LinPAC

Linear Projectile Aerodynamic Coefficients

Prediction of Aerodynamic Coefficients of Projectiles with Circular Body Configurations:

- Body alone (spin stabilized)
- Fin stabilized projectile
- Up to three wing sections guided projectile

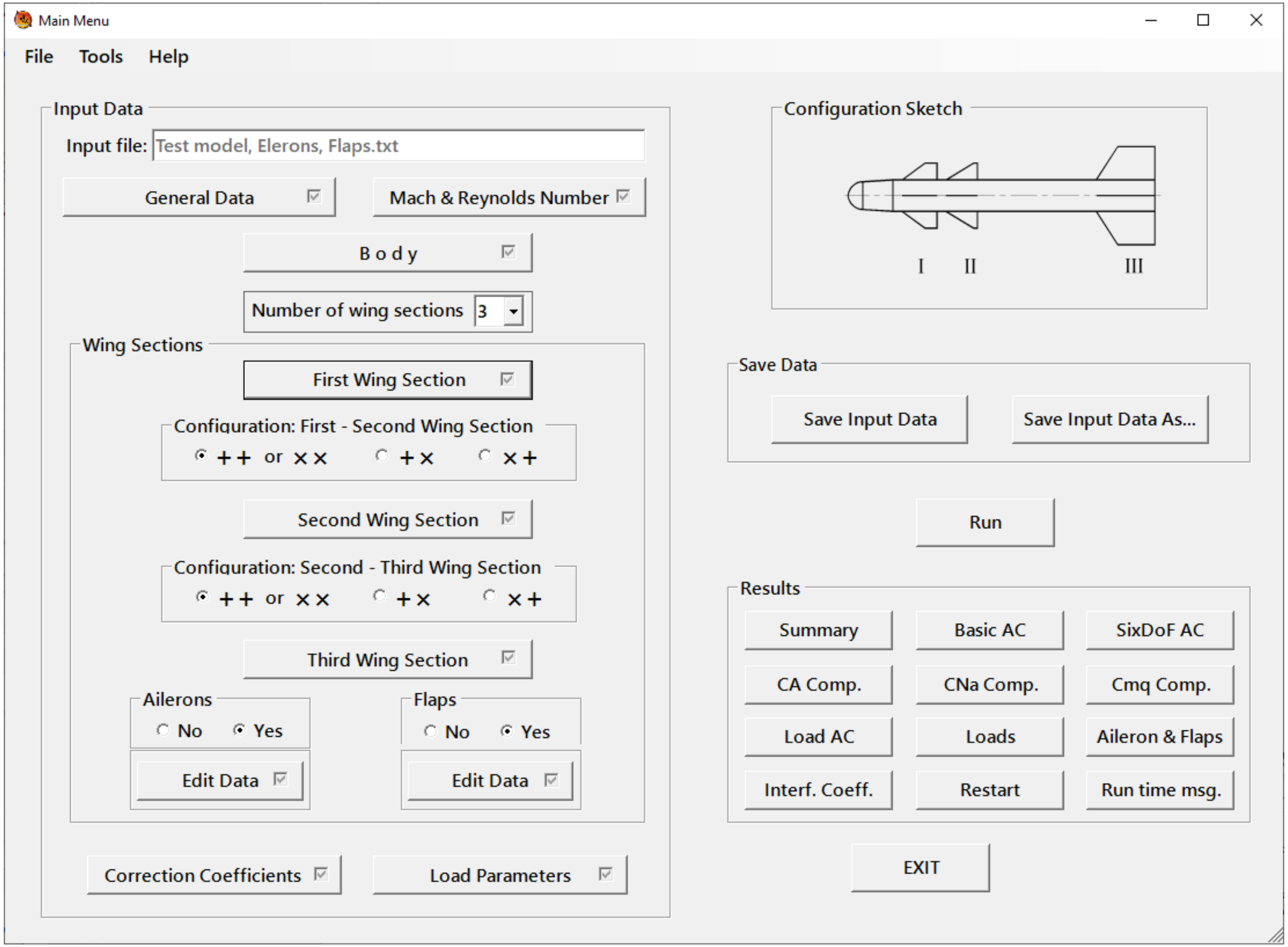
Version 5.0.0, May 2021.

Method	Combined semi-empirical and potential, based on published data collected from western and eastern countries.
Capability	Calculation of the derivatives of aerodynamics coefficients of the classical projectiles, rockets and missiles, with one, two or three wing sections and body alone for small angles of attack.
Purpose	Quick estimation of aerodynamics coefficients of projectiles, preliminary aerodynamic design, estimation of loads on projectiles and their components.
Uncertainty	Depends on configuration, up to 10 % for typical aerodynamic shapes.

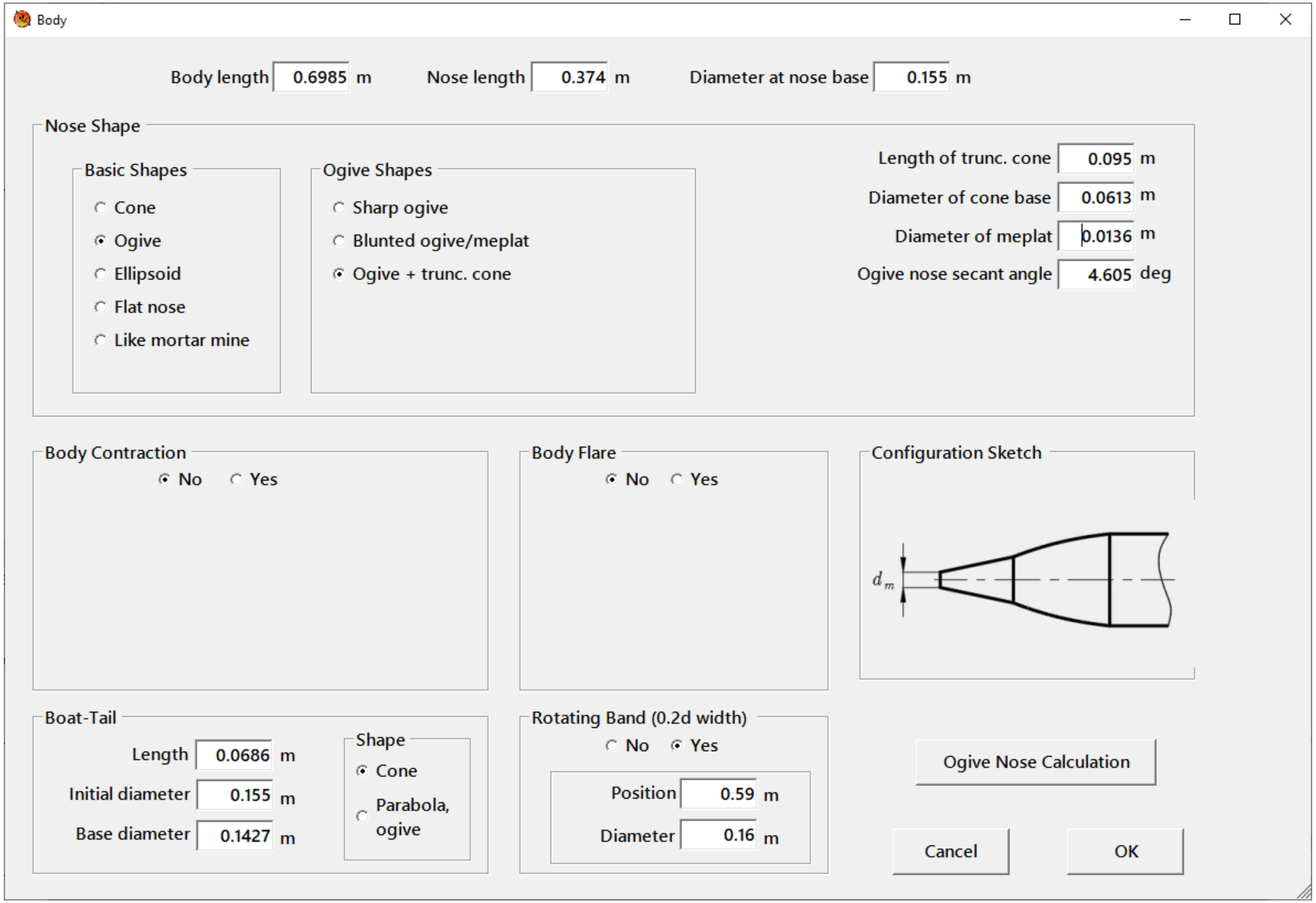
Ranges of basic input quantities

- Mach number: [0.1÷5.0],
- Body of revolution with maximum three different diameter,
- Body nose shape: cone, parabola, ogive, ellipse, and combination with spherical and truncated tip,
- Boat-tail shape: cone, parabola,
- Maximum three wing sections (“++”, “+x” and “x+” combinations),
- Wing shape: trapezoidal flat, trapezoidal wraparound,
- Number of fins: flat, cruciform, six and up to twelve fins,
- Wing aspect ratio [0.1,20], taper ratio [0,1], thickness ratio [0.01÷0.5],
- Wing airfoil shape: double wedge, modified double wedge, double sinusoid, flat plate,
- Ailerons, flaps on one wing section only ,
- Symmetric and differential deflection of fins (all sections).

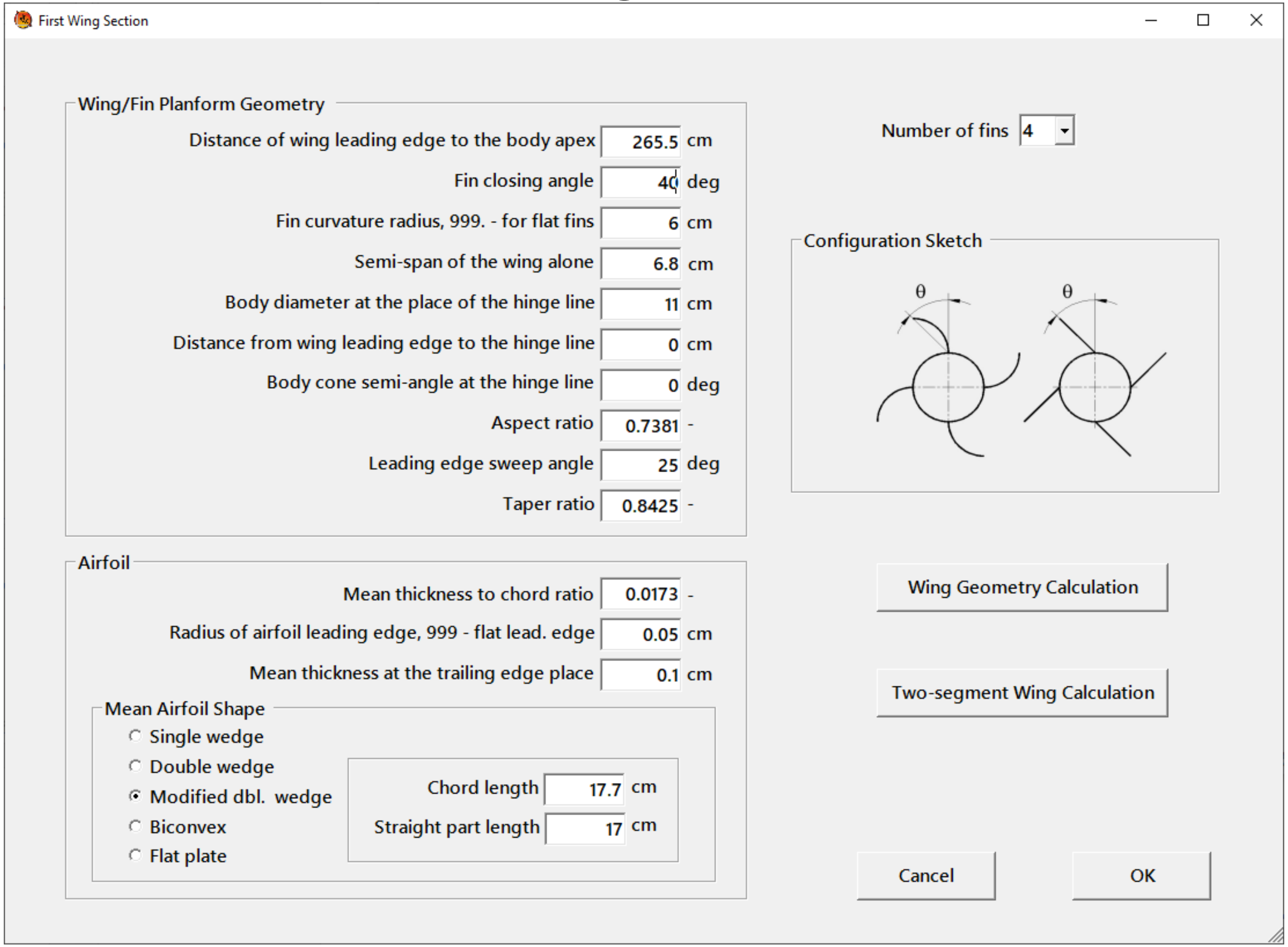
Main Menu


Main Menu
File
Tools
Help
Input Data
Input file:
Test model, Elerons, Flaps.txt
General Data
Mach & Reynolds Number
B o d y
Number of wing sections
3
Wing Sections
First Wing Section
Configuration: First - Second Wing Section
++ or ××
+×
×+
Second Wing Section
Configuration: Second - Third Wing Section
++ or ××
+×
×+
Third Wing Section
Ailerons
No
Yes
Edit Data
Flaps
No
Yes
Edit Data
Correction Coefficients
Load Parameters
Configuration Sketch
I
II
III
Save Data
Save Input Data
Save Input Data As...
Run
Results
Summary
Basic AC
SixDoF AC
CA Comp.
CNa Comp.
Cmq Comp.
Load AC
Loads
Aileron & Flaps
Interf. Coeff.
Restart
Run time msg.
EXIT

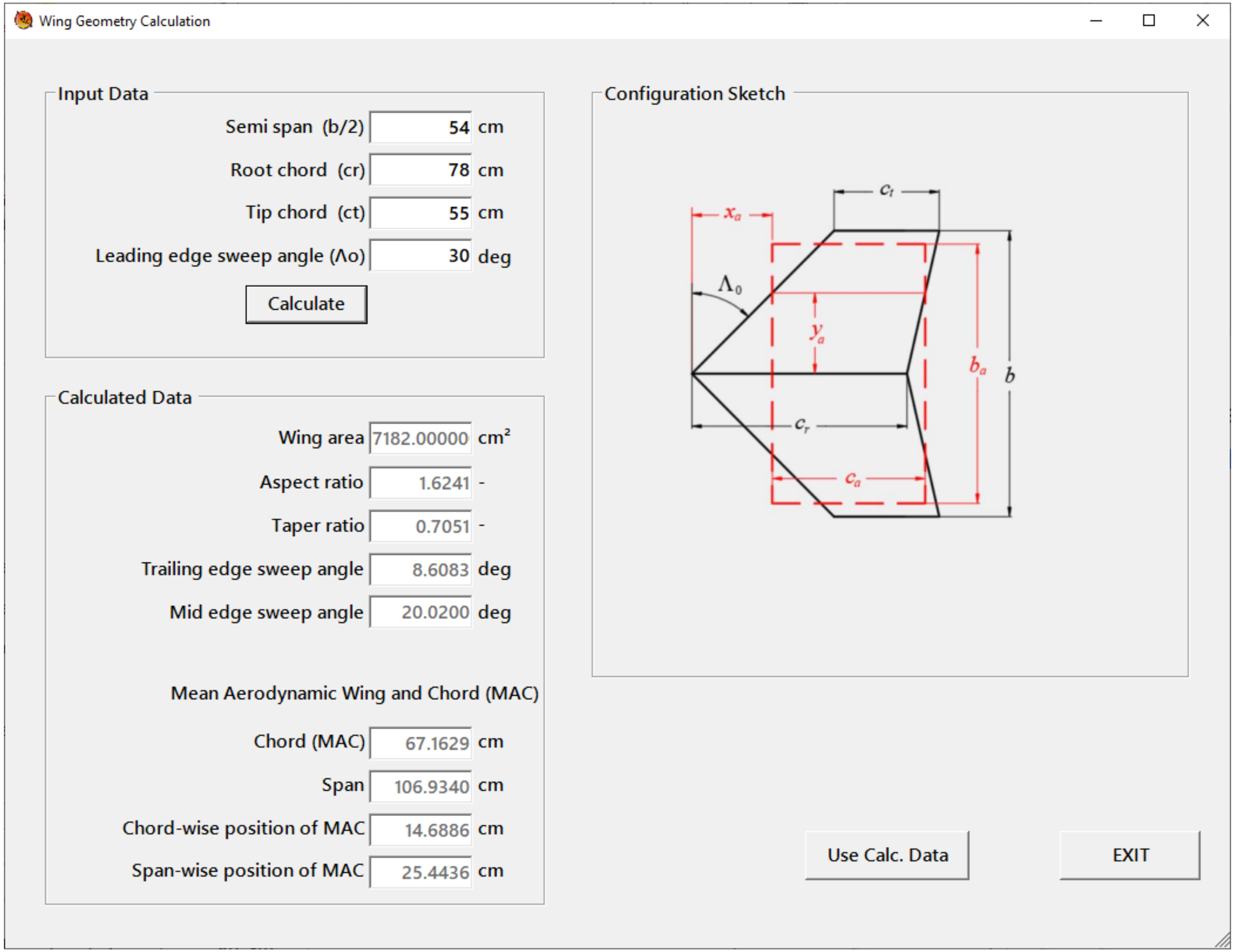
Body Data


Body
Body length 0.6985 m
Nose length 0.374 m
Diameter at nose base 0.155 m
Nose Shape
Basic Shapes
Cone
Ogive
Ellipsoid
Flat nose
Like mortar mine
Ogive Shapes
Sharp ogive
Blunted ogive/meplat
Ogive + trunc. cone
Length of trunc. cone 0.095 m
Diameter of cone base 0.0613 m
Diameter of meplat 0.0136 m
Ogive nose secant angle 4.605 deg
Body Contraction
No Yes
Body Flare
No Yes
Configuration Sketch
d_m
Boat-Tail
Length 0.0686 m
Initial diameter 0.155 m
Base diameter 0.1427 m
Shape
Cone
Parabola, ogive
Rotating Band (0.2d width)
No Yes
Position 0.59 m
Diameter 0.16 m
Ogive Nose Calculation
Cancel
OK

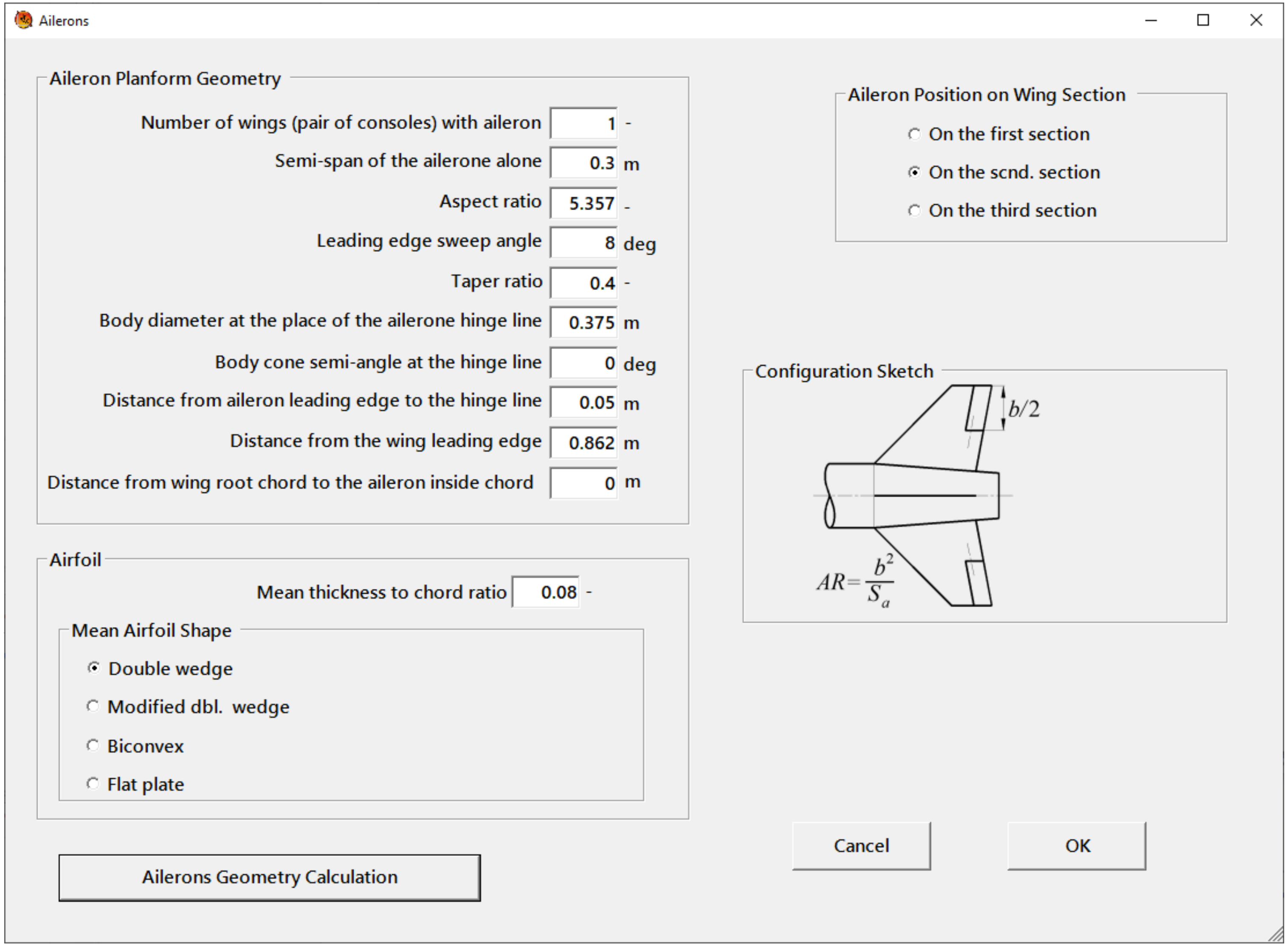
First Wing Section



Wing Parameters Calculation



Ailerons (Flaps) Geometry



Results

Files with calculated aerodynamic derivatives

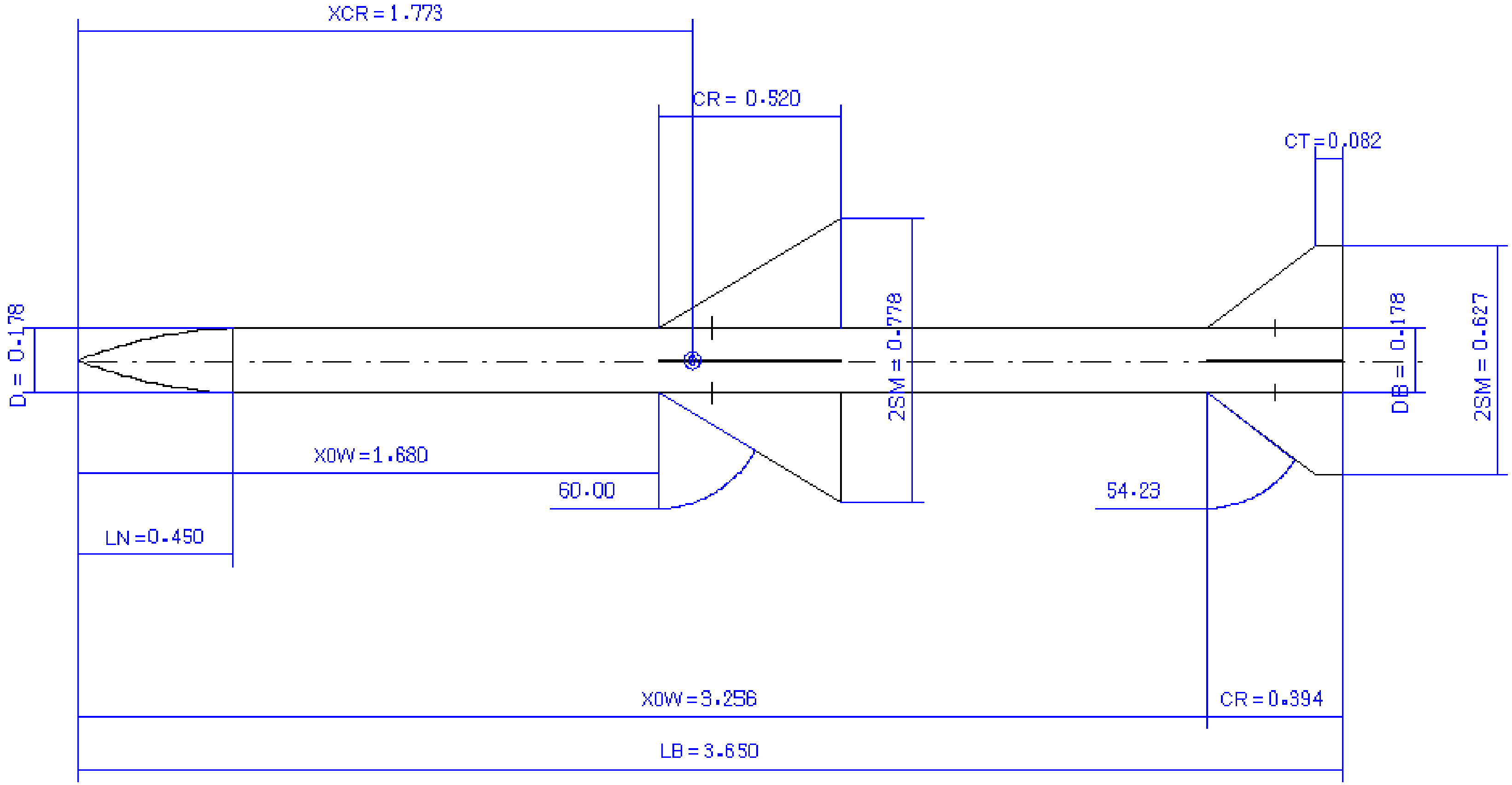
Sketch of projectile and diagrams of basic aerodynamic derivatives vs. Mach number

Aerodynamic Scheme of Projectile

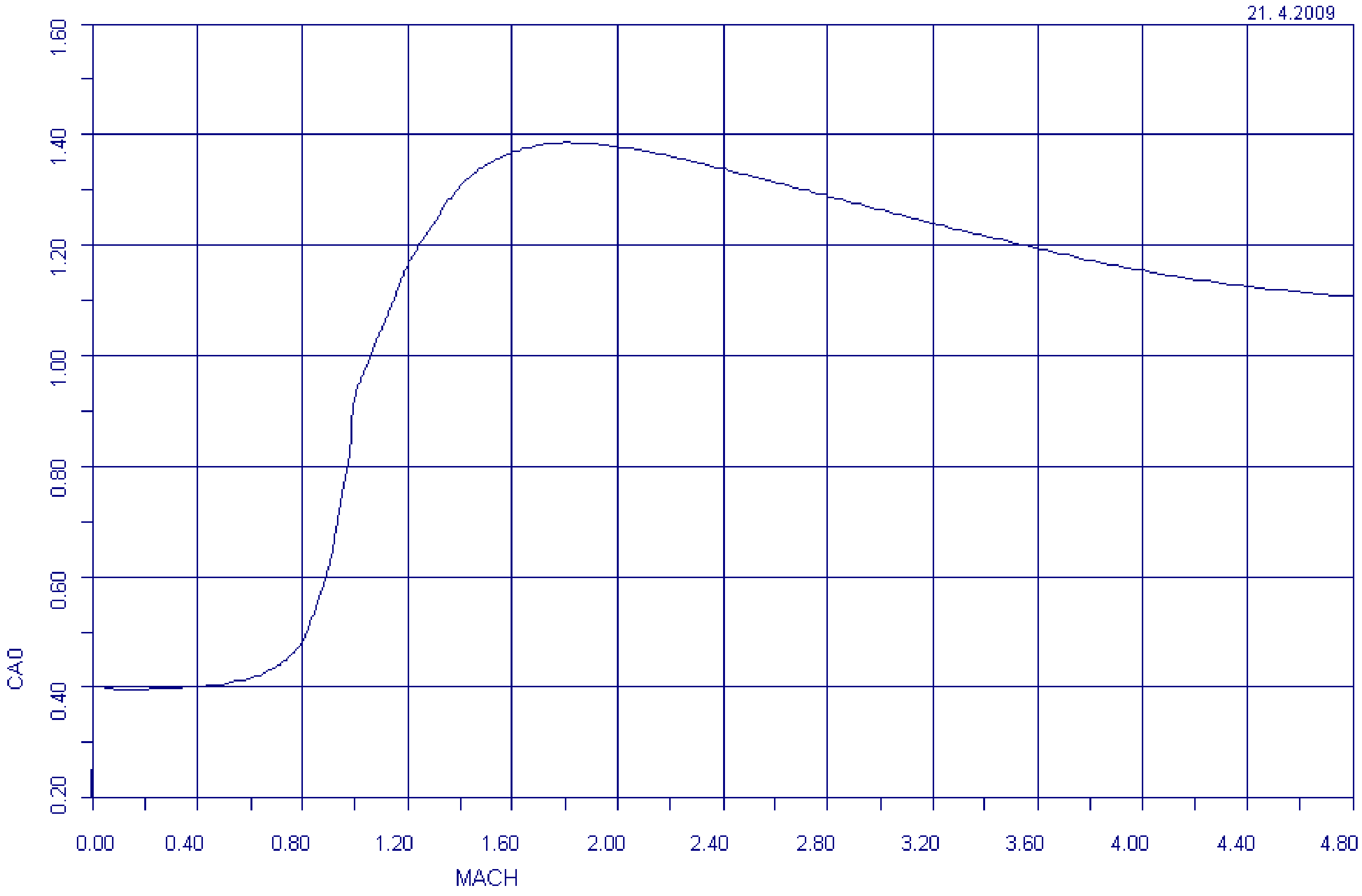
SAM Model

Demo Example

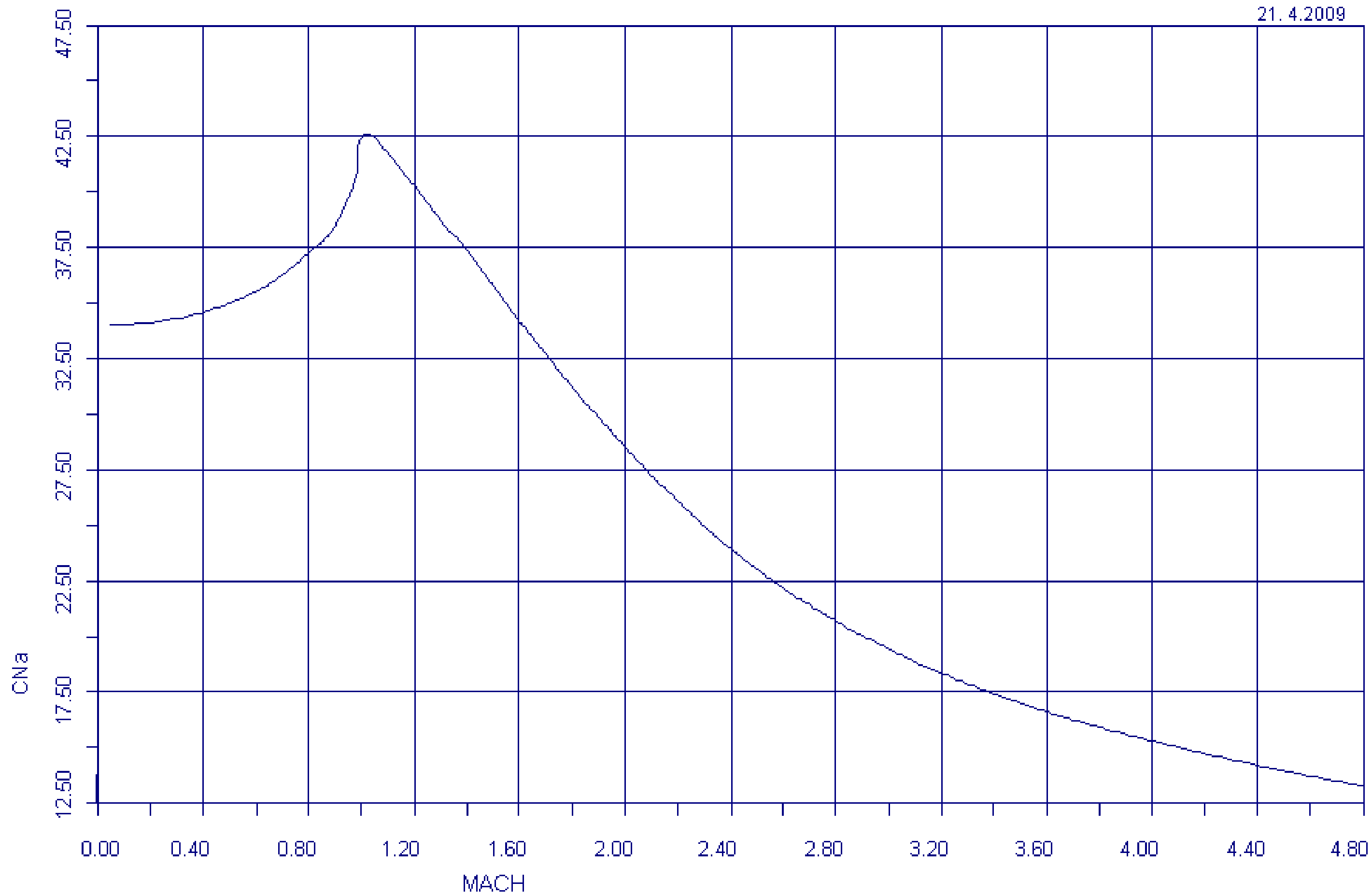
23. 4. 2009.



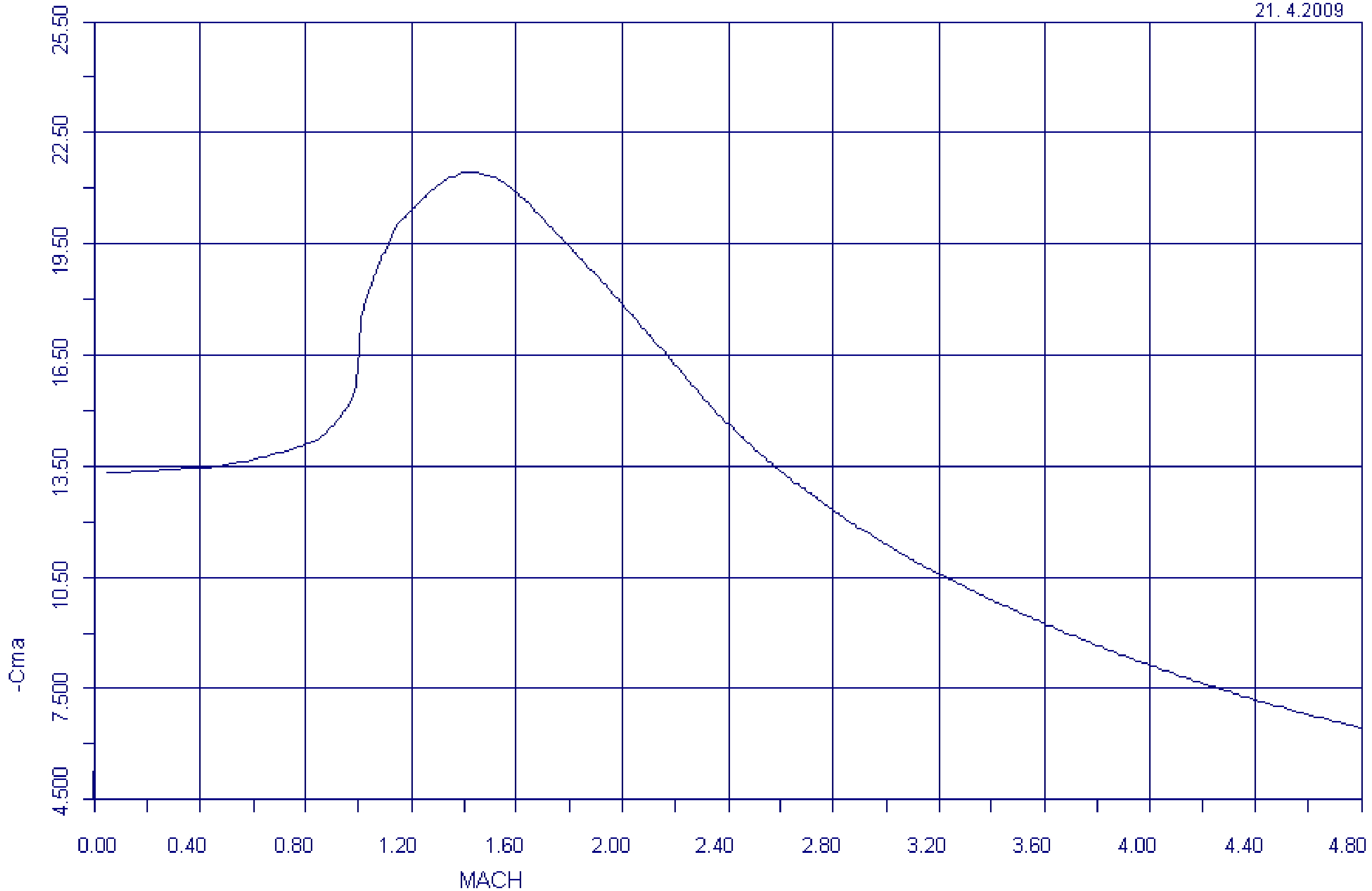
CA0 – Derivative



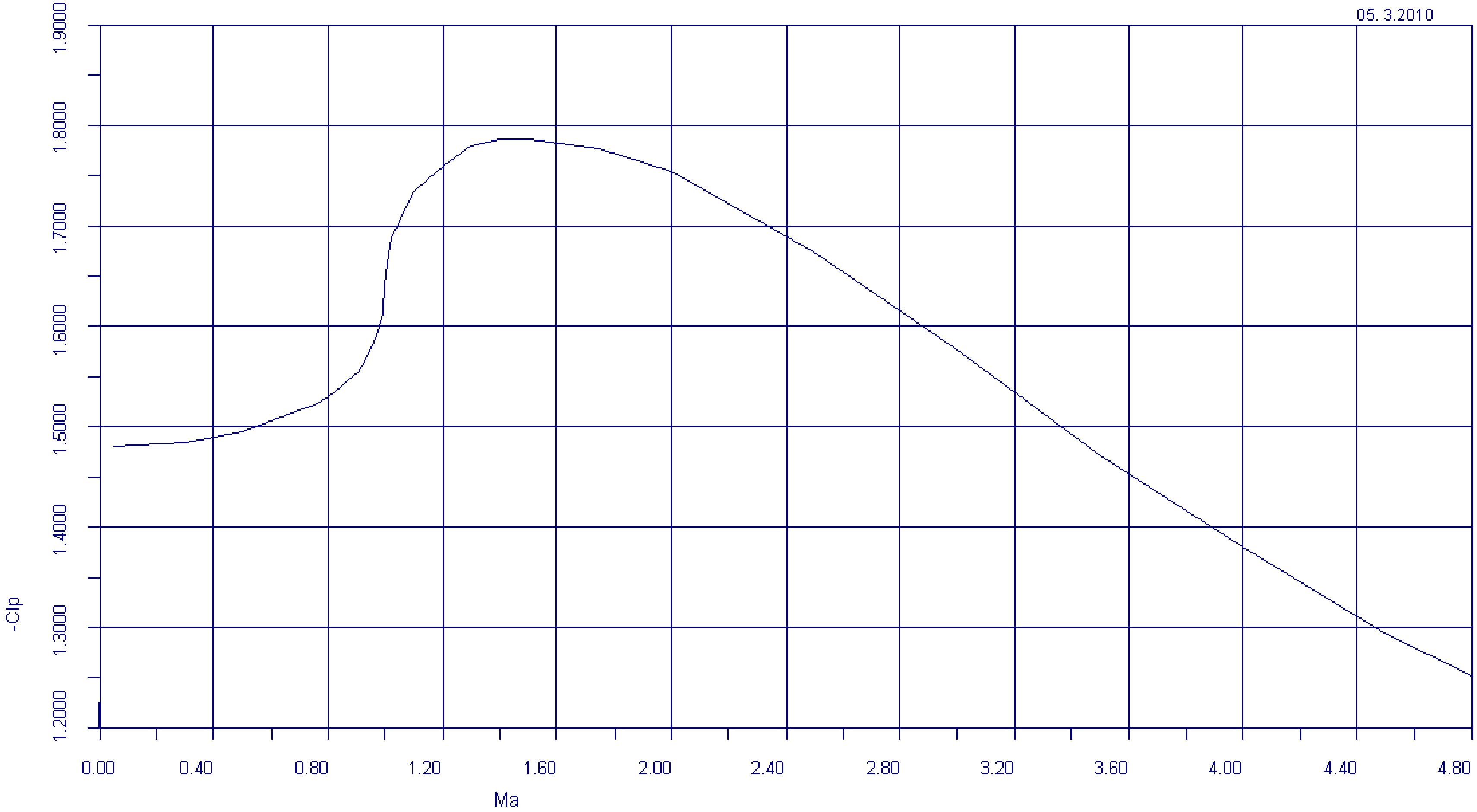
CNa – Derivative



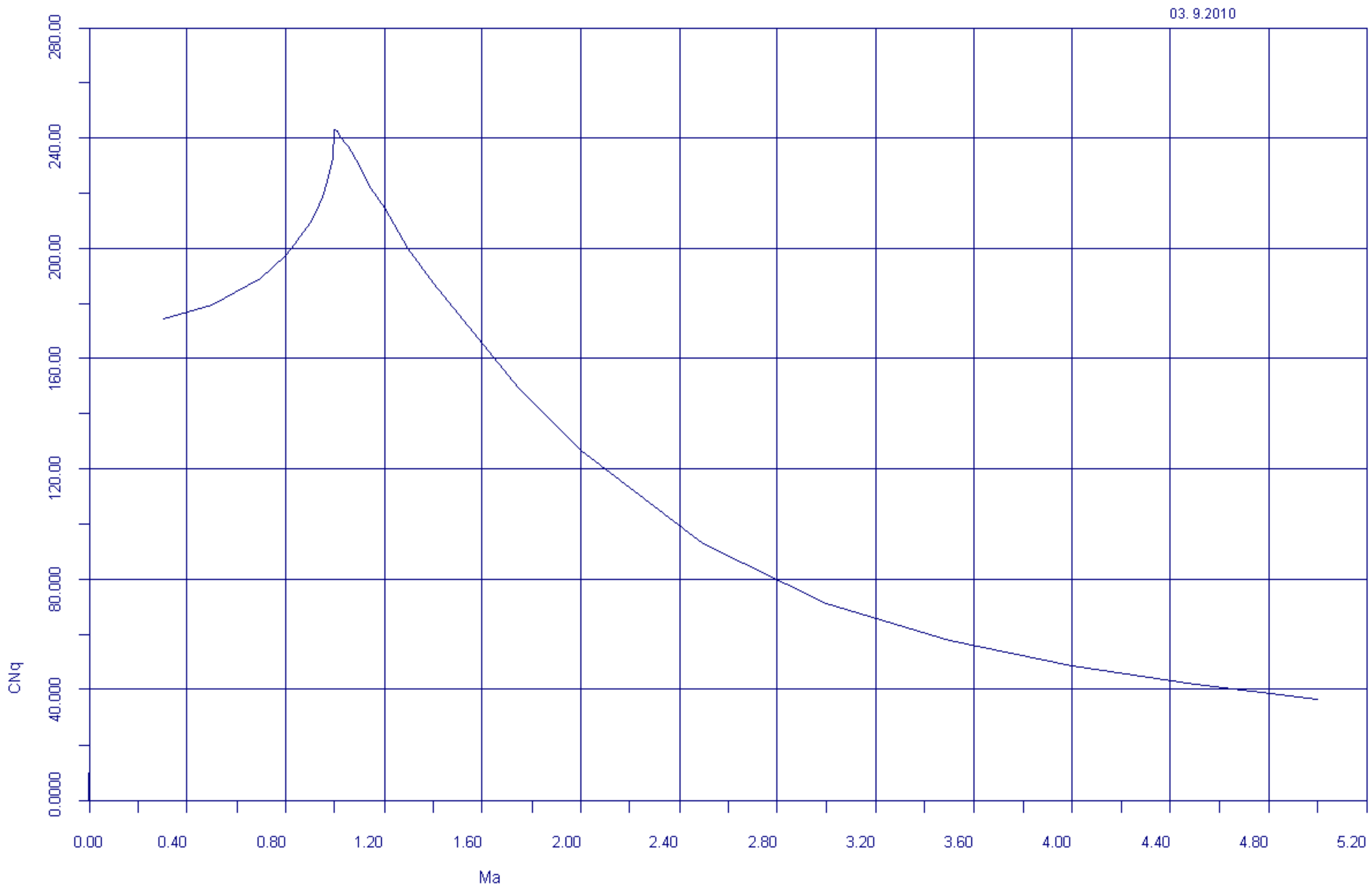
Cma – Derivative



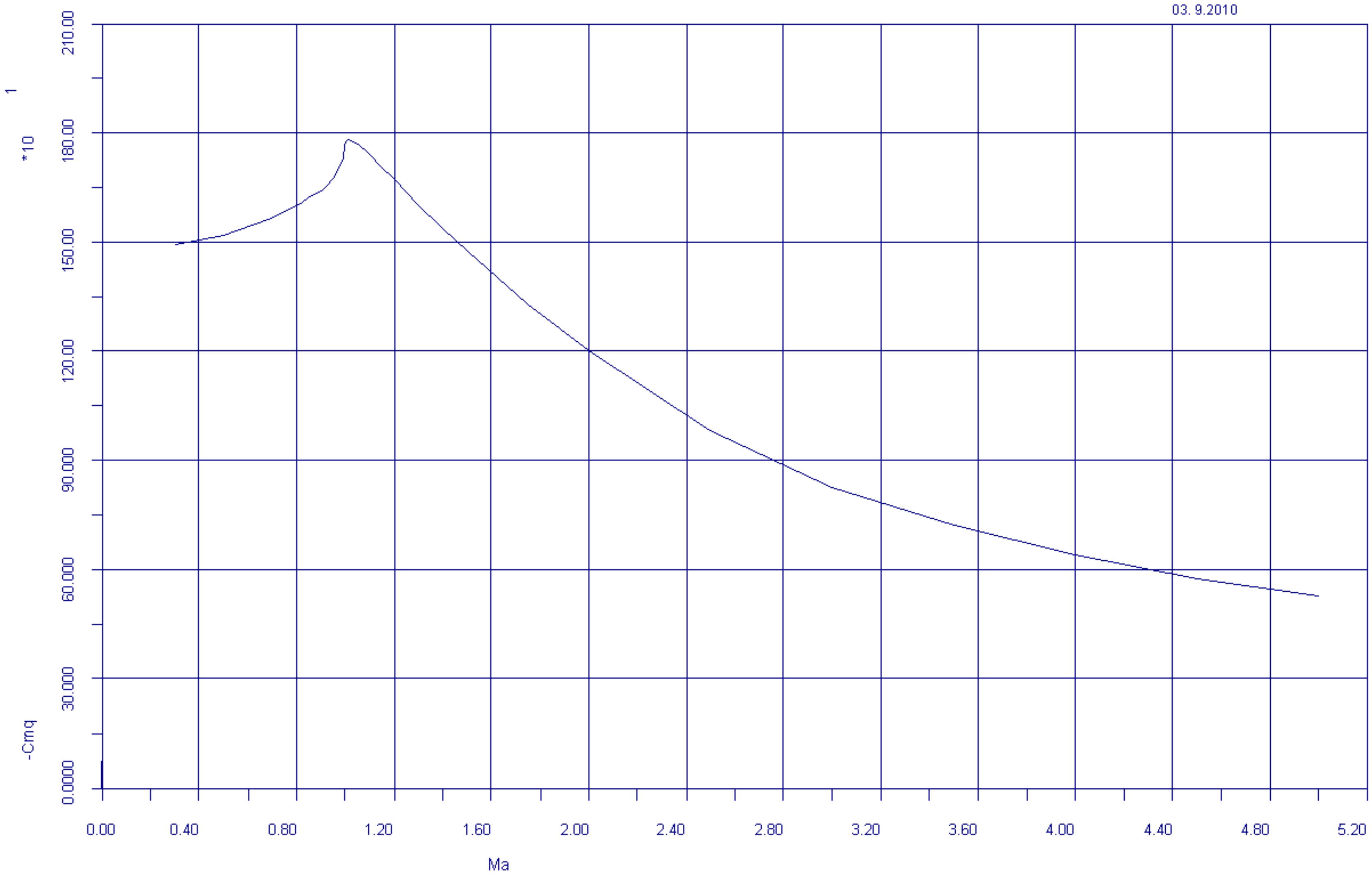
Clp – Derivative



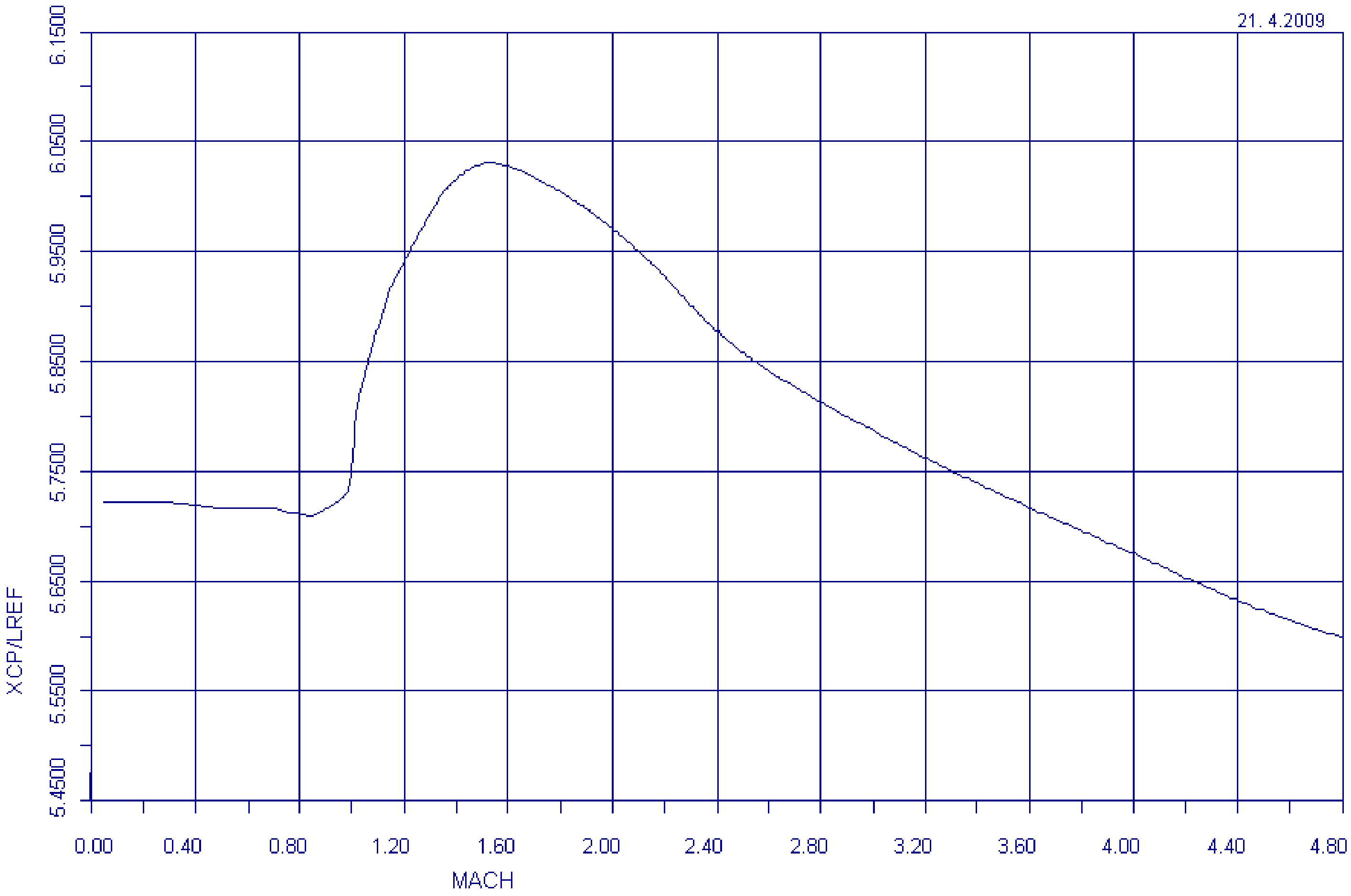
CNq – Derivative



CMq – Derivative



Xcp / lref


21. 4.2009
XCP/LREF
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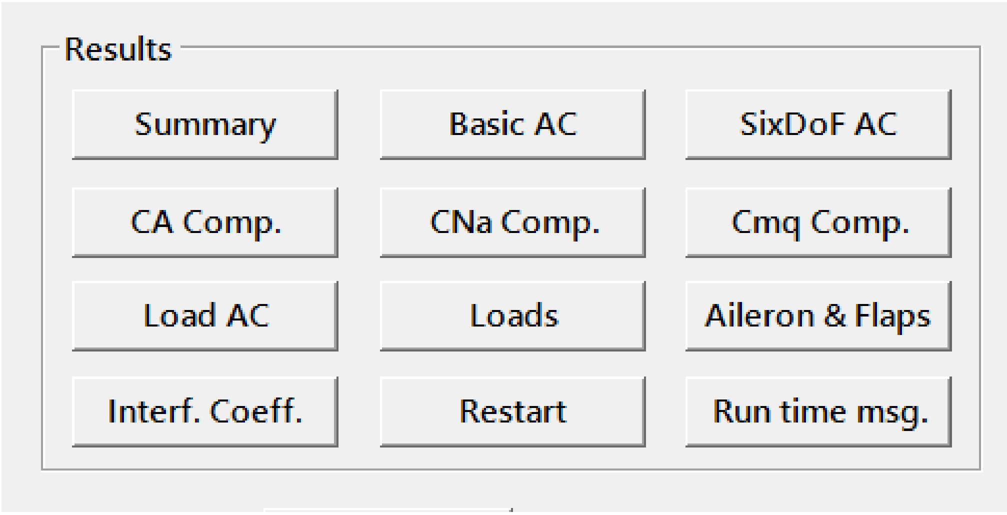
5.8500
5.7500
5.6500
5.5500
5.4500
0.00
0.40
0.80
1.20
1.60
2.00
2.40
2.80
3.20
3.60
4.00
4.40
4.80
MACH

Output Files



Output Files - Explanation

The following output files are formed upon the running the LinPAC program.

File Name		Short Description
Summary.dat	–	File contains input data and calculated aerodynamic coefficients.
Basic_AC.dat	–	File contains main aerodynamics coefficients.
SixDOF_AC.dat	–	File contains aerodynamics coefficients in the format to be input file for the program **Six degree of freedom motion** calculation.
CA_Comp.dat	–	File contains components of aerodynamics coefficients of axial force.
CNa_Comp .dat	–	File contains derivatives of aerodynamics coefficients of normal force for projectile components.
Cmq_Comp.dat	–	File contains damping derivatives coefficients of projectile and its components.
Load_AC.dat	–	File contains coefficients of loads on projectile components.
Loads.dat	–	File contains forces and moments on the projectile (loads), and forces and moments on all projectile components.
Flaps.dat	–	File contains aerodynamic coefficients of ailerons and flaps.
Interf._Coeff.dat	–	File contains interference coefficients according the slender body theory, coefficient of wing-tail vortex interference, and down wash angles.
Restart.dat	–	File contains input data to start (restart) program.
Messages.dat	–	File contains program run time messages.

Comparison with Experiments

On the next diagrams comparison of the calculation with experiment is shown for the following projectiles/models:

1. AGARD-B test model,
2. SPARROW III missile
3. Army-Navy BASIC FINNER test model

In calculation Reynolds number is adjusted to match the experimental values.

Comparison with Experiments

For the AGARD-B model data were taken from:

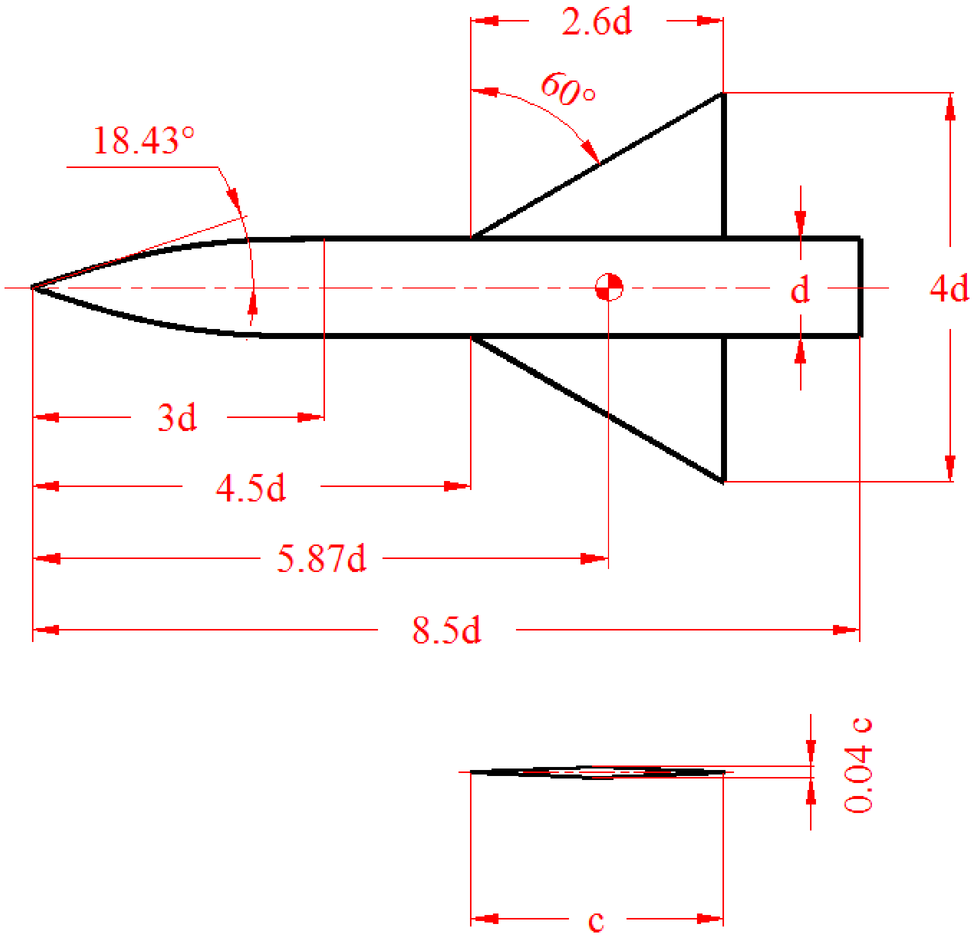
Piland, R.: "The zero-lift drag of a 60 degrees delta-wing-body combination (AGARD model 2) obtained from free-flight tests between Mach numbers of 0.8 and 1.7", NACA-TN-3081, 1954.

Bromm, F. Jr.: "Investigation of lift, drag, and pitching moment of a 60deg delta-wing-body combination (AGARD Calibration Model B) in the Langley 9-inch Supersonic Tunnel", NASA TN 3300, 1972.

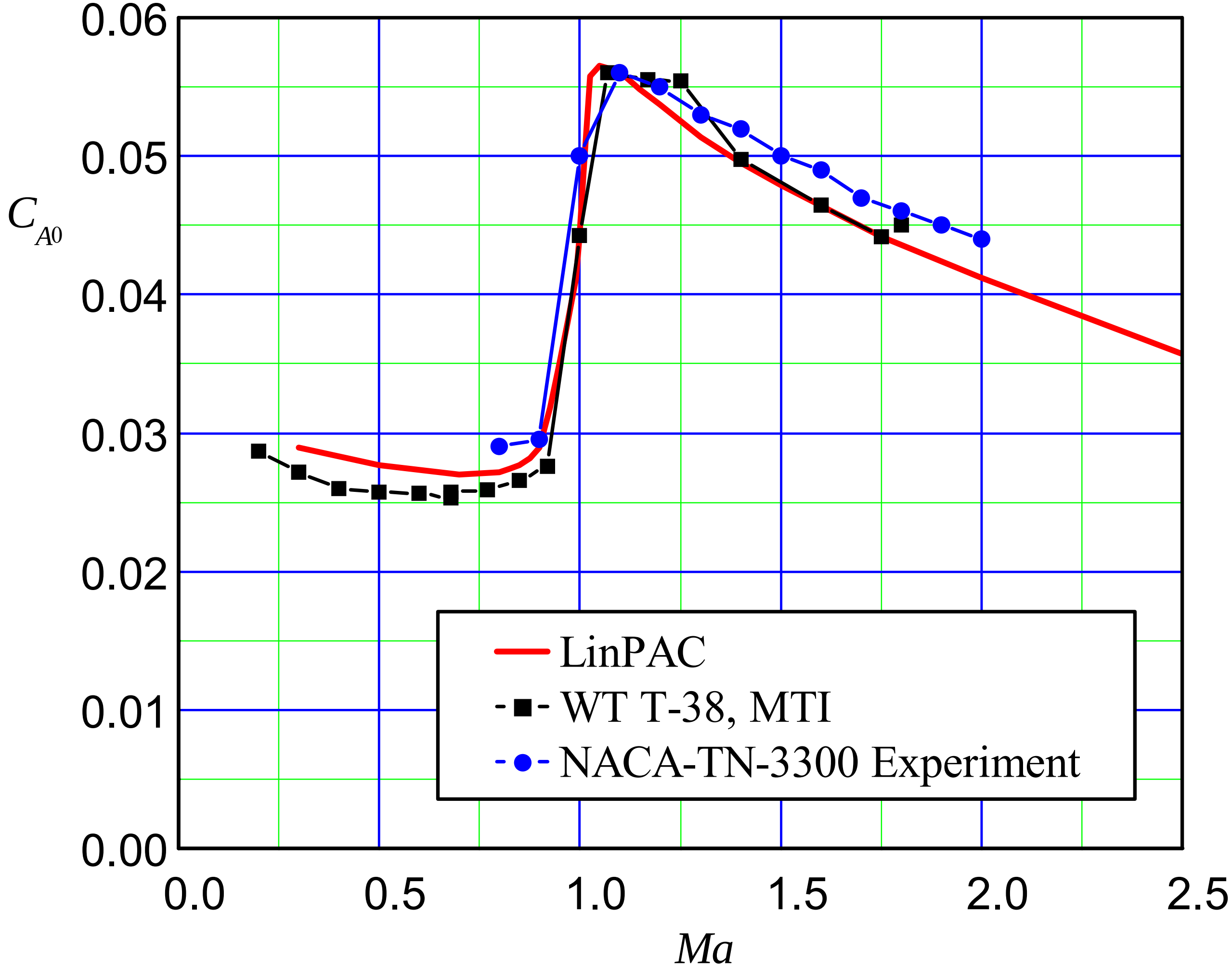
Damljanović, D., Vitić, A., Vuković, Dj.: Testing of AGARD-B Calibration Model in the T-38 Trisonic Wind Tunnel, Scientific-Technical Review,Vol.LVI,No.2,2006.

Comparison with Experiments – AGARD-B

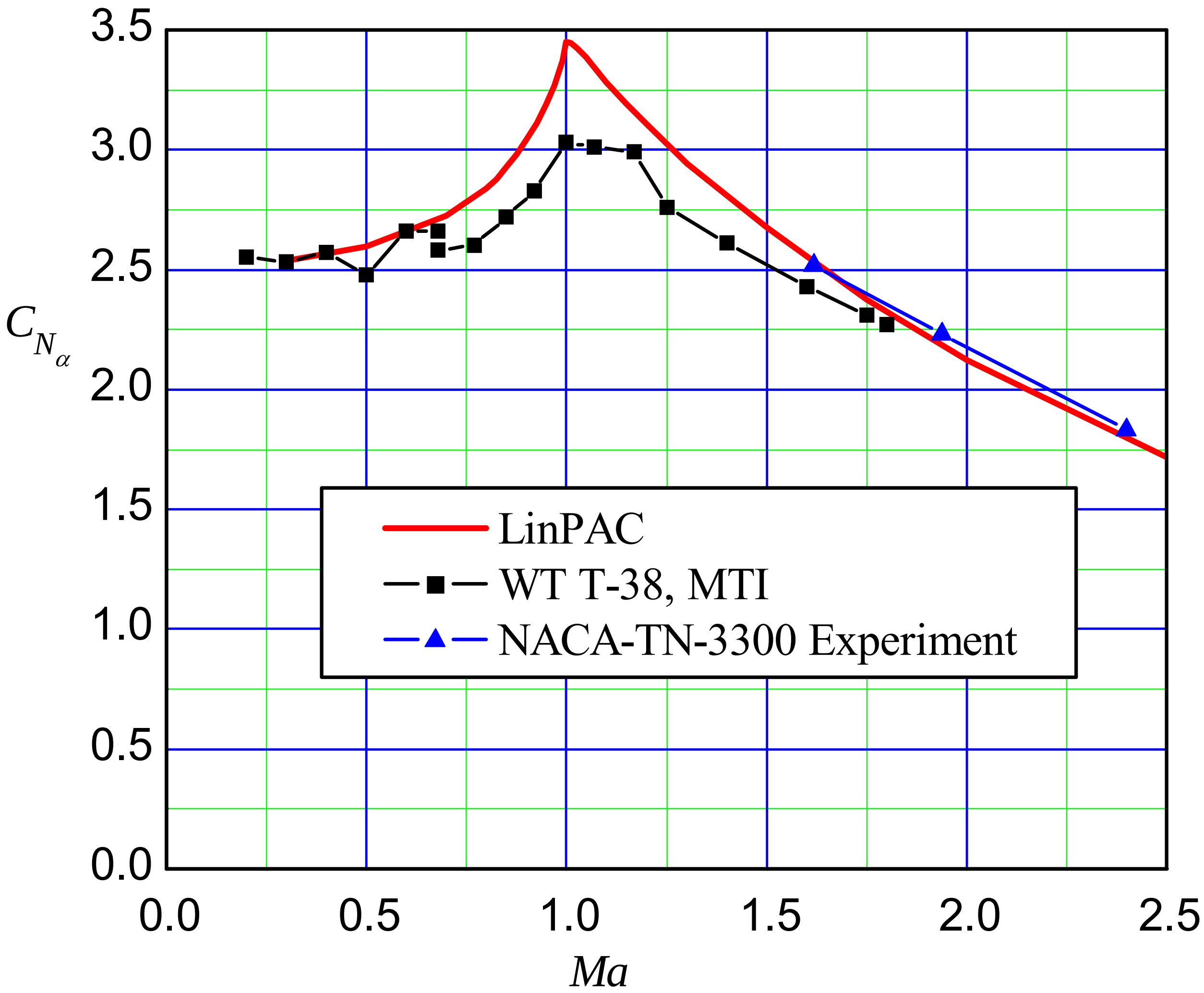
Sketch of AGARD-B Test model



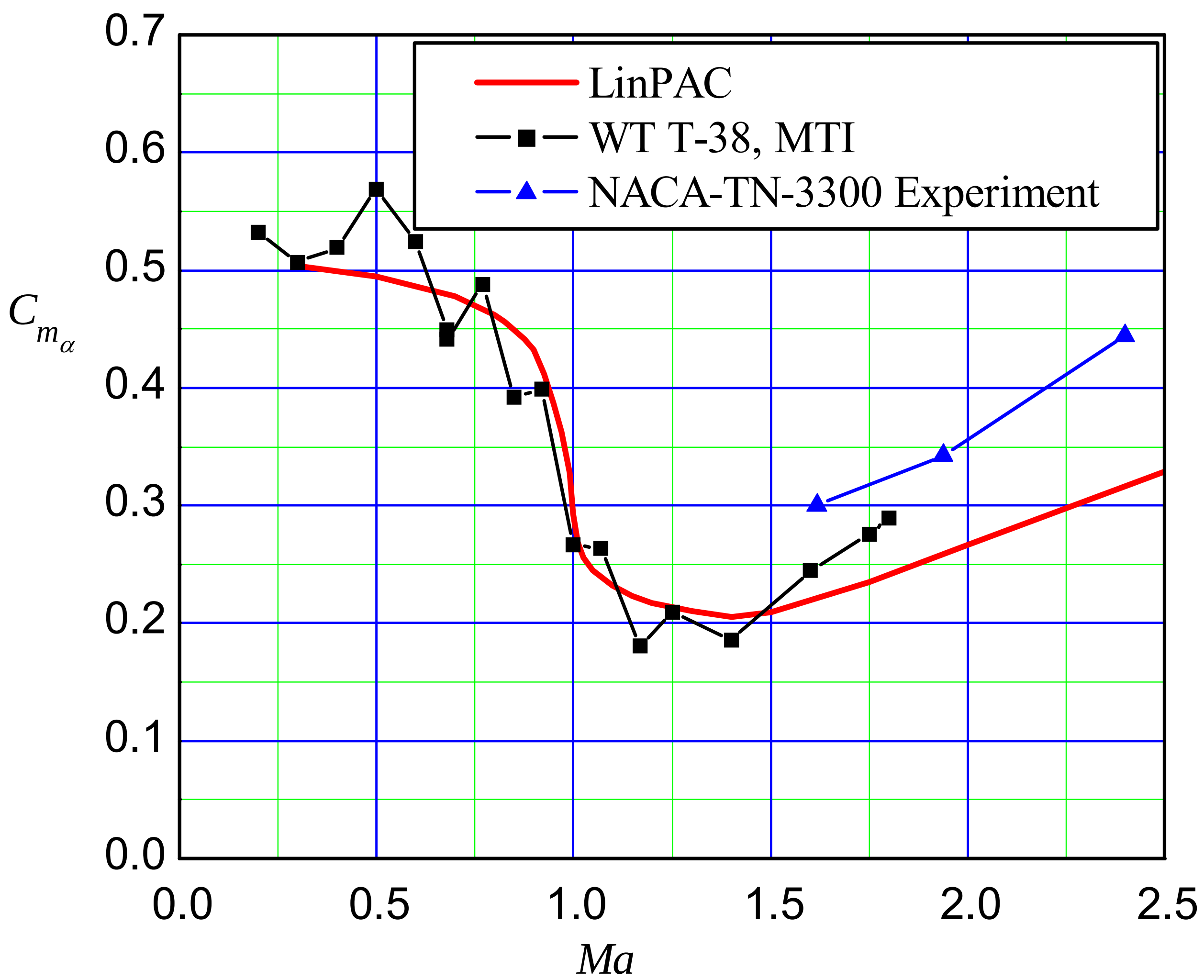
Comparison with Experiments – AGARD-B



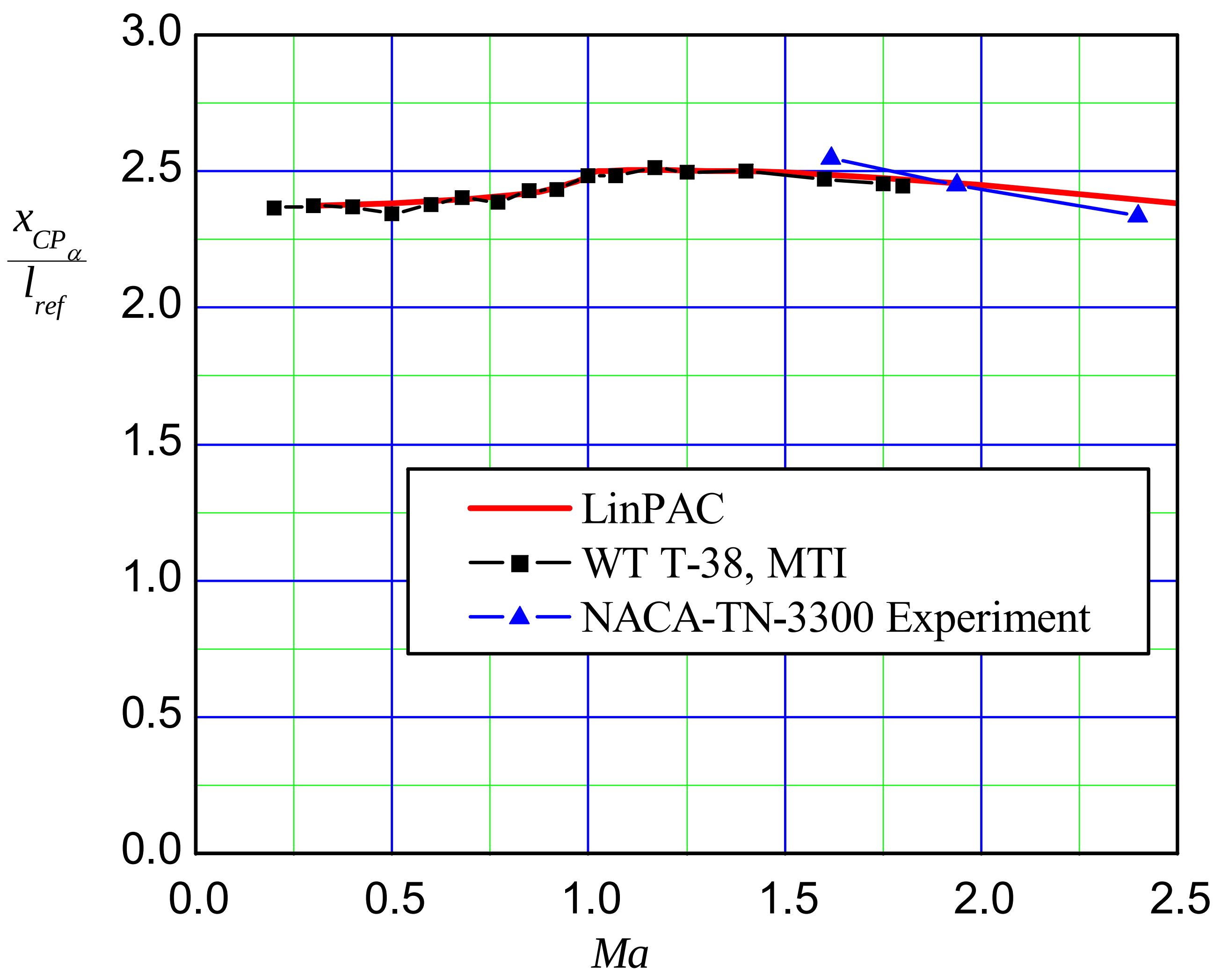
Comparison with Experiments – AGARD-B



Comparison with Experiments – AGARD-B



Comparison with Experiments – AGARD-B



Comparison with Experiments – SPARROW III

For the Sparrow model data were taken from:

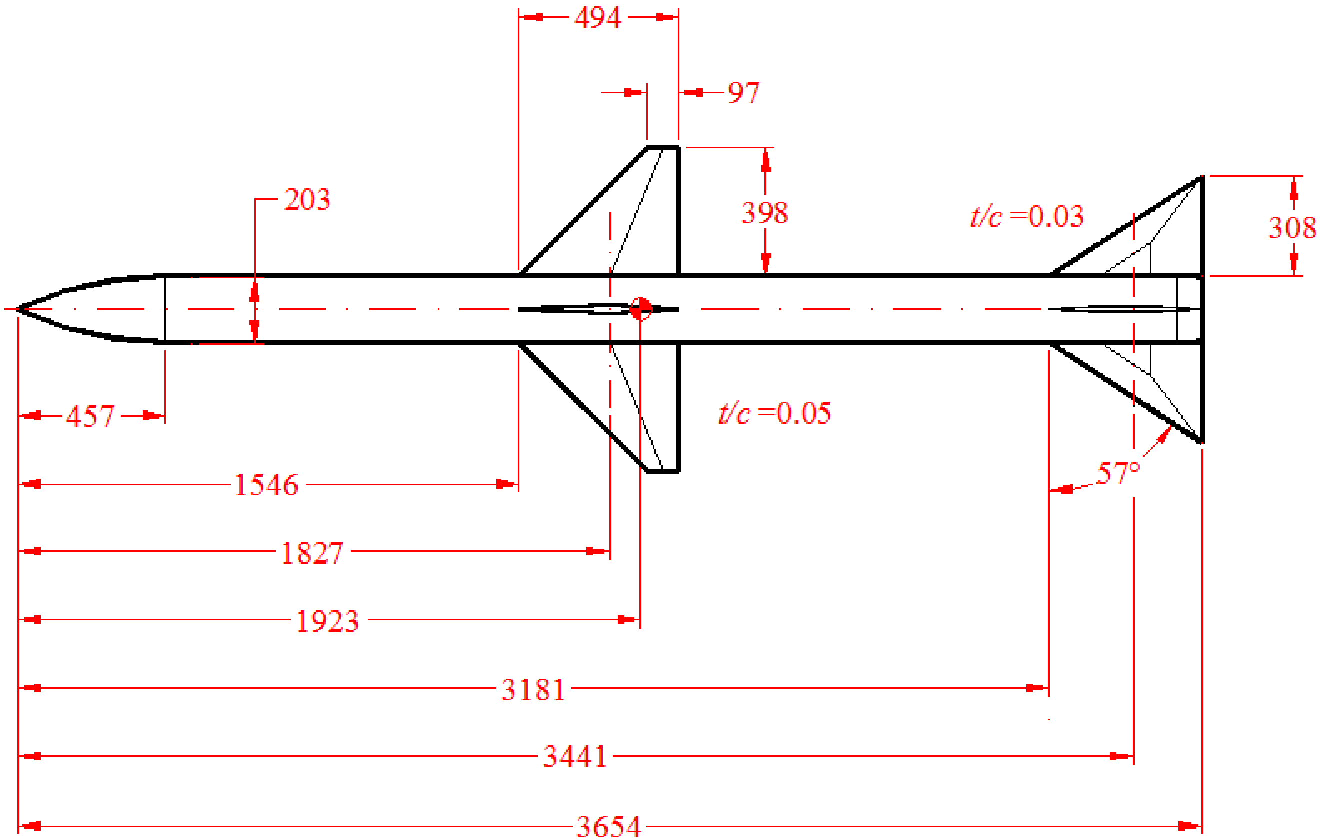
Monta, W. J.: "Supersonic aerodynamic characteristics of an air-to-air missile configuration with cruciform wings and in-line tail controls", NASA-TM-X-2666, 1972.

Monta, W. J.: “Supersonic Aerodynamic Characteristics of a Sparrow III Type Missile Model With Wing Controls and Comparison With Existing Tail-Control Results”, NASA, TP 1078, Nov. 1977.

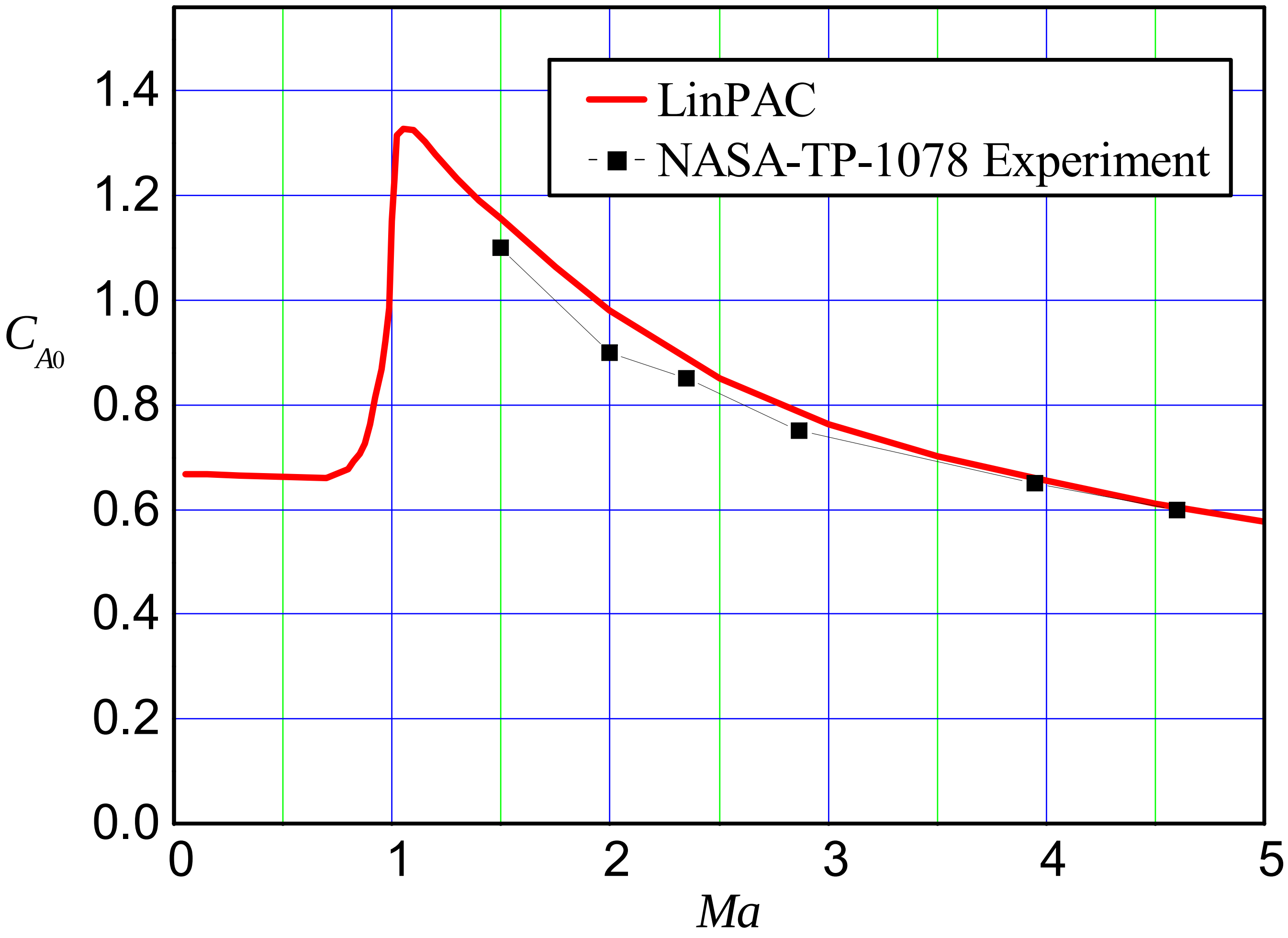
"Tail Control Sparrow Wind Tunnel Test at NASA/Ames Research Center", Raytheon Co., Raytheon Rept. BR-9105, Final Rept., Bedford, MA, April 1976.

Comparison with Experiments – SPARROW III

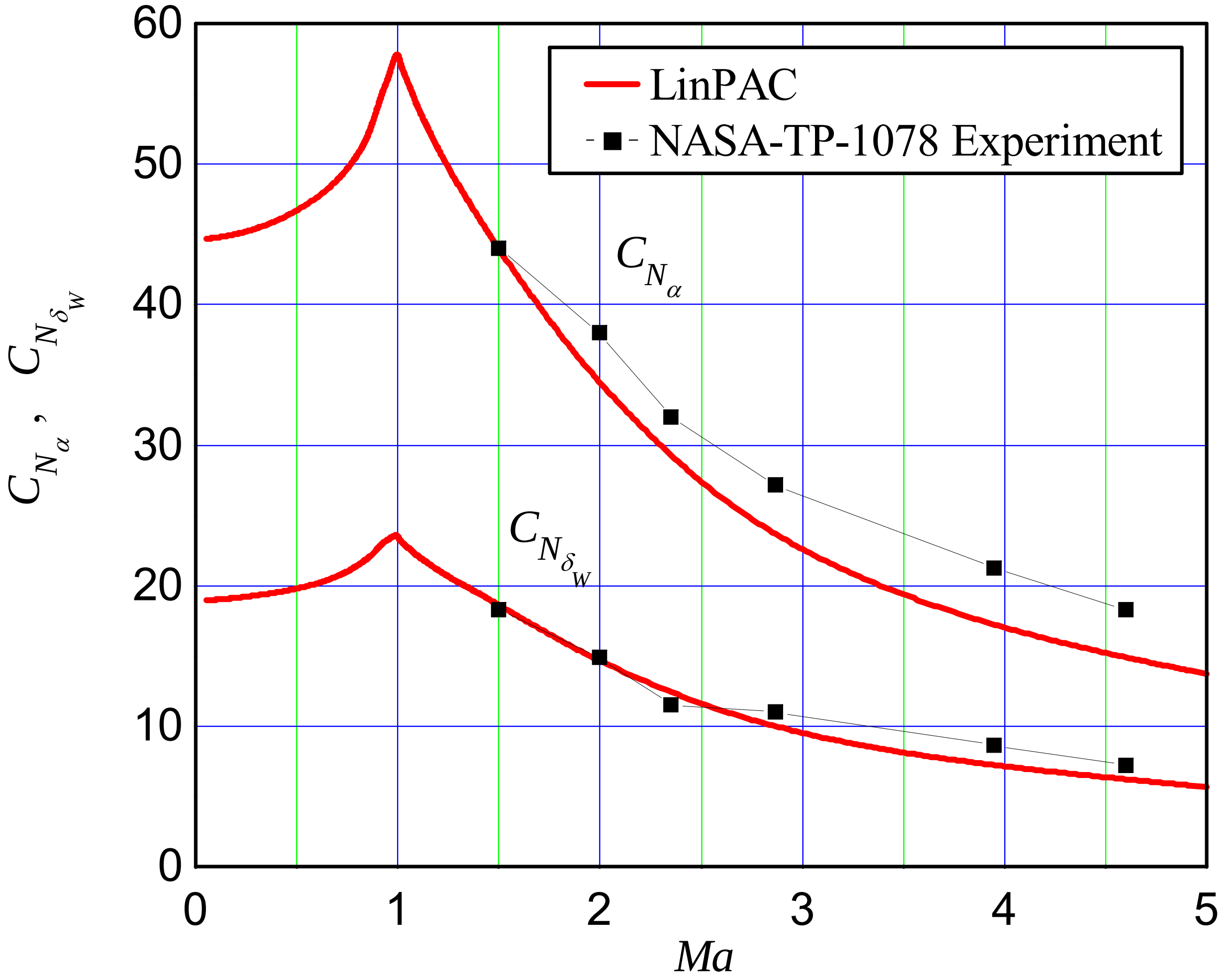
Sketch of Sparrow III missile



Comparison with Experiments – SPARROW III

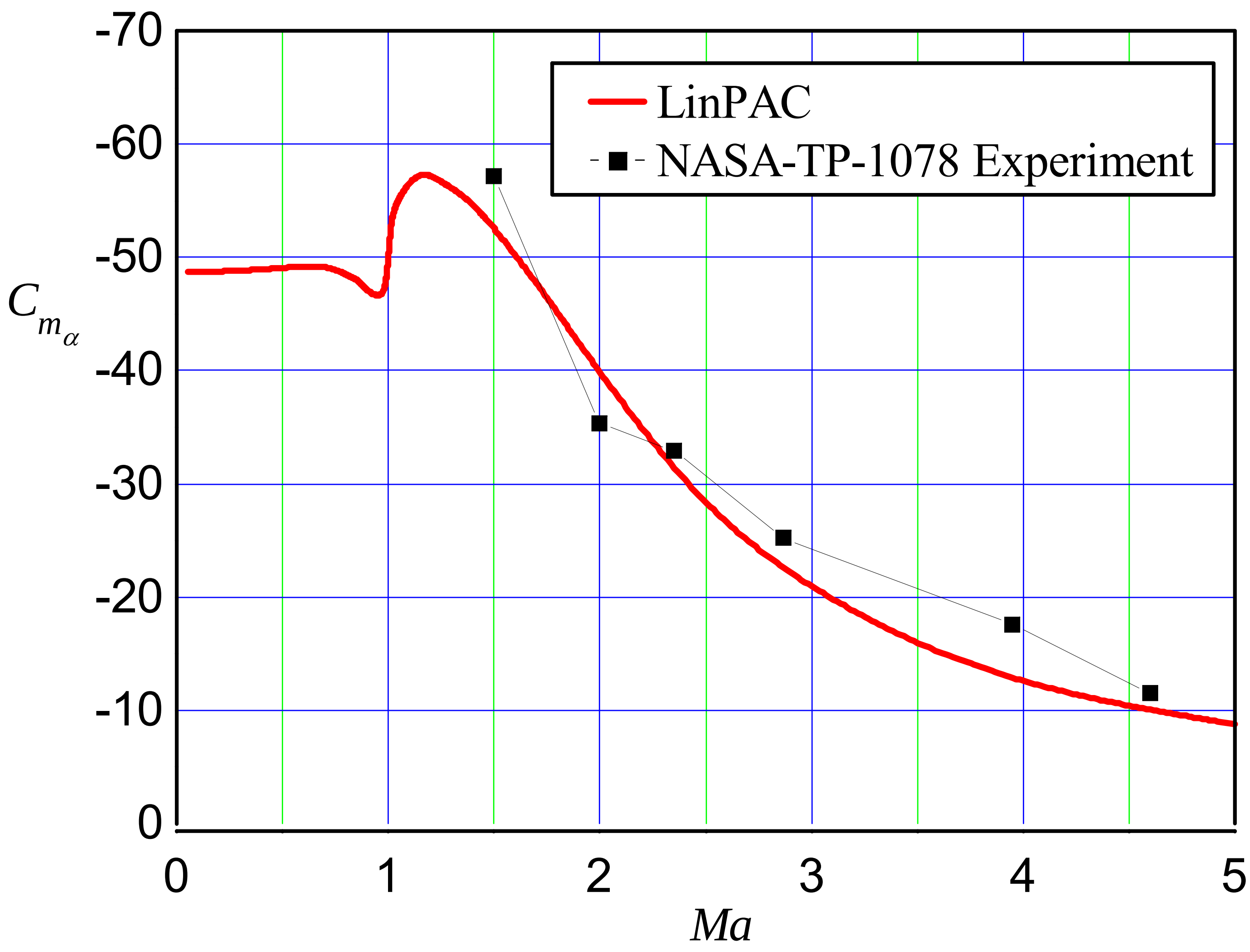


Comparison with Experiments – SPARROW III

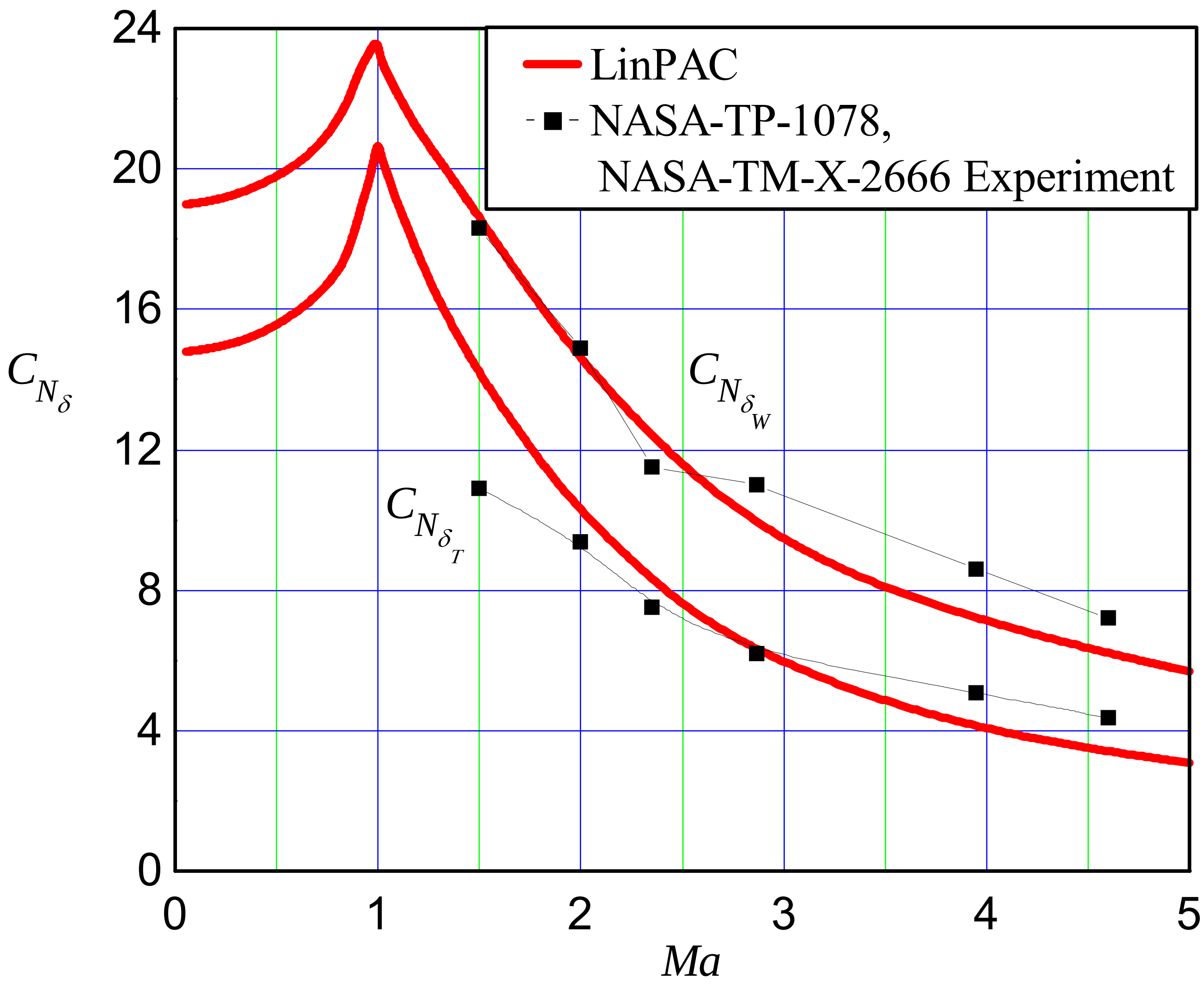


Notation on diagrams:
Subscript “W” – “Wing”
Subscript “T” – “Tail”

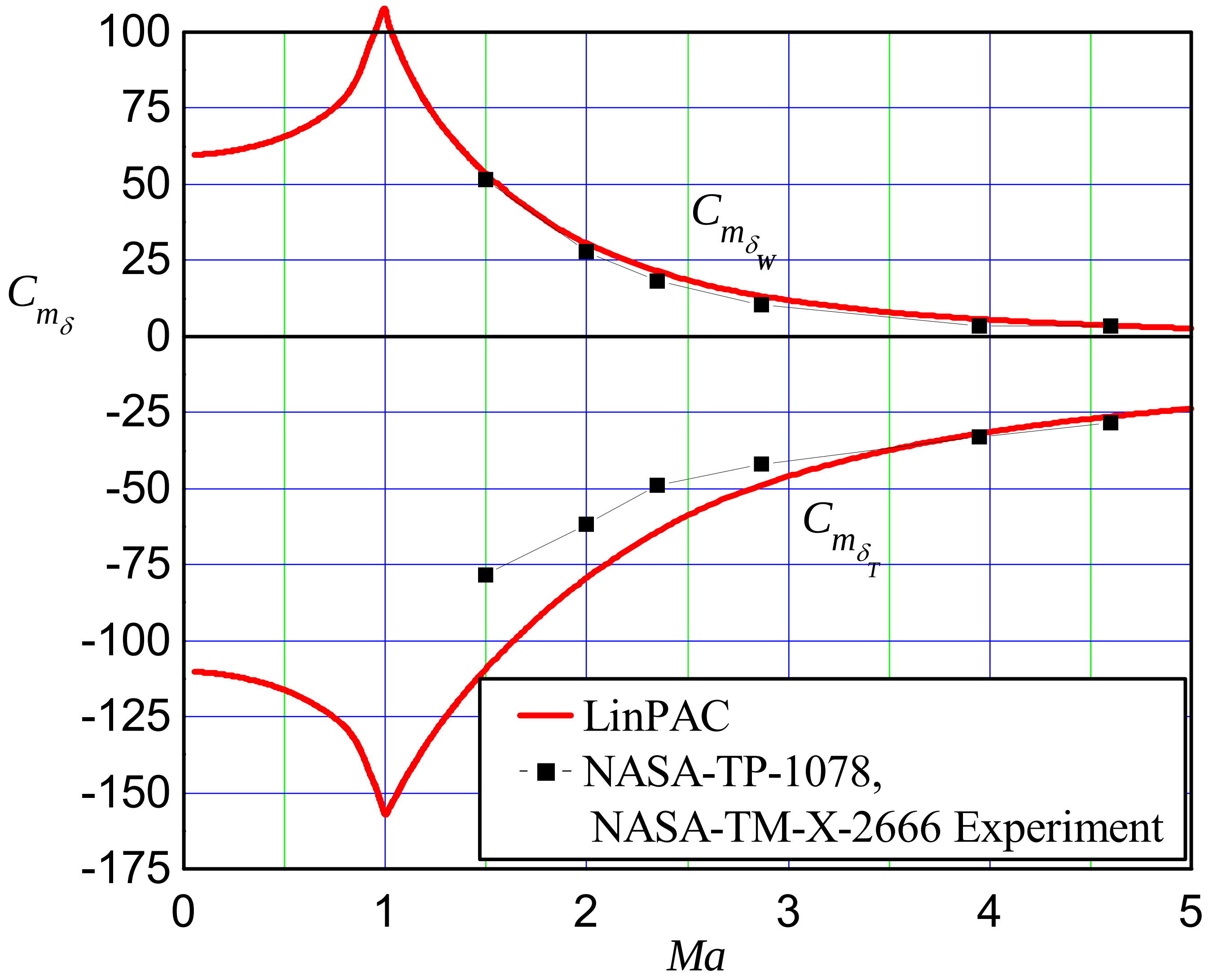
Comparison with Experiments – SPARROW III



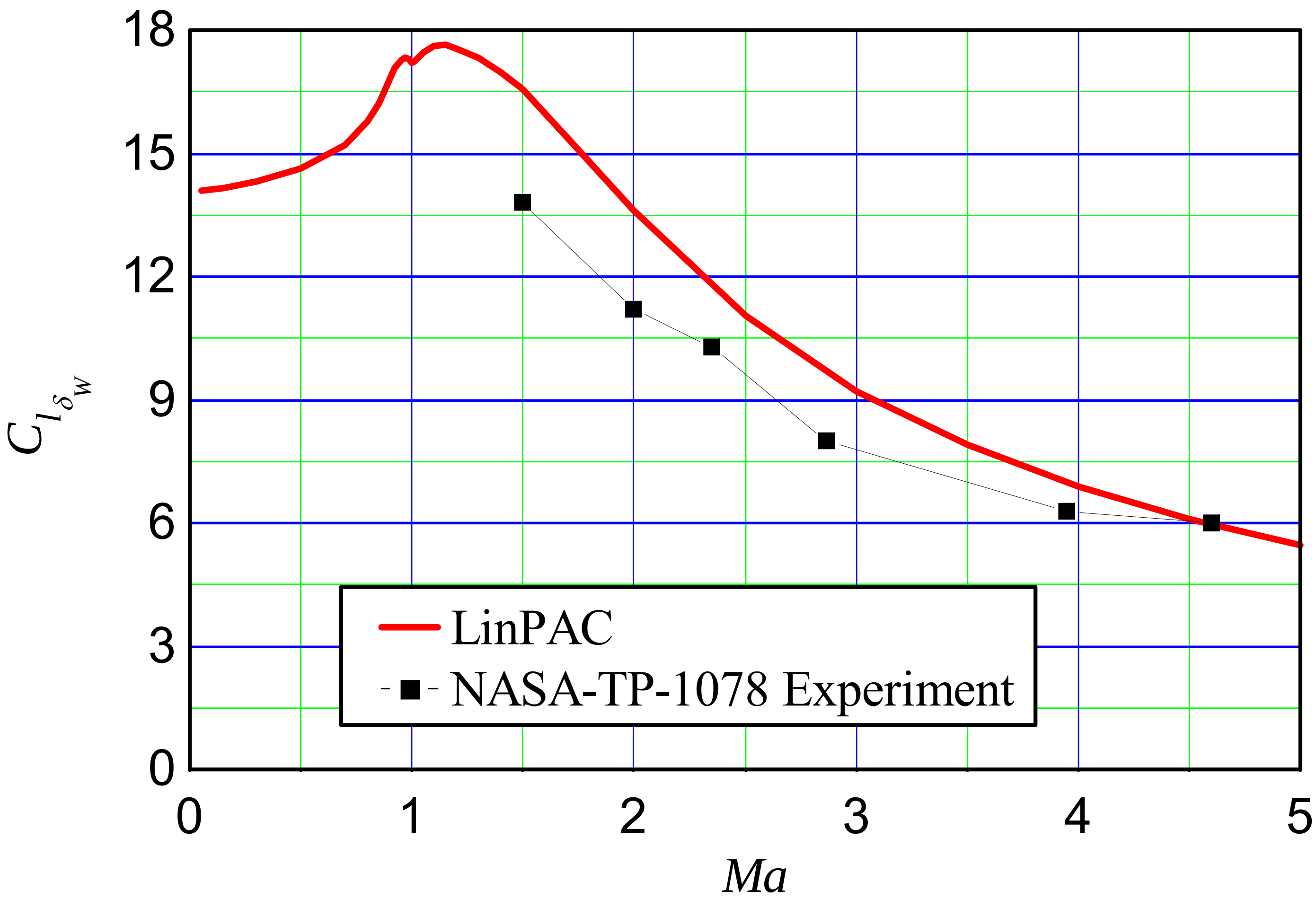
Comparison with Experiments – SPARROW III



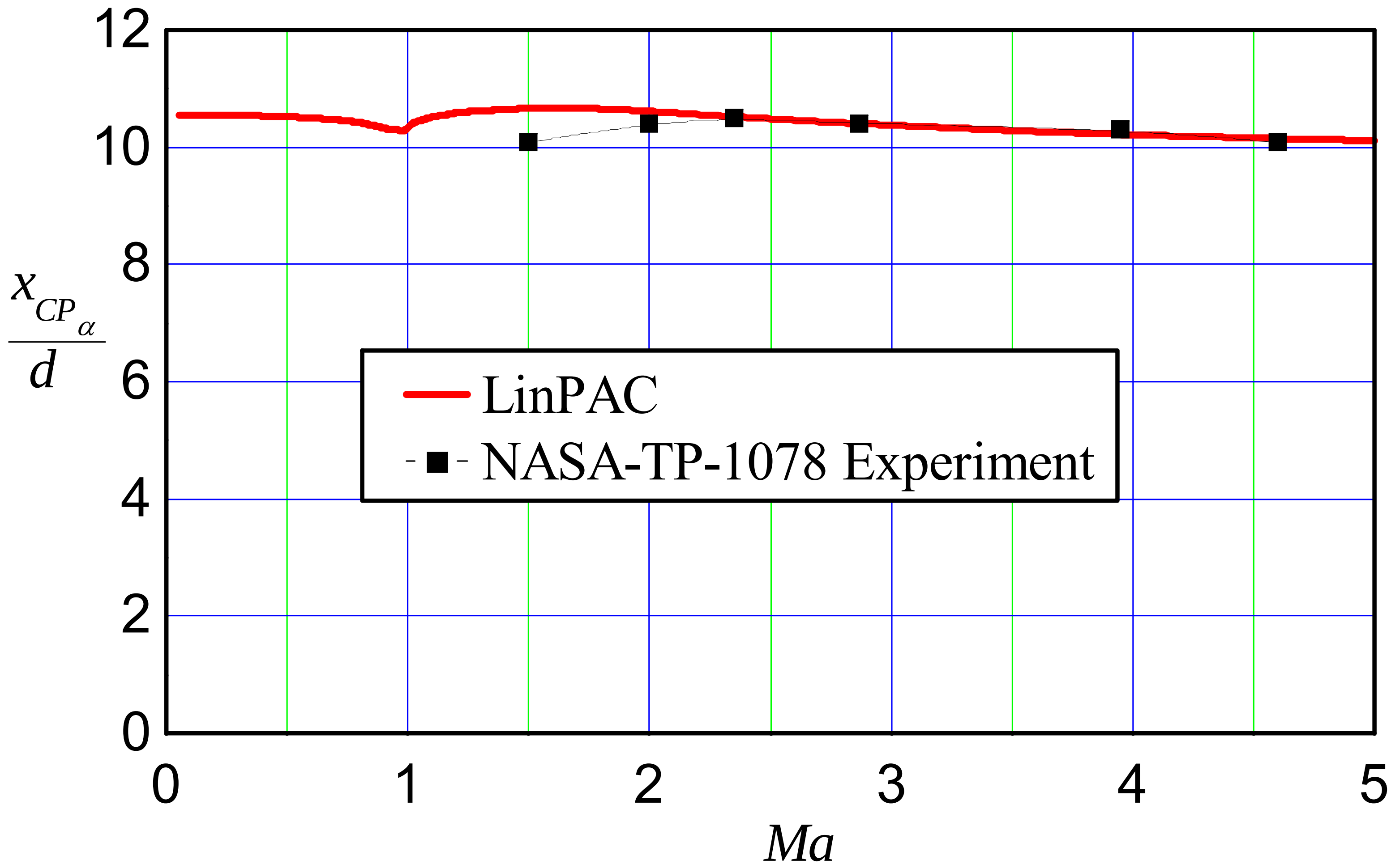
Comparison with Experiments – SPARROW III



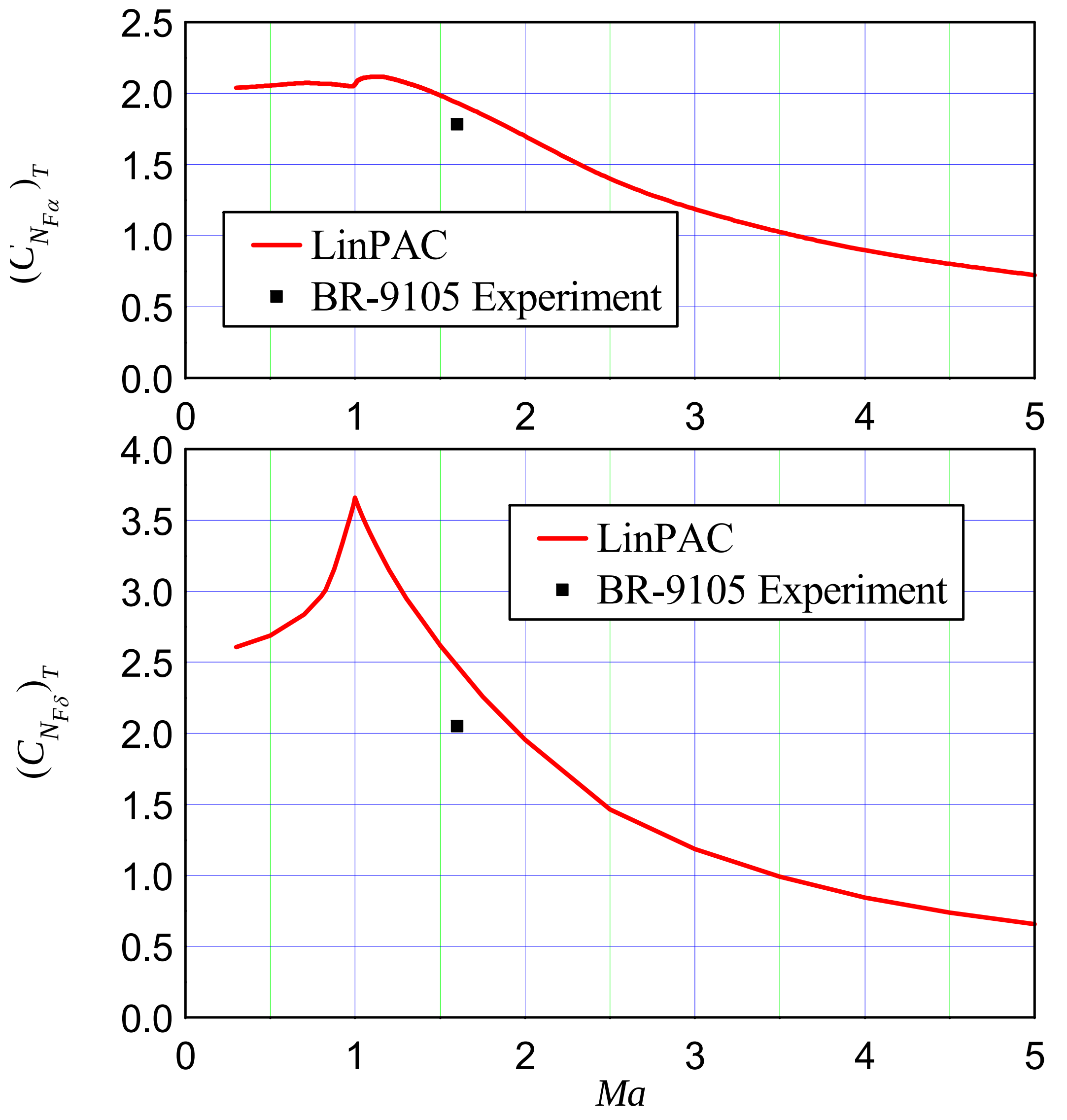
Comparison with Experiments – SPARROW III



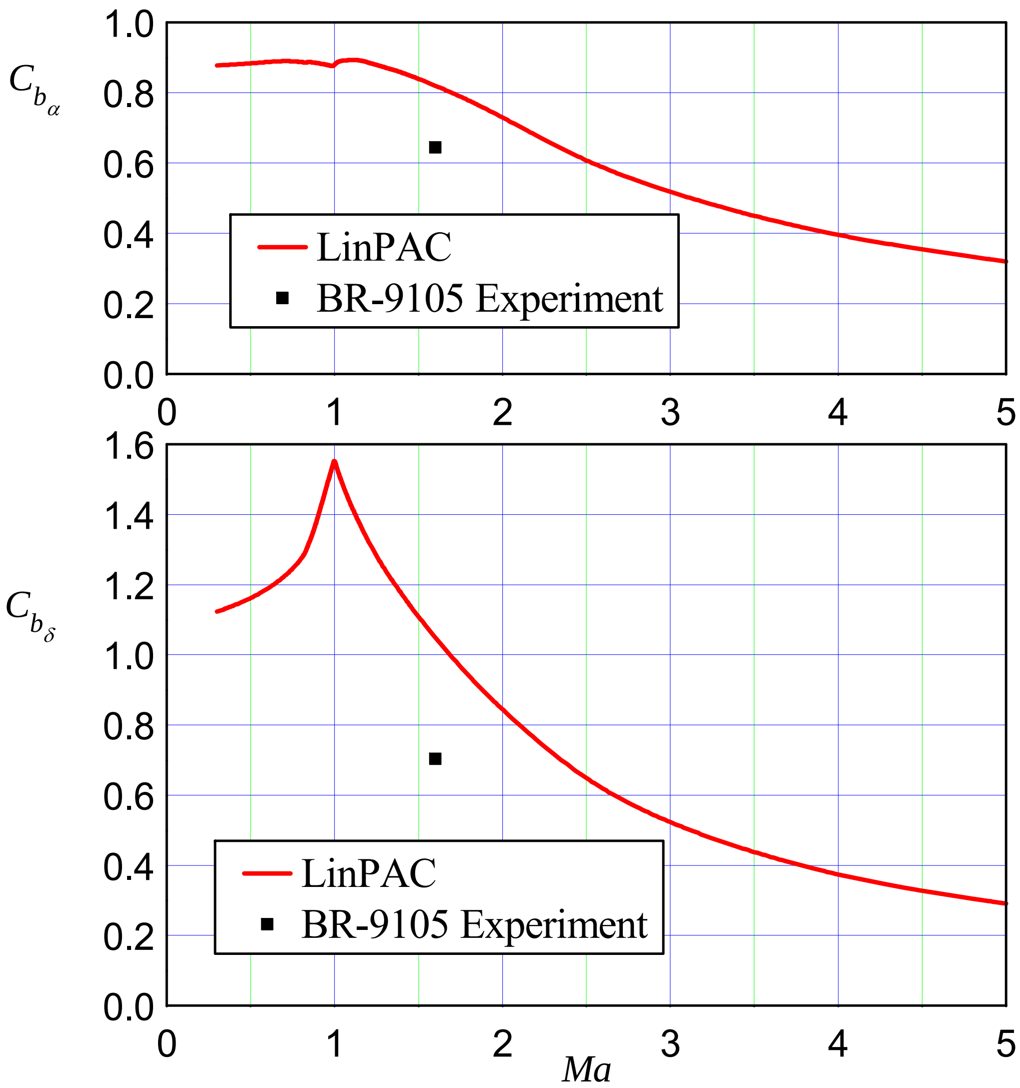
Comparison with Experiments – SPARROW III



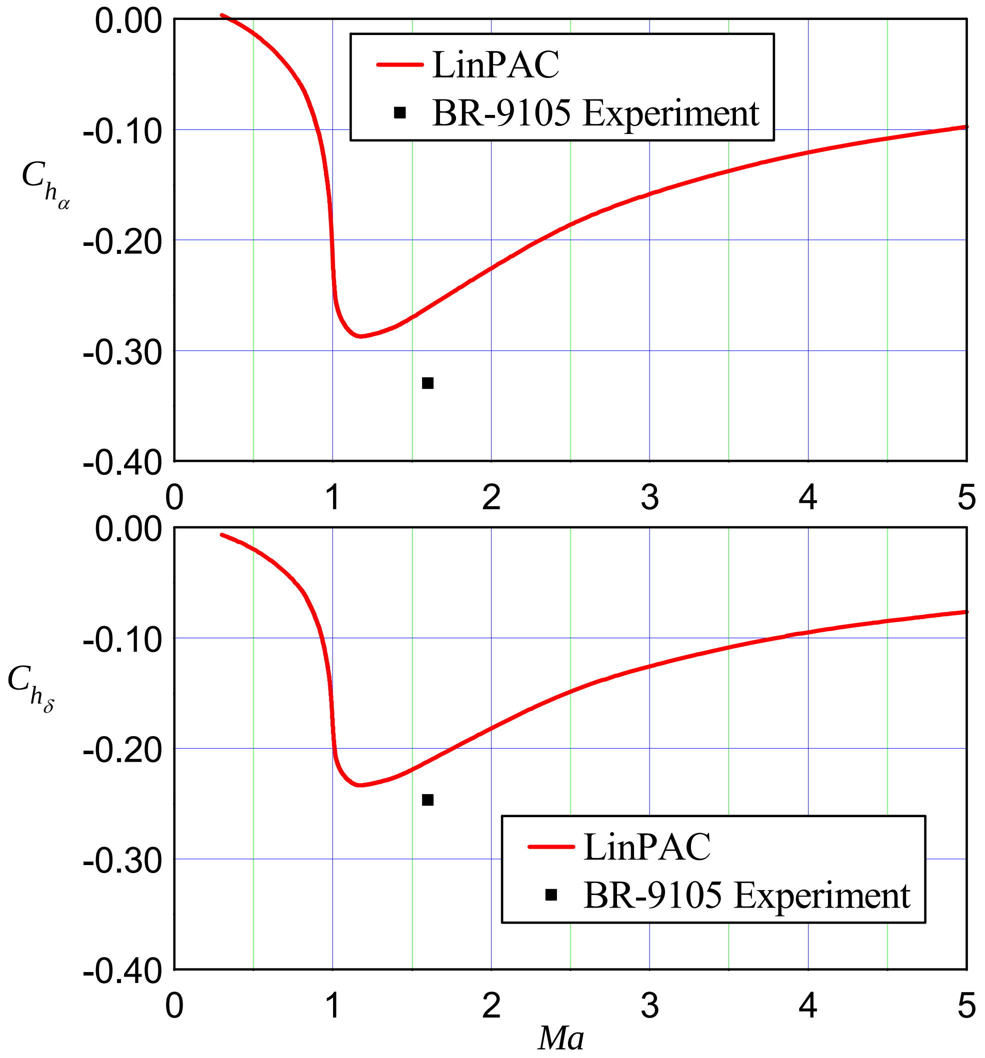
Comparison with experiments – SPARROW III



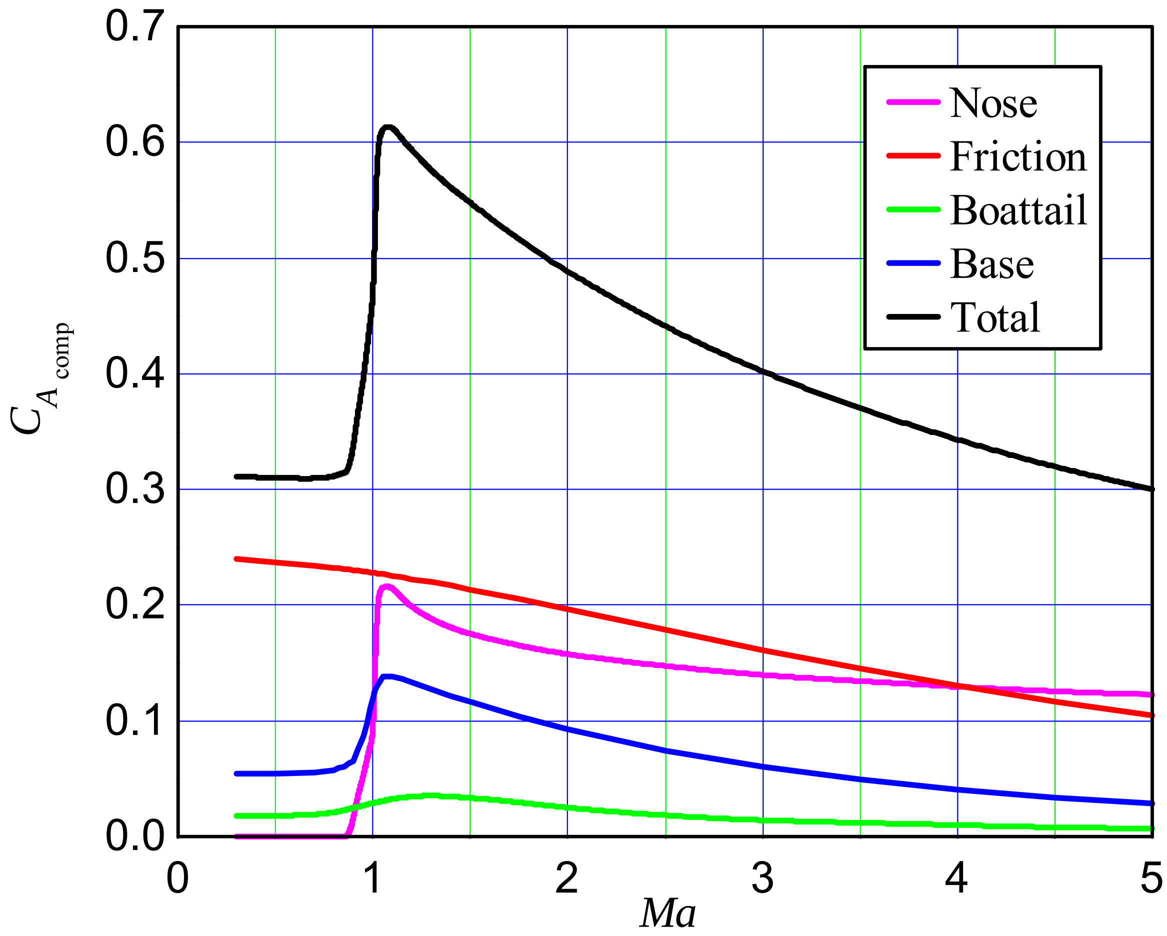
Comparison with Experiments – SPARROW III



Comparison with Experiments – SPARROW III



Sparrow III – Body alone AC



- Drag components of Sparrow III body alone with boattail d_b / d =0.85 and l_{bt} / d = 0.54.
- Data are printed in output file CA_comp.dat
- *Re*=0.2*10^6 = const to mach wind tunnel data.

Comparison with experiments – Basic Finner

For the Basic finner model data were taken from:

MacAllister, L. C.: “The Aerodynamic Properties of a Simple Non-Rolling Finned Cone-Cylinder Configuration Between Mach Number 1.0 and 2.5”, BRL Report No. 934, May 1955.

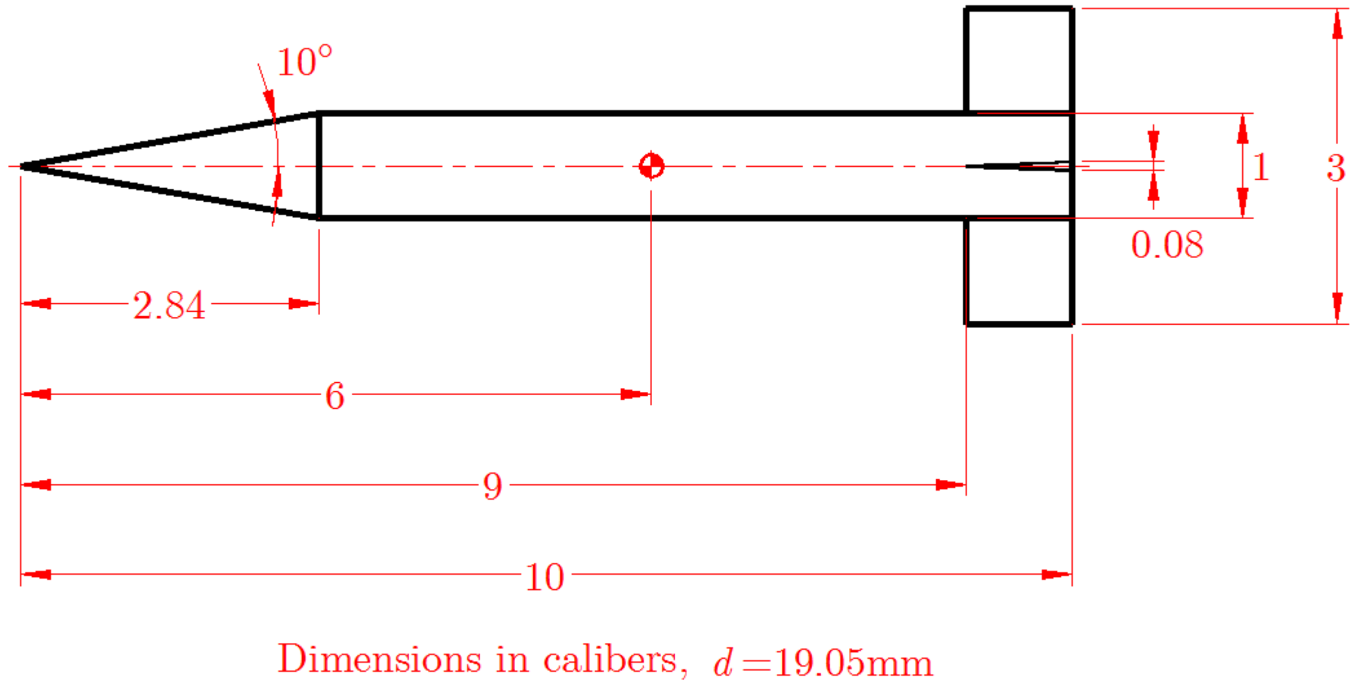
Shantz, I. and Graves, R.T.: "Dynamic and Static Stability Measurements of the Basic Finner at Supersonic Speeds", NAVORD Report 4516, 1960.

Regan, F. J.: "Roll Damping Moment Measurements for the Basic Finner at Subsonic and Supersonic Speeds," NAVORD Rept. 6652, June 1964.

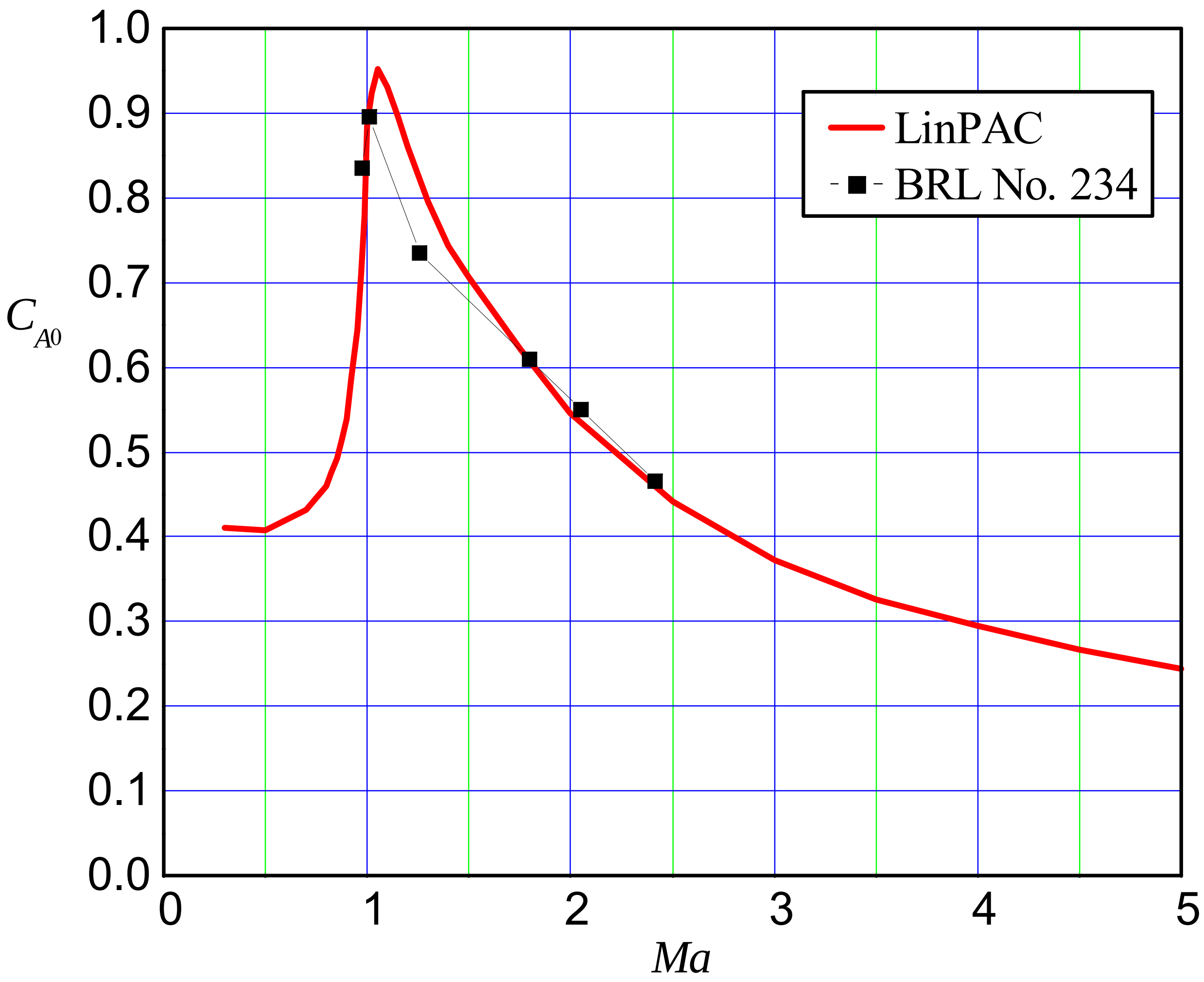
Murthy, H.S.: "Subsonic and Transonic Roll Damping Measure-ments on Basic Finner" AIAA-82-4042. Journal of Space-craft and Rockets, VOL. 19, NO. 1, Jan.-Feb. 1982., pp. 86-87.

Comparison with Experiments – Basic Finner

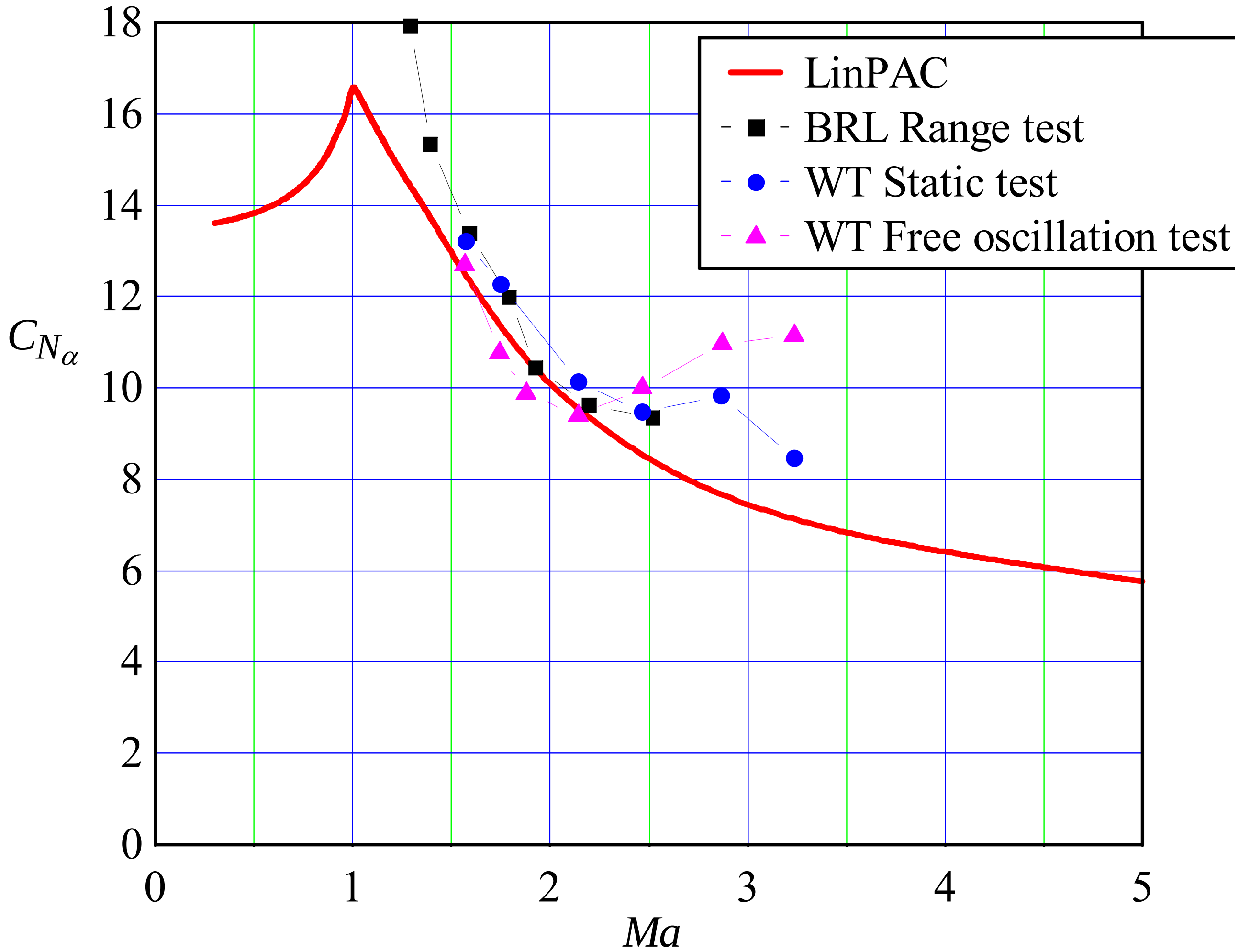
Sketch of the Army-Navy Basic Finner test model



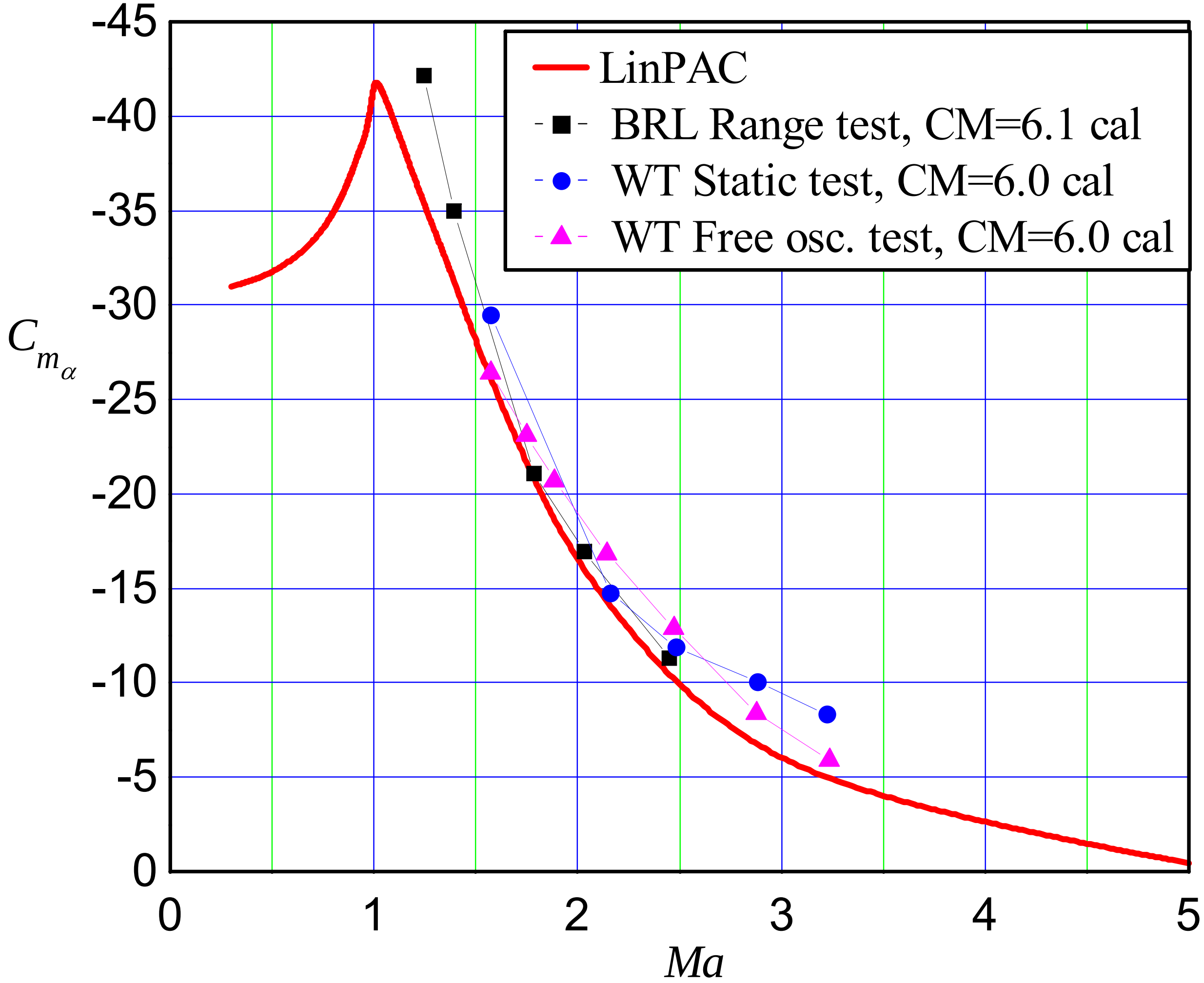
Comparison with Experiments – Basic Finner



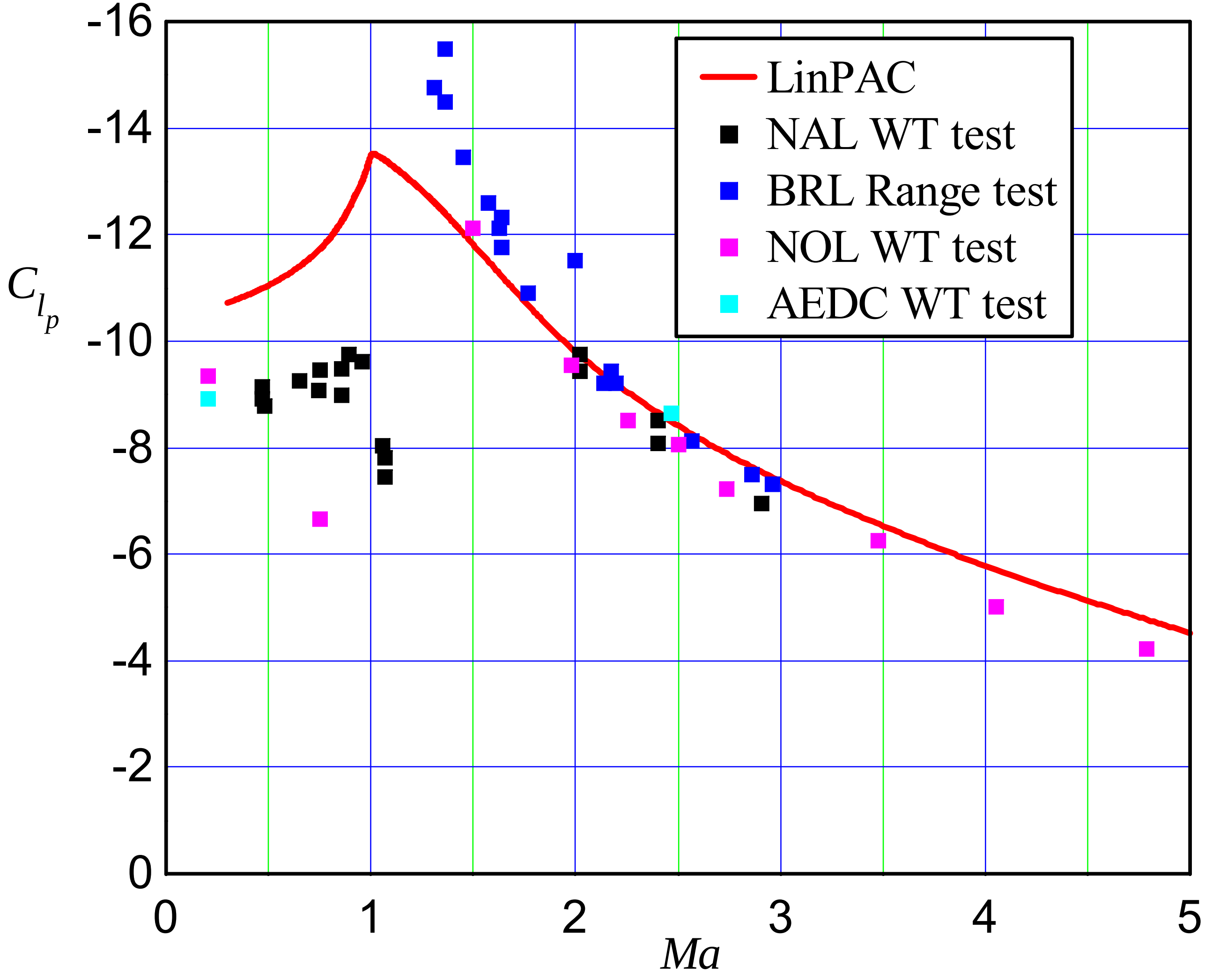
Comparison with Experiments – Basic Finner



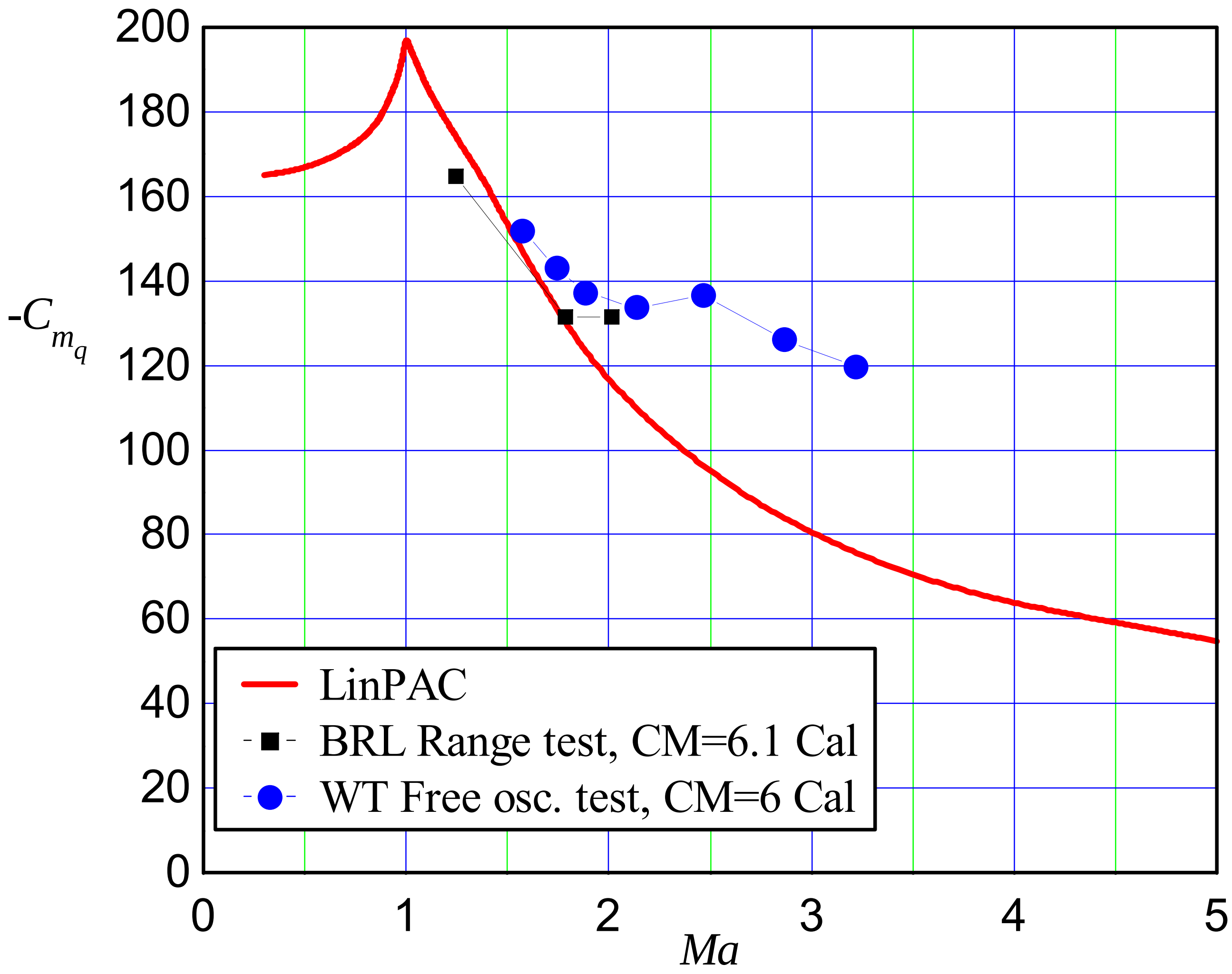
Comparison with Experiments – Basic Finner



Comparison with Experiments – Basic Finner



Comparison with Experiments – Basic Finner



Comparison with Experiments – Basic Finner