AD-A190 160 INTERACTIVE INPUT FOR PROJECTILE FAST DESIGN CODES PACKAGE(U) ARMY BALLISTIC RESEARCH LAB ABERDEEN PROVING GROUND MD A G MIKHAIL OCT 87 BRL-MR-3631 1/1

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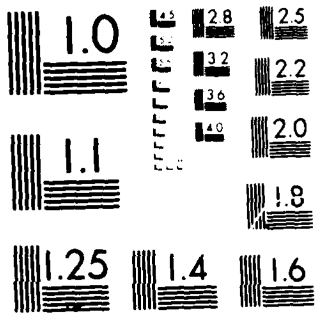

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MEMORANDUM REPORT BRL-MR-3631

INTERACTIVE INPUT FOR PROJECTILE FAST DESIGN CODES PACKAGE

AMEER G. MIKHAIL

OCTOBER 1987

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US ARMY BALLISTIC RESEARCH LABORATORY
ABERDEEN PROVING GROUND, MARYLAND

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UNCLASSIFIED
SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

Form Approved
OMB No 0704-0188
Exp Date Jun 30, 1986

1a. REPORT SECURITY CLASSIFICATION
UNCLASSIFIED

1b. RESTRICTIVE MARKINGS
AD A190 160

2a. SECURITY CLASSIFICATION AUTHORITY

2b. DECLASSIFICATION / DOWNGRADING SCHEDULE

3. DISTRIBUTION / AVAILABILITY OF REPORT
Approved for public release, distribution unlimited.

4. PERFORMING ORGANIZATION REPORT NUMBER(S)
BRL-MR-3631

5. MONITORING ORGANIZATION REPORT NUMBER(S)

6a. NAME OF PERFORMING ORGANIZATION
U.S. Army Ballistic Research Laboratory

6b. OFFICE SYMBOL *(If applicable)*
SLCBR-LF

7a. NAME OF MONITORING ORGANIZATION

6c. ADDRESS *(City, State, and ZIP Code)*
Aberdeen Proving Ground, MD 21005-5066

7b. ADDRESS *(City, State, and ZIP Code)*

8a. NAME OF FUNDING / SPONSORING ORGANIZATION

8b. OFFICE SYMBOL *(If applicable)*

9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER

8c. ADDRESS *(City, State, and ZIP Code)*

10. SOURCE OF FUNDING NUMBERS

PROGRAM ELEMENT NO.	PROJECT NO.	TASK NO.	WORK UNIT ACCESSION NO
62618A	1L162618AH80	00	001 AJ

11. TITLE *(Include Security Classification)*
INTERACTIVE INPUT FOR PROJECTILE FAST DESIGN CODES PACKAGE

12. PERSONAL AUTHOR(S)
MIKHAIL, AMEER G.

13a. TYPE OF REPORT
Memorandum Report

13b. TIME COVERED
FROM ________ TO ________

14. DATE OF REPORT *(Year, Month, Day)*

15. PAGE COUNT

16. SUPPLEMENTARY NOTATION

17. COSATI CODES

FIELD	GROUP	SUB-GROUP
01	01	
19	01	

18. SUBJECT TERMS *(Continue on reverse if necessary and identify by block number)*
Projectile Design; McDrag Code; Aerodynamic Prediction; Middle DATCOM Code; Fast Design Codes; NSWC-AP Code (Continued)

19. ABSTRACT *(Continue on reverse if necessary and identify by block number)*

A set of six fast computer codes, in FORTRAN, used in the preliminary design of projectiles is assembled. The codes are structured to form a closed-loop cycle for fast aerodynamic applications. The closed-loop cycle signifies the collection of codes to perform: 1) physical properties calculations, 2) aerodynamic predictions; and 3) simple trajectory calculations.

Six codes are assembled, four of which are for aerodynamic predictions. Of the four codes, two are for general configurations and applications, namely the Missile DATCOM and the NSWC-AP codes. The other two codes, which are for specialized configurations and calculations are the McDrag and FINNER (Donovan's) codes. The sixth code is for a simplified three degrees of freedom trajectory code (x, y and spin).

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20. DISTRIBUTION / AVAILABILITY OF ABSTRACT
☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT. ☐ DTIC USERS

21. ABSTRACT SECURITY CLASSIFICATION
UNCLASSIFIED

22a. NAME OF RESPONSIBLE INDIVIDUAL
Ameer G. Mikhail

22b. TELEPHONE *(Include Area Code)*
(301) 278-3773

22c. OFFICE SYMBOL
SLCBR-LF-R

DD FORM 1473, 84 MAR — 83 APR edition may be used until exhausted. All other editions are obsolete.

SECURITY CLASSIFICATION OF THIS PAGE
UNCLASSIFIED

18. Subject Terms (Continued)

Interactive Inputting
Lists of Input
Physical Properties Code
FORTRAN
McDrag Code
Finner (Donovan) Code
Trajectory Code (3DF)

19. Abstract (Continued)

Six interactive programs were written and developed to aid the nonfrequent or first-time user's of these codes. Lists and illustrations of the required input of each code are provided. These lists are based on the input actually required by the codes as described in their corresponding user's manuals. Each list is also followed by an example with a projectile configuration, dimensions and other specific data. The examples are set to correspond exactly to the list of input of each code.

The provided lists and examples can be utilized as a user's reference for the six codes. Also each code can be used separately or in a complete design cycle. The interactive codes were tested and closed-loop design cycles were actually performed for proofing the interactive codes.

ACKNOWLEDGMENTS

The help of Mr. Kyang Choi, a U.S. Army exchange engineer who was assigned to this effort during April-August 1985, is appreciated.

Mr. R. Pennekamp of the U.S. Army Ballistic Research Laboratory (BRL), Aberdeen Proving Ground, MD, is also thanked for providing the modified physical properties code.

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LIST OF FIGURES

I. INTRODUCTION

The purpose of this report is to describe and make available, a package of fast codes used for preliminary aerodynamic design of projectiles. List of required input and an example application for each code are provided. This report can also be used as a single reference text for the six codes. Each code can be used alone or together with the other codes to provide fast iterative changes to help satisfy user's aerodynamic and trajectory requirements.

Lists for the required input for four fast aerodynamic prediction codes for projectiles are included to facilitate an easier interactive procedure for inputting of parameters. A list for a three-degrees of freedom point-mass trajectory code and another for physical properties code are also included.

These codes are used for obtaining fast preliminary estimates for the aerodynamic coefficients for missiles and projectiles. However, one must be familiar with the required input for each code so that one is able to use these codes properly. Although the codes are fast (use less than 30 CPU seconds per single case, on a typical "mini" computer such as a VAX-780), the proper inputting for each code may take hours for the user who is unfamiliar with them. To help reduce this inputting problem for first-time or non-frequent users, programs were written to prompt the user on the screen of a CRT terminal with the required input and very brief description of the input. The input sequence is identical to that required by each code. These interactive programs, when completed in there entirety, result in a written logical "input" file for all the entered input, for later checking and for submittance with the corresponding source code. The lists provided in this report correspond to the exact input which the user will be prompted for interactively. Figures indicating nomenclature are provided for each code.

For highly experienced users, or for highly specialized applications, these lists may not be total substitutes for the original lengthy user's guide[1-6]. Users in those categories may, therefore, consult those references.

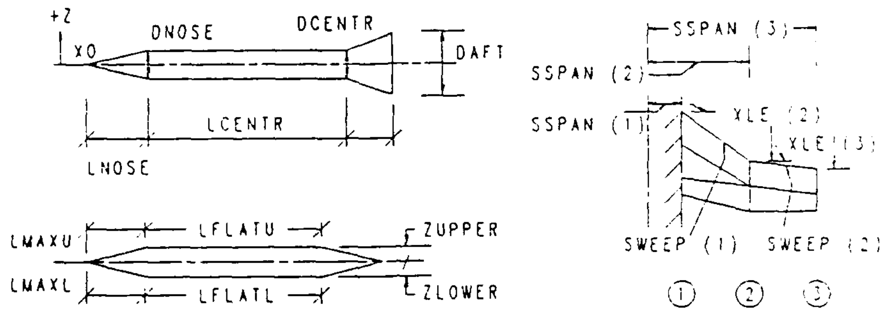
The six codes considered are:

- The Missile DATCOM Code[1]
- The NSWC-AP Code[2]
- The Mc-DRAG Code[3]
- The Finner Code[4]
- The 3DOF Trajectory Code[5]
- Projectile Physical Properties Code[6-7]

The four aerodynamic prediction codes and the projectile configurations they are most suited for are shown in Figure 1. Figure 2 illustrates the use of the six codes for preliminary aerodynamics design cycle.

II. THE MISSILE DATCOM CODE

1. LIST OF INPUT

MISSILE DATCOM CODE	
Application	For axisymmetric or elliptically-shaped body with one or two fin sets and an air breathing propulsion system.
Computes	C_N, C_L, C_M, X_{cp}, C_A, C_D, C_Y, C_n, C_ℓ, $C_{N\alpha}$, $C_{M\alpha}$, $C_{Y\beta}$, $C_{n\beta}$, $C_{\ell\beta}$
Output	Final aerodynamics results and intermediate aerodynamic calculations and logical data file for plotting
Geometry	
Input Required (in Order)	i Case ID (e.g., "XM-829 projectile") ii Any info comments (e.g. "with 4 fins only-sharp nose") Two lines allowed, separated by a carriage return iii Units chosen (ft, in, meter, mm) NAMELIST FLTCON 1. Number of angles of attack 2. Angles of attack, ALPH (DEG) 3. Sideslip angle, BETA (DEG) 4. Aerodynamic roll angle, PHI (DEG) 5. Number of Mach Numbers 6. Mach Numbers, MACH 7. Reynolds Numbers, REN, corresponding to each Mach Number (per ft if you choose in or ft or per meter if you choose cm or m) NAMELIST REFQ 1. Reference Area, SREF (ℓ^2) 2. Reference length (longitudinal - usually the maximum diameter), LREF (ℓ) 3. Reference length (lateral direction - usually the total length), LATREF (ℓ) 4. Surface roughness height, ROUGH (ℓ) 5. Longitudinal position of C.G., XCG (ℓ) 6. Vertical position of C.G., ZCG (ℓ) 7. Boundary layer type (laminar or turbulent), BLAYER

Input (Continued)

NAMELIST AXIBOD - Option 1 (Non-digitized input for the body (geometry)

1. X Station of nose tip, xo (ℓ)
2. Nose shape type (conical, ogive, cone or power series), TNOSE
3. Exponent for power law shapes $[(r/R)=(x/\ell)^n]$, POWER
4. Actual nose length, LNOSE (ℓ)
5. Nose section base diameter, DNOSE (ℓ)
6. Nose bluntness radius, BNOSE (ℓ)
7. Nose truncation, whether nose truncated or not, TRUNC
8. Center body length, LCENTR (ℓ)
9. Center body base diameter, DCENTER (ℓ)
10. Afterbody shape name (conical, ogive, cone) TAFT
11. Afterbody length, LAFT (ℓ)
12. Afterbody base diameter, DAFT (ℓ)

NAMELIST AXIBOD - Option 2 (digitized input for the body (geometry)

1. xo — Item No. 1
2. BNOSE — the same as in option 1 — Item No. 6
3. TRUNC — Item No. 7
4. Number of input stations for the total body, NX
5. Longitudinal stations, x (ℓ) (0.0, 0.1, 0.2...)
6. Radius at each x station, R (ℓ) (0.0, 0.02, 0.037..)
7. Indices of x stations where the surface slope is discontinuous, DISCON

NAMELIST $FINSET_n$

1. Type of fin cross-section, SECTYP
2. Semi-span stations from vehicle center line, SSPAN (ℓ) (maximum of 10)
3. Panel chord length at each SSPAN, CHORD (ℓ)
4. Axial station of chord leading edge at each SSPAN, XLE (ℓ)
5. Sweep-back angle at each SSPAN, SWEEP (DEG)
6. Station of the chord (ratioed to the local chord length) by which sweep angle was defined, STA, (0.0 for leading edge, 1.0 for trailing edge) at each SSPAN station
7. Maximum thickness of upper surface (i.e. panel half thickness), ZUPPER, Ratioed to local chord length, at each SSPAN station
8. Leading edge radius at each SSPAN station, LER (ℓ)
9. Number of fin panels (2 or 4), NPANEL
10. Roll orientation angle of first fin, clockwise from the vertical line (looking forward to the nose tip), FINPHI

Input (Continued)	
	OPTIONAL INPUT (ONLY FOR THE HEXAGONAL PROFILE) 11. Maximum thickness of lower surface, ZLOWER, Ratioed to local chord length, at each SSPAN station 12. Distance from leading edge to location of maximum thickness for upper surface, LMAXU, as a fraction of the local chord length, at each SSPAN station 13. The same as 11 but for the lower surface, LMAXL 14. Length of chord with constant thickness, for upper surface, LFLATU, as a fraction of the local chord length, at each SSPAN station 15. The same as 13 but for the lower surface, LFLATL NAMELIST $FINSET_n$ - inputs for user-defined airfoil (not presented here) NAMELIST DEFLCT 1. Deflection angle for each fin panel in finset 1 (DEG) 2. Deflection angle for each fin panel in finset 2 (DEG) 3. Axial stations of hinge lines, XHINGE (ℓ) NAMELIST INLET - not presented here, will be skipped automatically by the code if not specified in the input <u>CONTROL OPTIONS TO BE SELECTED*</u> 1. To print the results of a configuration build-up, "BUILD" 2. To print title for the case computed on each output page, "CASEID" 3. To ignore a previous case namelist input, "DELETE-name" 4. To set the system of units for user inputs, "DIM IN" (in, ft, cm, m) 5. To set all output derivatives per radian, "DERIV RAD" 6. To dump selected internal block data for printing, "DUMP CASE"

*To reduce the number of prompts the user has to respond to, only the following 9 control options (out of 23) will be allowed interactively:

Option Number from the List Above

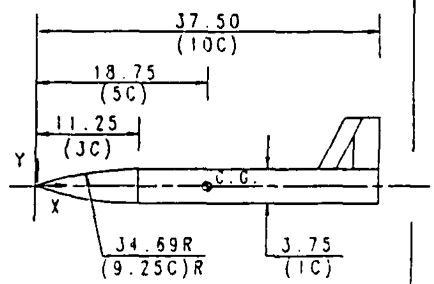
1.	(14)NO LAT ?	6.	(15)	PART ?
2.	(1)BUILD ?	7.	(5)	DERIV RAD ?
3.	(21)SAVE ?	8.	(22)	SOSE?
4.	(17)Pressures ?	9.	(23)	TRIM ?
5.	(12)NEXT CASE ?			

MISSILE DATCOM CODE (Continued)	
Input (Continued)	7. To dump the user-selected internal block data for printing, "DUMP name" 8. To specify the format of the data to be printed to tape unit 3, "FORMAT" 9. To select the Newtonian flow method for all Mach numbers > 1.4, "HYPER" 10. To define a NACA airfoil cross-section, "NACA" 11. To instruct the program to print all namelist data, "NAMELIST" 12. To terminate the case input data and to begin case, "NEXT CASE" 13. To check input without computing, "NOGO" 14. To inhibit the calculation of the lateral derivatives, "NOLAT" 15. To print partial aerodynamic output, "PART" 16. To provide data file for plotting, "PLOT" 17. To print pressure coefficient distributions, "PRESSURES" 18. To print the incremental aerodynamics, "PRINT AERO name" 19. To print the method-extrapolation messages, "PRINT "EXTRAP" 20. To print geometric characteristics, "PRINT GEOM name" 21. To retain the present namelist inputs, "SAVE" 22. To select the second-order shock expansion method, "SOSE" 23. To cause program to perform a trim calculation, "TRIM"

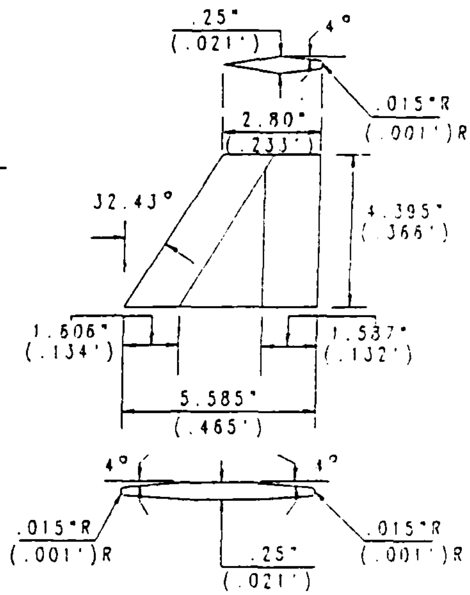
2. EXAMPLE

The given geometry is for a finned projectile with 4 fins. The flight conditions are: M = 2.36, Re = 3 × 10^6 per foot. Twenty angles of attack calculations are made (0° - 19°).

Option (1) for body geometry specification will be used. This option does not require a digitized body surface contour to be provided.



X(C)	0.0	.15	.30	.45	.60	.75	.90	1.05	1.2	1.5	1.8	2.1	2.4	2.7	3.0	10.0
Y(C)	0.0	.050	.097	.142	.183	.222	.259	.292	.323	.378	.422	.456	.481	.495	0.50	0.50



BODY DIMENSIONS, INCH (& CALIBER) | FIN DIMENSIONS, INCH (& FEET)

Input

NOTE: "cr" signifies "carriage return" for CRT terminal use

i. "B1W0F33 - McDonnell-Douglas Configuration"
ii. "4 Fins, at M = 2.36" and cr
"Case Run xx/xx/1985"
iii. Inches

NAMELIST FLTCON
1. 20.
2. 0. cr; 1. cr; 2. cr; ...;19. cr
3. 0.0
4. 0.0
5. 1.0
6. 2.36
7. 3.E+06

NAMELIST REFQ

1. cr (i.e., use the default value which is the area of the maximum diameter)
2. cr (i.e., use the default value which is the maximum diameter of the projectile)
3. cr (i.e., use the default value which is the maximum length of the projectile)
4. cr (i.e., use the default value which is zero)
5. 10.76
6. cr (i.e., use the default value which is zero)
7. cr (i.e., use the default value which is turbulent boundary layer)

Do you need to enter "body" inputs (yes or no - no means fin alone configuration) ? Yes
Which body specification option you choose: Option 1 or 2 ? 1

NAMELIST AXIBODY - Option 1

1. cr (i.e., use the default value, which is body nose starts at X = 0.0)
2. 1.0 (i.e., conical shape type)
3. (skipped because the power series shape for the nose geometry was not chosen)
4. 11.25
5. 3.75
6. cr (i.e., use of the default value, which is zero)
7. cr (i.e., use of the default value, "not truncated")
8. 26.25
9. 3.75

Is there an aft-body (yes or no)? No

10.
11. (skipped because there is no aft-body)
12.

NAMELIST AXIOBODY - Option 2

1.
2.
3.
4. (skipped because use of option 1 was specified)
5.
6.
7.

Is there fin set (yes or no)? Yes

NAMELIST FINSET 1

1. cr (i.e., use the default value, hexagonal cross-section)

Enter number of semi-span stations to be described? 2

2. 1.875 & cr and 6.278 & cr
3. 5.585 & cr and 2.7925 & cr

Will you specify x location or sweep angle for the leading edge at each semi span station? sweep angles

4. (skipped because sweep angles are chosen)

5a. 32.43 & cr and 32.43 & cr

b. XLE = 31.915

Specify chord station defining the sweep angle (0.0 for leading edge (default), or 1.0 for trailing edge)

6. 0.0 & cr and 0.0 & cr
7. .0284114 & cr and .0284144 & cr
8. 0.15 & cr and 0.0 & cr
9. cr (i.e., use the default value, which is 4 fins)
10. cr (i.e., use the default value, which is zero)

Only for the hexagonal airfoil, do you need to input optional data (yes or no)? Yes

11. cr (i.e., use the default value, i.e., ZLOWER = ZUPPER)
12. .278 & cr and 0.5 & cr
13. cr (i.e., use the default value, i.e., $LMAXL_1$ = $LMAXU_1$ and $LMAXL_2$ = $LMAXU_2$)
14. 0.428 & cr and 0.0 & cr
15. cr (i.e., use the default value, i.e., $LFLATL_1$ = $LFLATU_1$ and $LFLATL_2$ = $LFLATL_1$)

Do you have $FINSET_2$? No

NAMELIST $FINSET_2$

1.–15. (skipped because only one fin set exists)

Do you have fin deflection angles (yes or no)? No

NAMELIST DEFLCT

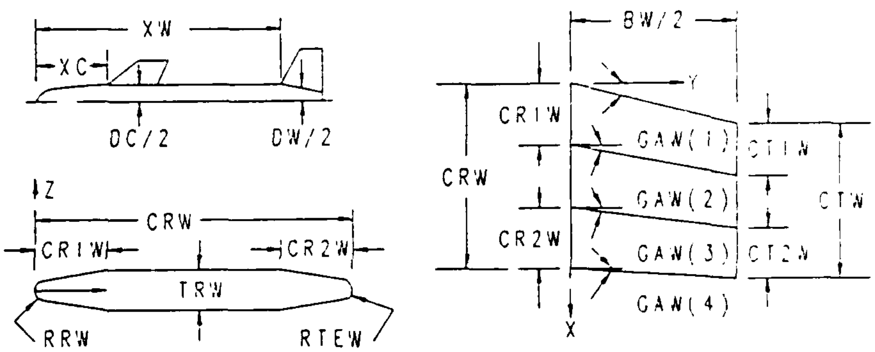
1.
2. (skipped because no fin deflection is specified)
3.

OPTIONS

1.	No Lat?	Yes, no LAT
2.	Build?	Yes
3.	Save?	No
4.	Pressures?	No
5.	Next Case?	Yes
6.	Part?	Yes
7.	Deriv Rad?	Yes
8.	SOSE?	Yes
9.	Trim?	No

III. NSWC-AP CODE

1. LIST OF INPUT

NSWC-AP CODE	
Application	For tactical missiles to Mach number 8 and angle of attack 180°
Computes	C_D, C_N, C_M, $C_{N\alpha}$, $C_{M\alpha}$, X_{C_p}, C_{ℓ_p}, $(C_{Mq} + C_{M\dot{\alpha}})$ versus Mach Number
Output	Four-page output
Geometry	
Input Required	TITLE AND REFERENCE QUANTITIES
(in Order) I.	1. Number of geometry cases to be run, M (usually one)
II.	2. New or old case to be computed, IMA
III.	3. Case title (e.g., "XM-829 projectile")
IV.	4. Configuration type (Body alone, Fin alone, Combination), NTYPE 5. Location of C.G. measured from nose, XCG (caliber) 6. Reference length (usually the maximum diameter), DIA (ft) 7. Rotating band height above body diameter, HB (caliber)
	OPTIONS
V.	1. High angle of attack option (yes or no), NH 2. Single or multiple Mach numbers in high alpha option, OPTMAC 3. Roll angle dependency at high alpha (yes or no), OPTPHI 4. Initial value of angle of attack for high alpha calculation (not less than 8°), ALF1 (DEG) 5. Final value for angle of attack for high alpha calculation, ALF2 (DEG) 6. Angle of attack increment for high alpha calculation, DELAF (DEG)

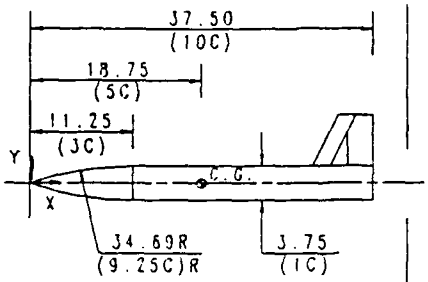
NSWC-AP CODE (Continued)	
Input (Continued)	7. LMSC improved calculations for pitch damping coefficient (yes or no), ILMSC (LMSC = Lockheed Missile Systems Corporation)
	8. NEAR improved calculations for transonic normal force (yes or no), NSWITCH (NEAR = Neilsen Engineering and Research Inc.)
VI.	9. Pressure coefficient distribution printing (yes or no), IPRINT
	10. Configuraton is spin stabilized (yes or no), ISPIN
	FLIGHT CONDITIONS and FIN LOCATION
	1. Number of Mach Numbers
	2. Reynolds Number, RMF (per ft per Mach number)
	3. Mach Number above which body-alone inviscid static aerodynamics is computed using BODY subroutine and lifting surface wave drag is computed using WINGHM subroutine, ALIMIT (The value of 4.0 is suggested, below which Van Dykes' small perturbation is used)
	4. Mach Number above which lifting surface-alone inviscid static and dynamic coefficients is computed using WINGHM subroutine and interference is neglected, ALIMS (The value of 4.5 is suggested, below which thin wing and slender body theories are used)
	5. Angle of attack (for all Mach numbers), AL (DEG)
	6. Tail (Wing) deflection angle, DELTAW (DEG)
	7. Canard (Wing) deflection angle, DELTAC (DEG)
VII.	8. Mach Numbers specified, AM
VIII.	9. Distance of tail leading edge from nose, XW (caliber)
	10. Mean diameter of body at tail root chord, DW (ft)
	11. Distance of canard leading edge from nose, XC (caliber)
	12. Mean diameter of body at the canard root chord, DC (caliber)
	TAIL
IX.	1. Airfoil type (double wedge or biconvex), IW
	2. Number of tail fins (2 or 4), NW
	3. Tail leading edge sweep angle, GAW(1) (DEG)
	4. Tail root chord, CRW (ft)
	5. Tail tip chord, CTW (ft)
	6. The span of 2 isolated tail panels (without the body), BW (ft)
	7. Leading edge radius at root chord, RRW (ft)
	8. Tail thickness at root, TRW (ft)
	9. Trailing edge radius of tail at root chord, RTEW (ft)
X.	10. Distance from trailing edge to first discontinuity downstream at the root chord, CR1W (ft)

NSWC-AP CODE (Continued)

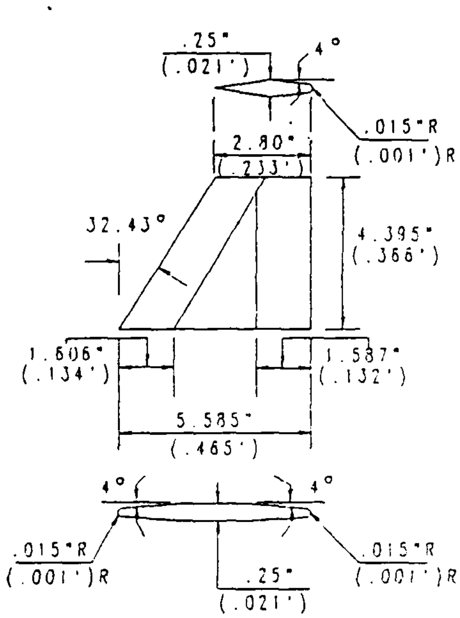
Input (Continued)	11. Distance from tail trailing edge to first discontinuity upstream at the root chord, CR2W (ft)
	12. Tail thickness at tip, TTW (ft)
	13. Tail leading edge radius at tip section, RTW (ft)
	14. Tail trailing edge radius at tip section, RTEW1 (ft)
	CANARD
XI.	1 - 14 The same as 1 - 14 for TAIL
	BODY
XII.	1. Nose tip type (pointed, blunt, truncated), NBLNT
	2. Number of points in a first nose section, KN(1)
	3. Number of points in a second nose section, KN(2)
	4. Number of points in the center body (constant radius), KN(3)
	5. Number of points in a boattail, KN(4)
	Are the points in a file or to be entered next? (if in a file, the code will skip to step 7)
XIII.	6. Longitudinal body coordinate, X (caliber), and the corresponding body radius, R (caliber), for each body point
	7. Constant which determines maximum body slope for $1.2 < M_\infty <$ ALIMIT, F, usually chosen .95

2. EXAMPLE

The same geometry and flight conditions as for the previous DATCOM code example; M = 2.36, Re = 3 × 10^6 per foot at 2° angle of attack.



X(C)	0.0	.15	.30	.45	.60	.75	.90	1.05	1.2	1.5	1.8	2.1	2.4	2.7	3.0	10.0
Y(C)	0.0	.050	.097	.142	.183	.222	.259	.292	.323	.378	.422	.456	.481	.495	0.50	0.50



BODY DIMENSIONS, INCH (& CALIBER) || FIN DIMENSIONS, INCH (& FEET)

Input

NOTE: "cr" signifies "carriage return" for CRT terminal use

TITLE AND REFERENCE QUANTITIES

I. 1. 1
II. 2. 3 (i.e., new case)
III. 3. "B1WOF34 - McD/Doug Configuration"
IV. 4. 2
5. 5.0
6. 0.3125
7. 0.0

OPTIONS

V. 1. 0 (No high angle of attack option)
2. 0 (Single Mach number)
3. 0 (No roll dependence)
4. 8.0
5. 20.0
6. 1.0
7. 0 (No LMSC calculations for pitch damping)
8. 1 (Yes, use NEAR calculations for normal force)
VI. 9. 2 (No printing of pressure distribution)
10. 2 (No spin stabilization)

FLIGHT CONDITIONS AND FIN LOCATION

1. 1
2. 1271186.44
3. 4.0
4. 4.5
5. 2.0
6. 0.0
7. 0.0
VII. 8. 2.36
VIII. 9. 8.511
10. 0.3125
11. 0.0
12. 0.3125

TAIL

IX. 1. 1 (modified double wedge)
2. 4
3. 32.43
4. 0.4654
5. 0.2327
6. 0.7325
7. 0.00125
8. 0.0208
9. 0.00125
10. 0.13383
X. 11. 0.13225
12. 0.020833
13. 0.0
14. 0.00125

CANARD

XI. 1. thru 14. (skipped, no CANARD is specified)

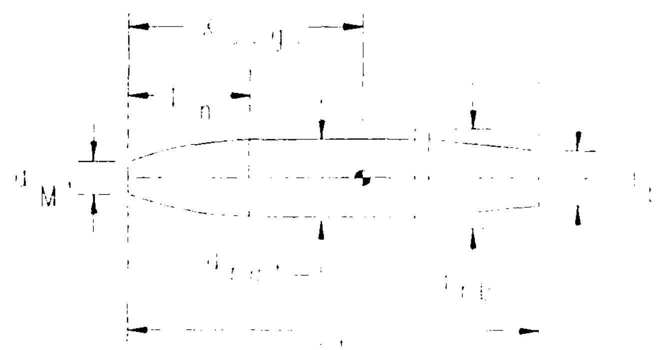
BODY

XII. 1. 0 (pointed nose)
2. 15
3. 0
4. 1
5. 0
(The body points will be entered next)
XIII. 6. (0.0, 0.0) and cr
(0.15, 0.0500) and cr
(0.30, 0.09722) and cr
(0.45, 0.14162) and cr
(0.60, 0.18327) and cr
(0.75, 0.22223) and cr
(0.90, 0.25852) and cr
(1.05, 0.29217) and cr
(1.20, 0.32322) and cr
(1.50, 0.37762) and cr
(1.80, 0.42188) and cr
(2.10, 0.45616) and cr

	(2.40, 0.48057) and cr
	(2.70, 0.49518) and cr
	(3.00, 0.5) and cr
	(10.0, 0.5) and cr
7.	0.95

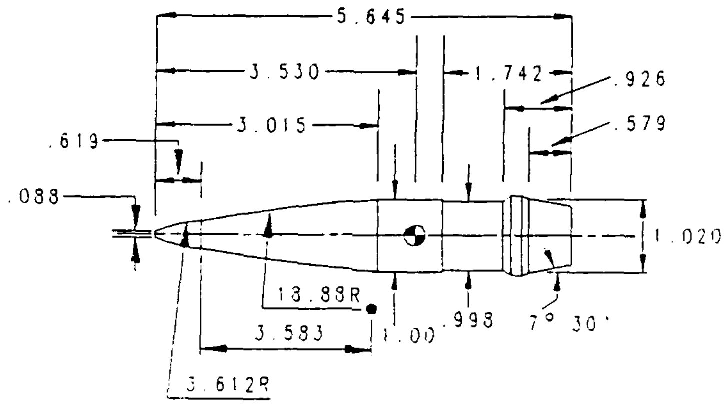
IV. THE MCDRAG CODE

1. LIST OF INPUT

MCDRAG CODE	
Application	For typical spin stabilized projectiles (no fins) in the Mach range of 0.5 to 4.0, at zero angle of attack only, and at sea level
Computes	Only total drag coefficient (itemization provided), versus Mach number
Output	Takes 0.5 seconds. Two-page output
Geometry	
Input Required (in Order)	1. Reference diameter, d_{ref} (in mm) 2. Projectile total length, L_t (in calibers) (Maximum of 9.99) 3. Total nose length, L_n (in calibers) 4. Nose body shape parameter, varies from 0.0 (for a cone) to 1.0 (for perfect tangent ogive) 5. Boattail length, L_{bt} (in calibers) 6. Projectile base diameter, d_b (in calibers) 7. Truncated nose diameter, d_M (in calibers) 8. Rotating band diameter, d_{rb} (in calibers) 9. Center of gravity, from nose, X_{CG} (in calibers) 10. Boundary layer type L/T or T/T (laminar flow on nose/turbulent flow on body, or turbulent/turbulent) 11. Alphanumeric title (projectile name - 10 characters maximum, i.e., "M-549")

2. EXAMPLE

The M-549 projectile is modeled. The code computes only C_D, for 24 Mach numbers between 0.5 and 4. The flow is selected to be turbulent on the nose surface as well as the cylindrical body surface. The case title is "M-549".



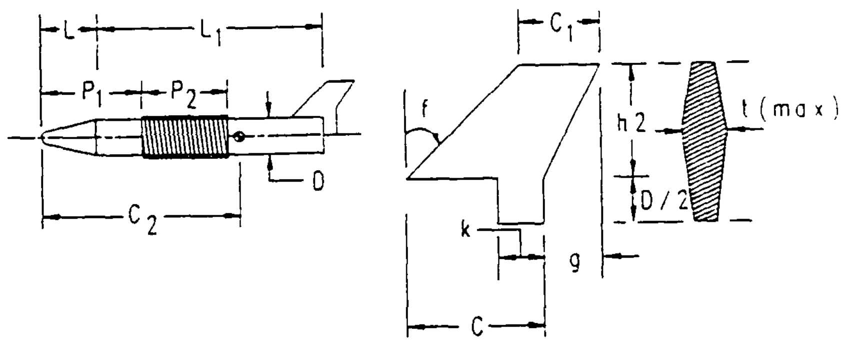
DIMENSIONS, CALIBERS
1 CALIBER = 154.72 mm

Input

1 - 154.72
2 - 5.645
3 - 3.015
4 - 0.5
5 - 0.579
6 - .845
7 - 0.088
8 - 1.02
9 - 3.53
10 - T/T
11 - "M-549"

V. THE "FINNER" (DONOVAN) CODE

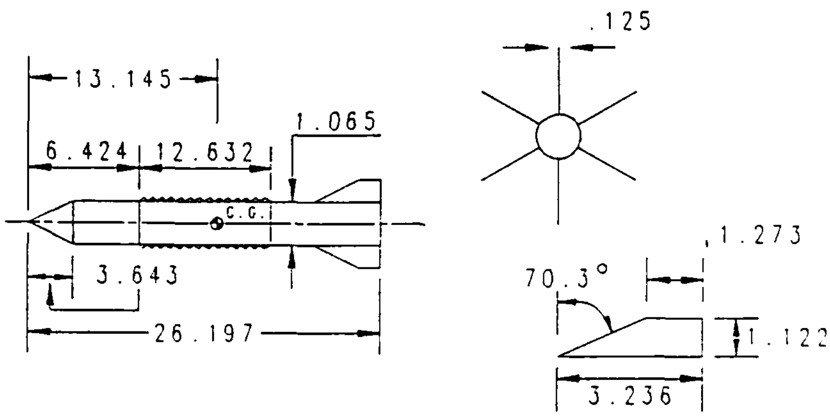
1. LIST OF INPUT

"FINNER" CODE (Donovan)	
Application	For long rod, fin stabilized projectiles in the Mach range 2.0 to 5.0, at zero angle of attack only, at sea level.
Computes	C_D, C_{N_α}, C_{M_α} versus Mach number at four pre-determined Mach numbers (2,3,4 and 5)
Output	Takes 0.5 seconds. No print out, all results appear on the screen, with plots for C_D, C_{N_α}, C_{M_α} versus Mach number. The velocity-range curve and the projectile configuration are plotted.
Geometry	
Input Required (in Order)	1. Number of fins (4 or 6) 2. Conical nose length, L (calibers) 3. Cylindrical body length, L_1 (calibers) 4. Groove location, from the nose, P_1 (calibers) 5. Groove length, P_2 (calibers) 6. Fin blade height, h_2 (calibers) 7. Fin blade length at root, C (calibers) 8. Fin root recess, g, if any (or zero) (calibers) 9. Fin blade extension from body, k, if any (or zero) (calibers) 10. Fin maximum thickness, t (calibers) 11. Fin sweep angle, f (degrees) 12. Fin blade length at the tip, C_1 (calibers) 13. Location of C.G. from the nose, C_2 (calibers) 14. Reference diameter in inches, D (set to zero if you specify melimeters)

THE "FINNER" (DONOVAN) CODE (Continued)	
Input (Continued)	15. Reference diameter in melimeters, D_1 (set to zero if you specify inches) 16. Normalized projectile weight, W in (caliber)^3 $W = \frac{\text{Weight (lb)}}{.03613 \times D^3 \text{ (diameter in inches)}}$ 17. Axial (cross-section) moment of inertia, I9, in (calibers)^5 $I9 = \frac{I_x \text{ (lb-in}^2\text{)}}{.03613 \times D^5 \text{ (diameter in inches)}}$ 18. Transverse moment of inertia about the C.G., I1, in (calibers)^5 $I1 = \frac{I_y \text{ (lb-in}^2\text{)}}{.03613 \times D^5 \text{ (diameter in inches)}}$ 19. Mach number at muzzle 20. Maximum range of interest, S (meters)

2. EXAMPLE

The geometry of the XM-829 projectile is considered. The code computes the case of zero alpha, at Mach numbers of 5.0, 4, 3.0 and 2.0. However, only the muzzle Mach number is required, which was taken as 5.0 in this example. This interactive procedure does not create an input file, but it directly executes the program as well, and both the results and the plots of the code will be flashed on the user's screen. (Must use a CRT terminal with plotting capability.)



DIMENSIONS IN INCHES

Projectile weight	- 4.3563 lbs
Projectile diameter	- 1.065 in
Axial (cross-sectional) moment of inertia	- .63632 lb-in^2
Transverse (longitudinal) moment of inertia	- 143.89 lb-in^2
Muzzle Mach number	- 5.0
Maximum range	- 2000. m

Input

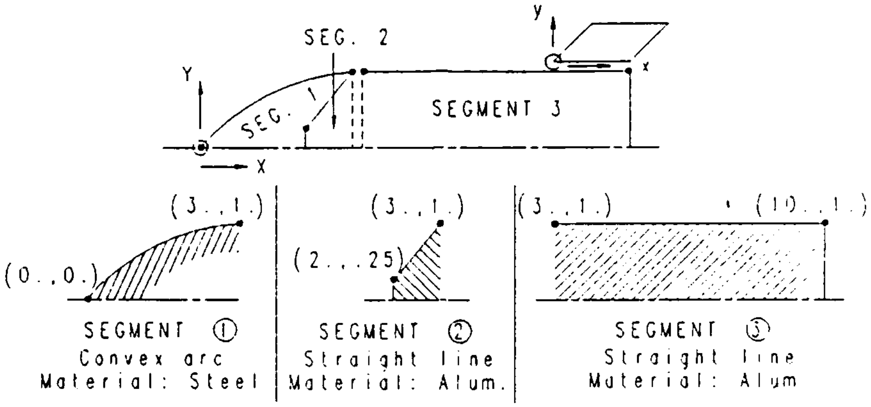
1 - 6	11 - 70.36
2 - 3.4179	12 - 1.19492
3 - 21.1774	13 - 12.3427
4 - 6.0319	14 - 1.065
5 - 11.861	15 - 0.0
6 - 1.05314	16 - 99.816
7 - 4.23361	17 - 14.066
8 - 0.0	18 - 2906.79
9 - 0.0	19 - 5.0
10 - .1178	20 - 2000.

VI. PROJECTILE PHYSICAL PROPERTIES CODE (PHYS-PROP)

1. BRIEF DESCRIPTION OF METHODOLOGY AND REMARKS:

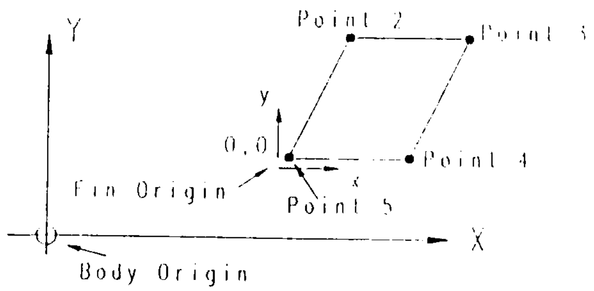
a. Body segments:

The body is specified through segments, each is enclosed by a body profile line. In the shown sketch, a body composed of three segments is described. The first segment is a convex arc, the second segment is bounded by a straight line and the third segment is of a different materiel and bounded with a straight line.



b. Fin description:

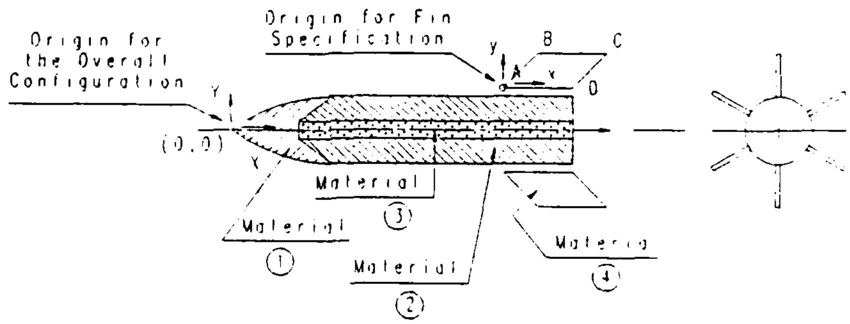
The fin data is entered by describing the fin profile. The profile is described by its boundary points. These points are referenced to a local fin coordinater system. The location of the fin coordinate system in the main body coordinate is shown in the diagram. Note that the profile points are ordered in a clockwise manner and the last point must coincide on the orgin of the fin coordinate system.



c) Units:

Units must be consistent. The length units to describe the physical geometry of the body must also be the length units of the density. For example, if a body is entered with length units of inches, the density units must be in Mass/in.[3] Note that the mass output of the code will be in those same mass units (examples of Mass units are pounds and kilograms). The fin units must be the same as those used to describe the main body.

2. LIST OF INPUT

"PHYS-PROP" Code	
Application	To compute physical properties of axisymmetric bodies with and without fins.
Computes	Projectile 1) Mass 2) Center of gravity 3) Moment of inertia about the axis of symmetry, I_{xx} (Axial) and 4) Moment of inertia about the c.g., I_{yy} (Transverse)
Output	Provides Mass, $X_{c.g.}$ (from nose), I_{xx}, and I_{yy}, displayed on the terminal screen in addition to a display of the projectile configuration.
Geometry	
Input Required (in order)	Note: "CR" designates "carriage return" 1 - Enter the selection of computer terminal being used (for graphics purpose) (e.g., Modgraph, Tektronix,...etc.) 2 - Do you need instructions for the program operating procedure? i) Enter CR for no. or ii) Enter x for yes, and after each screen display hit CR to get the next set of instructions. 3 - a) Designate an input file name (e.g., "xxx". The program will then create a file by the name "xxx.dat;...")

Input (Continued)	b) - if this was a new file name enter "CR" - if this was an old input file the program will skip to step No. 24 - if this was an old input file, but you made a mistake in entering the name, then enter "MISTAKE" 4 - Enter choice of Format in which the input file is to be written. (Choose "Free" FORMAT for newly created files). 5 - a) Enter a two-Digit Code for 1st Body Segment description (e.g., 21, or 16, etc.). The 1st digit represents a convex or concave arc, or a straight line. The 2nd digit is for drawing vertical lines on the drawing, and is optional. b) or Enter "X" for more instructions (then enter CR for continuation of the program, after the instructions are displayed) c) or Enter "0" if no more segments are to be specified. (the program then skips to step No. 23) 6 - a) Enter the same two-digit code for body segment 1 as entered in step (5a). b) or Enter "X" for more instruction <u>A. If Body Segment Specified is a Convex or Concave Arc</u> 7 - Enter the x and y of the center of the arc and the radius of arc (e.g.: 8., 2., 10.) 8 - Enter the x locations of the first and last points on that segment (e.g.: 10.1, 30.2) 9 - Enter the density of material under that body segment. (Then you will be routed back to step No. 5 for entering the next body segment.) <u>B. If the Body Segment Specified is a Straight Line</u> 10 - Enter which one of the following three methods for specification will be used for this segment. 1) the line slope (dy/dx) and the y-coordinate of one point 2) the x and y coordinates of two points on that segment (not necessarily the end points of that segment) 3) the line angle (degrees) and (x,y) of a point on that line (not necessarily an end point of that segment)

Input (Continued)	

B-1. When "The Line Slope (dy/dx) and y-coordinate" method is used

11 - Enter the "y" coordinate of a point on that line, and the slope.

12 - Enter the x values of the beginning and end points of that segment.

13 - Enter the density of materiel under that body segment. (Then you will be routed back to step No. 5 for entering the next body segment.)

B-2. When "Two-Point" Method is used

14 - Enter the x and y values of the 1st point.

15 - Enter the x and y values of the 2nd point.

16 - Are these two points the 1st and last points on the segment? (Y or N) (If (Y) the code skips to step No. 18).

17 - Enter the x values of the beginning and end points of that segment (e.g., 10.25, 16.7)

18 - Enter the density of materiel under that body segment. (The program will then return to step No. 5 for entering the next body segment.)

B-3. When "The Line Angle and a Point" Method is used

19 - Enter the angle in degrees (positive as counter-clockwise and zero at the positive x axis).

20 - Enter (x,y) of one point on that line.

21 - Enter the x values of the beginning and end points of that segment.

22 - Enter the density of materiel under that body segment. (The program will then return to step No. 5 for entering the next body segment.)

23 - Enter data format option if this is the last segment or enter "4" to continue entering more segments.

Input (Continued)

24 - Enter one of the following choices:

1) to add/edit fin data file (code then skips to step 25)
2) to edit main body data file (code then skips to step 38)
3) to list main body data file (code then skips to step 41)
4) to draw the total body on the screen (code then skips to step 43)
5) to calculate the physical properties (code then skips to step 45)
6) to change main body data file (code then skips to step 46)
7) to end the program (code then skips to step 47).

<u>(24-1) To add fin data file</u>

25 - Enter a choice:

1) to read-in an existing fin data file (code will proceed to step 26)
2) to create a new fin file (code will proceed to step 27)
3) to neglect fin considerations from calculations (i.e., body alone)
4) to edit the fin file
5) to continue the program (code will return to step 24).

26 - Enter the name of the existing fin file. (the program will then proceed by going back to step 24).

27 - a) Enter the file name where fin data will be stored. (if "xxxx", the code will create the file "xxxx.FIN;..")

b) Do you need help instructions? enter "x" for yes or enter "CR" for no and to continue on

28 - Enter x,y coordinates of the 1st point on the fin (do not enter the origin)

29 - a) Enter x,y coordinates of the 2nd point in the fin.
b) Enter x,y coordinates of the 3rd point in the fin.

.
.
.

z) Enter x,y coordinates of the i point in the fin.

"PHYS-PROP" Code (Continued)	
Input (Continued)	30 - Enter the x,y of the last point on the fin which must be (0.,0.), so that the fin specification is complete.

31 - Enter a choice of:
1) Edit (change) a fin point.
2) Delete a fin point.
3) Add a fin point
4) Draw fin profile. (enter "CR" after the plotting is completed, to get back to step 31)
5) Continue the code. (code will proceed to step 32)

32 - Enter the average thickness of the fin blade.

33 - Enter the x-location of the origin of the fin coordinate system with reference to the body origin.

34 - Enter the y-location of the origin of the fin coordinate system

35 - Enter the density of the fin material.

36 - Enter the number of fins.

37 - Enter an index of 1 to 5 if any change in fin specifications is necessary
or 0 to accept the already provided fin values (the code moves back to step 25)
To end the calculations and the program enter 0, then of the options of step 25, choose option 5 (which sends you back to options of step 24, where you choose option 5 to calculate the physical properties and then terminate the program).

(24-2) To Edit (Change) the Present Main Body Data File

38 - Enter one of the following choices:

1) To list the data in the file (code moves to step 39)
2) To change a piece of data in a particular line (code moves to step 40)
3) To change densities previously specified (code moves to step 44)
4) To add line(s) to the data file (code moves to step 46)
5) To delete a line from the data file (code moves to step 47)
6) To continue the program (code moves back to step 24)

"PHYS-PROP" Code (Continued)

Input (Continued)

39 - Enter the range of lines to be listed (e.g. 1 & cr 5) or "x x" to list all lines.

(The program will then move back to step 38 to continue)

40 - Enter the line number containing the piece of data.

41 - What is to be changed (a list of data definition is given)?

42 - What is the correct value of the item to be changed (say "V1")

43 - The value you want to replace is "V1", is this what you want to change? Y/N

(when yes, the code then moves back to step 38 to continue the program).

44 - What ranges of lines to be changed (e.g. n_1 & cr n_2)?

45 - What is the correct value for the density Ro(n_1) to Ro(n_2)?

(The code then moves back to step 38 to continue the program.)

46 - Enter data format choice:

1) For free format, for data entry from a terminal. (The code then moves back to step 5.)
2) For x,y profile format (i.e., for existing files)
3) For standard moment format (user must specify 9-element format)
4) To continue the program (the code then moves back to step 38)

47 - Enter the line number to be deleted.
(The code then moves back to step 38 to continue the program.)

<u>(24-3) To List the Main Body Data File</u>

48 - Enter the range of lines to be listed, or "xx" to list all lines.

49 - Enter "CR" to go back to step 24.

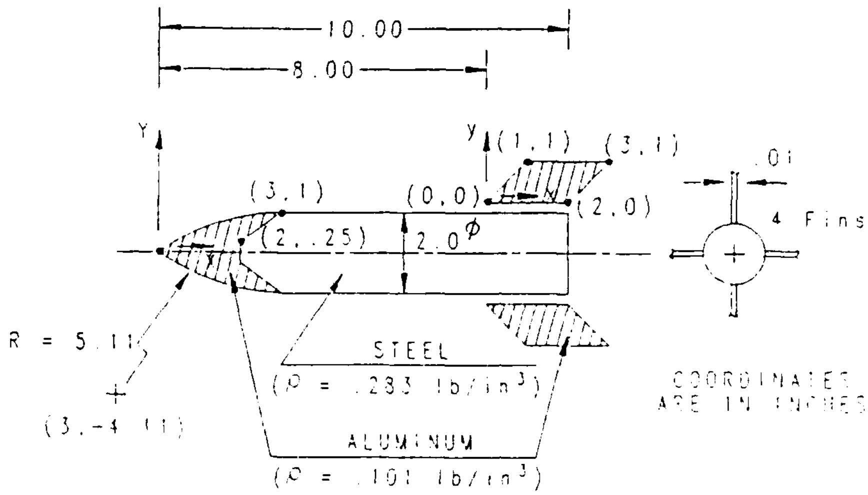
<u>(24-4) To Draw the Total Body</u>

50 - Enter the ratio of y-axis to x-axis propotionality for plotting purpose, usually "1.0" to give the real propotionality of the body

"PHYS-PROP" Code (Continued)	
Input (Continued)	51 - The configuration will be displayed on the screen; hit "CR" to continue the program (code moves back to step 24). (24-5) To Calculate the Physical Properties of the Configuration 52 - The results will be displayed on the screen. Enter "CR" to continue the program by going to step 24 (to end the program). (24-6) To Change an Existing Main-Body Data File 53 - Enter the full file name (e.g. zzzz.yyy;nn) if an existing file, or enter the present file name "xxx" which you specified in step 3a. (In both cases, the code moves back to step 38, where one should use option there to make changes) (24-7) To End the Program 54 - Enter "CR"

3. EXAMPLE

The geometry of the projectile considered is given in the drawing provided. The projectile has 4 fins, and is composed of only two materials, steel (ρ = .283 lb/in^3) and aluminum (ρ = .101 lb/in^3).



Input

Note: "CR" signifies "Carriage Return" for computer terminal use.

Remarks	Step No.	
	1 -	1 (Modgraph Terminal)
	2 -	X
	3a -	"EXAMPLE"
	b -	CR
	4 -	1
segment No. 1 is a convex arc ----------		
	5a -	10
	6a -	10
	7 -	3.,-4.11,5.11
	8 -	0.,3.
	9 -	.101
Program returns to step No. 5 -----------		
Segment No. 2 is a straight line specified by 2 points ----------------		
	5a -	22
	6a -	22
program skips to step No. 10 ------------		
	10 -	2
	11 -	
	12 -	skipped because they do not apply
	13 -	here

```
                                     | 14 -   2.,.25
                                     | 15 -   3.,1.0
                                     | 16 -   Y
                                     | 17 -   skipped because it does not apply
                                     |           here
                                     | 18 -   .283
program returns back to step No. 5 ------
segment No. 3 is a straight line
  specified by 2 points ----------------
                                     | 5a -   24
                                     | 6a -   24
program skips to step No. 10         |
                                     | 10 -   2
                                     | 11 -
                                     | 12 -   skipped by the program because
                                     | 13 -      they do not apply here
                                     | 14 -   3.,1.0
                                     | 15 -   10.,1.0
                                     | 16 -   Y
                                     | 17 -   skipped because it does not apply
                                     |           here
                                     | 18 -   .283
program returns back to step No. 5 ------
End of all 3 segments                | 5c -   0
program skips to step No. 23         |
                                     | 23 -   4
                                     | 24 -   1 (to add data file for fins)
                                     | 25 -   2 (to create a new file for fin)
                                     | 26 -   skipped by code (does not apply
                                     |           here)
                                     | 27a -  "EXAFIN"
                                     |    b - CR
                                     | 28 -   1.,1.
                                     | 29a -  3.,1.
                                     |    b - 2.,0.
                                     | 30 -   0.,0.
                                     | 31 -   4 (to draw fin configuration) then
                                     |               "CR"
program returns to step No. 31 ----------
                                     | 31 -   5 (to continue the program)
                                     | 32 -   .01
                                     | 33 -   8.0
                                     | 34 -   1.0
                                     | 35 -   .101
                                     | 36 -   4
                                     | 37 -   0 (to accept and enter all fin
                                     |               data provided)
program moves back to step No. 25 -------
                                     | 25 -   5 (to continue the code)
program moves back to step No. 24    |
                                     | 24 -   4 (to draw the whole body) & "CR"
program skips to step No. 43         |
                                     | 43 -   1.0
                                     | 44 -   CR
```

```
program moves back to step No. 24 -------
                                  | 24 -   5 (to calculate the physical
                                  |              properties) & "CR"
program moves to step No. 45 ------------
                                  | 45 -   CR
program moves back to step No. 24 -------
                                  | 24 -   7 (to end the program)
program skips to step No. 47 ------------
                                  | 47 -   CR
```

VII. THREE DEGREES OF FREEDOM (3-DF) POINT-MASS TRAJECTORY CODE

1. LIST OF INPUT

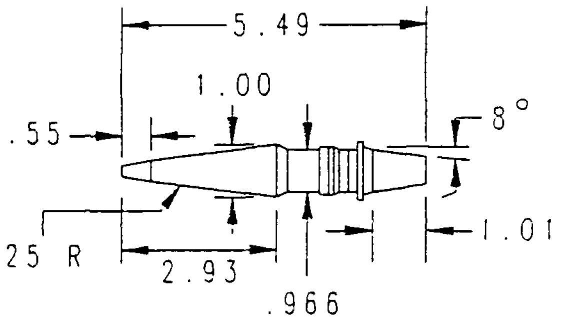
TRAJECTORY CODE INPUT	
Input Required (in Order)	1. Enter title (maximum of 70 characters) 2. Maximum body diameter, D (ft) 3. Elevation of target ZT (ft) 4. Projectile weight at launch, WTO (LB) 5. Projectile weight at rocket burnout, WTB (LB) 6. Specific impulse of rocket fuel, SPIS (sec) 7. Rocket motor burning time, SBT (sec) 8. Quadrant elevation, QE (deg) 9. Projectile velocity at launch, VO (ft/sec) 10. Ratio of desired drag coefficient curve to be actually used, to the drag curve that you will specify in step 24 (usually 1.0) 11. Ratio of desired static moment coefficient slope curve to be actually used, to the static moment slope curve that you will specify in step 26 (usually 1.0) 12. Yaw-drag coefficient, CDD2 (per radian^2) 13. Twist of rifling, TWIST (caliber per turn) 14. Roll damping moment coefficient, C_{ℓ_p} 15. Desired number of time intervals between automatic printouts 16. Axial radius of gyration, RGA (caliber) $(r_{xx} = (I_{xx}/mass)^{1/2})$ 17. Transverse radius of gyration, RGT (caliber) $(r_{yy} = (I_{yy}/mass)^{1/2})$ 18. Exponent in expression used to compute time interval (use the value of .35) 19. Numerator of expression used to compute time interval (use the value of 2) 20. Maximum length of time interval permitted (sec) (use the value of .3) 21. Elevation of launcher, ZO (ft) 22. Air temperature of launcher, TEMP (Deg. F°) 23. Nine elements of Mach number for the drag table, CDO(I,1) 24. Nine elements of the corresponding drag coefficient, CDO(I,2) 25. Nine elements of Mach number for the static moment coefficient table, CMA(I,1) 26. Nine elements of the corresponding slope of static moment (per radian) coefficient, CMA(I,2)

2. EXAMPLE

This case was taken from Reference 5, for the 175mm M 437 projectile (page 9-4). Conditions used were:

Quadrant Elevation - 45°
Target Elevation - 0 ft
Launch Elevation - 0 ft
Twist of Rifling - 20 Calibers per Turn

Launch Weight - 147.5 lbs
Launch Velocity - 3000 ft/sec
Reference Diameter - .573 ft
Muzzle Spin Rate - 260 rps
Air Temperature - 59 F°
Axial Radius of Gyration - .365 Caliber
Transverse Radius of Gyration - 1.297 Caliber
Roll Damping Coefficient - (-.015)



DIMENSIONS, CALIBERS

Nine Elements of Flight Characteristics

	Mach Number	Drag Coefficient	Mach Number	C_{M_α} (per radian)
1)	.8	.15	.8	2.7
2)	1.0	.2	1.0	3.9
3)	1.05	.34	1.05	2.5
4)	1.2	.36	1.2	2.0
5)	1.5	.3	1.5	1.6
6)	2.0	.24	2.0	1.55
7)	2.5	.2	2.5	1.549
8)	2.7	.195	2.7	1.548
9)	3.0	.19	3.0	1.55

Input

1 - "Trajectory for 175mm-M437"

2 - .573

3 - 0.0

4 - 147.5

5 - 147.5

6 - 0.0

7 - 0.0

8 - 45.0

9 - 3000.

10 - 1.0

11 - 1.0

12 - 5.8

13 - 20

14 - (-0.015)

15 - 20

16 - 0.365

17 - 1.297

18 - .35

19 - 2.0

20 - .3

21 - 0.0

22 - 59

23 - 0.8,1.0,1.05,1.2,1.5,2.0,2.5,2.7,3.

24 - 0.15,.2,.34,.36,.3,.24,.2,.195,.19

25 - 0.8,1.0,1.05,1.2,1.5,2.0,2.5,2.7,3.

26 - 2.7,3.9,2.5,2.0,1.6,1.55,1.549,1.548,1.55

VIII. USING AND RUNNING THE CODES

The codes are currently available only on the Digital Equipment Corp. (DEC) VAX computers 11/780 and 8600, with VMS operating system. Locally at BRL, the package of codes is located on disk "USERC" under the directory [MIKHAIL], in the subdirectory [.DESIGN].

To access these codes the user should enter:

$ SET DEF DISK$USERC:[MIKHAIL.DESIGN]

A short executive code by the name of AERODES.COM (which stands for Aerodynamic Design) allows the user to choose the desired code. The options (menu) presently available are:

Option No.		Code
1	for	NSWC-AP
2	for	Missile DATCOM
3	for	McDrag
4	for	Finner (Donovan)
5	for	Physical Properties
6	for	Trajectory (3DF)

The specific procedure to use either one is described next.

1. THE NSWC-AP CODE

a) To create interactively an input file, enter:

$ @ AERODES.COM

Then choose option 1, then you are asked to designate a name for an input file where the entered data will be stored. This file should, for convenience, be named

NSWC.INP

when the interactive inputing is successfully completed, an input file by that name will be created.

b) To use this input file to run the actual calculations.

i) interactively:

enter $ @ [MIKHAIL.NSWC]NSWCINT.COM

ii) through batch stream:

enter $ SUBMIT [MIKHAIL.NSWC]NSWCBATCH.COM

In both modes, an output file by the name of "NSWC.OUT;.." will be created for later examination or printing.

2. THE MISSILE DATCOM CODE

a) To create, interactively, an input file, enter

$ @ AERODES.COM

Then choose option 2 from the displayed list, then you are prompted to designate a name for the input file to be created. This file should, for convenience, be named:

DATCOM.INP

when the interactive inputing is successfully completed, an input file by that name will be created.

b) To use this input file to run the actual calculations:

i) interactively:

enter $ @ [MIKHAIL.DATCOM]DATCOM.COM

ii) through batch stream:

enter $ SUBMIT [MIKHAIL.DATCOM]DATCOM.COM

In both modes, an output file by the name of "DATCOM.OUT;.." will be created for later examination or printing. Also an aerodynamic coefficients file (a tabulation of Mach numbers versus the aerodynamic coefficients) will be created under the name "FOR003.DAT;.." when successful completion of the code is achieved.

3. THE MCDRAG CODE

a) To create, interactively, an input file enter

$ @ AERODES.COM

Then specify option 3 of the displayed options, then you will be prompted to designate a name for the input file to be created. This file should be named:

MCDRAG.INP

when the interactive inputing is successfully completed, an input file by that name will be created.

b) To use this input file to run the actual calculations:

i) interactively:

enter $ @ [MIKHAIL]MCDRAG.COM

ii) through batch stream:

enter $ SUBMIT [MIKHAIL]MCDRAG.COM

In both modes, an input file by the name of "MCDRAG.OUT;.." will be created for later examination or printing.

4. THE FINNER (DONOVAN) CODE

This code has the interactive inputting, the actual calculations, and the graphical display all in one package.

The user is advised to use a computer terminal with 1) graphics capability if the full use of this code capabilities is to be made; 2) paper copier to obtain the computed results and plots.

To run the code, which is possible only in interactive mode, enter

$ @ AERODES.COM

Then select option 4 in the diaplayed list of options. No input file is required or saved. The code will display the numerical results and the corresponding plots on the screen of the terminal. No output file is created.

5. THE PHYSICAL PROPERTIES CODE

As in the Finner code, this code has the interactive inputting procedure and the actual calculations combined in one package. The user is also advised to use a computer terminal with 1) graphic capability if the full use of this code capabilities is to be made; 2) paper copier to obtain a record of the computed results and configuration.

To run the code, which is possible only in interactive mode, enter

$ @ AERODES.COM

Then select option 5 in the displayed list of options. This code will display the result on the screen after the successful completion of the input. There is no output file, however, there is an input file created for later examination or editing.

The user will be prompted for designating a name for an input file. The name should be "PHYPROP" for Physical Properties. The program will then create the input file "PHYPROP.DAT;.." for the body input. For body with fins, an additional input file needs to be designated. If the name given is "PHYPROP", then the code will create the file "PHYPROP.FIN;.." .

These input files are intended for later checking modification, or re-running of the code instead of re-inputting the whole procedure.

6. THE 3DF TRAJECTORY CODE

a) To create, interactively, an input file, enter:

$ @ AERODES.COM

Then specify option 6 of the displayed options, Then you are prompted to designate the name for the input file to be created. This file name should be

TRAJ.INP

when the interactive inputing is successfully completed an input file by that name will be created.

b) To use this input file to run the actual calculations:

i) interactively:

enter $ @ TRAJ.COM

ii) through batch stream:

enter $ SUBMIT TRAJ.COM

In both modes, an output file by the name "TRAJ.OUT;.." will be created for later examination or printing.

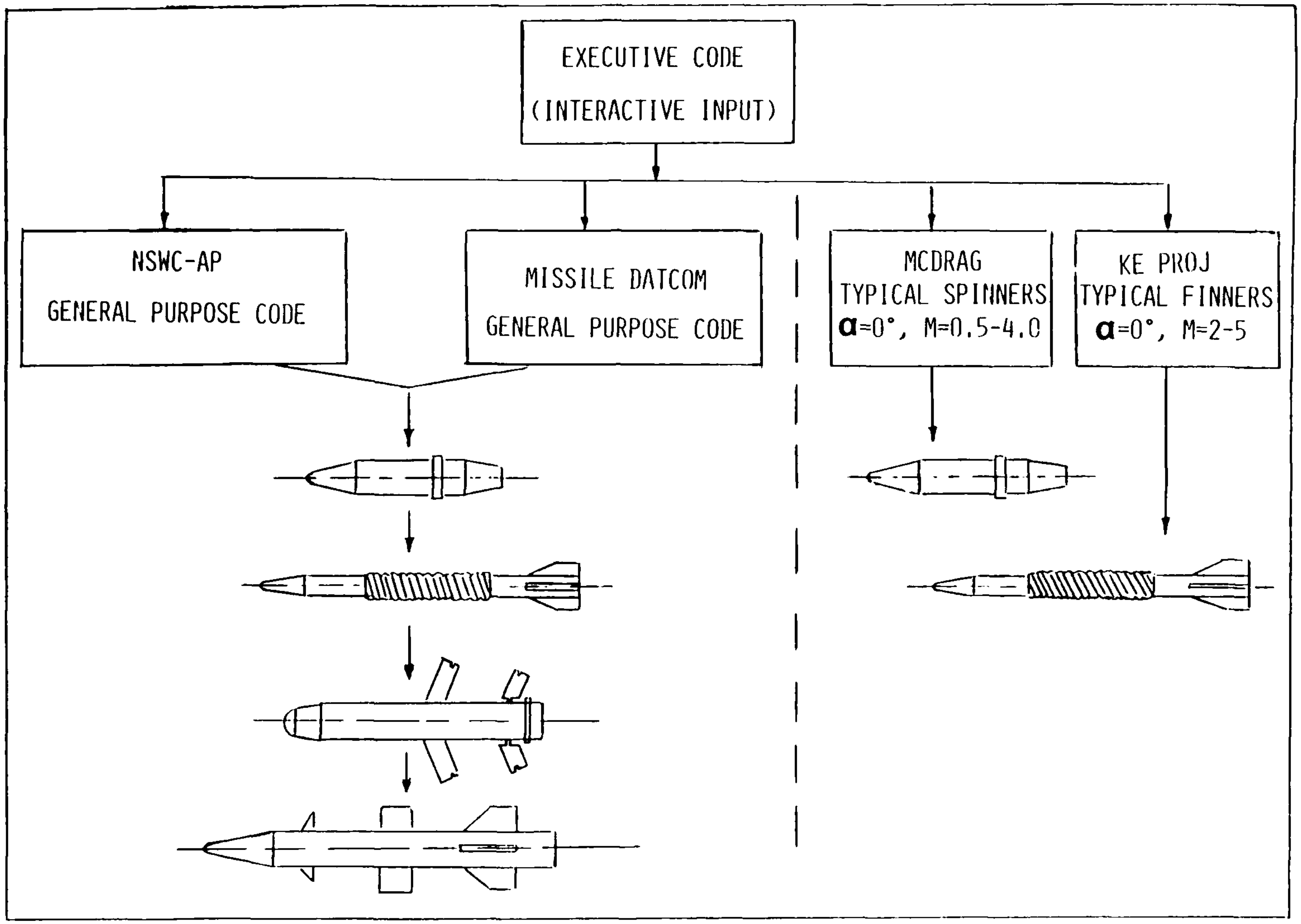


Figure 1. Projectile configurations for the four aerodynamic prediction codes.

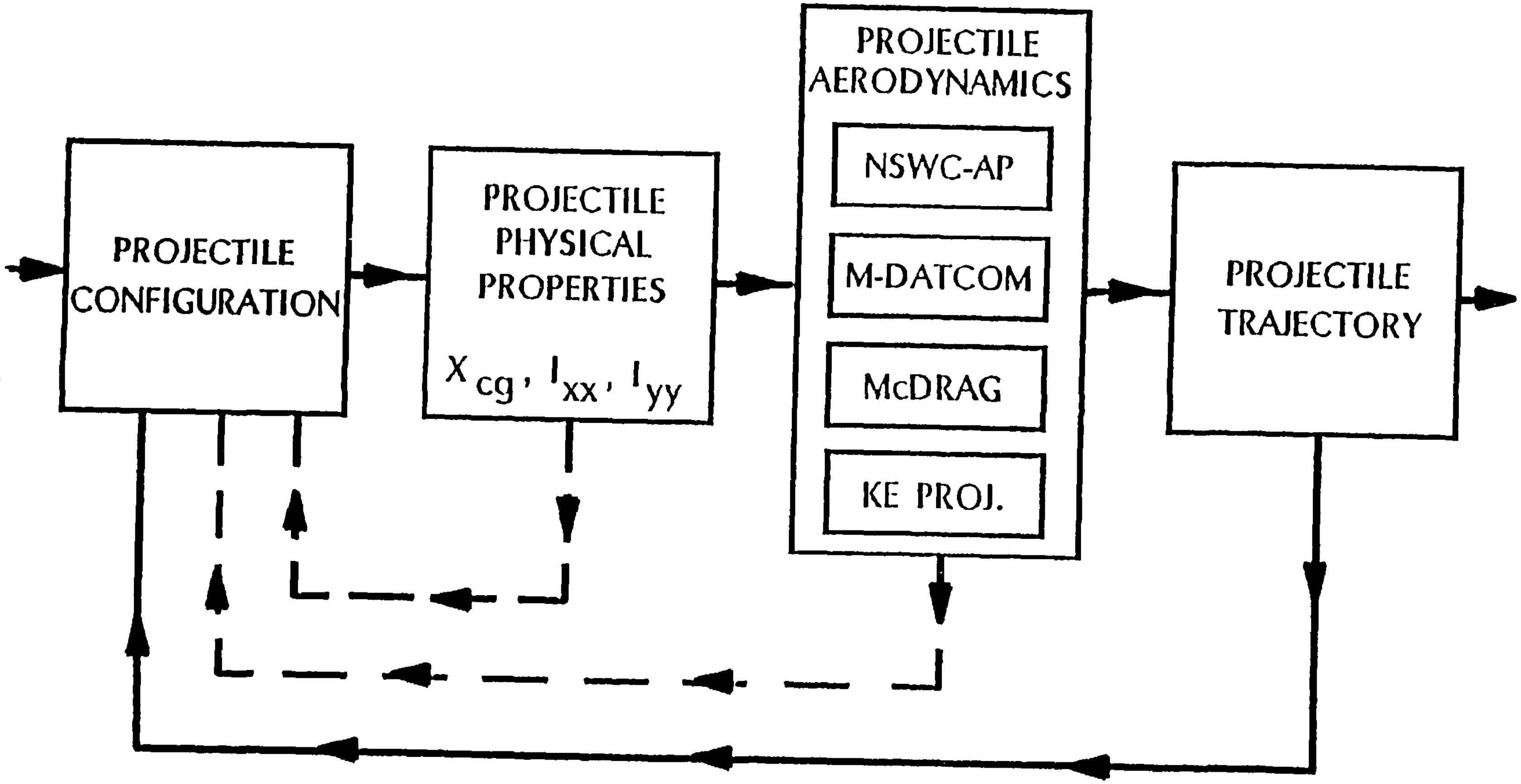


Figure 2. Projectile preliminary aerodynamics design cycle.

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