Report on the usage of the Generic Aerodata Model

Table of contents — page

DISCLAIMER

1 GENERIC AERODATA MODEL, GENERAL

The base for the generic configuration is a delta wing fighter/attack aircraft with a nose-wing (canard), as in fig 1 below. The control surfaces consist of fully movable nose-wings, four leading edge flaps and four elevons, (combined flaps, elevators and ailerons). There is also a conventional rudder for lateral stability.
Reference data (geometry), mass and inertia data are treated later in this document.

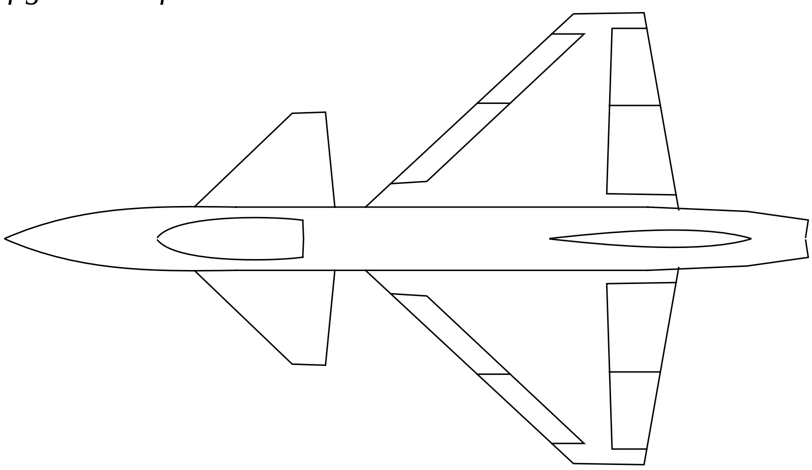
As a result of the choice of configuration, the aerodata model contains a number of non-linear effects such as: Mach number, transonic, dynamic effects at high angles of attack etc.

The aerodata model basically consists of **Aerodata tables** and **Fortran routines** for adding the different aerodynamic contributions into complete force, moment and hinge moment coefficients.
Routines for the reading (input) of those aerodata tables are also provided, along with routines to do linear interpolation in said tables.

Inputs to the aerodata routine are control surface deflections (as above) and flight conditions such as Mach number, altitude, angle of attack etc.
Other inputs are: landing gear in/out, nosewheel door open/closed, airbrakes in/out and engine airflow mass ratio (0.0 -> 3.0).

Outputs from the aerodata model are non dimensional force, moment and hinge moment coefficients, in the aerodata reference point. Forces and moments in the aircraft centre of gravity need to be calculated separately.
The reference point is the fix point (coordinates) on the model to which all aerodata are referred (measured). This point normally differs from the aircraft c.g and thus the results from the aerodata routine have to be transformed accordingly before used in a simulation model. How this is done is outlined later.

Figure 1: Configuration of the Generic Aerodata Model



2 GENERAL DATA AND CONVENTIONS

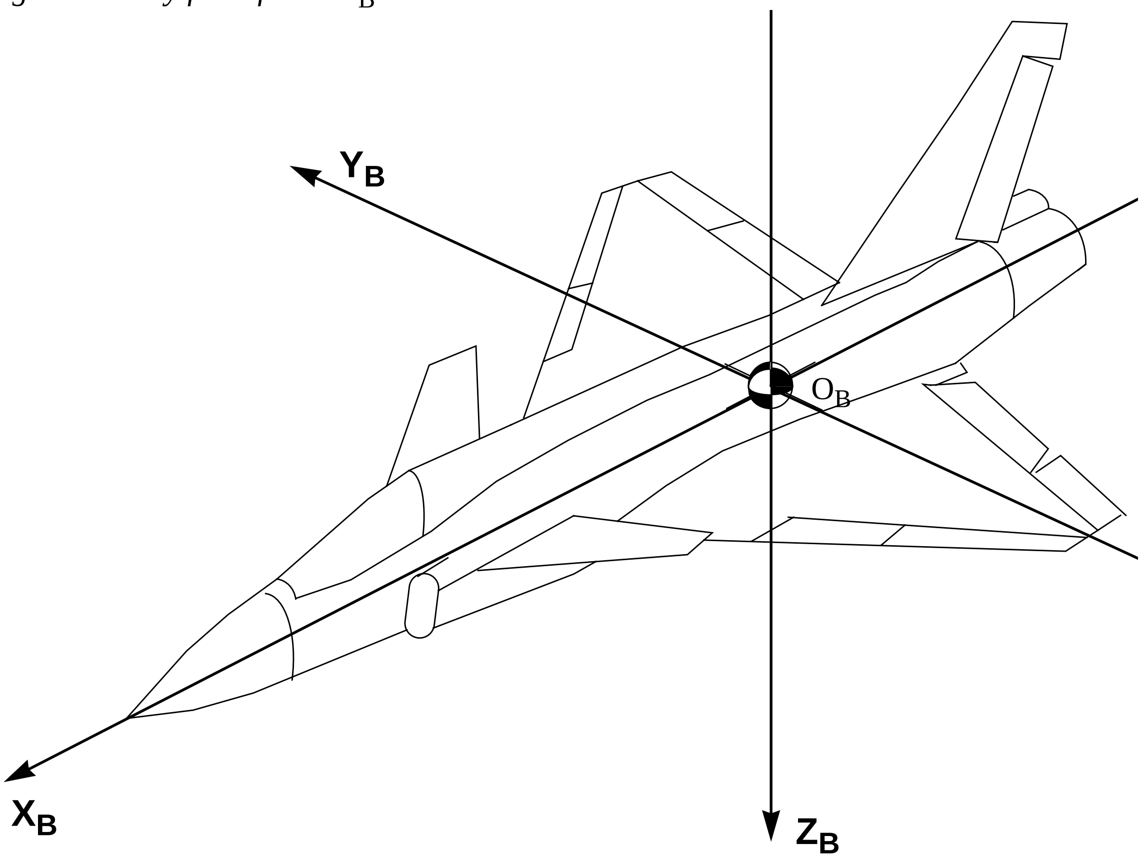
Max allowable deflection for control surfaces:

Canards	-55 -> +25 deg
Elevons	-30 -> +30 deg
Rudder	-25 -> +25 deg
Lead.edge.flap	-10 -> +30 deg
Airbrakes	max 55 deg

The overall flight envelope is defined according to five diagrams in *appendix 1*, p 10-14.

As seen below in the body fixed frame S_B, O_B is located in the aircraft centre of gravity.
The signs of all control surface deflections, with one exception as below, follow the right-hand rule[1].
The exception signwise is the leading edge flap.
The airbrakes deflect into the free stream, max setting angle as above.
States to define a flight condition such as angle of attack α, sideslip β, flight path angle γ etc are defined in the conventional manner according to *reference 1*.

Figure 2: Body fixed frame S_B



1 Positive rotation, assuming hinge line parallell to resp. S_B axis.

3 REFERENCE (GEOMETRY)- MASS- AND INERTIA DATA

The geometry reference data used to convert force and moment coefficients into forces and moments is given in the file: **ad_coeff.const** which is included in the aerodata model.

Table 1 below gives a suggestion on plausible combinations of mass and inertia data, in frame S_B, for different amounts of fuel, to be used for dynamic simulations.

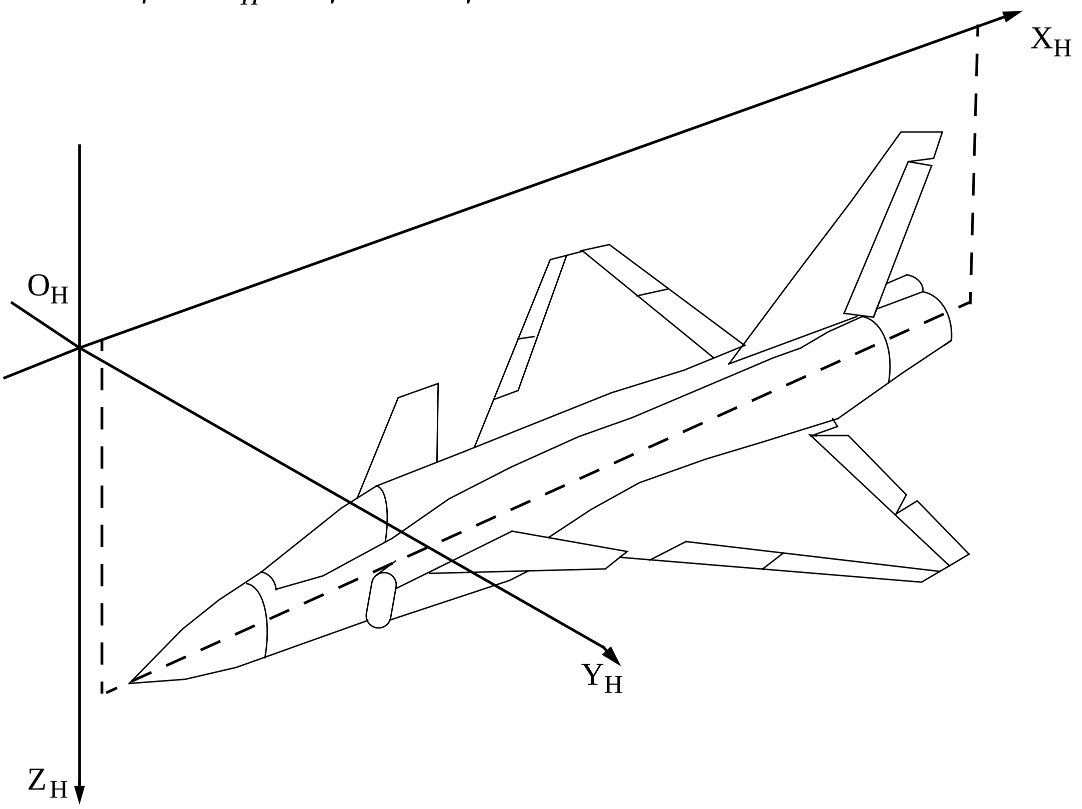
Table 1: mass and inertia data

Fuel (%)	**mass (kg)**	I_x **(kgm^2)**	I_y **(kgm^2)**	I_z **(kgm^2)**	I_{xz} **(kgm^2)**
100	10000	24000	84000	107000	2300
60	9100	21000	81000	101000	2500
30	8400	19000	79000	98000	2500

4 REFERENCE FRAMES FOR AERODATA AND AIRCRAFT

The aircraft is defined in a main frame S_H according to figure 3 where all x- and z-coordinates are positive.

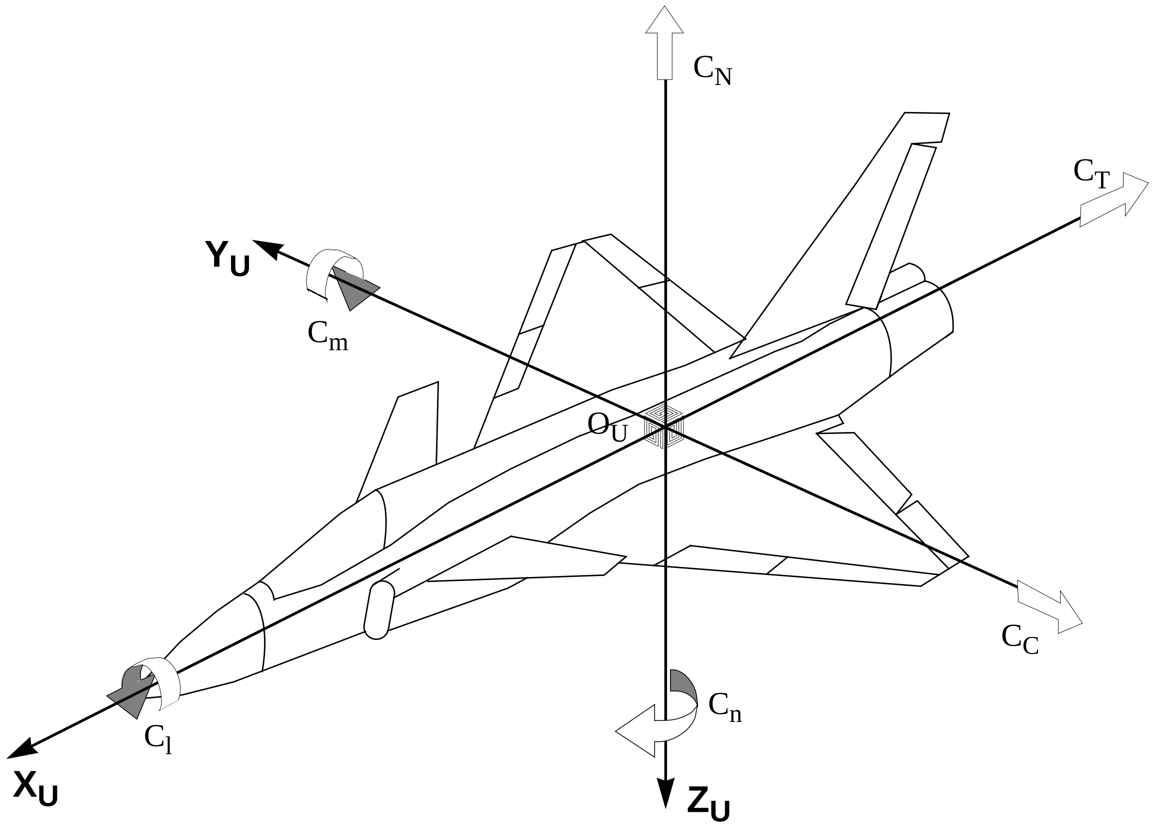
Figure 3: Main frame S_H to define aircraft



Aerodata is defined in another frame S_U according to figure 4, where also the aerodynamic forces and moments are determined. The arrows indicate positive forces and moments.

- Normal force C_N
- Tangential force C_T
- Side force C_C
- Pitching moment C_m
- Rolling moment C_l
- Yawing moment C_n

Figure 4: Frame S_U to define aerodata

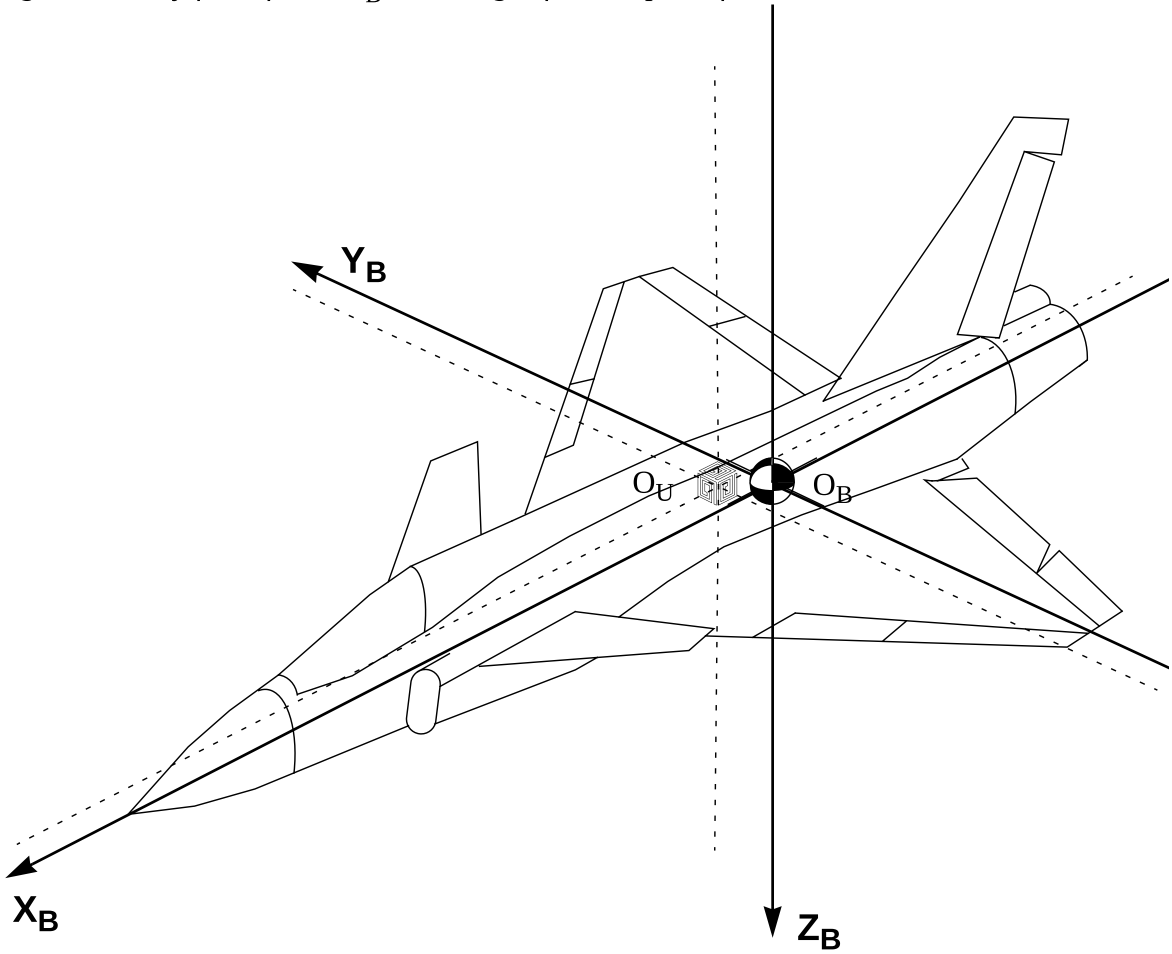


Expressed in the main frame S_H, the position for the reference point O_U in frame S_U is given by:

$$\bar{r}^{H}_{UH} = \begin{bmatrix} r^{H}_{xu} \\ r^{H}_{yu} \\ r^{H}_{zu} \end{bmatrix} \qquad \text{(meter)}$$

For the Generic Aerodata Model, the reference point r_x is determined to be 25% of the mean aerodynamic cord (MAC), calculated in the usual manner.
In practice though, no absolute coordinates are needed since transformation of forces and moments, from frame S_H to frame S_B, only is done on the *relative* distance between the points O_U and O_B. This is indicated in figure 5 below.

Figure 5: Body fixed frame S_B including reference point for aerodata



It is up to the user to determine the position of a/c centre of gravity (c.g), and thus get the proper deviation between O_U and O_B, in order to correctly transform aerodata, given in frame S_U, into aircraft c.g (O_B).
Suggested max deviation from r_x as defined above, is ± 0.3 m.

5 TRANSFORMATION OF AERODATA

How aerodynamic coefficients in the frame S_U is transformed into forces and moments (with dimension) in a/c centre of gravity, c.g, is assumed to be well-known. Nevertheless, a short summary is given below.

Reference data (areas, lenghts, span, chords) are all defined in the file: **ad_coeff.const**.

Furthermore we have q = dynamic pressure = $\rho v^2/2$ (N/m^2)
where ρ = density of the air (kg/m^3)
and v = aircraft speed (m/s).

We thus get:

N = normal force = $C_N * q * S_{ref}$ (N)

T = tangential force = $C_T * q * S_{ref}$ (N)

C = side force = $C_C * q * S_{ref}$ (N)

MY = pitching moment = $(C_m - C_N*X_{cg} + C_T*Z_{cg}) * q* Sref * Cref$ (Nm)

MX = rolling moment = $(C_l - C_C*Z_{cg} + C_N*Y_{cg}) * q * S_{ref} * B_{ref}$ (Nm)

MZ = yawing moment = $(C_n + C_C*X_{cg} - C_T*Y_{cg}) * q * S_{ref} * B_{ref}$ (Nm)

where X_{cg}, Y_{cg} and Z_{cg} are <u>deviations,</u> <u>with signs</u>, to c.g as discussed earlier.

From C_N and C_T above we can also define the lift- and drag coefficients:

$$C_L = C_N * \cos(\alpha) - C_T * \sin(\alpha)$$

$$C_D = C_N * \sin(\alpha) + C_T * \cos(\alpha)$$

where α = angle of attack

Hinge moments are calculated in a straight forward manner, using the correct reference area and chord for each control surface as defined in file: **ad_coeff.const.**

6 IMPLEMENTATION OF THE AERODATA MODEL

The Generic Aerodata Model, consisting mainly of Fortran routines and aerodata tables, is to be linked together with the user's own aircraft model, containing control system, engine model, equations of motion, I/O-routines etc.

For this reason, the aerodata model is completely open and must be compiled before linked into a libraryfile, which in turn is linked into the aircraft model as above.

The technique to link a complete model obviously varies with computer platform, compiler etc.
One example of how to do this is given in the so called **Makefile**, used in a UNIX environment, which is provided in the model. This file compiles and links the aerodata package into a library file called **gam.a**.
When creating your own simulation model, this file (gam.a) is in turn linked in a similar way with the user's other object files. If the file `gam.a` is put elsewhere than the current directory, please remember to give the full path, such as:
`LIBS = /usr/lib/gam.a`
Depending on computer platform, it may also be necessary to link some other libraries such as: `libm.a, libI77.a, libF77.a, libisam.a, libU77.a`

Makefile also compiles and links the program **testgam**, which is a useful, interactive, stand alone program, for reading (and printing) aerodata with varying inputs.
The output data file from 'testgam' is of a standard format used at Saab for both plotting- and database handling purposes. It presents aerodata (coefficients) and chosen parameter/variable in a straight forward table form. All input data are also listed on the output file.

Please observe that also a few non-Fortran files, such as **ad_coeff.const**, used as 'include files', must be present when linking.

Note here the importance of the file **datafilepath.h** which *must* contain the correct address (directory) for the aerodata tables, since this file is used when reading aerodata.

In general, the user is assumed to be familiar with the common programming languages used today and the programming techniques necessary to create a model where aerodata can be called upon as a subroutine.
A few small hints though when calling the aerodata model from **Matlab or other C-programs** might be useful:

- Remember to use ampersands when calling the subroutine 'aerodata', since C does not use call-by-reference, different from Fortran.
  Ex: `aerodata_(.....&drc_in, &dlc_in.....)`

- Remember also to include prototypes for the functions of `gam.a` that you use. This facilitates error checking between function call and definition.

All necessary information about used **input/output parameters** in the Aerodata Model can be found in the Fortran file 'input.f', where names, purposes and units are defined. Referring to this file, here is an explanation of how the various denominations of the elevon angles are related.

DEI = (DLIE + DRIE) * 0.5
DEY = (DLOE + DROE) *0.5
DE = (DEI + DEY) * 0.5
DAI = (DLIE - DRIE) * 0.5
DAY = (DLOE - DROE) * 0.5
DA = (DAI + DAY) * 0.5

Finally, since the Generic Aerodata Model is a fully open document (model), the user is free to implement any changes he/she chooses, both in algorithms and aerodata tables. For such changes, and consequences thereby, the user must take full responsibility, as stated in the DISCLAIMER paragraph on the cover page of this document.
A similar DISCLAIMER paragraph is attached to each individual program file that constitutes the aerodata model.

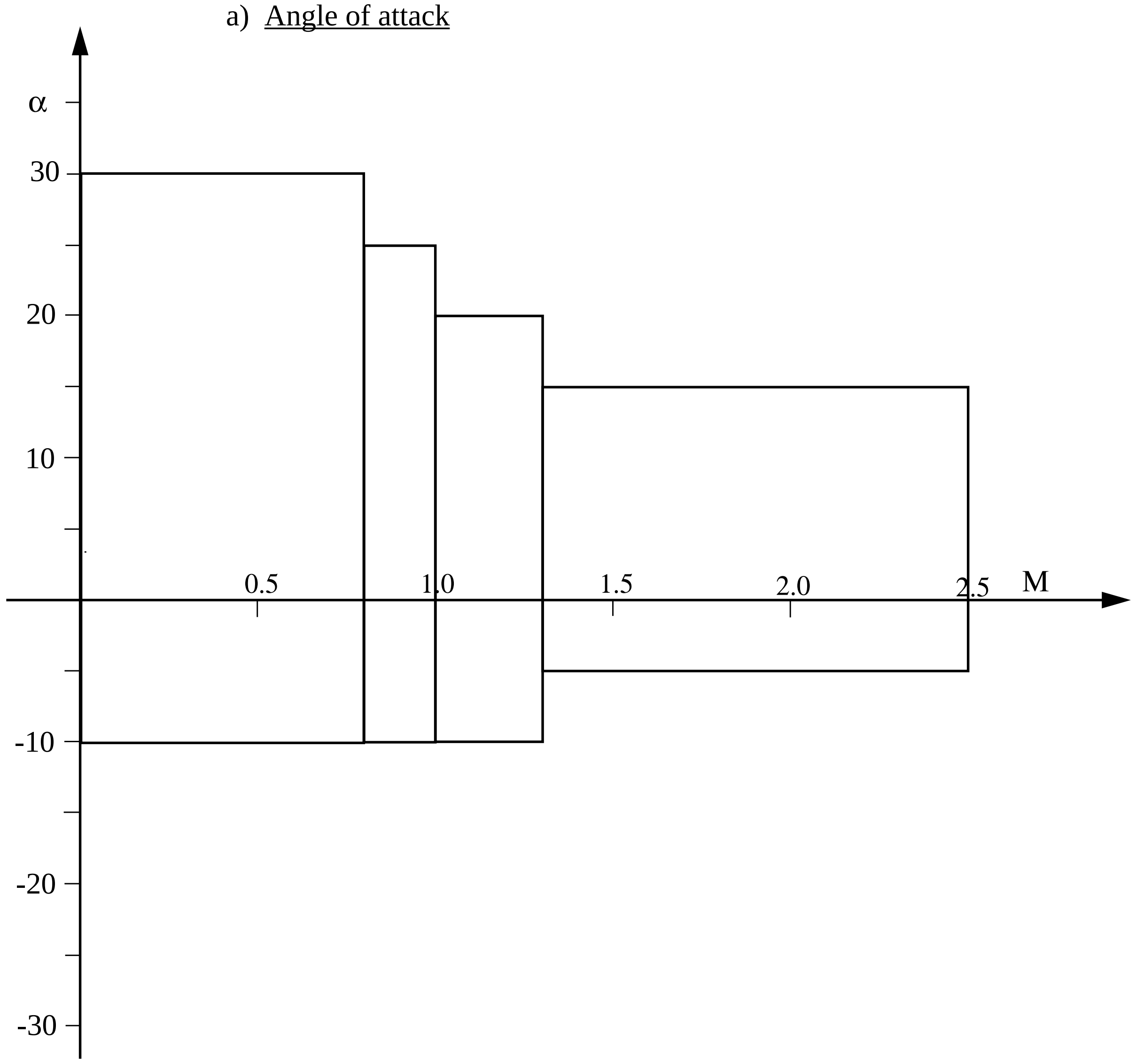
References

1. Etkin, Bernard: *Dynamics of Atmospheric Flight*, John Wiley & Sons, Inc, 1972.

APPENDIX 1: FLIGHT ENVELOPE

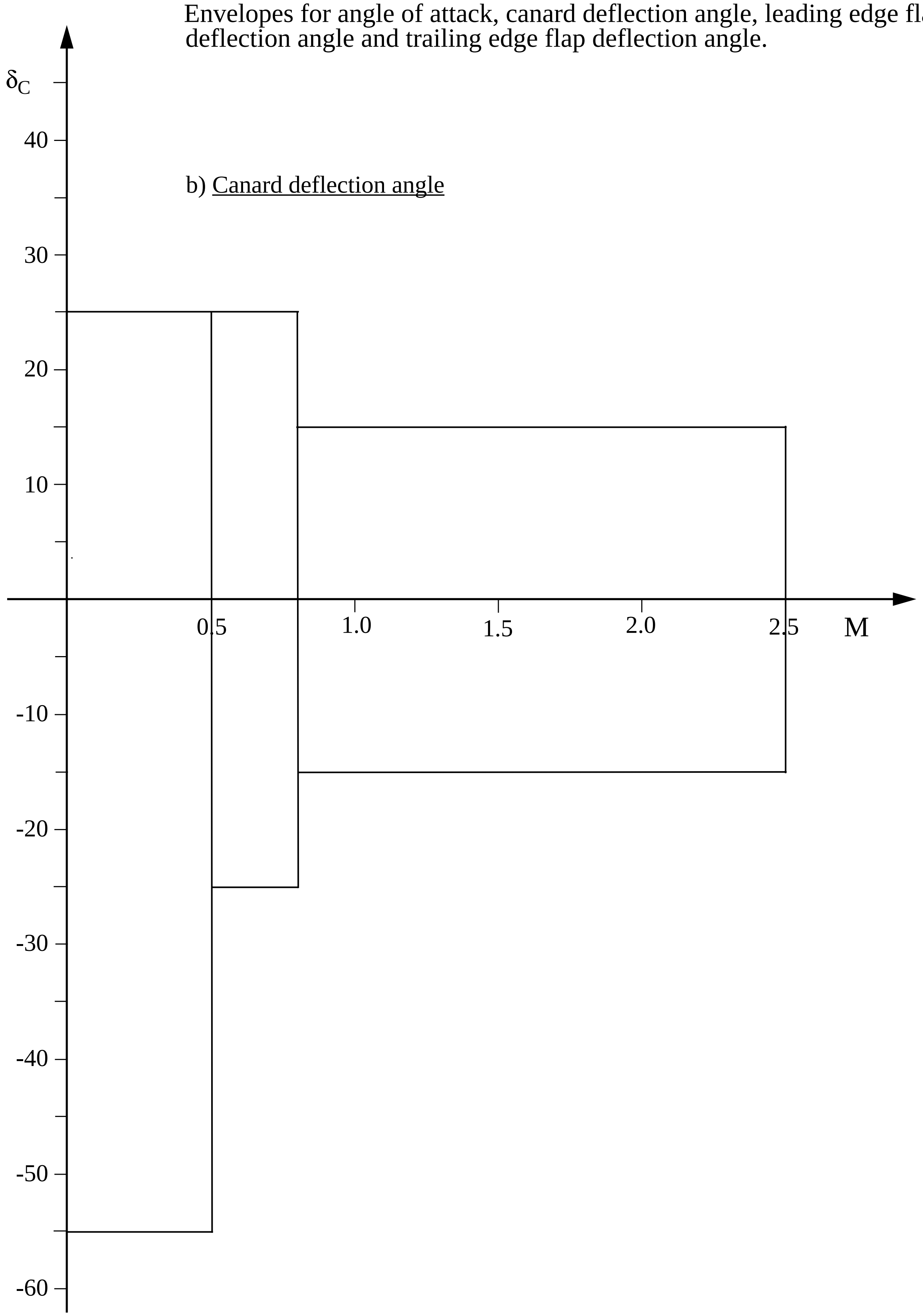
Envelopes for angle of attack, canard deflection angle, leading edge flap deflection angle and trailing edge flap deflection angle.

a) <u>Angle of attack</u>



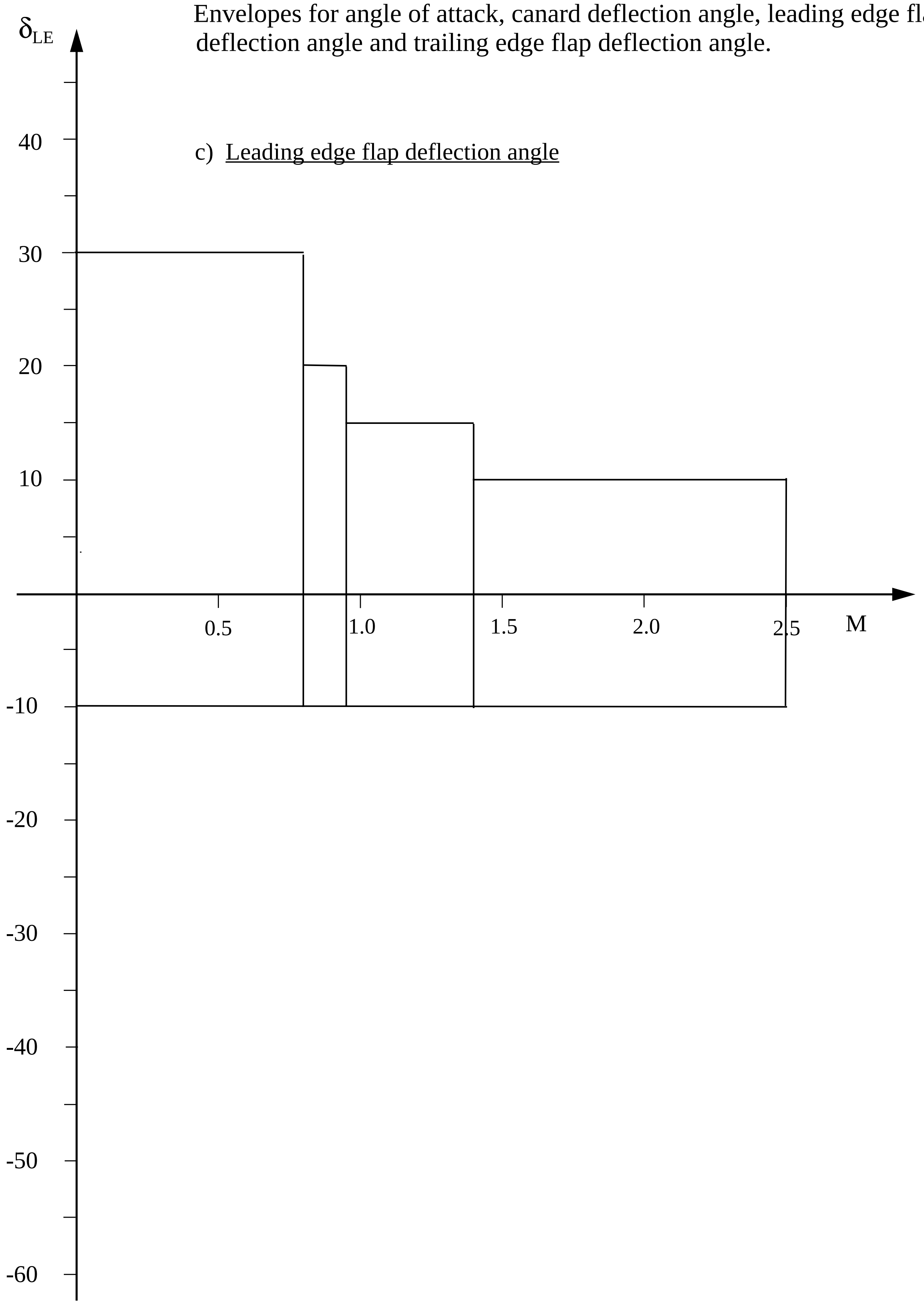
Envelopes for angle of attack, canard deflection angle, leading edge flap deflection angle and trailing edge flap deflection angle.

b) Canard deflection angle



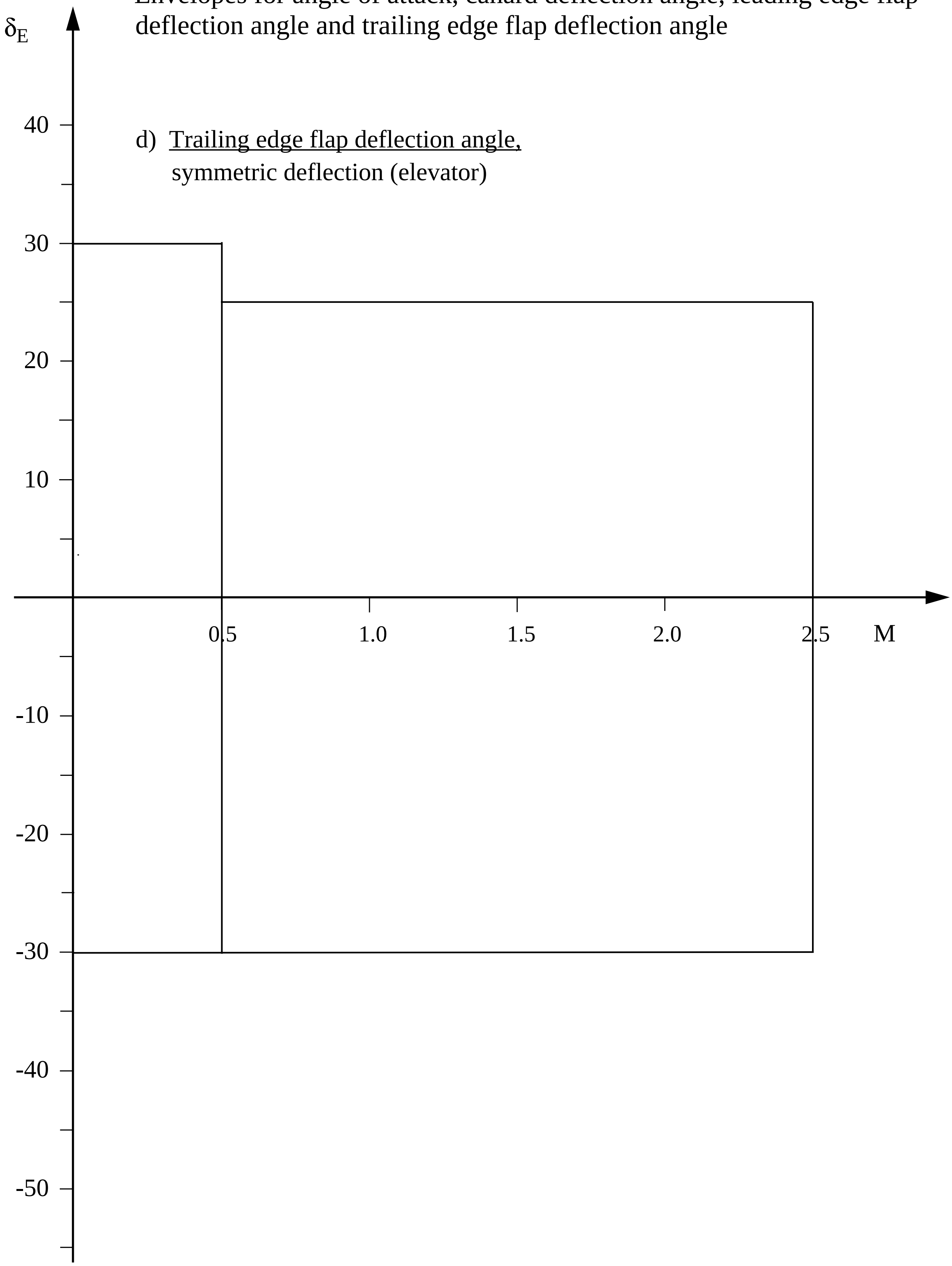
Envelopes for angle of attack, canard deflection angle, leading edge flap deflection angle and trailing edge flap deflection angle.

c) <u>Leading edge flap deflection angle</u>



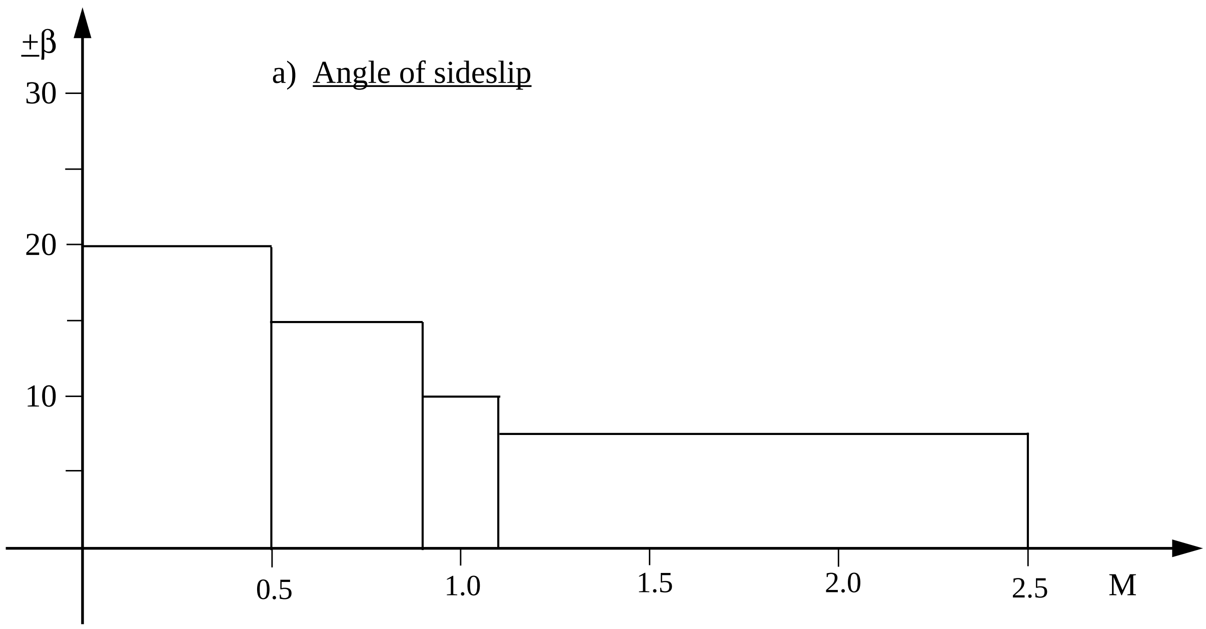
Envelopes for angle of attack, canard deflection angle, leading edge flap deflection angle and trailing edge flap deflection angle

d) Trailing edge flap deflection angle,
symmetric deflection (elevator)



Envelopes for sideslip and rudder deflection angle

a) Angle of sideslip



b) Rudder deflection angle