3688	-762	56	93	-172	2.11	-.25	2.12
90.0	4333	150	1632	3846	-1128	132	52	-171	1.81	-1.34	2.25
92.0	4642	157	2025	3930	-1399	236	33	-88	.52	-2.52	2.57
94.0	4955	166	2551	3987	-1480	283	25	-2	-.58	-2.73	2.79
96.0	5239	165	3100	4042	-1443	249	35	32	-.86	-1.97	2.15
98.0	5623	154	3562	4126	-1363	195	54	36	-.77	-1.18	1.41
100.0	5909	133	3817	4313	-1298	58	136	18	-.47	.47	.66
102.0	6159	130	3351	4617	-1350	-2	148	-94	.62	.92	1.11
104.0	6439	140	3889	4853	-1652	43	89	-183	1.35	.20	1.37
106.0	6721	135	3992	5023	-1985	62	86	-114	.66	.05	.66
108.0	6950	105	4149	5193	-2048	92	31	35	-.57	-.19	.60
110.0	7147	87	4359	5322	-1922	120	40	50	-.69	-.56	.89
112.0	7500	339	4693	5366	-2317	236	55	-493	3.12	-1.14	3.32
114.0	8345	439	5237	5514	-3426	273	76	-530	2.63	-1.09	2.85
116.0	9198	411	5770	5657	-4385	267	52	-431	1.66	-1.02	1.95
118.0	9979	365	6312	5754	-5154	272	35	-334	.97	-1.05	1.43

TABLE VI.- TIME LISTING OF SPECIFIC AIRCRAFT INFORMATION OUTPUT BY TLIST (TYPE II OUTPUT)

	SPHERE A	SPHERE B
PILOT	3	4
AIRCRAFT	1	2

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FIGHTER A — TARGET B — PAGE A 3.2

TIME	ALT	VEL	MACH	ROLL AN	PIT ANG	YAW ANG	ROLL RT	PIT RTE	YAW RTE	N ACC	L ACC	ALPHA	BETA	PS	AMLS
80.0	18566	996.9	.96	-100.59	-4.04	-116.98	3.08	1.32	-1.43	.08	.04	-1.19	-.52	384	0
82.0	18335	1028.4	.99	-61.17	-8.37	-114.49	5.71	-1.70	-2.48	-.37	.10	-1.91	-1.10	380	1
84.0	17953	1063.3	1.02	-65.13	-13.42	-113.83	-5.26	-3.43	-1.68	-.39	-.02	-1.85	.20	374	2
86.0	17408	1101.6	1.05	-74.89	-17.15	-111.56	4.53	-4.77	-1.08	-.65	-.01	-2.14	.08	367	2
88.0	16699	1142.6	1.09	-60.05	-20.88	-110.26	4.27	.03	-1.43	-.24	.03	-1.50	-.24	352	1
90.0	15863	1182.4	1.12	-47.48	-19.61	-116.29	-1.54	3.51	-1.15	2.26	-.01	1.85	.04	240	1
92.0	15052	1216.8	1.15	-31.58	-17.54	-121.15	18.07	4.79	-.85	2.17	-.02	1.60	.14	236	1
94.0	14299	1249.8	1.18	-29.71	-16.36	-123.19	-2.88	.56	-.58	1.54	.00	.78	-.03	265	1
96.0	13568	1281.7	1.21	-29.01	-16.31	-124.68	.01	.09	-.61	1.17	.02	.31	-.15	251	3
98.0	12824	1311.9	1.23	-24.27	-16.28	-126.05	1.68	.41	-.52	1.15	.02	.28	-.12	216	3
100.0	12073	1339.7	1.25	-17.40	-16.05	-127.14	.12	.73	-.39	1.14	.02	.23	-.09	175	2
102.0	11322	1364.9	1.27	-18.13	-15.94	-127.92	-1.29	-.29	-.35	.98	.03	.05	-.14	136	2
104.0	10557	1388.2	1.29	-12.77	-16.29	-128.48	6.52	.26	-.30	.84	.04	-.07	-.20	93	2
106.0	9797	1407.4	1.31	-7.30	-13.40	-129.34	-2.08	2.58	-.22	2.28	.01	1.24	-.04	-24	3
108.0	9176	1418.6	1.31	-12.96	-10.36	-130.31	-5.03	1.29	-.37	1.86	.02	.82	-.08	-63	3
110.0	8654	1426.8	1.32	-17.34	-9.31	-131.37	-.01	.73	-.38	1.45	.03	.43	-.12	-91	2
112.0	8276	1432.1	1.32	-18.28	-8.15	-132.53	3.24	.73	-.30	1.51	.03	.48	-.14	-132	4
114.0	7805	1434.5	1.32	-9.78	-6.90	-133.38	2.34	.81	-.19	1.55	.02	.48	-.07	-160	3
116.0	7471	1434.4	1.32	-9.37	-5.55	-133.95	-1.49	.74	-.18	1.53	.02	.45	-.06	-175	3
118.0	7205	1432.2	1.32	-10.16	-4.28	-134.53	-1.26	.87	-.19	1.45	.03	.38	-.10	-184	3

TABLE VII.- TIME LISTINGS OF ANGULAR RELATIONS BETWEEN TWO AIRCRAFT OUTPUT BY TLIST (TYPE III OUTPUT)

	SPHERE A	SPHERE B		LANGLEY RESEARCH CENTER DMS DATA PROCESSING					PAGE	20	
PILOT	3	4				10 18 71					
AIRCRAFT	1	2				RUN NUMBER 2					
	FIGHTER B		TARGET A	PAGE B 3.3							
TIME	RANGE	RANGE D	LAMBDA U	LAMBDA W	LAMBDA T	LAMBDA_A	LAMBDA E	DEV ANG	ANG OFF	IFLAG B	WEIGHT B
80.0	2917	99	-1.77	6.05	6.31	-6.06	-1.76	12.46	11.92	10112302	-19
82.0	3180	147	-3.14	4.96	5.86	-4.96	-3.13	6.82	6.18	10112300	-20
84.0	3478	148	1.32	4.77	4.95	-4.77	1.32	7.43	7.36	10112300	-20
86.0	3769	142	.75	3.61	3.69	-3.61	.75	6.76	9.03	10112300	-21
88.0	4047	138	-1.33	1.09	1.72	-1.09	-1.33	2.40	9.46	10112300	-21
90.0	4333	150	-5.02	.83	5.09	-.84	-5.02	3.65	5.97	10112300	-22
92.0	4642	157	-5.12	2.36	5.64	-2.37	-5.12	7.40	3.01	10112300	-22
94.0	4965	165	3.33	8.17	8.81	-8.18	3.29	11.74	.37	10112300	-23
96.0	5299	165	10.39	1.86	10.56	-1.89	10.39	12.93	2.84	10112300	-24
98.0	5623	154	9.02	-.59	9.04	.60	9.02	12.49	5.25	10112300	-24
100.0	5909	133	2.19	-3.01	3.72	3.01	2.19	6.79	5.54	10112300	-25
102.0	6169	130	-2.65	-2.41	3.58	2.41	-2.64	2.65	3.72	10112300	-26
104.0	6439	140	-6.79	-2.62	7.27	2.63	-6.78	5.53	1.38	10112300	-26
106.0	6721	135	-6.15	.67	6.18	-.67	-6.15	6.39	2.66	10112300	-27
108.0	6960	105	-3.44	-1.31	3.69	1.31	-3.44	3.47	6.13	10112100	-28
110.0	7147	87	-6.18	.21	6.19	-.22	-6.19	2.64	6.17	10112300	-29
112.0	7500	339	-41.39	3.02	41.48	-4.03	-41.32	31.20	9.45	10112500	-29
114.0	8345	439	10.30	39.71	40.81	-40.17	7.31	41.05	16.87	10112500	-30
116.0	9198	411	39.54	16.61	42.35	-21.15	37.59	42.44	22.53	10112500	-31
118.0	9979	365	41.87	3.44	41.98	-4.62	41.77	42.52	26.60	10112500	-32

TABLE VIII.- SPECIAL EVENT MARKERS OUTPUT BY SUBROUTINE FLAGER

	SPHERE A	SPHERE B
PILOT	3	4
AIRCRAFT	1	2

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TIME	SPHERE A GUN E F	SPHERE A MIS A E S F	SPHERE A MIS B E S F	SPHERE A MIS C E S F	SPHERE A BINGO FUEL	SPHERE A ALPHA >30	SPHERE A H L	SPHERE A H<0	SPHERE B GUN E F	SPHERE B MIS A E S F	SPHERE B MIS B E S F	SPHERE B MIS C E S F	SPHERE B BINGO FUEL	SPHERE B ALPHA >30	SPHERE B H L	SPHERE B H<0
160.0		E S	E			A					S					
162.0		E S	E			A					S					
164.0		E S	E								S					
166.0		E S	E								S					
168.0		E S	E								S					
170.0		E S F	E								S					
172.0		S								E	E S					
174.0		S								E	E S					
176.0		S								E	E S					
178.0		S								E	E S F					
180.0		S								E	E S					
182.0		S								E	E S					
184.0		S							E F	E	E					
186.0		S				A			E F	E	E					
188.0		S				A			E F	E	E					
190.0		S							E F	E	E					
192.0		S							E F	E	E					
194.0		S							E F	E	E					
196.0		S							E F	E	E					
198.0																

TABLE IX.- HISTOGRAMS GENERATED BY TTHIS

Range – Lambda A
Lambda A (Lambda B) – Range
Lambda A (+Range rate) – Range
Lambda A (-Range rate) – Range
Range – Altitude A
Lambda A – Altitude A
Lambda A – Altitude B
Altitude A – Altitude B
Velocity A – Altitude B
Velocity A – Altitude A
Normal Load A – Altitude A
Normal Load Factor A (Mach A) – Altitude A
Range – Lambda B
Lambda B (Lambda A) – Range
Lambda B (+Range rate) – Range
Lambda B (-Range rate) – Range
Range – Altitude B
Lambda B – Altitude B
Lambda B – Altitude A
Altitude B – Altitude A
Velocity B – Altitude A
Velocity B – Altitude B
Normal Load B – Altitude B
Normal Load Factor B (Mach B) – Altitude B

TABLE X.- THREE-WAY HISTOGRAM (λ_A, λ_B, R) OUTPUT BY SUBROUTINE TTHIS

	SPHERE A	SPHERE B
PILOT	5	4
AIRCRAFT	1	2

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***** HISTOGRAM *****

PERCENTAGE OF TIME WITHIN THREE-WAY INTERVAL
LAMBDA SPHERE B SUB(LAMBDA SPHERE A) VS RANGE
DATA AT EVERY .5 SECS FROM 0. TO 241.0 SECONDS

***** HISTOGRAM *****

LAMBDA B (DEGREES)	LAMBDA A (DEGREES)	RANGE (THOUSANDS OF FEET) 0. - 2.	2. - 4.	4. - 6.	6. - 8.	8. - 10.	10. - 15.	15. - 20.	OVER 20.
0 - 10	0 - 10	0.00	0.00	0.00	0.00	0.00	0.00	.83	0.00
	10 - 20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	20 - 40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	40 - 60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	60 - 90	0.00	.21	1.24	.21	0.00	0.00	0.00	0.00
	90 - 120	.21	5.59	0.00	.41	0.00	0.00	0.00	0.00
	120 - 180	3.93	18.43	1.66	0.00	0.00	0.00	0.00	0.00
10 - 20	0 - 10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	10 - 20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	20 - 40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	40 - 60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	60 - 90	.41	.21	1.24	0.00	0.00	0.00	0.00	0.00
	90 - 120	.41	6.21	0.00	1.24	0.00	0.00	0.00	0.00
	120 - 180	1.24	12.63	2.07	0.00	0.00	0.00	0.00	0.00
20 - 40	0 - 10	0.00	0.00	0.00	0.00	0.00	.21	0.00	0.00
	10 - 20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	20 - 40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	40 - 60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	60 - 90	.21	3.31	0.00	.83	0.00	0.00	0.00	0.00
	90 - 120	.21	3.11	0.00	.62	.62	0.00	0.00	0.00
	120 - 180	1.24	10.14	1.66	0.00	0.00	0.00	0.00	0.00
40 - 60	0 - 10	0.00	0.00	.21	.41	.62	.83	0.00	0.00
	10 - 20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	20 - 40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	40 - 60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	60 - 90	0.00	0.00	0.00	.41	0.00	0.00	0.00	0.00
	90 - 120	.41	0.00	0.00	.62	.62	0.00	0.00	0.00
	120 - 180	0.00	4.55	1.66	.83	.21	0.00	0.00	0.00

TABLE XI.- FASTON OUTPUT SUMMARY

Display	Parameter	Units	HASTE name	Narrow band intervals	Broad band intervals
1	Range	1000's of feet	RBA	0-2, 2-4, 4-6, 6-8, 8-10, 10-15, 15-20	0-2, 0-4, 0-6, 0-8, 0-10, 0-15, 0-20
2	Total λ of sphere A	Degrees	ATOT(1)	0-10, 10-20, 20-40, 40-60, 60-90, 90-120, >120	0-10, 0-20, 0-40, 0-60, 0-90, 0-120
3	Total λ of sphere B	Degrees	ATOT(2)	Same as 2	Same as 2
4	Velocity of sphere A	100's of feet per second	VELTOT(1)	0-4, 4-6, 6-8, 8-10, 10-12, 12-14, >14	None
	Velocity of sphere B	100's of feet per second	VELTOT(2)	Same as sphere A	None
5	Altitude of sphere A	1000's of feet	HAB(1)	0-5, 5-10, 10-15, 15-20, 20-25, 25-30, 30-40, >40	None
	Altitude of sphere B	1000's of feet	HAB(2)	Same as sphere A	None
6	Normal load of sphere A	g units	NZ(1)	0-2, 2-4, 4-6, 6-8, 8-10, >10	None
	Normal load of sphere B	g units	NZ(2)	Same as sphere A	None
7	Positive range rate	100's of feet per second	RBADOT	0-2, 2-4, 4-6, 6-8, 8-10, 10-15, 15-20, >20	0-2, 0-4, 0-6, 0-8, 0-10, 0-15, 0-20
8	Negative range rate	100's of feet per second	RBADOT	Negative of display 7	Negative of display 7

TABLE XII.- PERCENTAGE OF TIME SPENT IN DIFFERENT INTERVALS OF ALTITUDE AS FUNCTION OF TIME INTO RUN OUTPUT BY SUBROUTINE FASTON

	SPHERE A	SPHERE B
PILOT	6	5
AIRCRAFT	1	2

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P E R C E N T A G E S O F T I M E

	ALTITUDE (K FEET) SPHERE A								ALTITUDE (K FEET) SPHERE B							
TIME	0-5	5-10	10-15	15-20	20-25	25-30	30-40	40--	0-5	5-10	10-15	15-20	20-25	25-30	30-40	40--
25.0	0.00	0.00	.22	.78	0.00	0.00	0.00	0.00	0.00	0.00	.31	.69	0.00	0.00	0.00	.02
50.0	0.00	0.00	.11	.66	.23	0.00	0.00	0.00	0.00	0.00	.16	.58	.26	0.00	0.00	.01
75.0	0.00	0.00	.07	.44	.38	.11	0.00	0.00	0.00	0.00	.11	.39	.50	0.00	0.00	.23
100.0	0.00	0.00	.05	.57	.30	.08	0.00	0.00	0.00	0.00	.08	.48	.44	0.00	0.00	.17
125.0	0.00	0.00	.04	.65	.24	.06	0.00	0.00	0.00	0.00	.23	.42	.35	0.00	0.00	.14
150.0	.04	.04	.08	.59	.20	.03	0.00	0.00	.02	.11	.23	.35	.29	0.00	0.00	.11
175.0	.04	.09	.15	.50	.17	.05	0.00	0.00	.02	.11	.28	.34	.25	0.00	0.00	.10
200.0	.04	.08	.25	.44	.15	.04	0.00	0.00	.02	.03	.33	.34	.22	0.00	0.00	.09
225.0	.03	.12	.29	.39	.13	.04	0.00	0.00	.04	.16	.30	.30	.20	0.00	0.00	.08

TABLE XIII.- FIRST PAGE OF S1RUN OUTPUT

* * * N A S A P R E L I M I N A R Y * * * * DMS DATA PROCESSING * * * * N A S A P R E L I M I N A R Y * * *

	SPHERE A	SPHERE B
PILOT	13	3
AIRCRAFT	5	4

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I.C. C

G U N A N D M I S S I L E S U M M A R Y

TIME OF FIRST ENTRY INTO ENVELOPE	GUNS	MISSILE A	MISSILE B	MISSILE C
SPHERE A	115.5 SECS	23.0 SECS	43.5 SECS	62.0 SECS
SPHERE B	NEVER	25.5 SECS	26.5 SECS	NEVER

	SECS INTO FLIGHT - SPHERE A 30	60	90	120	180	END	SECS INTO FLIGHT- SPHERE B 30	60	90	120	180	END
SECS ON OFFENSE /	22.5	49.0	79.0	109.0	169.0	229.0	25.0	38.5	53.0	57.5	57.5	70.5
SECS ON OFFENSE WITH ADVANTAGE /	0.0	13.0	28.5	54.0	114.0	161.0	2.5	2.5	2.5	2.5	2.5	2.5
SECS IN GUNFIRE ENVELOPES /												
TARGET LAMBDA > 120 DEGS /												
ATTACKER LAMBDA < 1 DEGS /	-0.0	-0.0	-0.0	-0.0	2.0	2.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0
ATTACKER LAMBDA < 2 DEGS /	-0.0	-0.0	-0.0	-0.0	9.0	9.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0
ATTACKER LAMBDA < 3 DEGS /	-0.0	-0.0	-0.0	-0.0	19.5	19.5	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0
ATTACKER LAMBDA < 5 DEGS /	-0.0	-0.0	-0.0	-0.0	31.0	31.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0
ATTACKER LAMBDA < 10 DEGS /	-0.0	-0.0	-0.0	4.0	37.5	37.5	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0
TARGET LAMBDA > 90 DEGS /												
ATTACKER LAMBDA < 1 DEGS /	-0.0	-0.0	-0.0	-0.0	2.0	2.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0
ATTACKER LAMBDA < 2 DEGS /	-0.0	-0.0	-0.0	-0.0	9.0	9.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0
ATTACKER LAMBDA < 3 DEGS /	-0.0	-0.0	-0.0	-0.0	19.5	19.5	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0
ATTACKER LAMBDA < 5 DEGS /	-0.0	-0.0	-0.0	-0.0	31.0	32.5	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0
ATTACKER LAMBDA < 10 DEGS /	-0.0	-0.0	-0.0	7.5	41.0	43.5	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0
SECS OF GUNFIRE IN ENVELOPES /												
TARGET LAMBDA > 120 DEGS /												
ATTACKER LAMBDA < 1 DEGS /	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0
ATTACKER LAMBDA < 2 DEGS /	-0.0	-0.0	-0.0	-0.0	2.0	2.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0
ATTACKER LAMBDA < 3 DEGS /	-0.0	-0.0	-0.0	-0.0	4.5	4.5	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0
ATTACKER LAMBDA < 5 DEGS /	-0.0	-0.0	-0.0	-0.0	6.5	6.5	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0
ATTACKER LAMBDA < 10 DEGS /	-0.0	-0.0	-0.0	-0.0	6.5	6.5	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0
TARGET LAMBDA > 90 DEGS /												
ATTACKER LAMBDA < 1 DEGS /	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0
ATTACKER LAMBDA < 2 DEGS /	-0.0	-0.0	-0.0	-0.0	2.0	2.0	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0
ATTACKER LAMBDA < 3 DEGS /	-0.0	-0.0	-0.0	-0.0	4.5	4.5	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0
ATTACKER LAMBDA < 5 DEGS /	-0.0	-0.0	-0.0	-0.0	6.5	6.5	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0
ATTACKER LAMBDA < 10 DEGS /	-0.0	-0.0	-0.0	-0.0	6.5	6.5	-0.0	-0.0	-0.0	-0.0	-0.0	-0.0
SECS IN MISSILE A ENVELOPE /	5.0	11.5	23.5	51.5	74.0	118.0	3.0	4.5	5.5	5.5	5.5	5.5
SECS IN MISSILE B ENVELOPE /	0.0	5.5	15.0	42.0	64.5	105.0	1.0	1.0	1.0	1.0	1.0	1.0
SECS IN MISSILE C ENVELOPE /	0.0	0.0	2.5	22.0	44.5	61.5	0.0	0.0	0.0	0.0	0.0	0.0

TABLE XIV.- SECOND PAGE OF S1RUN OUTPUT

```
*** N A S A   P R E L I M I N A R Y ****      DMS DATA PROCESSING      **** N A S A   P R E L I M I N A R Y ***

          SPHERE A  SPHERE B                                                           PAGE    152
   PILOT     13        3                            4 18 72
AIRCRAFT      5        4                         RUN NUMBER  49                         I.C.    C

                        PERCENTAGE OF GUNFIRE TIME WITHIN ONE-WAY INTERVALS
                                      -------

DEVIATION ANGLE      0 TO 10    10 TO 45    45 TO 90    90...   (DEGREES)
----------------------------------------------------------------------------------------------------------
      SPHERE A  /       7.69       92.31        0.00        0.00
      SPHERE B  /       0.00        0.00        0.00        0.00

RANGE              0 TO 1    1 TO 3    3 TO 5    5 TO 12    12...   (THOUSANDS OF FEET)
----------------------------------------------------------------------------------------------------------
      SPHERE A  /  76.92     23.08      0.00      0.00       0.00
      SPHERE B  /   0.00      0.00      0.00      0.00       0.00

ANGLE OFF            0 TO 45    45 TO 90        90 TO 135   135 TO 180   (DEGREES)
----------------------------------------------------------------------------------------------------------
      SPHERE A  /     100.00        0.00        0.00        0.00
      SPHERE B  /       0.00        0.00        0.00        0.00
```

TABLE XV.- EXAMPLE OF THIRD AND FOURTH TYPE PAGE OF S1RUN OUTPUT

*** N A S A   P R E L I M I N A R Y ****   DMS DATA PROCESSING   **** N A S A   P R E L I M I N A R Y ***

	SPHERE A	SPHERE B		
PILOT	13	3	4 18 72	PAGE 153
AIRCRAFT	5	4	RUN NUMBER 49	I.C. 0

PERCENTAGES OF OFFENSIVE TIME WITHIN ONE-WAY INTERVALS

RANGE	0 TO 1	1 TO 3	3 TO 5	5 TO 12	12...	(THOUSANDS OF FEET)
SPHERE A /	14.19	58.30	21.18	6.33	0.00	
SPHERE B /	1.42	44.68	30.50	23.40	0.00	

RANGE RATE	...-3	-3 TO -1	-1 TO 0	0 TO 1	1 TO 3	3...	(THOUSANDS OF FPS)
SPHERE A /	0.00	2.62	51.53	45.85	0.00	0.00	
SPHERE B /	0.00	8.51	82.27	9.22	0.00	0.00	

ALTITUDE	...0	0 TO 10	10 TO 20	20 TO 30	30...	(THOUSANDS OF FEET)
SPHERE A /	0.00	42.36	50.22	7.42	0.00	
SPHERE B /	0.00	17.73	48.23	34.04	0.00	

DEVIATION ANGLE	0 TO 10	10 TO 45	45 TO 90	90...	(DEGREES)
SPHERE A /	5.02	40.17	47.82	6.99	
SPHERE B /	7.80	.71	47.52	43.97	

MACH	0 TO .8	.8 TO 1.2	1.2 ...
SPHERE A /	95.20	4.80	0.00
SPHERE B /	90.78	9.22	0.00

NORMAL LOAD	0 TO 2.5	2.5 TO 5	5...	(GEES)
SPHERE A /	32.75	62.23	5.02	
SPHERE B /	43.97	51.77	1.42	

TABLE XVI.- S1RUN GUNFIRE AND MISSILE LAUNCH OUTPUT

```
*** N A S A   P R E L I M I N A R Y ****     DMS DATA PROCESSING     **** N A S A   P R E L I M I N A R Y ***

          SPHERE A   SPHERE B                                                       PAGE    155
   PILOT     13         3                          4 18 72
  AIRCRAFT    5         4                       RUN NUMBER  49                        1.C.    C

                                    G U N B U R S T S   B Y   T I M E

  PLANE IN SPHERE A STARTS GUNFIRE BURST AT TIME 125.0
  PLANE IN SPHERE A STOPS FIRING GUN AT TIME 125.5.  APK FOR BURST =  .9993

  PLANE IN SPHERE A STARTS GUNFIRE BURST AT TIME 128.0
  PLANE IN SPHERE A STOPS FIRING GUN AT TIME 128.5.  APK FOR BURST =  .9997

  PLANE IN SPHERE A STARTS GUNFIRE BURST AT TIME 142.5
  PLANE IN SPHERE A STOPS FIRING GUN AT TIME 143.0.  APK FOR BURST =  .9336

  PLANE IN SPHERE A STARTS GUNFIRE BURST AT TIME 145.0
  PLANE IN SPHERE A STOPS FIRING GUN AT TIME 150.0.  APK FOR BURST = 1.0000

  BOUT TERMINATES AT TIME 240.0

  ACCUMULATIVE APK
       SPHERE A     1.0000
       SPHERE B     0.0000

  MEAN AMLS
       SPHERE A      6.8
       SPHERE B      3.7

                             M I S S I L E   L A U N C H E S   B Y   T I M E

  PLANE IN SPHERE A LAUNCHES MISSILE TYPE A IN     ENVELOPE    AT TIME   95.5
  PLANE IN SPHERE A LAUNCHES MISSILE TYPE F IN     ENVELOPE    AT TIME   97.0
```

TABLE XVII.- TYPICAL FIRST MOMENT TIME LISTING OUTPUT BY M123S

```
* * *  N A S A   P R E L I M I N A R Y  * * * *      DMS DATA PROCESSING      * * * *  N A S A   P R E L I M I N A R Y  * * *

         SPHERE A  SPHERE B                                                              PAGE      8
   PILOT     4         3                              3 21 72
 AIRCRAFT    6         2                           RUN NUMBER  28                          I.C.   1

                                                F I R S T    M O M E N T S
```

TIME	RANGE	RANGE DOT	SPHERE A VEL	SPHERE A ALT	SPHERE A N ACC	SPHERE A LAMBDA TOT	SPHERE B VEL	SPHERE B ALT	SPHERE B N ACC	SPHERE B LAMBDA TOT
10.0	5.1302E+03	-6.5527E+02	9.2362E+02	1.5093E+04	3.5271E+00	4.2260E+01	9.5744E+02	1.5469E+04	3.9222E+00	6.2278E+01
20.0	5.1571E+03	-5.0593E+02	7.8060E+02	1.5798E+04	3.6423E+00	3.7855E+01	8.5814E+02	1.7096E+04	4.0412E+00	6.6693E+01
30.0	4.6682E+03	-1.8498E+02	6.9322E+02	1.6420E+04	3.2301E+00	5.3215E+01	7.7860E+02	1.7409E+04	3.9696E+00	8.5631E+01
40.0	4.9936E+03	-2.4149E+02	6.6578E+02	1.6003E+04	3.2853E+00	4.7414E+01	7.1362E+02	1.7201E+04	3.7152E+00	7.8095E+01
50.0	4.4527E+03	-1.7122E+02	6.3177E+02	1.5702E+04	3.1299E+00	5.3135E+01	6.7398E+02	1.6619E+04	3.5894E+00	7.9482E+01
60.0	4.1114E+03	-1.6285E+02	6.2299E+02	1.5193E+04	3.1873E+00	5.5952E+01	6.4089E+02	1.5995E+04	3.4501E+00	7.7042E+01
70.0	4.2643E+03	-1.0391E+02	6.0424E+02	1.4865E+04	3.0983E+00	6.1264E+01	6.1327E+02	1.5428E+04	3.3122E+00	7.7152E+01
80.0	4.1349E+03	-1.3258E+02	5.8225E+02	1.4780E+04	2.9269E+00	6.2519E+01	5.8923E+02	1.5006E+04	3.1399E+00	7.3246E+01
90.0	4.2449E+03	-5.2588E+01	5.7231E+02	1.4596E+04	2.8887E+00	7.1073E+01	5.6652E+02	1.4761E+04	2.9947E+00	7.6358E+01
100.0	4.5360E+03	-8.2959E+01	5.7045E+02	1.4223E+04	2.9624E+00	6.9901E+01	5.5838E+02	1.4299E+04	3.0184E+00	7.1573E+01
110.0	4.3556E+03	-6.9998E+01	5.7057E+02	1.3718E+04	3.0599E+00	7.1308E+01	5.4907E+02	1.3829E+04	2.9966E+00	7.1911E+01
120.0	4.5044E+03	-6.1511E+01	5.7006E+02	1.3154E+04	3.1579E+00	7.1906E+01	5.4402E+02	1.3249E+04	3.0505E+00	7.0997E+01
130.0	4.3634E+03	-7.5764E+01	5.6947E+02	1.2519E+04	3.2564E+00	7.0803E+01	5.3666E+02	1.2635E+04	3.0675E+00	6.9399E+01
140.0	4.3984E+03	-5.2067E+01	5.6661E+02	1.1889E+04	3.3242E+00	7.1611E+01	5.2921E+02	1.2019E+04	3.0783E+00	7.0484E+01
150.0	4.3548E+03	-7.0358E+01	5.6228E+02	1.1269E+04	3.3647E+00	6.9045E+01	5.2069E+02	1.1413E+04	3.0624E+00	7.0029E+01
160.0	4.2579E+03	-5.4398E+01	5.5536E+02	1.0725E+04	3.3550E+00	6.8244E+01	5.1050E+02	1.0911E+04	2.9987E+00	7.3486E+01
170.0	4.1558E+03	-6.5442E+01	5.4630E+02	1.0284E+04	3.2864E+00	6.6650E+01	5.0276E+02	1.0458E+04	2.9727E+00	7.3308E+01
180.0	4.0747E+03	-5.7741E+01	5.4243E+02	9.8665E+03	3.2989E+00	6.6260E+01	4.9548E+02	1.0039E+04	2.9375E+00	7.4499E+01
190.0	3.9354E+03	-5.8092E+01	5.3723E+02	9.4621E+03	3.2939E+00	6.5582E+01	4.9109E+02	9.6212E+03	2.9521E+00	7.4289E+01
200.0	3.7898E+03	-5.3334E+01	5.3231E+02	9.0440E+03	3.2849E+00	6.6111E+01	4.8562E+02	9.1908E+03	2.9417E+00	7.5052E+01
210.0	3.6844E+03	-5.7420E+01	5.2533E+02	8.6891E+03	3.2476E+00	6.5969E+01	4.7885E+02	8.8344E+03	2.9011E+00	7.4635E+01
215.5	3.6274E+03	-4.8853E+01	5.1934E+02	8.5353E+03	3.1802E+00	6.6780E+01	4.7458E+02	8.6723E+03	2.8679E+00	7.5035E+01

TABLE XVIII.- TYPICAL INITIAL CONDITION INFORMATION OUTPUT BY M123S

```
* * *  N A S A   P R E L I M I N A R Y  * * * *      DMS DATA PROCESSING      * * * *  N A S A   P R E L I M I N A R Y  * * *

        SPHERE A   SPHERE B                                                           PAGE      7
  PILOT      4          3                      3 21 72
AIRCRAFT     6          2                   RUN NUMBER  28                              I.C.   1


                                    I N I T I A L    C O N D I T I O N S


                                    RANGE =    12000

                                                      SPHERE A    SPHERE B
                                    LAMBDA AZIMUTH        -.00         .00
                                    VELOCITY            951.25      951.24
                                    ALTITUDE             15000       15000
                                    ROLL                  -.00        0.00
                                    PITCH                  .67        2.06
                                    YAW                -180.00        0.00
```

TABLE XIX.- TYPICAL NWC MISSILE PROGRAM TIME LISTING OUTPUT

* * * N A S A P R E L I M I N A R Y * * * * DMS DATA PROCESSING * * * * N A S A P R E L I M I N A R Y * * *

	SPHERE A	SPHERE B		
PILOT	6	4	10 21 72	PAGE 46
AIRCRAFT	1	2	RUN NUMBER 1	I.C. 0

ATAM 48 SPHERE B FIRES MISSILE

LGA = 40 RMIN = 1000 RMAX = 30000 TR(2) = 25 GA(2) = 45

LAUNCH CONDITIONS ***LIMIT STOP******** AND MAX GA,TR,GN ************************ **INTERCEPT DATA*** *****VALUES COMPUTED AT RSTP***************

TIME	RANGE	GA	TR	T2	GA2	TR2	SLRNG	GN	ALM	TCF	MISC	CLCVEL	RSTP	AANG	EANG	RANG	MVEL	CANG	ALF	LANG	GAX	TIMP
104.0	1819	29	17	.5	38	26	1763	0.0			LIMIT STOP		PHI DOT									
104.5	1816	30	17	.5	39	25	1767	0.0			LIMIT STOP		PHI DOT									
105.0	1818	31	16	.5	40	25	1776	0.0			LIMIT STOP		PHI DOT									
105.5	1826	32	16	.5	42	25	1789	0.0			LIMIT STOP		PHI DOT									
106.0	1838	34	16	.6	44	26	1800	0.0			LIMIT STOP		PHI DOT									
106.5	1854	35	16	.5	45	24	1827	0.0			LIMIT STOP	LAMBDA ANGLE										
107.0	1872	36	16	.5	45	23	1854	0.0			LIMIT STOP	LAMBDA ANGLE										
107.5	1893	38	15	.4	46	22	1884	0.0			LIMIT STOP	LAMBDA ANGLE										
108.0	1918	39	15	.4	46	21	1916	0.0			LIMIT STOP	LAMBDA ANGLE										
108.5	1946	40	15	0.0	0	0	0	0.0			ENVELOPE	LAUNCH G ANG										
109.0	1979	41	14	0.0	0	0	0	0.0			ENVELOPE	LAUNCH G ANG										
109.5	2017	42	14	0.0	0	0	0	0.0			ENVELOPE	LAUNCH G ANG										
110.0	2066	42	12	0.0	0	0	0	0.0			ENVELOPE	LAUNCH G ANG										
110.5	2122	42	8	0.0	0	0	0	0.0			ENVELOPE	LAUNCH G ANG										
111.0	2161	40	5	0.0	0	0	0	0.0			ENVELOPE	LAUNCH G ANG										
111.5	2162	38	5	0.0	43	15	0	24.5	20.3	2.8	1.0	1554	195	-75	-0	-119	1948	41	2	13	19	114.3

TABLE XX.- TYPICAL NWC MISSILE PROGRAM SUMMARY PAGE

```
* * *  N A S A   P R E L I M I N A R Y  * * * *      DMS DATA PROCESSING      * * * *  N A S A   P R E L I M I N A R Y  * * *

        SPHERE A  SPHERE B                                                                  PAGE    306
   PILOT     3         5                       12 15 71
AIRCRAFT     1         2                     RUN NUMBER . 4

ATAM 4B                                  SPHERE B FIRES MISSILE

                                        L A U N C H   S T A T I S T I C S

                        SIMULATED LAUNCHES (1 EVERY     .50 SECONDS)
                            OUT OF ENVELOPE             304
                            IN ENVELOPE - MISSES        112
                            IN ENVELOPE - HITS          100

                        DMS LAUNCHES
                            OUT OF ENVELOPE               0
                            IN ENVELOPE - MISSES          0
                            IN ENVELOPE - HITS            0

                        SIMULATED LAUNCHES WITH DELAY
                            IN ENVELOPE-TOTAL LAUNCHES   10
                            IN ENVELOPE-IMPACTS
                               GIMBAL ANGLE LE 40 DEGS    5
                               GIMBAL ANGLE LE 20 DEGS    4
```

TABLE XXI.- TYPICAL PAGE OF LAUNCH REPORT OUTPUT BY PROGRAM LAUNCH

* * * N A S A   P R E L I M I N A R Y * * * *   DMS DATA PROCESSING   * * * * N A S A   P R E L I M I N A R Y * * *

	SPHERE A	SPHERE B		
			IC= 1	PAGE NUMBER 6
PILOT	13	03		TAPE NUMBER 202015
AIRCRAFT	5	4		RUN NUMBER 31
WEAPONS	B A C	A C		RUN DATE 02/04/72

SPHERE A

TIME (SEC)	ALT. (FT)	MACH NO	G	HEAD (DEG)	ASPECT (DEG)	RANGE (FT)	IN ZONE A B C	LAUNCH/IMPACT SIM. A B C	LAUNCH/IMPACT PILOT A B C
62.5	16487	.42	2.6	21.2	155.0	2680	H H .	. . .	. . .
63.0	16344	.43	2.7	19.2	154.2	2794	H V .	. . .	. . .
63.5	16178	.44	2.9	16.7	152.7	2897	H V .	. . .	. . .
64.0	15988	.45	3.1	14.3	152.3	2988	H V .	. . .	. . .
64.5	15778	.46	3.3	12.4	152.7	3073	H V .	. V .	. . .
65.0	15549	.47	3.4	10.7	153.0	3151	H V .	. V .	. . .
65.5	15305	.48	3.5	8.6	152.8	3221	H V .	. V .	. . .
66.0	15048	.50	3.7	6.7	152.5	3280	H V .	. V .	. . .
66.5	14784	.51	3.8	5.4	151.5	3327	V V .	. V .	. . .
67.0	14514	.52	3.9	3.9	150.2	3359	V V V	. - .	. . .
67.5	14243	.53	3.9	2.5	148.6	3376	V V V	. V .	. . .
68.0	13974	.54	3.8	2.6	146.6	3376	V V V	. V .	. . .
68.5	13709	.56	3.9	4.1	144.4	3355	V V V	V V .	. . .
69.0	13449	.57	3.9	4.0	142.3	3316	V V V	V V V	. . .
69.5	13199	.58	4.0	2.9	140.3	3257	V V H	V V V	. . .
70.0	12960	.59	4.2	2.9	138.4	3179	H V H	V - -	. . .
70.5	12736	.60	4.2	3.2	136.6	3083	H V H	V V .	. . .
71.0	12528	.61	3.8	2.3	135.1	2970	H V H	- V .	. . T
71.5	12335	.62	4.3	3.0	134.1	2841	H V H	. V .	. . T
72.0	12161	.63	4.6	4.0	133.4	2699	H V H	. V .	. . T
72.5	12009	.64	4.3	3.3	133.0	2545	H V H	. V .	. . T
73.0	11879	.65	4.5	3.2	133.0	2382	H V H	. - .	. . T
73.5	11771	.65	4.4	2.0	133.8	2212	H V H	. V .	. . T
74.0	11684	.66	4.2	1.7	135.0	2036	H V H	. V .	. . .
74.5	11619	.66	5.0	1.2	137.0	1856	H H H	. V .	. . .

SPHERE B

TIME (SEC)	ALT. (FT)	MACH NO	G	HEAD (DEG)	ASPECT (DEG)	RANGE (FT)	IN ZONE A B C	LAUNCH/IMPACT SIM. A B C	LAUNCH/IMPACT PILOT A B C
62.5	13902	.59	3.1	139.5	40.4	2680	. . .	. . .	. . .
63.0	13594	.60	4.7	132.9	37.8	2794	. . .	. . .	. . .
63.5	13293	.60	4.6	132.4	35.1	2897	. . .	. . .	. . .
64.0	13002	.61	4.3	135.0	32.5	2988	. . .	. . .	. . .
64.5	12719	.62	4.4	135.7	30.1	3073	. . .	. . .	. . .
65.0	12448	.62	5.0	134.3	27.7	3151	. . .	. . .	. . .
65.5	12193	.62	5.0	134.0	25.5	3221	. . .	. . .	. . .
66.0	11957	.62	5.1	132.8	23.2	3280	. . .	. . .	. . .
66.5	11742	.62	5.3	130.7	20.8	3327	. . .	. . .	. . .
67.0	11551	.62	5.2	129.1	18.5	3359	. . .	. . .	. . .
67.5	11384	.61	5.2	126.7	16.1	3376	. . .	. . .	. . .
68.0	11244	.60	5.5	123.0	14.1	3376	. . .	. . .	. . .
68.5	11132	.59	5.1	121.0	12.6	3355	. . .	. . .	. . .
69.0	11048	.58	5.1	118.6	11.4	3316	. . .	. . .	. . .
69.5	10993	.57	4.9	116.3	10.0	3257	. . .	. . .	. . .
70.0	10965	.56	4.8	113.8	8.6	3179	. . .	. . .	. . .
70.5	10963	.55	4.6	111.4	7.2	3083	. . .	. . .	. . .
71.0	10986	.53	4.3	109.9	6.6	2970	. . .	. . .	. . .
71.5	11028	.52	4.1	108.3	6.5	2841	. . .	. . .	. . .
72.0	11087	.51	3.9	107.6	5.9	2695	. . .	. . .	. . .
72.5	11159	.50	3.7	107.2	5.8	2545	. . .	. . .	. . .
73.0	11242	.48	3.5	107.8	6.3	2382	. . .	. . .	. . .
73.5	11330	.46	3.2	108.6	6.7	2212	. . .	. . .	. . .
74.0	11421	.45	3.0	109.8	8.2	2036	. . .	. . .	. . .
74.5	11512	.43	2.7	112.2	9.7	1856	. . .	. . .	. . .

TABLE XXII.- TYPICAL LAUNCH SUMMARY REPORT AND IMPACT MATRIX OUTPUT BY PROGRAM LAUNCH

```
* * *  N A S A   P R E L I M I N A R Y  * * * *        DMS DATA PROCESSING        * * * *  N A S A   P R E L I M I N A R Y    * * *

                                                   L A U N C H   S U M M A R Y   R E P O R T
                                                   * * * * * *   * * * * * * *   * * * * * *

                          *                  SPHERE   A                       *                  SPHERE   B                  *
 TAPE      RUN     RUN  *  PT AC  WEAPON      TIME       IMPACT-TOTALS        *  PT AC  WEAPON     TIME      IMPACT-TOTALS   *
NUMBER    DATE     NO.  *        LAR  NUM  IN-ZONE SIMULATED   PILOT          *        LAR  NUM  IN-ZONE SIMULATED  PILOT    *
                        *          A  B  C  A  B  C  A  B  C  A  B  C         *          A  B  C  A  B  C  A  B  C  A  B  C  *
                        *                                                     *                                              *
2C2015 C2/04/72    39  *  13   5   B  A  C   7 26 12  1  4  2  C  0  0*  03   4        A  C  0  3  0  0  0  0  C  0  0*       IC=  2



EAPON    SPHERE A    SPHERE B                       I M P A C T   M A T R I X   R E P O R T
  A          1           4                          * * * * * *   * * * * * *   * * * * * *
  B          2           5
  C          3           6

                        *
 TAPE      RUN     RUN  *                                        I M P A C T   M A T R I X
NUMBER    DATE     NO.  *                                              WEAPON / TIME
                        *
2C2015 02/04/72    39  *  SIMULATED       1      2      2      2      3      2      3
                        *              38.0   38.0   41.0   69.0  131.5  18C.C  180.0    0.C    0.0    C.0    0.0    0.0    0.0    0.0
   IC=  2               *  PILOT
                        *               0.0    C.C    0.0    0.0    0.0    0.0    0.0    0.0    0.0    C.0    0.0    0.0    0.0    0.0
```

TABLE XXIII.- TYPICAL CUMULATIVE OUTPUT BY PROGRAM OUTCOME

C U M U L A T I V E

P R O B A B I L I T Y   M A T R I X

L O A D		
WEAP/LOC	SPHERE A	SPHERE B
A	0	0
B	4	4
C	0	0

PROBABILITY OF LOSS FOR SPHERE A
SIMULATED

RUN DATE	03/01/72
PAGE NUMBER	12
START TIME	0.0
STOP TIME	60.0
WEAPON - ACROSS	2
- DOWN	5

SINGLE SHOT KILL PROBABILITIES

A	.01	.01
B	1.00	1.00
C	.01	.01

	0.00	.05	.10	.15	.20	.25	.30	.35	.40	.45	.50	.55	.60	.65	.70	.75	.80	.85	.90	.95	1.00
0.00	0.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.0000	.000
.05	.020	.020	.019	.018	.018	.017	.017	.016	.016	.015	.013	.014	.014	.013	.013	.012	.012	.012	.011	.011	.011
.10	.040	.039	.038	.036	.035	.034	.033	.032	.031	.030	.029	.028	.027	.026	.025	.025	.024	.023	.023	.022	.022
.15	.060	.058	.056	.054	.052	.051	.049	.047	.046	.044	.043	.041	.040	.039	.038	.037	.036	.035	.034	.033	.032
.20	.079	.076	.074	.071	.069	.067	.065	.062	.060	.058	.057	.055	.053	.052	.050	.049	.047	.046	.045	.044	.043
.25	.098	.094	.091	.088	.085	.083	.080	.077	.075	.072	.070	.068	.066	.064	.062	.060	.059	.057	.056	.055	.053
.30	.116	.112	.108	.105	.101	.098	.095	.092	.089	.086	.083	.081	.078	.076	.074	.072	.070	.068	.067	.065	.064
.35	.133	.129	.125	.121	.117	.113	.109	.106	.103	.100	.096	.094	.091	.088	.086	.083	.081	.079	.077	.075	.074
.40	.150	.145	.141	.136	.132	.128	.124	.120	.116	.113	.109	.106	.103	.100	.097	.095	.092	.090	.088	.086	.084
.45	.167	.162	.156	.152	.147	.142	.138	.134	.129	.126	.122	.118	.115	.112	.109	.106	.103	.100	.098	.096	.094
.50	.183	.177	.172	.166	.161	.156	.151	.147	.142	.138	.134	.130	.127	.123	.120	.117	.114	.111	.108	.106	.104
.55	.199	.192	.187	.181	.175	.170	.165	.160	.155	.151	.146	.142	.138	.134	.131	.127	.124	.121	.118	.116	.113
.60	.214	.207	.201	.195	.189	.183	.178	.173	.168	.163	.158	.154	.149	.145	.142	.138	.135	.131	.128	.126	.123
.65	.228	.221	.215	.208	.202	.196	.191	.185	.180	.175	.170	.165	.160	.156	.152	.148	.145	.141	.138	.135	.132
.70	.242	.235	.228	.222	.215	.209	.203	.197	.191	.186	.181	.176	.171	.167	.163	.159	.155	.151	.148	.145	.142
.75	.256	.249	.241	.234	.228	.221	.215	.209	.203	.197	.192	.187	.182	.177	.173	.169	.165	.161	.157	.154	.151
.80	.269	.262	.254	.247	.240	.233	.227	.220	.214	.209	.203	.198	.192	.188	.183	.179	.174	.170	.167	.163	.160
.85	.282	.274	.266	.259	.252	.245	.238	.232	.225	.219	.214	.208	.203	.198	.193	.188	.184	.180	.176	.172	.169
.90	.294	.286	.278	.271	.263	.256	.249	.242	.236	.230	.224	.218	.213	.208	.203	.198	.193	.189	.185	.181	.178
.95	.306	.298	.290	.282	.274	.267	.260	.253	.246	.240	.234	.228	.223	.217	.212	.207	.203	.198	.194	.190	.187
1.00	.317	.309	.300	.293	.285	.277	.270	.263	.257	.250	.244	.238	.232	.227	.221	.216	.212	.207	.203	.199	.195

TABLE XXIV.- TYPICAL PROGRAM MULTI2 OUTPUT GIVING MEANS OF IMPORTANT PARAMETERS

MULTI-RUN SUMMARY 03/08/72 I.C. 4 - ALL DATA RUNS - A/C A(SPHERE A) VS A/C B(SPHERE B) 3. 2

M E A N S

	SECS INTO FLIGHT - SPHERE A						SECS INTO FLIGHT - SPHERE B					
	30	60	90	120	180	END	30	60	90	120	180	END
SECS ON OFFENSE	3.3	5.3	6.8	10.2	21.4	31.3	28.8	57.9	87.3	113.2	164.1	221.2
SECS ON OFFENSE WITH ADVANTAGE	.3	.3	.3	.9	6.5	7.2	25.7	52.9	80.8	103.9	149.2	197.2
SECS IN GUNFIRE ENVELOPES												
TARGET LAMBDA > 120 DEGS												
ATTACKER LAMBDA < 1 DEGS	0.0	0.0	0.0	0.0	0.0	0.0	.0	.0	.0	.1	.2	.6
ATTACKER LAMBDA < 2 DEGS	0.0	0.0	0.0	0.0	0.0	0.0	.1	.2	.2	.5	1.2	2.3
ATTACKER LAMBDA < 3 DEGS	0.0	0.0	0.0	0.0	0.0	0.0	.1	.3	.5	1.1	2.1	4.8
ATTACKER LAMBDA < 5 DEGS	0.0	0.0	0.0	0.0	0.0	0.0	.3	1.4	2.5	5.9	10.2	18.7
ATTACKER LAMBDA < 10 DEGS	0.0	0.0	0.0	0.0	0.0	0.0	.4	3.3	6.4	12.7	21.5	39.1
TARGET LAMBDA > 90 DEGS												
ATTACKER LAMBDA < 1 DEGS	0.0	0.0	0.0	0.0	0.0	0.0	.0	.0	.0	.1	.3	.6
ATTACKER LAMBDA < 2 DEGS	0.0	0.0	0.0	0.0	0.0	0.0	.1	.2	.2	.5	1.2	2.3
ATTACKER LAMBDA < 3 DEGS	0.0	0.0	0.0	0.0	0.0	0.0	.1	.3	.5	1.1	2.2	4.9
ATTACKER LAMBDA < 5 DEGS	0.0	0.0	0.0	0.0	0.0	0.0	.3	1.4	2.6	6.0	10.5	19.2
ATTACKER LAMBDA < 10 DEGS	0.0	0.0	0.0	0.0	0.0	0.0	.5	3.4	6.6	12.9	22.2	40.1
SECS OF GUNFIRE IN GUN ENVELOPES												
TARGET LAMBDA > 120 DEGS												
ATTACKER LAMBDA < 1 DEGS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.1
ATTACKER LAMBDA < 2 DEGS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.4
ATTACKER LAMBDA < 3 DEGS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.0	.8
ATTACKER LAMBDA < 5 DEGS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.0	.1	.8	3.7
ATTACKER LAMBDA < 10 DEGS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.1	.3	1.7	7.0
TARGET LAMBDA > 90 DEGS												
ATTACKER LAMBDA < 1 DEGS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.1
ATTACKER LAMBDA < 2 DEGS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.4
ATTACKER LAMBDA < 3 DEGS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.0	.8
ATTACKER LAMBDA < 5 DEGS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.0	.1	.8	3.7
ATTACKER LAMBDA < 10 DEGS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.1	.3	1.8	7.0
SECS IN MISSILE A ENVELOPE	.5	.8	1.5	2.1	7.5	9.7	15.5	39.2	65.4	85.5	123.8	164.3
SECS IN MISSILE B ENVELOPE	.4	.4	.8	1.2	4.7	6.1	13.8	33.9	58.6	77.9	113.0	150.8
SECS IN MISSILE C ENVELOPE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

TABLE XXV.- TYPICAL STANDARD DEVIATION OUTPUT BY PROGRAM MULTI2

MULTI-RUN SUMMARY   C3/08/72   I.C. 4 - ALL DATA RUNS - A/C A(SPHERE A) VS A/C B(SPHERE B)   3. 3

STANDARD DEVIATIONS

	SECS INTO FLIGHT - SPHERE A						SECS INTO FLIGHT - SPHERE B					
	30	60	90	120	180	END	30	60	90	120	180	END
SECS ON OFFENSE	4.4	5.9	7.6	10.6	23.1	31.7	2.8	4.1	5.4	8.4	20.3	20.4
SECS ON OFFENSE WITH ADVANTAGE	.9	.9	.9	1.5	12.4	12.4	5.3	8.9	11.1	17.2	34.7	41.9
SECS IN GUNFIRE ENVELOPES												
TARGET LAMBDA > 120 DEGS												
ATTACKER LAMBDA < 1 DEGS	0.0	0.0	0.0	0.0	0.0	0.0	.1	.1	.1	.2	.4	.8
ATTACKER LAMBDA < 2 DEGS	0.0	0.0	0.0	0.0	0.0	0.0	.3	.3	.4	.9	1.9	2.9
ATTACKER LAMBDA < 3 DEGS	0.0	0.0	0.0	0.0	0.0	0.0	.3	.5	1.0	2.1	3.8	6.2
ATTACKER LAMBDA < 5 DEGS	0.0	0.0	0.0	0.0	0.0	0.0	.9	3.0	4.9	9.9	14.9	21.8
ATTACKER LAMBDA < 10 DEGS	0.0	0.0	0.0	0.0	0.0	0.0	1.3	7.3	12.6	21.4	30.4	44.8
TARGET LAMBDA > 90 DEGS												
ATTACKER LAMBDA < 1 DEGS	0.0	0.0	0.0	0.0	0.0	0.0	.1	.1	.1	.2	.4	.8
ATTACKER LAMBDA < 2 DEGS	0.0	0.0	0.0	0.0	0.0	0.0	.3	.3	.4	.9	1.9	2.9
ATTACKER LAMBDA < 3 DEGS	0.0	0.0	0.0	0.0	0.0	0.0	.3	.5	1.0	2.1	3.8	6.1
ATTACKER LAMBDA < 5 DEGS	0.0	0.0	0.0	0.0	0.0	0.0	.9	3.0	4.9	9.8	14.7	21.5
ATTACKER LAMBDA < 10 DEGS	0.0	0.0	0.0	0.0	0.0	0.0	1.3	7.5	12.7	21.4	30.0	44.1
SECS OF GUNFIRE IN GUN ENVELOPES												
TARGET LAMBDA > 120 DEGS												
ATTACKER LAMBDA < 1 DEGS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.3
ATTACKER LAMBDA < 2 DEGS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.9
ATTACKER LAMBDA < 3 DEGS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.1	2.1
ATTACKER LAMBDA < 5 DEGS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.1	.3	1.6	6.4
ATTACKER LAMBDA < 10 DEGS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.4	.7	3.3	11.8
TARGET LAMBDA > 90 DEGS												
ATTACKER LAMBDA < 1 DEGS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.3
ATTACKER LAMBDA < 2 DEGS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.9
ATTACKER LAMBDA < 3 DEGS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.1	2.1
ATTACKER LAMBDA < 5 DEGS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.1	.3	1.6	6.4
ATTACKER LAMBDA < 10 DEGS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.4	.7	3.3	11.8
SECS IN MISSILE A ENVELOPE	1.9	2.0	2.8	3.8	11.9	13.9	5.7	13.6	16.4	23.0	40.8	57.5
SECS IN MISSILE B ENVELOPE	1.4	1.4	1.3	2.3	8.5	9.9	6.4	13.6	17.6	23.3	42.4	61.3
SECS IN MISSILE C ENVELOPE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

TABLE XXVI.- TYPICAL t-TEST OUTPUT BY PROGRAM MULTI2

MULTI-RUN SUMMARY   03/08/72   I.C. 4 - ALL DATA RUNS - A/C A(SPHERE A) VS A/C B(SPHERE B)   3. 4

COMPARISON BETWEEN SPHERES

	SECS INTO FLIGHT - T STATISTICS						SECS INTO FLIGHT- D.F.					
	30	60	90	120	180	END	30	60	90	120	180	END
SECS ON OFFENSE	17.0	25.2	29.9	26.4	16.1	17.5	22	22	22	22	22	22
SECS ON OFFENSE WITH ADVANTAGE	16.5	20.5	25.1	20.6	13.4	15.1	22	22	22	22	22	22
SECS IN GUNFIRE ENVELOPES												
TARGET LAMBDA > 120 DEGS												
ATTACKER LAMBDA < 1 DEGS	1.0	1.0	1.0	1.9	1.8	2.4	22	22	22	22	22	22
ATTACKER LAMBDA < 2 DEGS	1.0	1.8	1.3	2.0	2.1	2.7	22	22	22	22	22	22
ATTACKER LAMBDA < 3 DEGS	1.0	1.9	1.5	1.9	1.9	2.6	22	22	22	22	22	22
ATTACKER LAMBDA < 5 DEGS	1.0	1.6	1.8	2.1	2.4	3.0	22	22	22	22	22	22
ATTACKER LAMBDA < 10 DEGS	1.0	1.5	1.3	2.1	2.4	3.0	22	22	22	22	22	22
TARGET LAMBDA > 90 DEGS												
ATTACKER LAMBDA < 1 DEGS	1.0	1.0	1.0	1.9	2.2	2.6	22	22	22	22	22	22
ATTACKER LAMBDA < 2 DEGS	1.0	1.8	1.3	2.0	2.2	2.8	22	22	22	22	22	22
ATTACKER LAMBDA < 3 DEGS	1.0	1.9	1.5	1.9	2.0	2.7	22	22	22	22	22	22
ATTACKER LAMBDA < 5 DEGS	1.0	1.6	1.8	2.1	2.5	3.1	22	22	22	22	22	22
ATTACKER LAMBDA < 10 DEGS	1.3	1.6	1.8	2.1	2.6	3.2	22	22	22	22	22	22
SECS OF GUNFIRE IN GUN ENVELOPES												
TARGET LAMBDA > 120 DEGS												
ATTACKER LAMBDA < 1 DEGS	0.0	0.0	0.0	0.0	0.0	1.0	22	22	22	22	22	22
ATTACKER LAMBDA < 2 DEGS	0.0	0.0	0.0	0.0	0.0	1.5	22	22	22	22	22	22
ATTACKER LAMBDA < 3 DEGS	0.0	0.0	0.0	0.0	1.0	1.3	22	22	22	22	22	22
ATTACKER LAMBDA < 5 DEGS	0.0	0.0	1.0	1.4	1.7	2.0	22	22	22	22	22	22
ATTACKER LAMBDA < 10 DEGS	0.0	0.0	1.0	1.5	1.8	2.0	22	22	22	22	22	22
TARGET LAMBDA > 90 DEGS												
ATTACKER LAMBDA < 1 DEGS	0.0	0.0	0.0	0.0	0.0	1.0	22	22	22	22	22	22
ATTACKER LAMBDA < 2 DEGS	0.0	0.0	0.0	0.0	0.0	1.5	22	22	22	22	22	22
ATTACKER LAMBDA < 3 DEGS	0.0	0.0	0.0	0.0	1.0	1.3	22	22	22	22	22	22
ATTACKER LAMBDA < 5 DEGS	0.0	0.0	1.0	1.4	1.7	2.0	22	22	22	22	22	22
ATTACKER LAMBDA < 10 DEGS	0.0	0.0	1.0	1.5	1.9	2.1	22	22	22	22	22	22
SECS IN MISSILE A ENVELOPE	8.7	9.7	13.3	12.4	9.5	9.1	22	22	22	22	22	22
SECS IN MISSILE B ENVELOPE	7.1	8.5	11.3	11.4	8.7	8.1	22	22	22	22	22	22
SECS IN MISSILE C ENVELOPE	0.0	0.0	0.0	0.0	0.0	0.0	22	22	22	22	22	22

TABLE XXVII.- TYPICAL THREE-WAY HISTOGRAM OF n_z, M, AND h OUTPUT BY PROGRAM MULTI2

MULTI-RUN SUMMARY 03/08/72 I.C. 4 - ALL DATA RUNS - A/C A(SPHERE A) VS A/C B(SPHERE B) 3. 5

MEAN PERCENTAGES OF TIME
INTERVALS OF LOAD, MACH, AND ALTITUDE
FIRST 180 SECS SPHERE A

LOAD (G S)	MACH	ALTITUDE (THOUSANDS OF FEET) ... 0.	0. - 10.	10. - 20.	20. - 30.	30. ...
0.0 - 2.5						
	0. - .8	0.0	5.2	14.5	1.4	0.0
	.8 - 1.2	.2	10.9	3.4	0.0	0.0
	1.2 ...	0.0	2.5	0.0	0.0	0.0
2.5 - 5.0						
	0. - .8	0.0	7.7	5.2	.2	0.0
	.8 - 1.2	.3	7.8	1.8	0.0	0.0
	1.2 ...	0.0	0.0	0.0	0.0	0.0
5.0 ...						
	0. - .8	0.0	7.4	1.7	0.0	0.0
	.8 - 1.2	.6	19.3	.7	0.0	0.0
	1.2 ...	0.0	0.0	0.0	0.0	0.0

TABLE XXVIII.- TYPICAL THREE-WAY HISTOGRAM OF λ_A, λ_B, AND R OUTPUT BY PROGRAM MULTI2

MULTI-RUN SUMMARY 03/08/72 1.C. 4 - ALL DATA RUNS - A/C A(SPHERE A) VS A/C B(SPHERE B) 3. 9

FIRST 180 SECS - MEAN PERCENTAGES OF TIME
INTERVALS OF LAMBDA A, LAMBDA B, RANGE

LAMBDA A (DEGS)	LAMBDA B	RANGE (THOUSANDS OF FEET) 0. - 1.	1. - 3.	3. - 5.	5. - 12.	12 ...
0 - 10						
	0 - 10	0.000	.057	.450	.589	1.108
	10 - 20	1.327	5.401	4.709	10.757	.289
	20 - 40	.416	1.616	.912	1.904	.104
	40 - 60	.762	1.616	1.558	3.532	.104
	60 - 90	.242	.842	.669	1.904	.104
	90 ...	.127	.635	.312	1.535	.185
10 - 20						
	0 - 10	0.000	0.000	0.000	0.000	0.000
	10 - 20	0.000	0.000	0.000	0.000	0.000
	20 - 40	0.000	0.000	.023	0.000	0.000
	40 - 60	0.000	0.000	.023	.162	.023
	60 - 90	0.000	.069	0.000	0.000	0.000
	90 ...	.115	.161	.115	.185	0.000
20 - 40						
	0 - 10	0.000	0.000	0.000	0.000	0.000
	10 - 20	0.000	.023	.069	.092	0.000
	20 - 40	0.000	.092	.023	0.000	0.000
	40 - 60	0.000	.046	0.000	.069	.046
	60 - 90	0.000	.092	.185	.069	.115
	90 ...	.138	.046	0.000	.323	.369
40 - 60						
	0 - 10	.023	.023	0.000	.162	0.000
	10 - 20	.023	.046	.092	.092	0.000
	20 - 40	0.000	.069	.115	.323	.115
	40 - 60	.046	.138	.138	.185	0.000
	60 - 90	0.000	.023	.162	.138	.069
	90 ...	.161	.023	0.000	.139	.739
60 - 90						
	0 - 10	0.000	.046	.162	.300	.069
	10 - 20	0.000	.139	.370	.369	0.000
	20 - 40	.023	.161	.208	.323	.208
	40 - 60	0.000	.439	.254	.323	.162
	60 - 90	.185	.069	.208	.554	.323
	90 ...	.346	.046	0.000	.415	.254
90 ...						
	0 - 10	1.327	5.401	4.709	10.757	.289
	10 - 20	.416	1.616	.912	1.904	.104
	20 - 40	.762	1.616	1.558	3.532	.104
	40 - 60	.242	.842	.669	1.904	.104
	60 - 90	.127	.635	.312	1.535	.185
	90 ...	.057	.450	.589	1.108	.785

TABLE XXIX.- TYPICAL SINGLE RUN OUTPUT FROM PROGRAM BZONE

* * * N A S A   P R E L I M I N A R Y * * * *   OMS DATA PROCESSING   * * * * N A S A   P R E L I M I N A R Y * * *

FIRST ENTRIES AND TIMES IN ZONES

	SPHERE A	SPHERE B
PILOT	13	14
AIRCRAFT	5	4

2 8 72

RUN NUMBER 10

PAGE 41

I.C. 1

LAMBDA A/C 4

AMBDA A/C 5 /ZONE-	FIRST ENTRY 1	FIRST ENTRY 2	FIRST ENTRY 3	TOTAL TIME 1	TOTAL TIME 2	TOTAL TIME 3	2 SECS. IN ZONE 1	2 SECS. IN ZONE 2	2 SECS. IN ZONE 3	4 SECS. IN ZONE 1	4 SECS. IN ZONE 2	4 SECS. IN ZONE 3	6 SECS. IN ZONE 1	6 SECS. IN ZONE 2	6 SECS. IN ZONE 3
L.T. 10 DEGS /	0.00	96.50	161.50	0.00	4.00	16.50	0.00	96.50	161.50	0.00	0.00	161.50	0.00	0.00	161.50
L.T. 20 DEGS /	43.50	94.50	101.00	5.50	9.50	30.00	43.50	94.50	101.00	43.50	94.50	101.00	0.00	94.50	154.50
L.T. 40 DEGS /	41.00	48.50	71.50	11.00	27.50	42.00	41.00	75.50	71.50	41.00	75.50	101.00	41.00	75.50	101.00
L.T. 60 DEGS /	17.00	37.50	69.50	20.50	46.00	49.00	17.00	57.00	69.50	38.00	57.00	69.50	38.00	57.00	101.00
L.T. 90 DEGS /	13.50	12.50	50.00	27.50	68.50	58.50	13.50	32.00	69.50	13.50	32.00	69.50	13.50	53.50	101.00
L.T. 10 DEGS /							0	1	8	0	0	4	0	0	2
L.T. 20 DEGS /							2	3	14	1	1	7	0	1	4
L.T. 40 DEGS /							4	9	18	1	4	8	1	2	5
L.T. 60 DEGS /							9	16	21	3	7	10	1	4	5
L.T. 90 DEGS /							12	25	25	5	11	12	2	5	5

LAMBDA A/C 5

AMBDA A/C 4 /ZONE-	FIRST ENTRY 1	FIRST ENTRY 2	FIRST ENTRY 3	TOTAL TIME 1	TOTAL TIME 2	TOTAL TIME 3	2 SECS. IN ZONE 1	2 SECS. IN ZONE 2	2 SECS. IN ZONE 3	4 SECS. IN ZONE 1	4 SECS. IN ZONE 2	4 SECS. IN ZONE 3	6 SECS. IN ZONE 1	6 SECS. IN ZONE 2	6 SECS. IN ZONE 3
L.T. 10 DEGS /	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
L.T. 20 DEGS /	0.00	0.00	0.00	.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
L.T. 40 DEGS /	17.00	16.00	0.00	8.50	2.50	0.00	17.00	0.00	0.00	42.00	0.00	0.00	0.00	0.00	0.00
L.T. 60 DEGS /	17.00	13.50	0.00	20.50	7.00	0.00	17.00	13.50	0.00	38.00	0.00	0.00	38.00	0.00	0.00
L.T. 90 DEGS /	17.00	11.00	0.00	36.50	19.50	0.00	17.00	11.00	0.00	37.50	11.00	0.00	37.50	0.00	0.00
L.T. 10 DEGS /							0	0	0	0	0	0	0	0	0
L.T. 20 DEGS /							0	0	0	0	0	0	0	0	0
L.T. 40 DEGS /							3	0	0	1	0	0	0	0	0
L.T. 60 DEGS /							9	2	0	3	0	0	1	0	0
L.T. 90 DEGS /							15	6	0	5	3	0	3	0	0

TABLE XXX.- TYPICAL MULTIRUN OUTPUT FROM PROGRAM BZONE

* * * N A S A P R E L I M I N A R Y * * * * OMS DATA PROCESSING * * * * N A S A P R E L I M I N A R Y * * *

FIRST ENTRIES ANC TIMES IN ZONES

SPHERE A SPHERE B PAGE 42

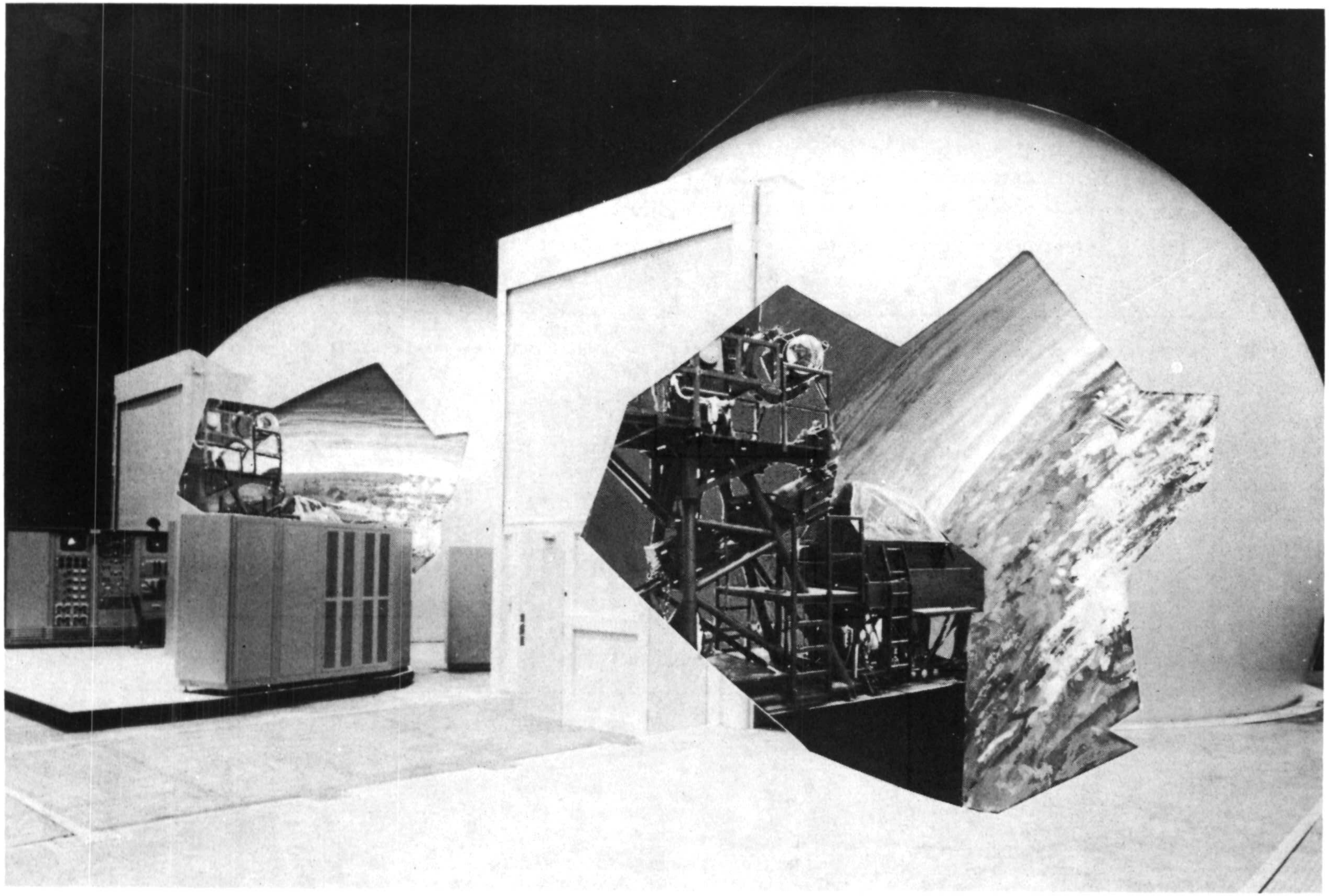
AIRCRAFT 5 4 AVERAGE VALUES (20 RUNS) I.C. 1

LAMBDA A/C 4

AMBDA A/C 5 /ZONE-	*****FIRST ENTRY***** 1	2	3	*****TOTAL TIME***** 1	2	3	***2 SECS. IN ZONE*** 1	2	3	***4 SECS. IN ZONE*** 1	2	3	***6 SECS. IN ZONE 1	2	3
L.T. 10 DEGS /	50.64	78.79	86.97	1.29	6.97	31.97	104.00	100.77	93.62	I	98.00	92.97	I	156.50	99.03
NO. RUNS /	7	17	17	7	17	17	1	13	17	0	7	16	0	2	15
L.T. 20 DEGS /	33.50	55.87	71.86	5.13	16.25	40.94	34.46	61.12	77.92	30.94	79.56	80.50	22.67	75.42	95.71
NO. RUNS /	13	20	18	20	20	18	12	20	18	9	17	18	3	13	17
L.T. 40 DEGS /	30.37	31.80	68.05	11.30	29.72	45.82	37.11	48.10	66.69	32.07	51.66	72.83	33.25	56.97	72.83
NO. RUNS /	19	20	20	20	20	20	19	20	18	15	19	18	12	17	18
L.T. 60 DEGS /	24.67	20.80	63.45	15.40	43.92	50.90	31.97	30.00	66.37	41.71	34.00	63.94	31.15	50.55	70.92
NO. RUNS /	20	20	20	20	20	20	20	20	20	19	20	18	17	20	18
L.T. 90 DEGS /	22.10	14.50	41.37	20.92	62.42	56.97	22.92	17.50	60.27	24.12	21.02	57.66	28.70	31.62	60.26
NO. RLNS /	20	20	20	20	20	20	20	20	20	20	20	19	20	20	19
L.T. 10 DEGS /							1.00	2.85	14.00	I	1.71	6.94	I	1.50	4.40
L.T. 20 DEGS /							2.83	6.10	18.22	1.44	2.65	8.39	1.33	2.08	5.24
L.T. 40 DEGS /							4.11	11.70	22.78	1.87	5.21	10.56	1.17	2.88	6.50
L.T. 60 DEGS /							5.70	17.55	22.75	2.42	7.50	11.83	1.24	3.95	6.94
L.T. 90 DEGS /							7.95	26.10	25.15	3.30	11.40	12.26	1.55	6.40	7.32

LAMBDA A/C 5

AMBDA A/C 4 /ZONE-	*****FIRST ENTRY***** 1	2	3	*****TOTAL TIME***** 1	2	3	***2 SECS. IN ZONE*** 1	2	3	***4 SECS. IN ZONE*** 1	2	3	***6 SECS. IN ZONE 1	2	3
L.T. 10 DEGS /	37.50	47.90	I	1.90	1.60	I	61.50	34.00	I	I	I	I	I	I	I
NO. RUNS /	5	5	0	5	5	C	1	1	0	0	0	0	0	0	0
L.T. 20 DEGS /	29.78	58.50	132.50	2.35	3.79	4.50	24.07	64.40	132.50	41.00	23.75	132.50	I	I	I
NO. RUNS /	9	7	1	20	7	1	7	5	1	2	2	1	0	0	0
L.T. 40 DEGS /	31.39	69.21	92.83	6.38	6.13	5.83	33.10	76.75	105.75	25.20	58.92	109.83	23.50	49.30	108.75
NO. RUNS /	18	12	6	20	12	6	15	10	4	10	6	3	6	5	2
L.T. 60 DEGS /	24.67	59.63	98.39	15.40	12.00	9.83	31.97	67.37	88.00	41.71	70.15	78.62	31.15	69.75	109.50
NO. RUNS /	20	15	9	20	15	9	20	12	5	19	10	4	17	8	3
L.T. 90 DEGS /	18.47	49.38	86.27	33.10	23.72	11.50	18.47	63.47	90.82	25.97	78.97	90.22	22.82	84.00	95.79
NO. RUNS /	20	20	13	20	20	13	20	18	11	20	16	9	19	14	7
L.T. 10 DEGS /							1.00	1.00	I	I	I	I	I	I	I
L.T. 20 DEGS /							1.57	1.40	2.00	1.00	1.00	1.00	I	I	I
L.T. 40 DEGS /							2.73	2.40	3.50	1.40	1.17	1.67	1.17	1.00	1.50
L.T. 60 DEGS /							5.70	5.17	7.20	2.42	2.30	4.00	1.24	1.63	3.00
L.T. 90 DEGS /							13.35	10.11	5.45	5.45	4.88	2.67	3.26	3.00	2.00



L-71-2152

Figure 1.- Langley differential maneuvering simulator (DMS).

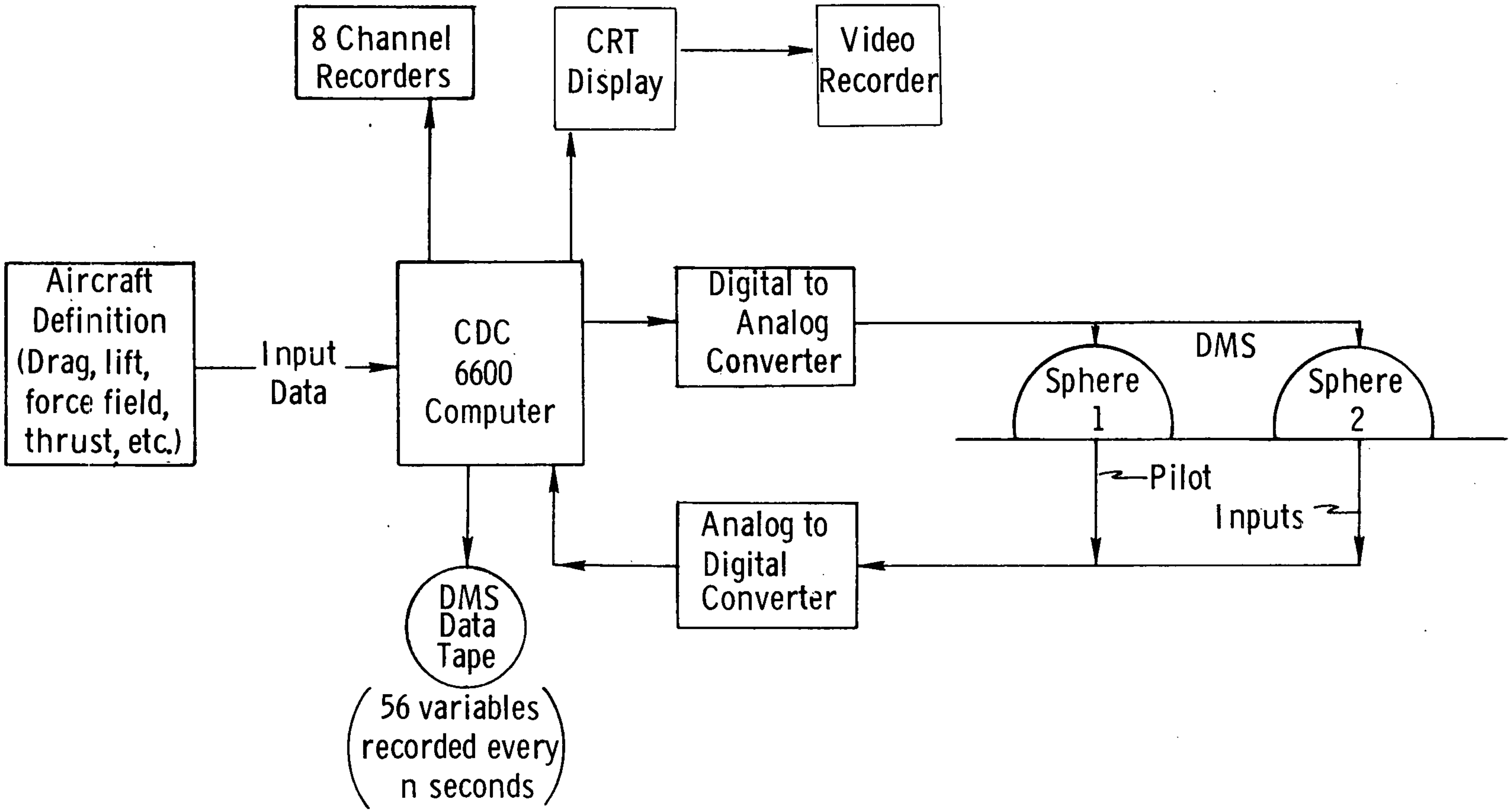


Figure 2.- DMS elements.

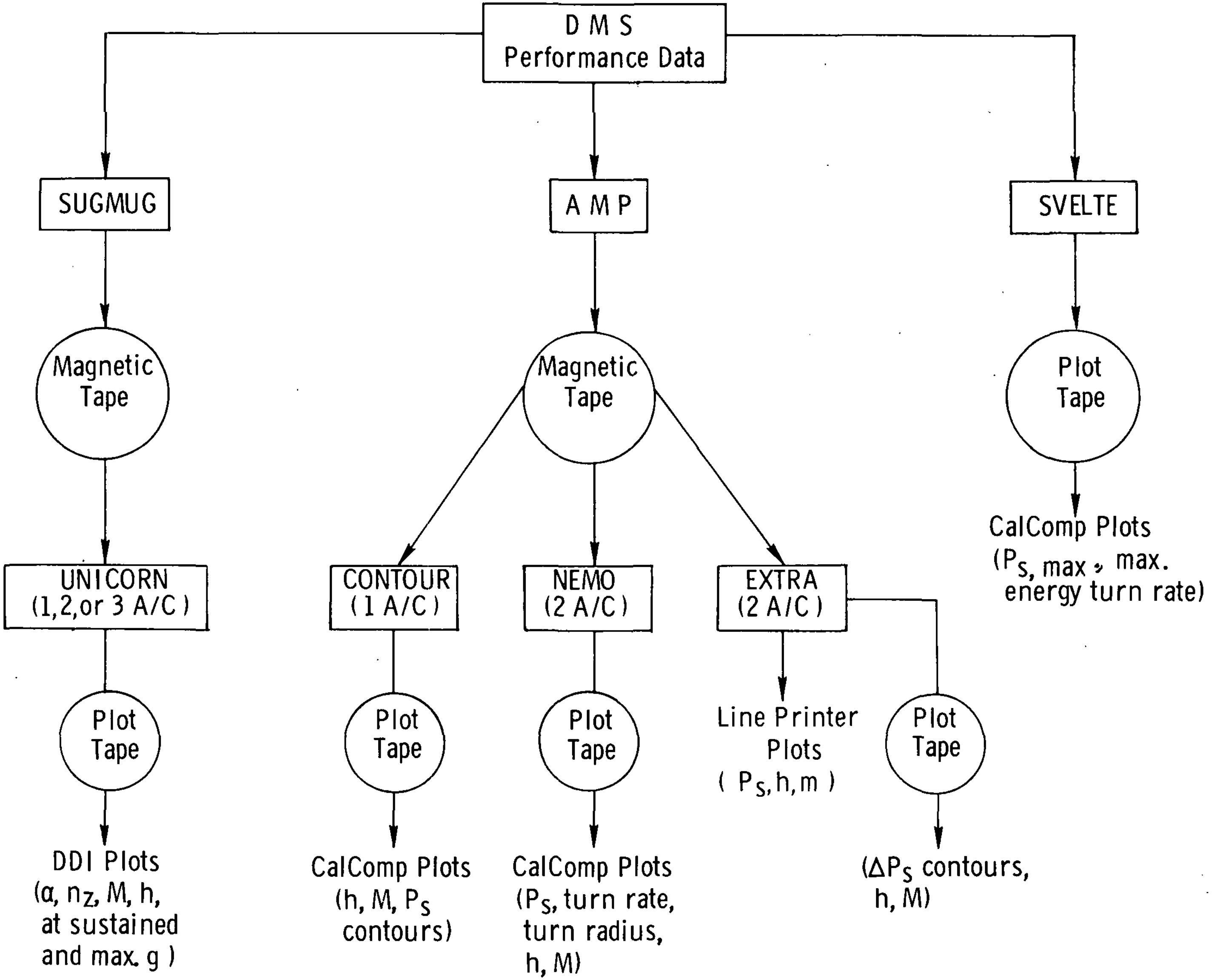


Figure 3.- DMS specific excess power programs.

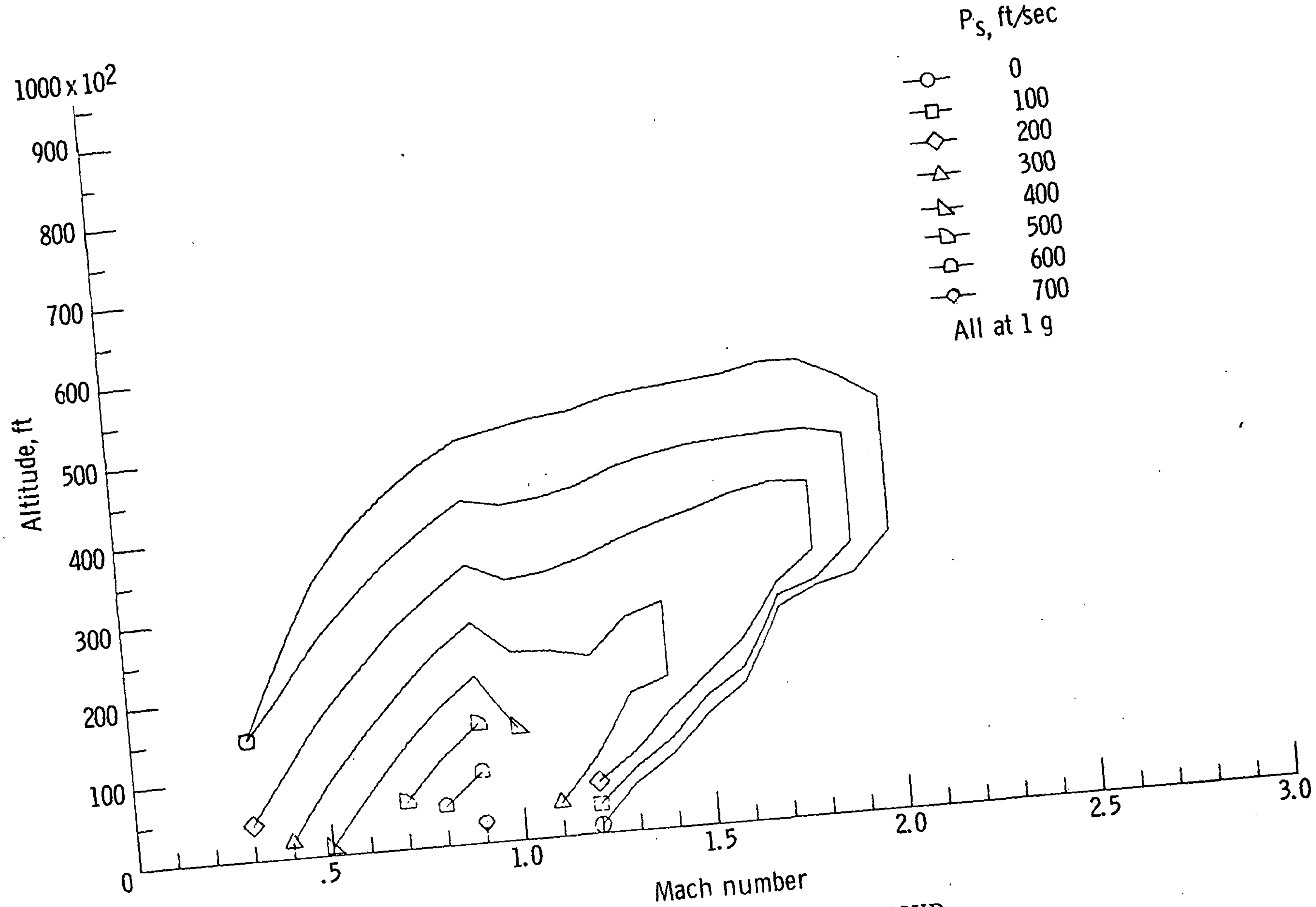


Figure 4.- Typical output of program CONTOUR.

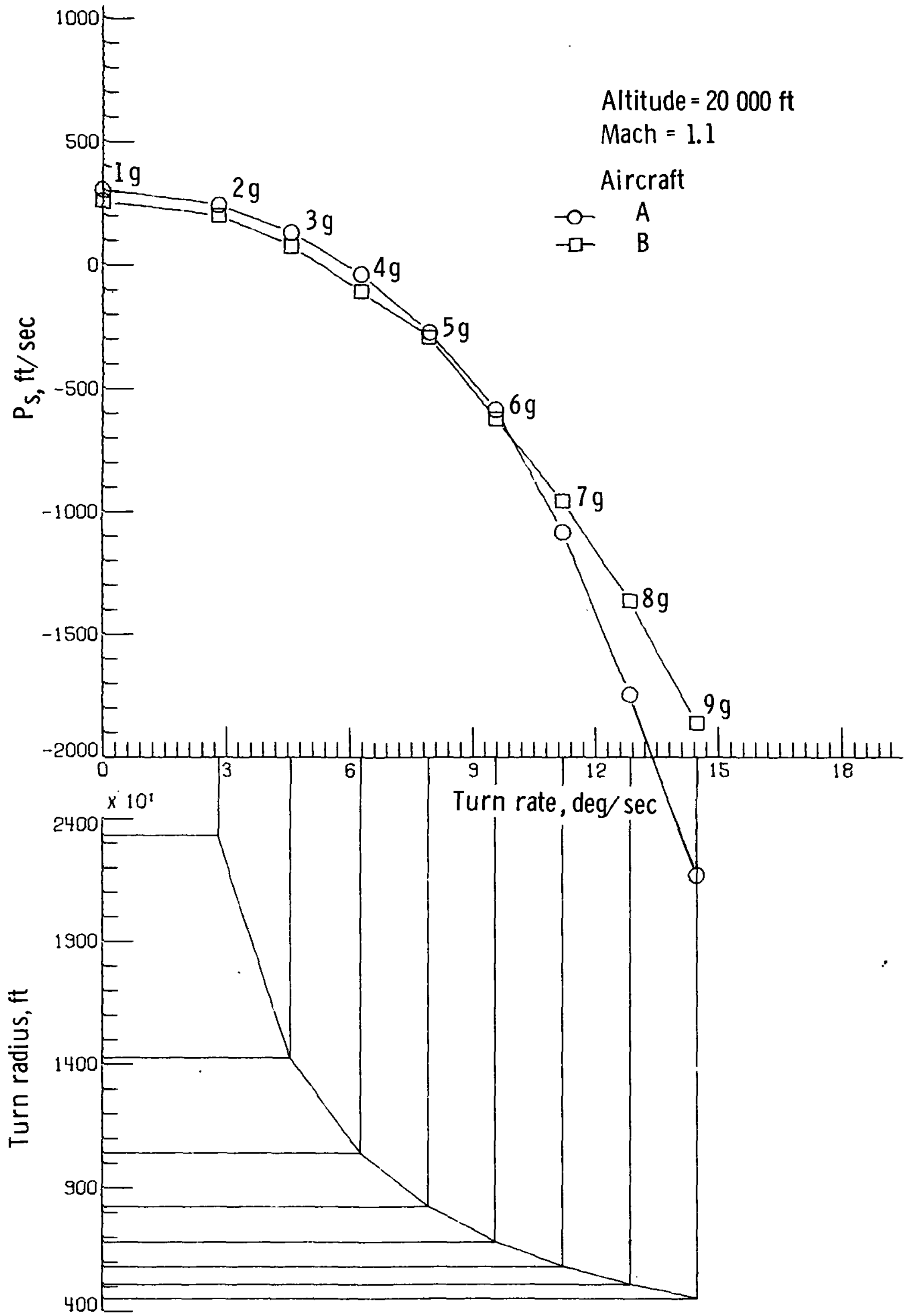


Figure 5.- Typical output of program NEMO.

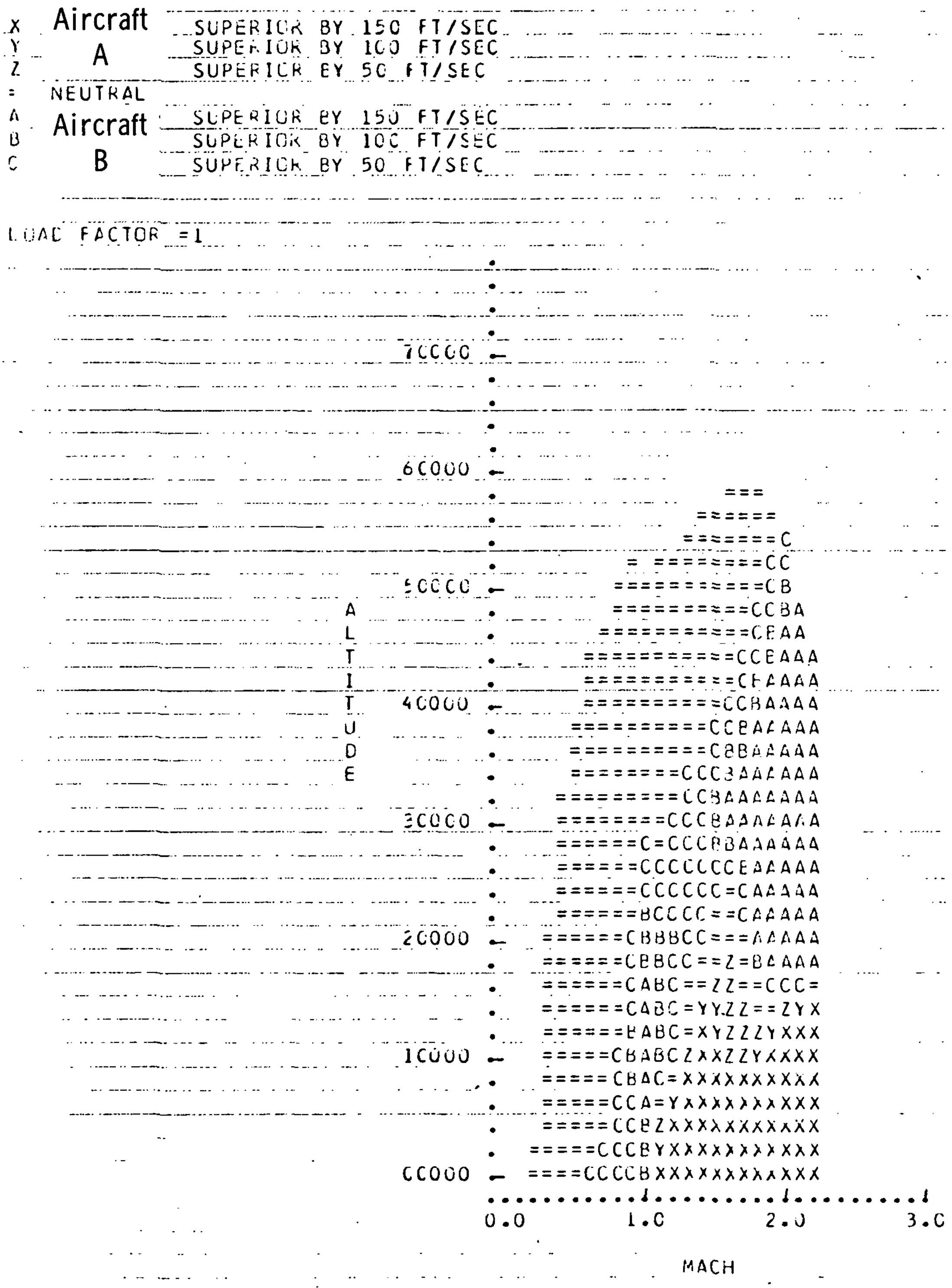


Figure 6.- Typical output of program EXTRA.

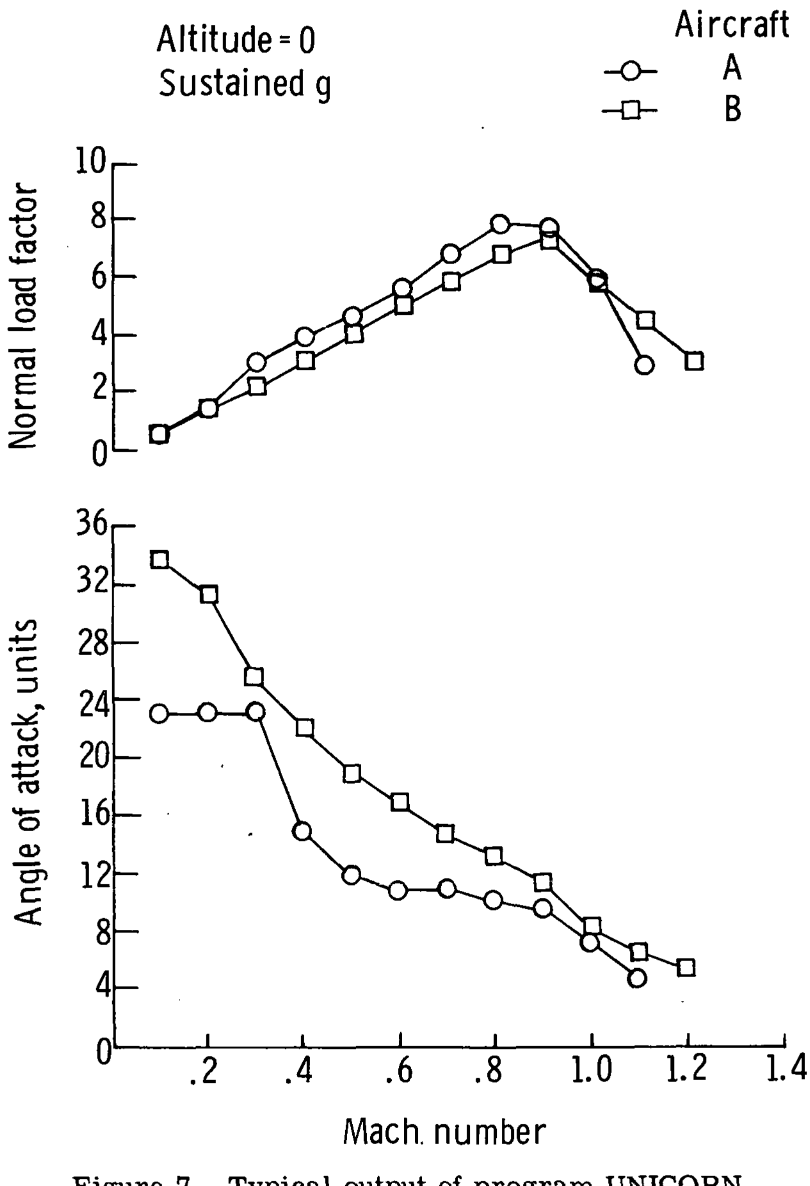


Figure 7.- Typical output of program UNICORN.

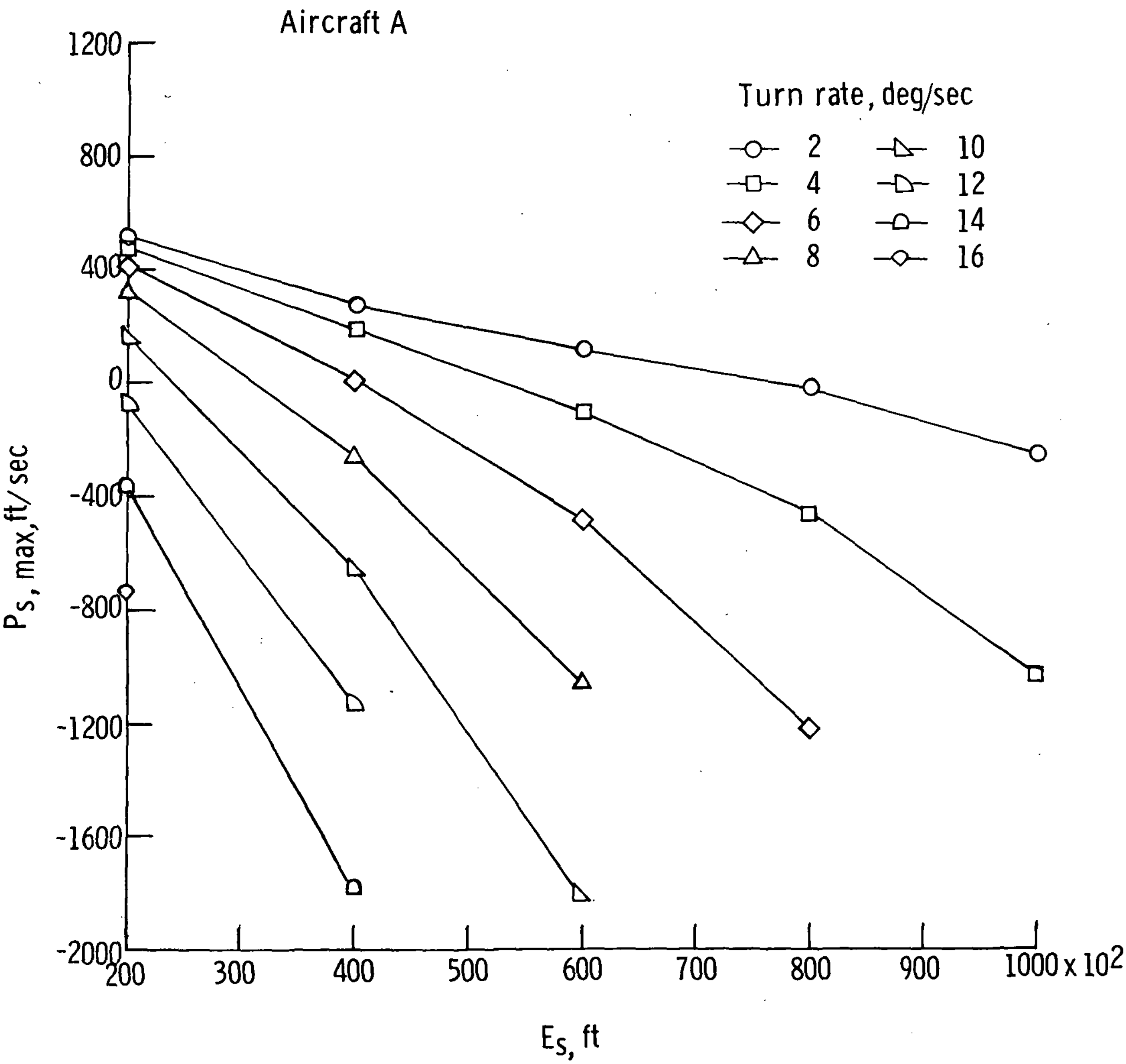


Figure 8.- Typical output of program SVELTE.

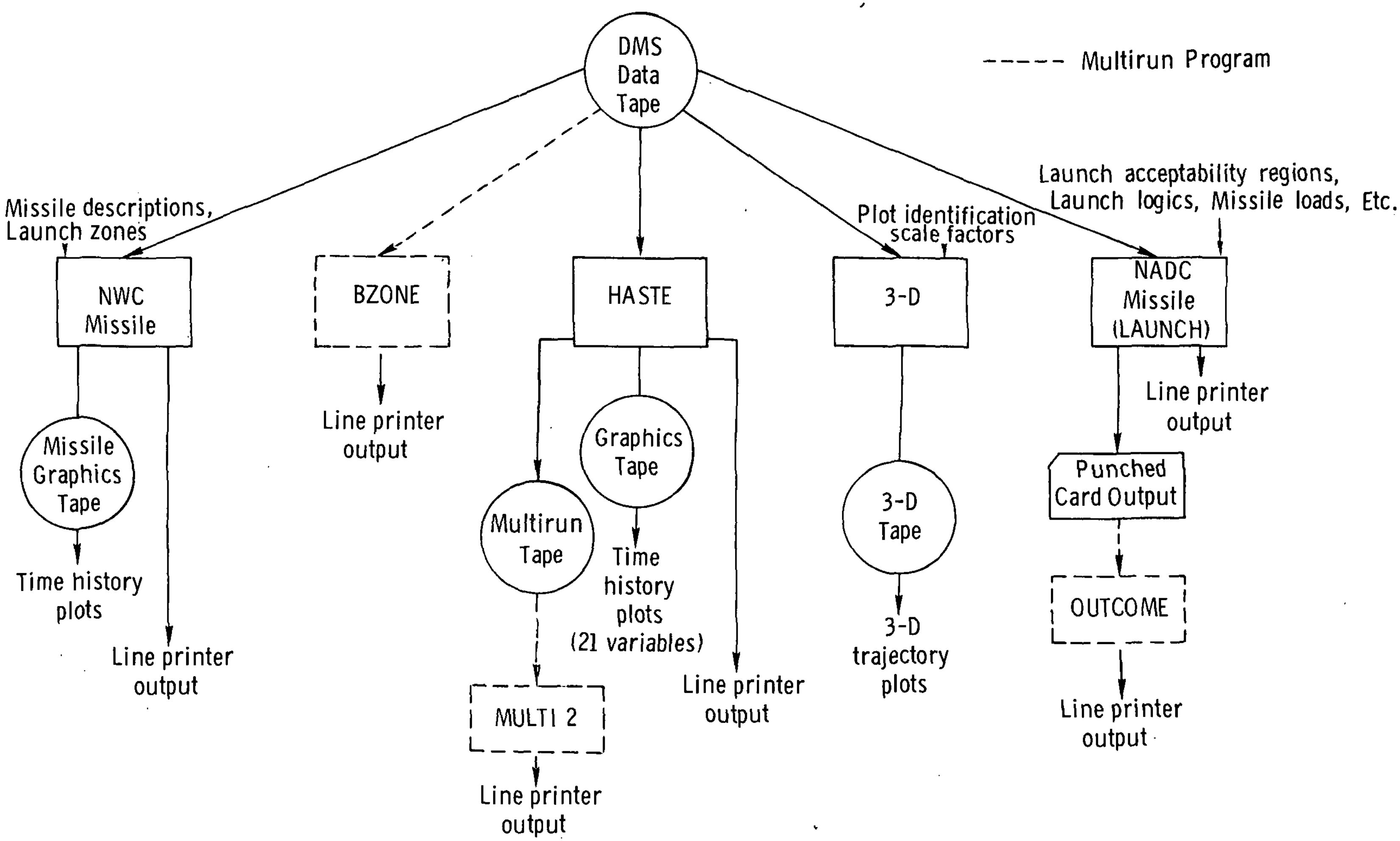


Figure 9.- Programs using DMS results.

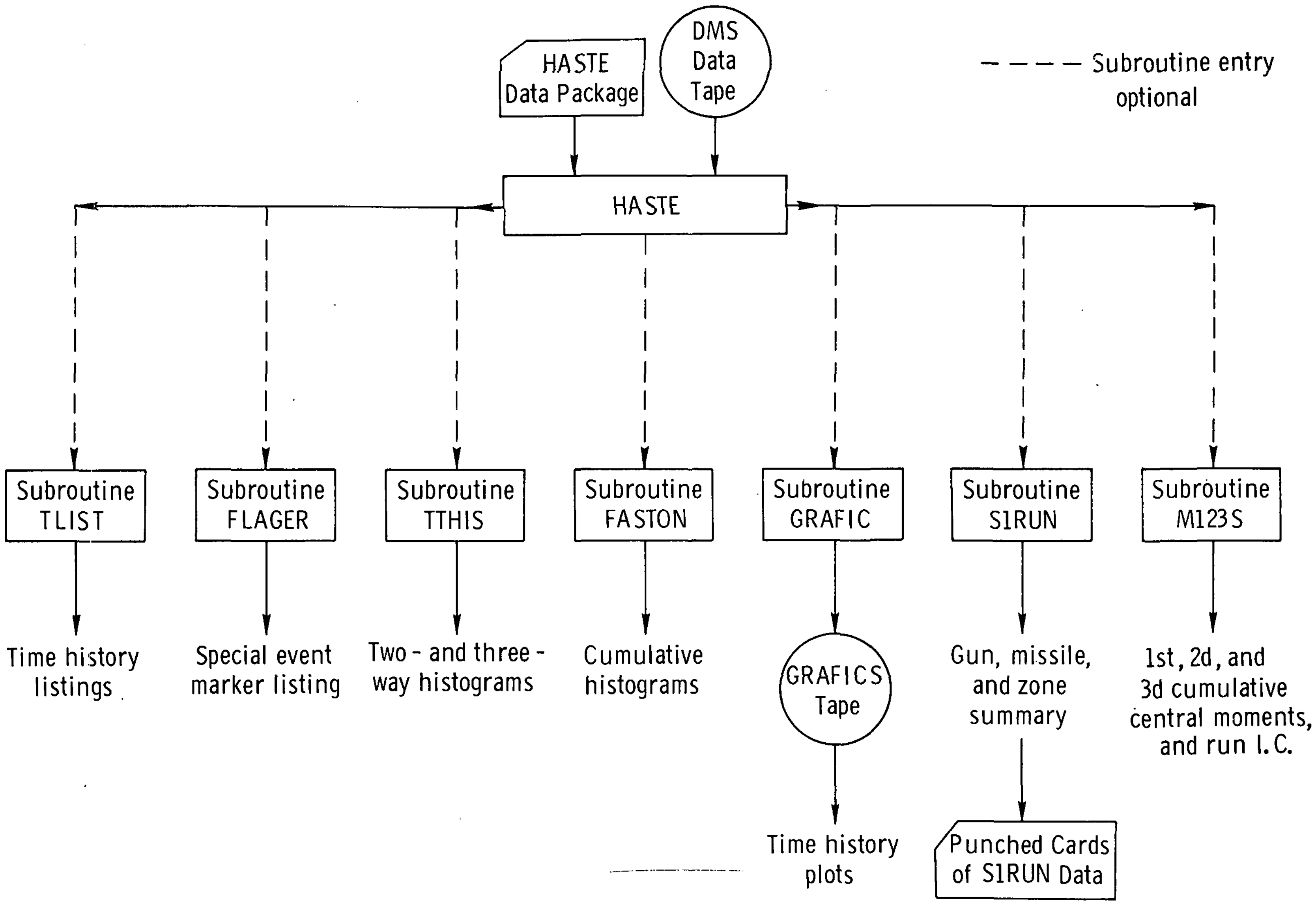


Figure 10.- Main subroutines used in HASTE and types of output provided.

$$\lambda = \cos^{-1}(x/R)$$

$$\varepsilon = \cos^{-1}\left(\frac{\vec{V} \cdot \vec{R}}{|V|\,|R|}\right)$$

$$(\text{Angle-off})_A = 180^\circ - \varepsilon_B$$

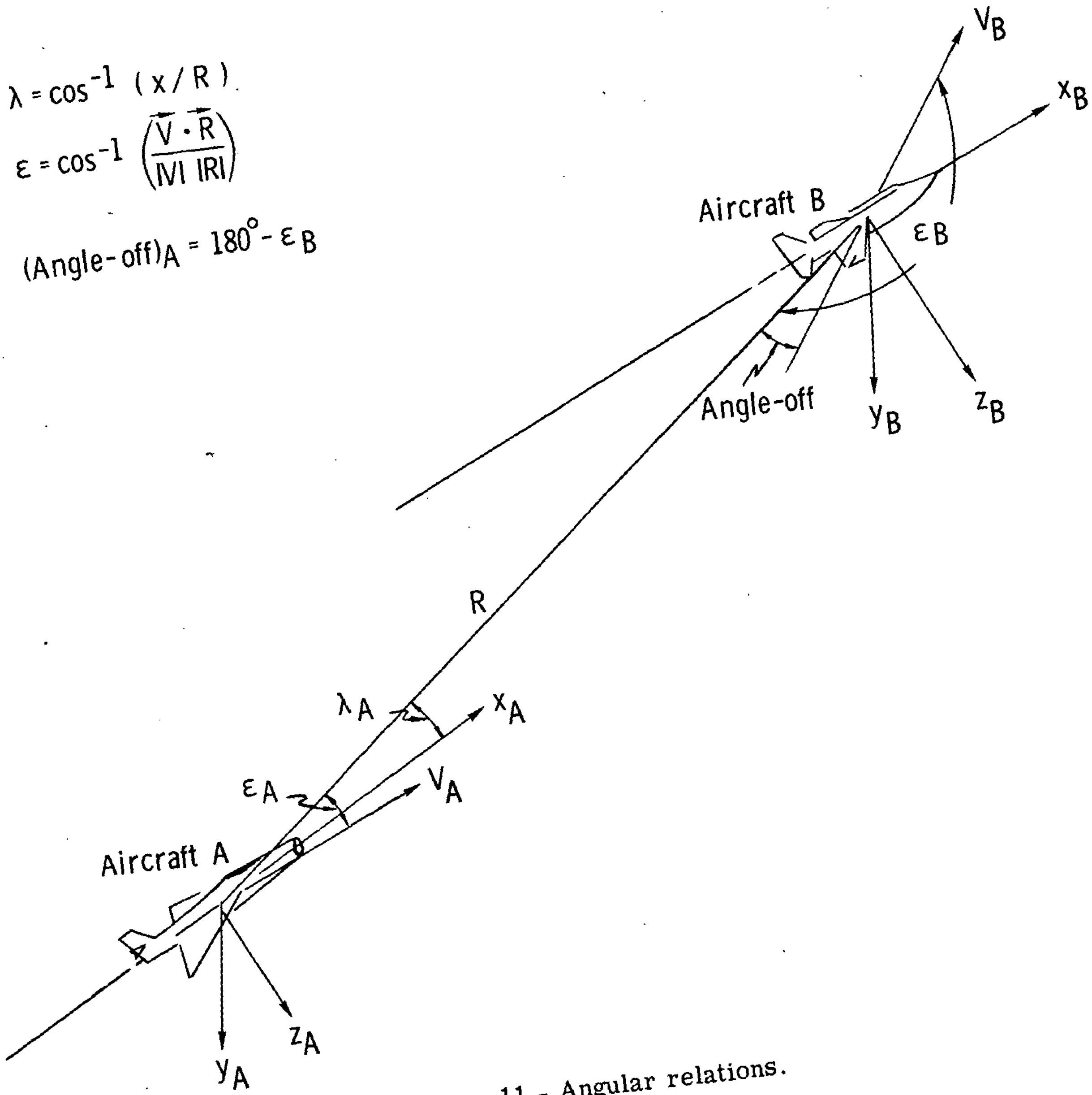


Figure 11.- Angular relations.

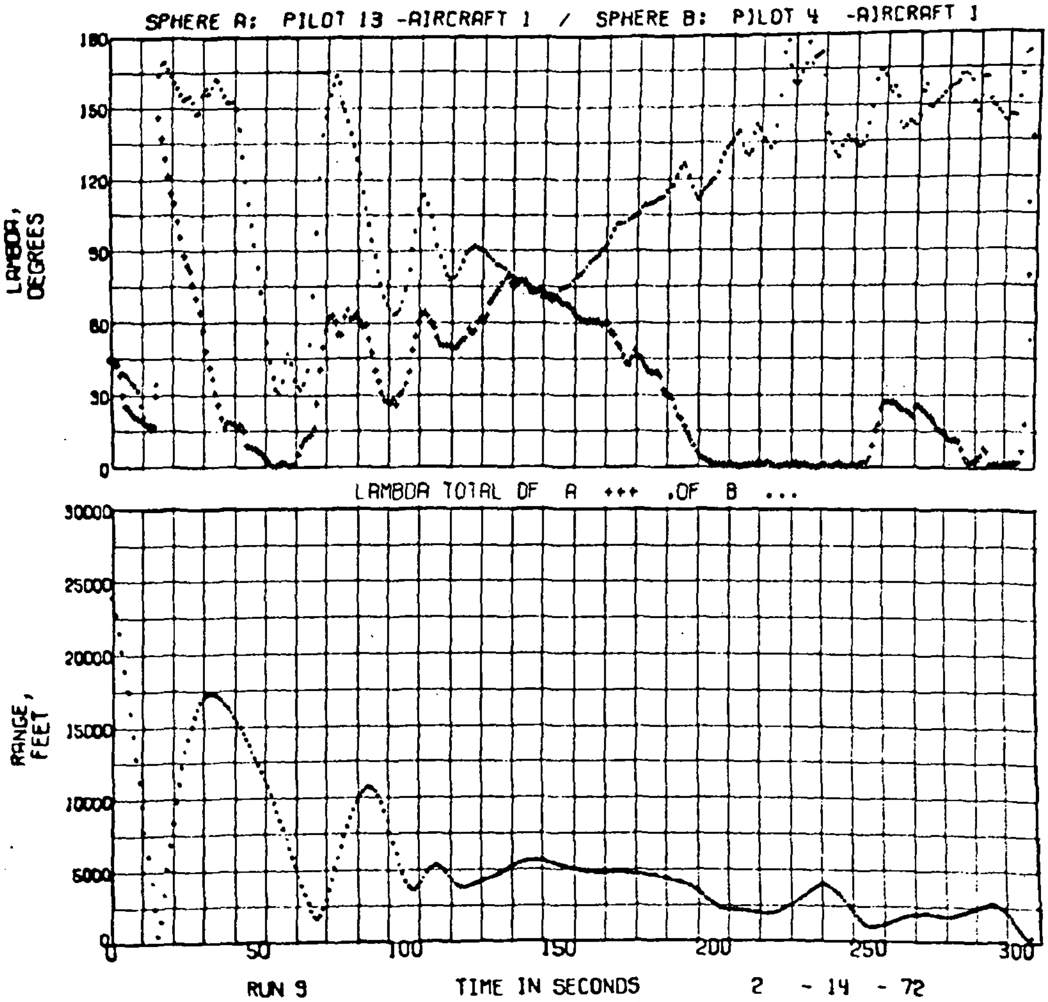


Figure 12.- Time histories of range and off-boresight angle for both aircraft A and B provided by subroutine GRAFIC.

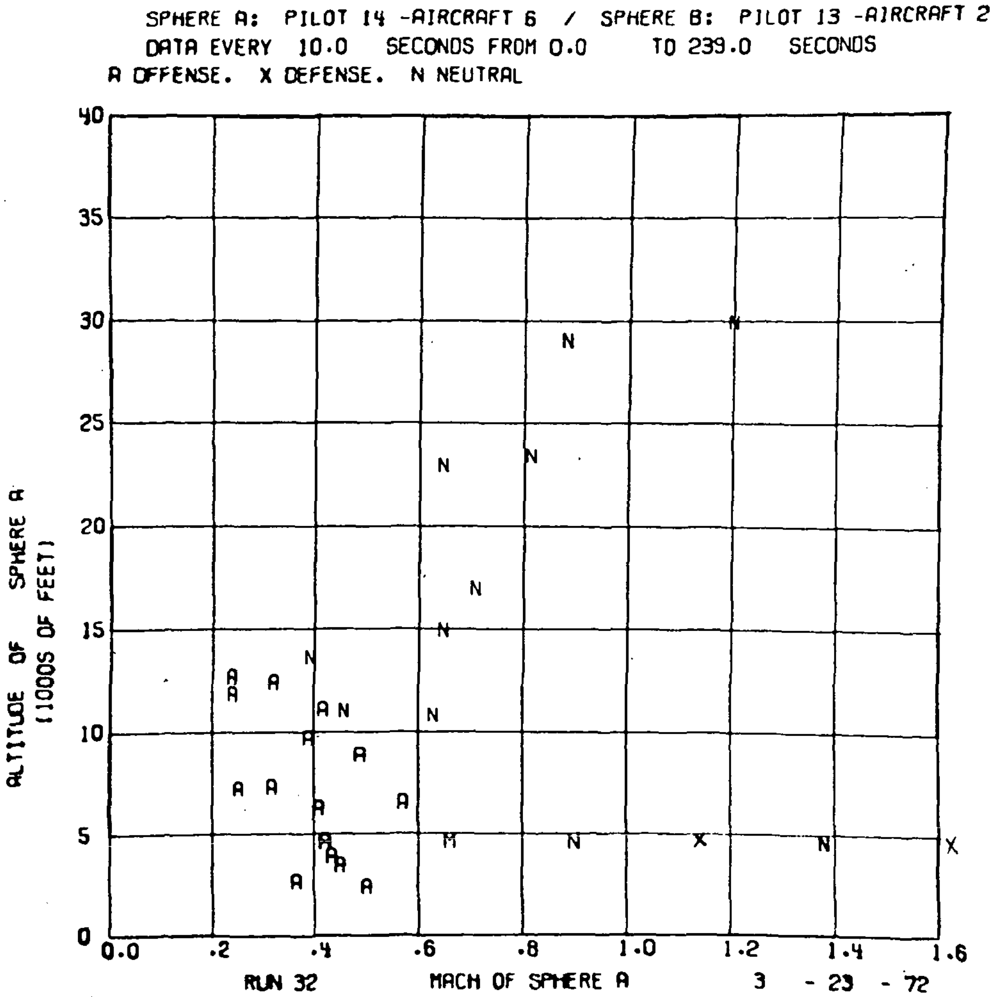


Figure 13.- Typical Mach-altitude plot output by program GRAFIC.

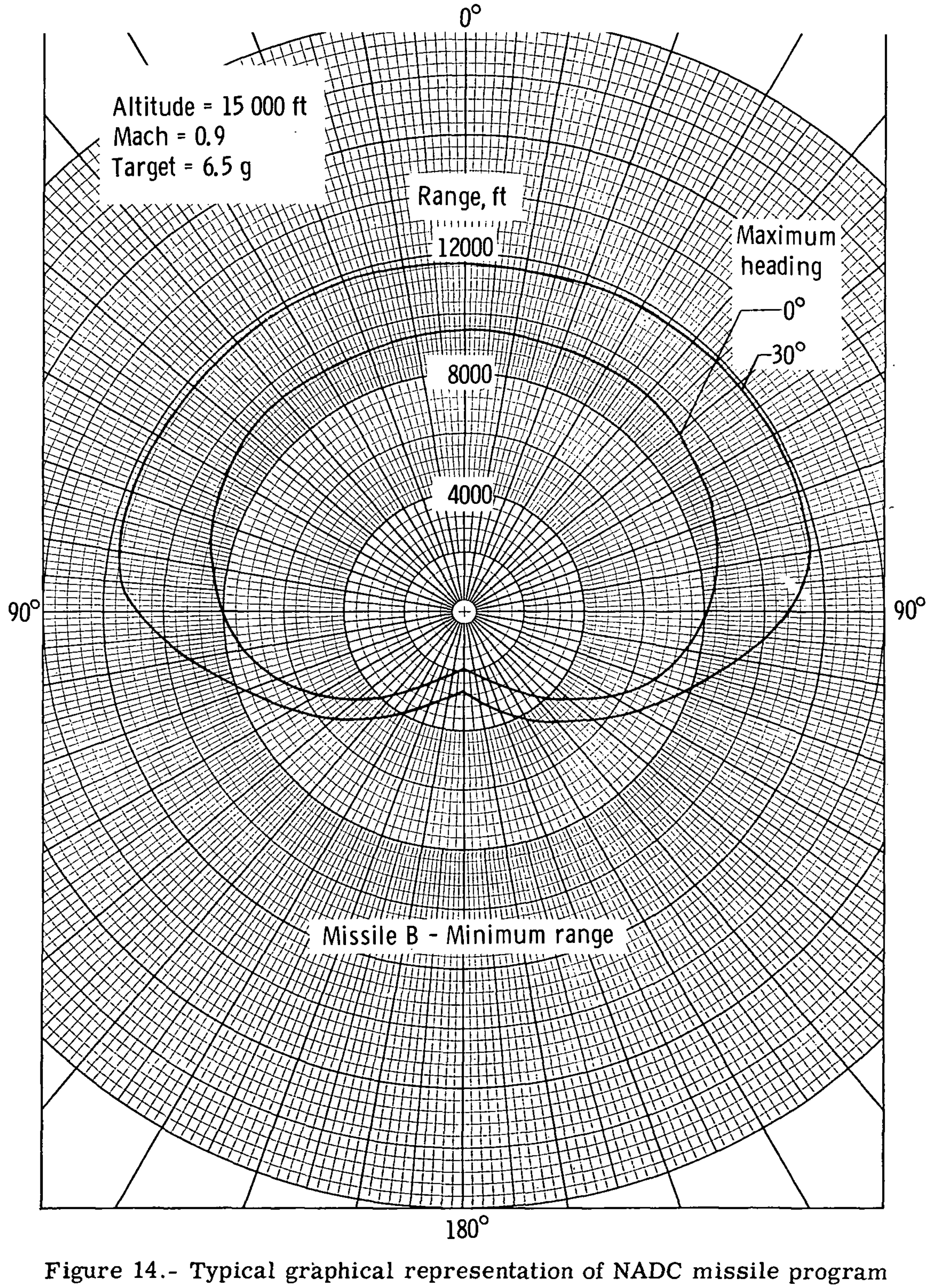


Figure 14.- Typical graphical representation of NADC missile program launch acceptance region (LAR) table.

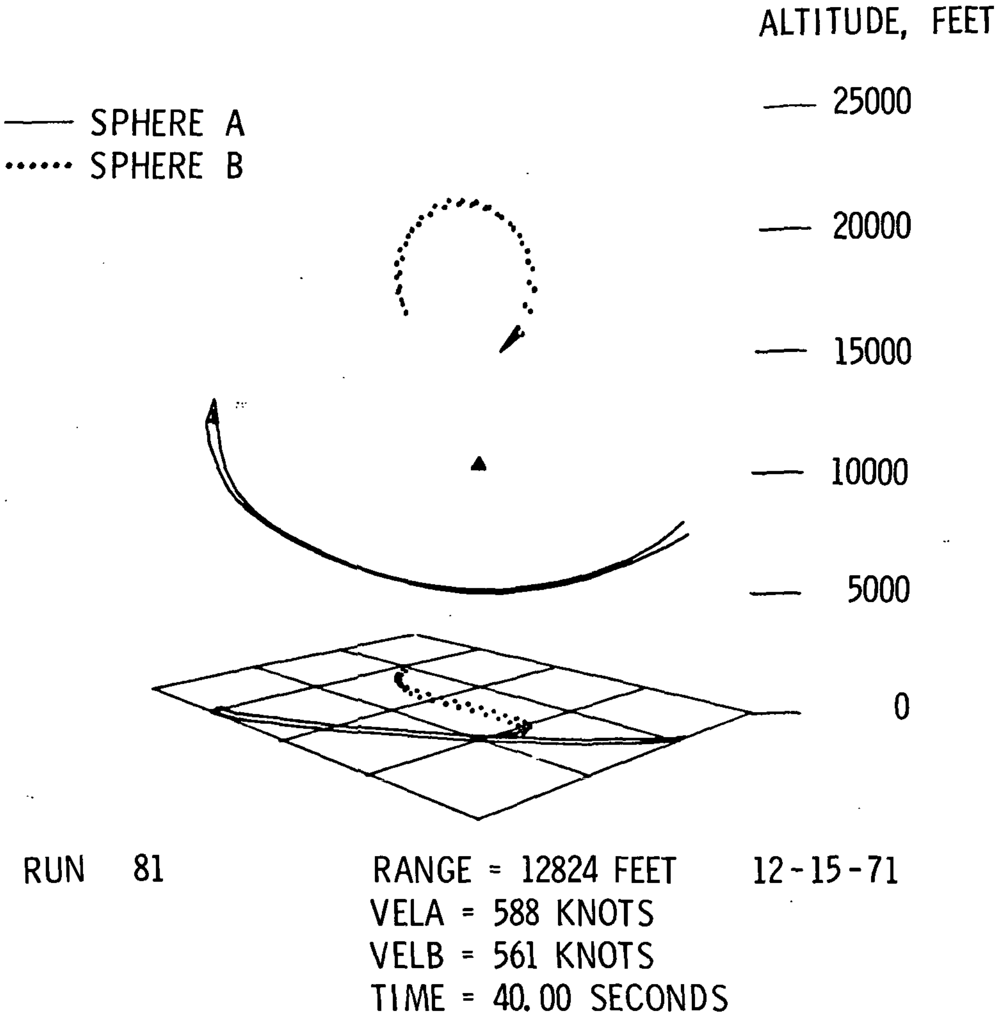


Figure 15.- Typical Program 3-D output.

Zone 1	Head-on	$\lambda_T < 60^\circ$
Zone 2	Beam	$60^\circ \leqq \lambda_T < 120^\circ$
Zone 3	Tail	$\lambda_T \geqq 120^\circ$

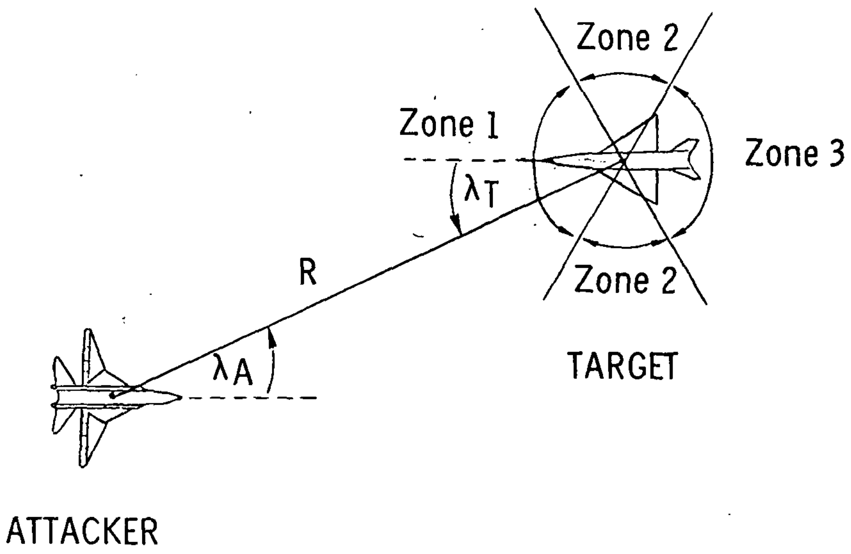


Figure 16.- Program BZONE zone definition.

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