USER'S MANUAL FOR THE MARTIN—MARIETTA HIGH ANGLE OF ATTACK AERODYNAMIC METHODOLOGY FOR BODY-TAIL MISSILES

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Aeroballistics Directorate
Technology Laboratory

JUNE 1978

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**Title:** User's Manual for the Martin-Marietta High Angle of Attack Aerodynamic Methodology for Body-Tail Missiles

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**Abstract:**
This report documents the computer program developed by the Army to evaluate and implement an aerodynamic methodology developed by the Martin Marietta Corporation. The methodology was developed to predict aerodynamic forces on slender missile bodies with low aspect ratio tails at low and high angles of attack, at arbitrary roll angles for both transonic and supersonic velocities.
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I. INTRODUCTION

The Martin Marietta Corporation, Orlando Division, has developed an aerodynamic methodology and published a report (Ref. 1) under Contract No. DAAH01-74-C-0621 with the US Army. The report describes the development and application of semiempirical methods for predicting aerodynamic characteristics of slender body and body-tail configurations.

In an effort to evaluate the Martin Methodology, a computer program was developed to incorporate the various theoretical and empirical procedures called for in the Martin report. The results of this evaluation are covered in detail in Ref. 2. As a follow-up to the Martin Methodology analysis, a few modifications of the methodology were accomplished in an attempt to correct certain disagreements found between measured experimental data and associated predictions derived from the methodology.

This report is intended to be a user’s guide for the use of the methodology program. The methods and procedures used in developing the aerodynamic methodology are covered extensively in Ref. 1 and only those modifications to the methodology implemented by the Army will be discussed in this report.

II. PROGRAM CAPABILITIES

The Aerodynamic Methodology Program can predict aerodynamic characteristics of slender body and body-tail missile configurations, to include the following predictions:

1) Body alone normal force, center of pressure, and axial force.
2) Isolated tail panel normal force and center of pressure.
3) Mutual interference effects that enable the prediction of normal force and center of pressure of body-tail combinations.

The program in its present form was developed to predict these characteristics for missiles with four fins in cruciform configuration, with the fin trailing edges flush with the missile body base. The fin numbering convention, as well as the conventions for angle of attack (α) and roll angle (ϕ), are shown in Figure 1.

The range of input parameters for the program are:

1) Mach number 0.8 to 3.0
2) Angle of attack 0 to 180 for isolated components (roll angle = 0), 0 to 45 for body-tail combinations at arbitrary roll angles from 0 to 180.
3) Tail leading edge sweep angle 0 to 70 degrees
4) After-body length (calibers) 6 to 18
5) Nose length (calibers) 1.5 to 3.5
6) Tail taper ratio 0 to 1
7) Tail aspect ratio .5 to 2.0 (aspect ratio of two tail panels joined at root chord)

III. DISCUSSION

Certain modifications of the original methodology were incorporated into the methodology computer program. These modifications were an attempt to correct certain disagreements between experimentally obtained data and associated predictions from the methodology which became apparent during an evaluation of the original methodology (Ref. 2).

The modifications are limited to the body alone normal force prediction methods and involve the addition of newly obtained unpublished data. Specifically, equation 16, page 36 as depicted in Figure 20 of Ref. 1, has been eliminated and replaced by values of \( \eta \) (correlation factor for end effects) as shown in Figure 2 of this report. In addition, the crossflow drag coefficient versus crossflow Mach number curve shown in Figure 22a of Ref. 1, has been replaced by Figure 3 of this report.

Comparisons of predictions generated from the original methodology and those with the above modifications, compared with the experimental data, are shown in Figures 4 through 10 of this report.
Figure 2. Values of $n$. 

\[ M_n = M_0 \sin \alpha \]
Figure 4a. Original methodology.
Alpha = 44.92  Mach No. = 1
Normal Force Coeff. And Center of Pressure Location
For Configuration B3T1-5

Figure 4b. Modified methodology.
B2T1-5
Mach No. = 1
Alpha = 44.88
Methodology—(-)
Experiment—-(+)

Normal Force Coeff. and Center of Pressure Location
For Configuration B2T1-5

Figure 5a. Original methodology.
Alpha = 44.88    Mach No. = 1
Normal Force Coeff. And Center of Pressure Location
For Configuration B2T1-5

Figure 5b. Modified methodology.
B1T3-1
Mach No. = 1
Alpha = 44.25
Methodology -- (−)
Experiment -- (+)

Figure 6a. Original methodology.
BIT3-1
Mach No. = 1
Alpha = 44.25
Methodology---(-)
Experiment---(+)
B173-1
Mach No. = 1
Alpha = 34.95
Methodology -- (-)
Experiment -- (+)

Normal Force Coeff. and Center of Pressure Location
For Configuration B173-1

Figure 7a. Original methodology.
B173-1
Mach No. = 1
Alpha = 34.55
Methodology---(-)
Experiment---(+)
**Figure 8b.** Modified methodology.

**BIT2-3**
- Mach No. = 1
- Alpha = 44.92
- Methodology: (−)
- Experiment: (+)
Figure 9a. Original methodology.
Appendix A. PROGRAM UTILIZATION

The proper format and sequence for the input cards are shown in Table A-1.

<table>
<thead>
<tr>
<th>CARD</th>
<th>SYMBOL REFERENCE</th>
<th>FORMAT (FORTRAN)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Title card for each configuration</td>
<td>12A6</td>
</tr>
<tr>
<td>2</td>
<td>AR,S,CR,LAMDA,ALE</td>
<td>5F10.3</td>
</tr>
<tr>
<td>3</td>
<td>LND,LAD,D</td>
<td>3F10.3</td>
</tr>
<tr>
<td>4</td>
<td>ALF1,ALF2,DELAFA,MACH,RN,OPTPHI,OPTMAC</td>
<td>4F10.3,F13.2,F12</td>
</tr>
</tbody>
</table>

AR = Tail aspect ratio (two tail panels joined at root chord)
S = Tail Semispan including body, \((b + D)/2\), inches
CR = Tail root chord - Inches
LAMDA = Tail taper ratio
ALE = Tail leading edge sweep angle - Degrees
LND = Nose length - Calibers
LAD = After-body length - Calibers
D = Body diameter - Inches
ALF1 = Beginning angle of attack for angle of attack sweep - Deg.
ALF2 = Ending angle of attack for angle of attack sweep - Deg.
DELAFA = Angle of attack increment for alpha sweep - Degrees
MACH = Free stream Mach number
RN = Reynolds number - /Ft.
OPTPHI = 1 to calculate aerodynamic coefficients as a function of roll angle. Roll angle is automatically varied between 0° and 90° in increments of 10°. No additional data cards are required. See Sample Configuration 2 Input Data.
= 0 to delete calculation of aerodynamic coefficients as a function of roll angle
OPTMAC = 1 allows for multiple Mach numbers for the configuration and angle of attack range determined by the four cards Table A-1. Additional Mach numbers are added after the four cards of Table A-1, one Mach number per card using F10.3 Format
= 0 for single Mach number only

TABLE A-1
MULTIPLE CASE CAPABILITY:

Additional configurations can be input simply by repeating the card sequence of Table A-1.

If OPTMAC = 1, however, a blank card must follow the last Mach number card before the program will accept additional configurations.

Table A-2 shows a sample input card arrangement. Using this input card arrangement the program will predict aerodynamic coefficients for sample configuration No. 1 for Mach No. equal .8 and for angles of attack from 0.0 to 45. degrees in 5 degree increments. Since OPTPHI is 0 for sample configuration No. 1, the coefficients will be given versus angle of attack only (roll angle equals 0 degrees). Now, OPTMAC equals 1, therefore additional predictions will be made for the same configuration and angle of attack range for Mach numbers: .9, 1.0, 1.1, 1.2, and 1.3. A blank card follows the Mach number cards for sample configuration No. 1, which signals the program to read additional configurations.

The program then reads the cards for sample configuration No. 2, and computes the predictions of the aerodynamic coefficients and centers of pressure for this configuration. Now, since OPTPHI equals 1 in this case, these predictions will be given as a function of roll angle, for the angle of attack range 0 to 40 degrees. Also, since OPTMAC equals 0 for this case, the predictions will be made for Mach No. equal 2.0 only.

The resulting output for these sample input cards are found in Table A-3.

As a guide for time and storage requirements, the following figures for the CDC 6600 are provided:

Compile Time - 14 seconds
Execution Time - 2 seconds
Storage - Less than 100K.
<table>
<thead>
<tr>
<th>FORTRAN STATEMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>SAMPLE CONFIGURATION 1: OPT.PHI = 0, OPT.MAC = 1</td>
</tr>
<tr>
<td>1...0 ... 3...7...5...7...5 ... 0...0 ... 7...5 ... 9...6...4</td>
</tr>
<tr>
<td>3...1 ... 7...0 ... 3...7...5 ... 5...0 ... 7...0 ... 0...0 ... 0...0 ... 0...0</td>
</tr>
<tr>
<td>0...0 ... 4...5 ... 5...0 ... 1...8 ... 7...0 ... 0...0 ... 0...0 ... 0...0</td>
</tr>
<tr>
<td>0...9 ... 0 ... 0 ... 0 ... 0 ... 0 ... 0</td>
</tr>
<tr>
<td>1...0 ... 0 ... 0 ... 0 ... 0</td>
</tr>
<tr>
<td>1...1 ... 0 ... 0 ... 0 ... 0</td>
</tr>
<tr>
<td>1...2 ... 0 ... 0 ... 0 ... 0</td>
</tr>
<tr>
<td>1...3 ... 0 ... 0 ... 0 ... 0</td>
</tr>
<tr>
<td>(BLANK CARD)</td>
</tr>
<tr>
<td>SAMPLE CONFIGURATION 2: OPT.PHI = 1, OPT.MAC = 0</td>
</tr>
<tr>
<td>1...0 ... 3...7...5 ... 5...0 ... 5 ... 5...0 ... 0...0</td>
</tr>
<tr>
<td>3...1 ... 8...2 ... 3...7...5 ... 2 ... 6...5...0 ... 0...0 ... 0...0</td>
</tr>
<tr>
<td>0...0 ... 4 ... 1 ... 2 ... 0 ... 0 ... 0 ... 0</td>
</tr>
<tr>
<td>0...0 ... 0 ... 0 ... 0 ... 0</td>
</tr>
</tbody>
</table>
TABLE A-3.

<table>
<thead>
<tr>
<th>SAMPLE CONFIGURATION</th>
<th>OPTPHI=0, OPTMAC=1</th>
</tr>
</thead>
<tbody>
<tr>
<td>INPUT PARAMETERS</td>
<td></td>
</tr>
<tr>
<td>MACH</td>
<td>1.40</td>
</tr>
<tr>
<td>TAIL ASPECT RATIO</td>
<td>1.00</td>
</tr>
<tr>
<td>TAIL TAPER RATIO</td>
<td>0.00</td>
</tr>
<tr>
<td>TAIL L.E. SWEEP ANGLE</td>
<td>75.96 DEGREES</td>
</tr>
<tr>
<td>TAIL ROOT CHORD</td>
<td>7.550</td>
</tr>
<tr>
<td>NOSE LENGTH</td>
<td>5.000 CAL.</td>
</tr>
<tr>
<td>AFTER BODY LENGTH</td>
<td>7.500 CAL.</td>
</tr>
<tr>
<td>BODY DIAMETER</td>
<td>3.75</td>
</tr>
<tr>
<td>TAIL SEMI-SPAN</td>
<td>3.75</td>
</tr>
<tr>
<td>REYNOLDS NUMBER</td>
<td>7000000.00</td>
</tr>
</tbody>
</table>

| OUTPUT DEFINITIONS   |                     |
| CB= BODY ALONE NORMAL FORCE COEFFICIENT |
| XCPB= BODY ALONE CENTER OF PRESSURE     |
| CNT= TAIL ALONE NORMAL FORCE COEFFICIENT|
| XCP= TAIL ALONE CENTER OF PRESSURE      |
| CNTB= TAIL IN PRESENCE OF BODY NORMAL FORCE COEFFICIENT |
| XCPB= TAIL (IN PRESENCE OF BODY) CHORDWISE CENTER OF PRESSURE/TAIL ROOT CHORD (MEASURED AFT FROM ROOT CHORD LEADING EDGE) |
| XCPB= TAIL (IN PRESENCE OF BODY) SPANWISE CENTER OF PRESSURE/TAIL SEMI-SPAN (EXCLUDING XCPB= CENTER OF PRESSURE OF BODY PLUS TAIL BODY) MEASURED OUTWARD FROM BODY CONFIGURATION (CAL. FROM NOSE) |
| CNTB= NORMAL FORCE COEFFICIENT OF BODY PLUS TAIL CONFIGURATION |
| CA= AXIAL FORCE COEFFICIENT             |

<table>
<thead>
<tr>
<th>ALPHA</th>
<th>ISOLATED COMPONENTS</th>
<th>BODY TAIL CONFIGURATION</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CB</td>
<td>XCPB</td>
</tr>
<tr>
<td>-------</td>
<td>----</td>
<td>------</td>
</tr>
<tr>
<td>1.00</td>
<td>0.00</td>
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<tr>
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<td>2.711</td>
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<td>3.181</td>
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<tr>
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<tr>
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<tr>
<td>8.00</td>
<td>5.701</td>
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</tr>
<tr>
<td>9.00</td>
<td>5.709</td>
<td>3.927</td>
</tr>
<tr>
<td>10.00</td>
<td>7.039</td>
<td>3.927</td>
</tr>
</tbody>
</table>
### SAMPLE CONFIGURATION 1  OPTRINO = 0 TRAC = 1

**INPUT PARAMETERS**

- **MACH =** 0.90
- **TAIL ASPECT RATIO =** 1.00
- **TAIL TAPER RATIO =** 2.00
- **TAIL L.E. SWEEP ANGLE = 75.96 DEGREES**
- **TAIL ROOT CHORD =** 7.508
- **NOSE LENGTH =** 3.000 CAL.
- **AFTER BODY LENGTH =** 7.000 CAL.
- **BODY DIAMETER =** 3.75
- **TAIL SEMI-SPAN (INCLUDING BODY) =** 3.75
- **REYNOLDS NUMBER =** 780000.00

### OUTPUT DEFINITIONS

- **CMB =** BODY ALONE NORMAL FORCE COEFFICIENT
- **XCPB =** BODY ALONE CENTER OF PRESSURE
- **CNT =** TAIL ALONE NORMAL FORCE COEFFICIENT
- **XCEPT =** TAIL ALONE CENTER OF PRESSURE
- **XCNTR(B)=** TAIL IN PRESENCE OF BODY NORMAL FORCE COEFFICIENT
- **XCP(B)=** TAIL (IN PRESENCE OF BODY) CHORDWISE CENTER OF PRESSURE/TAIL ROOT CHORD (MEASURED AS AFT FROM ROOT CHORD LEADING EDGE)
- **YCP(B)=** TAIL (IN PRESENCE OF BODY) SPANWISE CENTER OF PRESSURE/TAIL SEMI-SPAN (EXCLUDING BODY) MEASURED OUTWARD FROM BODY CONFIGURATION (CAL. FROM NOSE)
- **XCNTR(B)+T=** CENTER OF PRESSURE OF BODY PLUS TAIL CONFIGURATION (CAL. FROM NOSE)
- **XCP(B)+T=** NORMAL FORCE COEFFICIENT OF BODY PLUS TAIL CONFIGURATION
- **CA =** AXIAL FORCE COEFFICIENT

### ALPHA 1 ISOLATED COMPONENTS

<table>
<thead>
<tr>
<th>ALPHA</th>
<th>CMB</th>
<th>XCPB</th>
<th>CNT</th>
<th>XCEPT</th>
<th>XCNTR(B)</th>
<th>XCP(B)</th>
<th>YCP(B)</th>
<th>XCNTR(B)+T</th>
<th>XCP(B)+T</th>
<th>CA</th>
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<tbody>
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<td>2.729</td>
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<td>0.287</td>
<td>0.648</td>
<td>0.235</td>
<td>0.315</td>
<td>0.456</td>
<td>0.55</td>
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<tr>
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<td>2.886</td>
<td>0.143</td>
<td>0.651</td>
<td>0.287</td>
<td>0.648</td>
<td>0.235</td>
<td>0.315</td>
<td>0.456</td>
<td>0.55</td>
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<tr>
<td>0.08</td>
<td>0.246</td>
<td>2.886</td>
<td>0.143</td>
<td>0.651</td>
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<td>0.648</td>
<td>0.235</td>
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<td>0.10</td>
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<td>2.886</td>
<td>0.143</td>
<td>0.651</td>
<td>0.287</td>
<td>0.648</td>
<td>0.235</td>
<td>0.315</td>
<td>0.456</td>
<td>0.55</td>
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</tbody>
</table>

### BODY TAIL CONFIGURATION

<table>
<thead>
<tr>
<th>ALPHA</th>
<th>CMB</th>
<th>XCPB</th>
<th>CNT</th>
<th>XCEPT</th>
<th>XCNTR(B)</th>
<th>XCP(B)</th>
<th>YCP(B)</th>
<th>XCNTR(B)+T</th>
<th>XCP(B)+T</th>
<th>CA</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00</td>
<td>0.900</td>
<td>2.729</td>
<td>0.800</td>
<td>0.651</td>
<td>0.287</td>
<td>0.648</td>
<td>0.235</td>
<td>0.315</td>
<td>0.456</td>
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<tr>
<td>0.05</td>
<td>0.246</td>
<td>2.886</td>
<td>0.143</td>
<td>0.651</td>
<td>0.287</td>
<td>0.648</td>
<td>0.235</td>
<td>0.315</td>
<td>0.456</td>
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</tr>
<tr>
<td>0.08</td>
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<td>0.648</td>
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<td>0.143</td>
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<td>0.235</td>
<td>0.315</td>
<td>0.456</td>
<td>0.55</td>
</tr>
</tbody>
</table>

### General

The table above presents various coefficients and measurements for different values of **ALPHA**, which is the angle of attack. The coefficients include normal force, center of pressure, and axial force, among others, for both isolated and combined (body + tail) configurations. The values are given for different **ALPHA** values, showing how these parameters change with the angle of attack.
**INPUT PARAMETERS**

- **MACH = 1.00**
- **TAIL ASPECT RATIO = 1.00**
- **TAIL TAPER RATIO = 0.60**
- **TAIL L.E. SWEEP ANGLE = 74.94 DEGREES**
- **TAIL ROOT CHORD = 7.00**
- **NOSE LENGTH = 7.000 CAL.**
- **AFTER BODY LENGTH = 7.000 CAL.**
- **BODY DIAMETER = 2.75**
- **TAIL SPIKE-SPAN (EXCLUDING BODY) = 2.75**
- **REYNOLDS NUMBER = 7000000.00**

**OUTPUT DEFINITIONS**

- **CNB = BODY ALONE NORMAL FORCE COEFFICIENT**
- **CLC = BODY ALONE CENTER OF PRESSURE COEFFICIENT**
- **CNP = TAIL ALONE NORMAL FORCE COEFFICIENT**
- **CRP = TAIL ALONE CENTER OF PRESSURE COEFFICIENT**
- **CRP(C) = TAIL IN PRESENCE OF BODY CENTER OF PRESSURE**
- **CNP(C) = TAIL IN PRESENCE OF BODY CENTER OF PRESSURE**
- **CNP(C) = TAIL IN PRESENCE OF BODY CENTER OF PRESSURE**
- **CNP(C) = TAIL IN PRESENCE OF BODY CENTER OF PRESSURE**
- **CNB(T) = BODY MEASURED OUTFAR FROM BODY**
- **CLC(T) = NORMAL FORCE COEFFICIENT OF BODY**
- **CNP(T) = NORMAL FORCE COEFFICIENT OF BODY**
- **CRP(T) = NORMAL FORCE COEFFICIENT OF BODY**
- **CNBP = NORMAL FORCE COEFFICIENT OF BODY**
- **CLBP = NORMAL FORCE COEFFICIENT OF BODY**
- **CNPB = NORMAL FORCE COEFFICIENT OF BODY**
- **CRPB = NORMAL FORCE COEFFICIENT OF BODY**
- **CNB(T) = BODY MEASURED OUTFAR FROM BODY**
- **CLC(T) = NORMAL FORCE COEFFICIENT OF BODY**
- **CNP(T) = NORMAL FORCE COEFFICIENT OF BODY**
- **CRP(T) = NORMAL FORCE COEFFICIENT OF BODY**
- **CNBP = NORMAL FORCE COEFFICIENT OF BODY**
- **CLBP = NORMAL FORCE COEFFICIENT OF BODY**
- **CNPB = NORMAL FORCE COEFFICIENT OF BODY**
- **CRPB = NORMAL FORCE COEFFICIENT OF BODY**

**TOP CONFIGURATION**

<table>
<thead>
<tr>
<th>LPHA</th>
<th>ISOLED COMPONENTS</th>
<th>TAIL CONFIGURATION</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CNB</td>
<td>CLC</td>
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<td>0.09</td>
<td>0.009</td>
<td>0.009</td>
</tr>
</tbody>
</table>

**CA = AXIAL FORCE COEFFICIENT**
### Sample Configuration 1 Optimum Optimally

<table>
<thead>
<tr>
<th>INPUT PARAMETERS</th>
</tr>
</thead>
<tbody>
<tr>
<td>MACH = 1.20</td>
</tr>
<tr>
<td>TAIL ASPECT RATIO = 1.00</td>
</tr>
<tr>
<td>TAIL TAPER RATIO = 0.60</td>
</tr>
<tr>
<td>TAIL L.E. SWEET ANGLE = 75.96 DEGREES</td>
</tr>
<tr>
<td>TAIL ROOT CHORD = 7.550</td>
</tr>
<tr>
<td>NOSE LENGTH = 3.000 CAL.</td>
</tr>
<tr>
<td>AFTER BODY LENGTH = 7.000 CAL.</td>
</tr>
<tr>
<td>BODY DIAMETER = 3.75</td>
</tr>
<tr>
<td>TAIL TERTIARY (INCLUDING BODY) = 3.75</td>
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<tr>
<td>REYNOLDS NUMBER = 7000000.00</td>
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</table>

### Output Definitions

- CDB = BODY ALONE NORMAL FORCE COEFFICIENT
- XCPB = BODY ALONE CENTER OF PRESSURE
- XCD = TAIL ALONE NORMAL FORCE COEFFICIENT
- XCPT = TAIL ALONE CENTER OF PRESSURE
- XCDPB = TAIL IN PRESENCE OF BODY NORMAL FORCE COEFFICIENT
- XCPTB = TAIL (IN PRESENCE OF BODY) CENTER OF PRESSURE
- XCDPB = TAIL ROUGHED CENTER OF PRESSURE OF BODY PLUS TAIL
- XCDPBT = NORMAL FORCE COEFFICIENT OF BODY PLUS TAIL CONFIGURATION
- CA = AXIAL FORCE COEFFICIENT

### Table

<table>
<thead>
<tr>
<th>ALPHA</th>
<th>ISOLATED COMPONENTS</th>
<th>BODY TAIL CONFIGURATION</th>
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<td>CDB</td>
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All values in units.
### Sample Configuration 1

**GPFHM=6, OPTMAC=1**

**Input Parameters**

- **MACH** = 1.36
- **TAIL ASPECT RATIO** = 1.00
- **TAIL TAPER RATIO** = 0.00
- **TAIL L.E. SWEEP ANGLE** = 75.96 DEGREES
- **TAIL ROOT CHORD** = 7.00
- **NOSE LENGTH** = 3.000 CAL.
- **AFTER BODY LENGTH** = 7.000 CAL.
- **BODY DIAMETER** = 3.75
- **TAIL SEMI-SPAN (INCLUDING BODY)** = 3.75
- **REYNOLDS NUMBER** = 700000.00

**Output Definitions**

- **CMB** = BODY ALONE NORMAL FORCE COEFFICIENT
- **XCMB** = BODY ALONE CENTER OF PRESSURE
- **CNT** = TAIL ALONE NORMAL FORCE COEFFICIENT
- **XCT** = TAIL ALONE CENTER OF PRESSURE
- **CXTCB** = TAIL (IN PRESENCE OF BODY) NORMAL FORCE COEFFICIENT
- **XCTCB** = TAIL (IN PRESENCE OF BODY) CENTER OF PRESSURE/TAIL ROOT CHORD (MEASURED AFT FROM ROOT CHORD LEADING EDGE)
- **XCTCB** = TAIL (IN PRESENCE OF BODY) CENTER OF PRESSURE/TAIL SEMI-SPAN (EXCLUDING CONFIGURATION (CALLED FROM NOSE)
- **XCTCB** = BODY PLUS TAIL CONFIGURATION
- **XCTCB** = AXIAL FORCE COEFFICIENT

**Alpha vs. Isolated Components**

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<th>ALPHA</th>
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PROGRAM MAINTAPES, TAPE67

THIS PROGRAM USES AN AERODYNAMIC METHODOLOGY DEVELOPED BY THE

MARTIN MARIETTA CORP. TO PREDICT AERODYNAMIC COEFFICIENTS OF

MISSILES WITH LOW ASPECT RATIO TAILS AT LOW AND HIGH ANGLES OF

ATTACK AND ARBITRARY ROLL ANGLES.

THF INPUT PARAMETERS AND THEIR LIMITS FOR THIS METHOD ARE:

MACH = MACH NUMBER .5 TO 3.0

ALPHA = ANGLE OF ATTACK (DEG) 0 TO 180 (0 TO 45 FOR ROLL)

ALE = TAIL LEADING EDGE SWEEP ANGLE (DEG) 0 TO 70 DEG

LAN = AFTER BODY LENGTH IN CAL. 6 TO 18

LND = NOSE LENGTH IN CAL. 1.5 TO 3.5

LAMDA = TAIL TAPER RATIO 0 TO 1

AP = TAIL ASPECT RATIO (TWO PANELS) 0.5 TO 3.5

ALF1 = BEGINNING ALPHA FOR CURVED ALPHA SWEEP (DEG)

ALF2 = END POINT FOR ALPHA SWEEP (DEG)

DELAF = ALPHA INCREMENT FOR ALPHA SWEEP (DEG)

RN = REYNOLDS NUMBER/FT.

S = TAIL SEMI SPAN INCLUDING BODY+(B*D)/2 INCHES

CR = TAIL ROOT CHORD INCHES

C = BODY DIAMETER INCHES

OPTIMAC = 1 GIVES NO PREDICTIONS VS. ROLL ANGLE

OPTIMAC = 2 GIVES AERODYNAMIC COEFFICIENTS AND CENTER OF

PRESSURE AS A FUNCTION OF ROLL ANGLE

OPTIMAC = 4 ALLOWS FOR MULTIPLE MACH NO. CALCULATIONS FOR

A GIVEN CONFIGURATION

OPTIMAC = 6 CALCULATIONS FOR SINGLE MACH NO. ONLY

INTEGER OPTIMAC

DIMENSION NAME (12)

REAL MACH,LAMDA,LND,LAN,118

GO TO 11
1 IF(OPTIMAC.EQ.11) GO TO 17

11 READ(5,203) (NAME(i),i=1,12)

17 IF(OPTIMAC.EQ.4) GO TO 25

40 READ(5,203) RN,CR,LAMDA,ALF

25 READ(5,203) LND,LAN,ALF

15 READ(5,203) ALF1,ALF2,DELAF,MACH,RN,OPTIMAC

GO TO 2

2 READ(5,203) MACH

26 IF(MACH.EQ.0.1) GO TO 11

3 WRITE(6,140)

5 WRITE(6,140)

7 WRITE(6,140)

9 WRITE(6,140)

11 WRITE(6,140)

13 WRITE(6,140)

15 WRITE(6,140)

17 WRITE(6,140)

19 WRITE(6,140)

21 WRITE(6,140)

23 WRITE(6,140)

25 WRITE(6,140)

27 WRITE(6,140)

29 WRITE(6,140)

31 WRITE(6,140)

33 WRITE(6,140)
SUBROUTINE CNTT (ALPHA, LAMDA, MACH, CNT)

C
C THIS SUBROUTINE CALCULATES TAIL NORMAL FORCE COEFFICIENT OF
C AN ISOLATED TAIL
C
C ALPHA = ANGLE OF ATTACK (DEGREES)
C LAMDA = TAIL TAPER RATIO
C MACH = MACH NUMBER
C AS = ASPECT RATIO
C CNT = TAIL NORMAL FORCE COEFFICIENT (ISOLATED TAIL)
C
C
DIMENSION FFLTFT(5,5,5), FPLMAC(5,5), FPLAR(5,5), FPLARE(5,5)

1 CCNT(13), SCALM(9,5), CMATE(23)

+ CCNT(13), ACHT(5,5,5), SCOLMAC(5,5), CMAC(13)

20 F5ST(1,5,3,3), F50MT(1,9), F50RT(1,3), F5OLRT(1,3)

+ F5PLRT(1,3), F5PLARE(1,3), F5PLAR(1,3)

C CCNT(13), SCNT(13), SCALF(13)

DATA F(5,5,5,5,5) = 1.56, 9.92, 8.65, 8.78, 8.74, 7.584, 7.895, 7.296/

20 DATA ACHT(5,5,5) = 0.0000, 0.0000, 0.0000, 0.0000, 0.0000/

30 DATA SCOLMAC(5,5) = 1.0000, 1.0000, 1.0000, 1.0000, 1.0000/

40 DATA CMAC(13) = 1.0000, 1.0000, 1.0000, 1.0000, 1.0000/

50 DATA SCNT(13) = 1.0000, 1.0000, 1.0000, 1.0000, 1.0000/

60 DATA SCALF(13) = 1.0000, 1.0000, 1.0000, 1.0000, 1.0000/

70 DATA CMATE(23) = 1.0000, 1.0000, 1.0000, 1.0000, 1.0000/

80 DATA FPLARE(5,5) = 1.0000, 1.0000, 1.0000, 1.0000, 1.0000/

90 DATA FPLRT(1,3) = 1.0000, 1.0000, 1.0000, 1.0000, 1.0000/

100 DATA F5OLRT(1,3) = 1.0000, 1.0000, 1.0000, 1.0000, 1.0000/

110 DATA F5PLRT(1,3) = 1.0000, 1.0000, 1.0000, 1.0000, 1.0000/
SUBROUTINE IBT

RETURN

80 IFLAG = 0
  - JFLAG = 1
  IBT = IBT
  MACH = 2.0
  GO TO 90

100 IFLAG = 0
  IBT = IBT
  MACH = MACH
  GO TO 100

10 IF (MACH .GE. 2.0) GO TO 90

100 RETURN

90 CALL LOOK(1*H2AS+T1BAS+LAMDA+T1BLM+2.0+1)
  CALL LOOK1(F10R+TFDS+DB+TDFR+1.1+1+1)
  I1 = 1BAS+F10R
  CALL LOOK1(T2BAS+T2BAS+LAMDA+T2BLM+11+11+1)
  CALL LOOK1(F2M+TF2M+MACH+TF2MACH+2.0+1)
  I2 = 12BAS+F2M
  CALL LOOK1(F3M+TF3M+MACH+TF3MACH+1.0+1)
  I3 = 1.4+3.0

140 IF (ALPHA .LT. 90.) GO TO 105
  IBTO = 11+SIGN(ALPHA+RAD)
  GO TO 110

105 IF (ALPHA .GE. 90.) GO TO 120
  IBTO = 11-11-12+SIGN(ALPHA+90.)+25.
  GO TO 110

145 RETURN

120 IBTO = -11.325+12+11.2+12+15.2+16+16.3+32+12+1+1+1+1+11+11+1+11+11+1+1+1
  IF (MACH .GT. 90.) IF (MACH .LT. 180.) THEN RETURN

110 IBTO = IBTO

565 FORMAT(1X,R15,1X,R15,1X,R15,1X,R15)
  RETURN

END
SUBROUTINE AXIAL  7/4/74  OPT+1

FIN 4.2+74355  04/27/78  14.19.37.  PAGE 3

IF(ALPHA.GE.160.4) GO TO 15 019140
CA = CA-(CA+CAPI)+S1N(ALPHA/57.2957) 019150
GO TO 40 019160
15 CONTINUE 019170
CA = CAPI 019180
GO TO 40 019190
60 IF(ALPHA.GE.40.0) GO TO 50 019200
CA = (1.0+COS 0.150324)2 * (MACH/LND)2 + (0.04412)2 * (MACH/LND)2 * 2 + 0.0928 + 019210
4*MACH(LND)2 * 2 - (0.004*MACH(LND)+6) * (6.7) 019220
MACH**2 019230
CALL CSFERN(MACH,CF) 019240
CASE = (4.0/5.0)*CF+0.000 019250
75 CA = CAW + CASE + CD9 019260
CA = CAO 019270
GO TO 40 019280
50 IF(ALPHA.GE.160.0) GO TO 60 019290
27.4985*(MACH)**4 - (2.26668*(MACH)**5 019310
2) + (CA0*(CA-CAPI)+S1N(ALPHA/57.2957) 019320
GO TO 40 019330
60 CA = CA + CAPI 019340
57.4985*(MACH)**4 - (2.26668*(MACH)**5 019350
CA = CAO 019360
40 CONTINUE 019370
RETURN 019380
END 019390
SUBROUTINE CSF(REAL MACH,CFS)

C THIS PROGRAM CALCULATES THE SKIN FRICTION COEFFICIENT ON THE BODY

5 C
R = REYNOLDS NUMBER
MACH = MACH NUMBER
CFS = SKIN FRICTION COEFFICIENT

10 REAL MACH,LAM

G = 1.4
LAM = 1.0/SQRT(1.0+1.0/MACH**2)**1.0
CFS1 = 0.074*(1.0/R)+2.1*G/(1.0+0.4+MACH**2)**1.0
CFS2 = (ASIN(LAM)/LAM)+1.0/SQRT(1.0+MACH**2)**1.0
CFS3 = (ASIN(LAM)/LAM)+1.0/SQRT(1.0+MACH**2)**1.0
CFS = CFS1 + CFS2 + CFS3

156 C
N = 1

DFCDF = ((CFS-CF3)/CF2+CF2+CF1)

CFS1 = CF2 - DCFDF+CF2
IF(CF2.GT.3.0) GO TO 15
CFS1 = CF1 - DCFDF+CF1
15

N = N + 1

20 DCFDF = ((CFS-CF3)/CF2+CF2+CF1)

CFS1 = CF2 - DCFDF+CF2
IF(CF2.GT.3.0) GO TO 15
CFS1 = CF1 - DCFDF+CF1

25 N = N + 1

30 DCFDF = ((CFS-CF3)/CF2+CF2+CF1)

CFS1 = CF2 - DCFDF+CF2
IF(CF2.GT.3.0) GO TO 15
CFS1 = CF1 - DCFDF+CF1

35 N = N + 1

40 
RETURN
END
<table>
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<tr>
<th>SUBROUTINE LOOK3</th>
<th>7A78</th>
<th>OPT=1</th>
<th>FTN 4.2*74555</th>
<th>04/27/78 14:19:35</th>
<th>PAGE 1</th>
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<td>SUBROUTINE LOOK3</td>
<td>FTN 4.2*74555</td>
<td>04/27/78 14:19:35</td>
<td>PAGE 1</td>
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<tr>
<td>C</td>
<td></td>
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<td>C THREE-DIMENSIONAL TABLE LOOKUP ROUTINE (+ = RETURNED VALUES)</td>
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<tr>
<td>C F = FT(x+y+z)</td>
<td>(RETURNED VALUES)</td>
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<td>C FT FUNCTION TABLE FT(x+y+z)</td>
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<td>C NR NO. OF ROWS IN FT-TABLE</td>
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<td>C MULT = 0 USE PREVIOUS X+Y+Z</td>
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<td>C DIMENSION FT(x+y+z)</td>
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<tr>
<td>C = 1</td>
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<td>C 3 CALL LOOK(x+y+z)</td>
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<td>C IF KEEP = 1</td>
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SUBROUTINE LOOK2 74/74 OPT=1

SUBROUTINE LOOK2(F,FT=NR+X*XT+NX+Y*YT+NY+IX+IY+MULT)
C***********************************************
C TWO-DIMENSIONAL TABLE LOOKUP ROUTINE (* = RETURNED VALUES)
C F = FT(X+Y)
C FT FUNCTION TABLE FT(NR+NC)
C NR NO. OF ROWS IN FT-TABLE
C NC NO. OF COLUMNS IN FT-TABLE
C X+T WORKING VALUES OF INDEPENDENT VARIABLES
C XT=TT INDEPENDENT VARIABLE TABLES
C NX=NY DIMENSION OF XT+YT TABLES
C IX,ITY X+Y INDEXES ON PREVIOUS LOOKUP (UPDATED ON EACH CALL)
C MULT =0 USE PREVIOUS X+Y
C =1 LOOKUP NEW X+Y
C***********************************************

15 DIMENSION FT(I),XT(I),YT(I)
IF(MULT=1)Go TO 20
1 CALL INDEX(F,X+T,NR+TY+KEEP+RY)
   I = 1+(IY-1)*NR
   II = 1+NR
   2 CALL LOOK1(F,FT(I),X+YT+NX+IX+MULT)
   F=FT(KEEP+13)+3
   3 CALL LOOK1(F,FT(I),XT+NX+IX+IY)
   F=FT+RY+F
   4 RETURN
   END
18420
Appendix B. DESCRIPTION OF SUBROUTINES AND PROGRAM LISTING

Table B-1 lists the subroutines and gives their basic function.

A detailed description of each subroutine will not be included in this report. The logic and procedures required of each included method are discussed in detail in Reference 1. The applicable section of Reference 1 for each of the Methodology Program Subroutines is listed in Table B-1.

**TABLE B-1. LIST OF PROGRAM ELEMENTS**

<table>
<thead>
<tr>
<th>SUBPROGRAM NAME</th>
<th>REF. 1 SECTION</th>
<th>FUNCTION OF SUBPROGRAM</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAIN</td>
<td></td>
<td>Controls input and output to the program. Uses various subroutines to calculate aerodynamic coefficients and centers of pressure for total missile and isolated components.</td>
</tr>
<tr>
<td>CNTPHI</td>
<td>SEC.5.2.1</td>
<td>Calculates tail normal force coefficient in presence of a cylindrical body as a function of roll angle. (Angle of attack limited to 0 to 45 degrees).</td>
</tr>
<tr>
<td>CNTT</td>
<td>SEC.5.1.4</td>
<td>Calculates tail normal force coefficient of an isolated tail (angle of attack 0 to 180 degrees).</td>
</tr>
<tr>
<td>BRIT</td>
<td></td>
<td>Contains data required by several other Methodology subroutines. Data is taken from British Data Sheets. (Reference 3).</td>
</tr>
<tr>
<td>CNBOD</td>
<td>SEC.5.1.1</td>
<td>Calculates body alone normal force coefficient (angle of attack 0 to 180 degrees).</td>
</tr>
<tr>
<td>XCPBOD</td>
<td>SEC.5.1.2</td>
<td>Calculates body alone center of pressure measured in calibers from the nose. (Angle of attack 0 to 180 degrees).</td>
</tr>
<tr>
<td>IBTT</td>
<td>SEC.5.2.4</td>
<td>Calculates body normal carry over force coefficient.</td>
</tr>
<tr>
<td>XCPBTX</td>
<td>SEC.5.2.5</td>
<td>Calculates tail-to-body carry over normal force center of pressure.</td>
</tr>
<tr>
<td>XCPBTB</td>
<td>SEC.5.2.2</td>
<td>Calculates the tail chordwise center of pressure (upper and lower bound)/tail root chord, measured aft from root chord leading edge.</td>
</tr>
<tr>
<td>SUBPROGRAM NAME</td>
<td>REF. 1 SECTION</td>
<td>FUNCTION OF SUBPROGRAM</td>
</tr>
<tr>
<td>----------------</td>
<td>---------------</td>
<td>------------------------</td>
</tr>
<tr>
<td>YCPTS</td>
<td>SEC.5.2.3</td>
<td>Calculates tail spanwise center of pressure for isolated tail.</td>
</tr>
<tr>
<td>XCPTT</td>
<td>SEC.5.1.5</td>
<td>Calculates chordwise center of pressure for isolated tail for roll angle = 0.</td>
</tr>
<tr>
<td>PHCC</td>
<td></td>
<td>Required by several other Methodology Subroutines.</td>
</tr>
<tr>
<td>AXIAL</td>
<td>SEC.5.1.3</td>
<td>Calculates the axial force coefficient for the missile body.</td>
</tr>
<tr>
<td>CSF</td>
<td>SEC.5.1.3</td>
<td>Calculates the skin friction coefficient for the missile body.</td>
</tr>
<tr>
<td>LOOK1</td>
<td></td>
<td>One-dimensional table look-up subroutine.</td>
</tr>
<tr>
<td>LOOK2</td>
<td></td>
<td>Two-dimensional table look-up subroutine.</td>
</tr>
<tr>
<td>LOOK3</td>
<td></td>
<td>Three-dimensional table look-up subroutine.</td>
</tr>
<tr>
<td>INDEX</td>
<td></td>
<td>Required for subroutines LOOK1, LOOK2, and LOOK3.</td>
</tr>
</tbody>
</table>

A complete program listing follows.
REFERENCES


3. Royal Aeronautical Society, Data Sheets, Wings 5.01.03.03, 5.01.03.04, 5.01.03.05, and 5.01.03.06.
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