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Piecewise Polynomial Model of the Aerodynamic Coefficients of the Generic Transport Model and its Equations of Motion

Torbjørn Cunis¹, Laurent Burlion², and Jean-Philippe Condomines³

Abstract

The purpose of this document is to illustrate the piecewise polynomial model which has been derived from windtunnel measurement data of the Generic Transport Model (GTM) using the pwpfit toolbox. For implementation details and use in MATLAB, please refer to the source code at https://github.com/pwpfit/GTMpw.

Preliminaries

If not stated otherwise, all variables are in SI units. We will refer to the following axis systems of ISO 1151-1: the *body axis system* (x_f, y_f, z_f) aligned with the aircraft's fuselage; the *air-path axis system* (x_a, y_a, z_a) defined by the velocity vector \mathbf{V}_A ; and the *normal earth-fixed axis system* (x_g, y_g, z_g) . The orientation of the body axes with respect to the normal earth-fixed system is given by the attitude angles Φ, Θ, Ψ and to the air-path system by angle of attack α and side-slip β ; the orientation of the air-path axes to the normal earth-fixed system is given by azimuth χ_A , inclination γ_A , and bank-angle μ_A . (Fig. 1.)



(a) Longitudinal axes $(\beta = \mu_A = 0)$.

(b) Horizontal axes ($\gamma_{\rm A} = 0$).

Fig. 1: Axis systems with angles and vectors. Projections into the plane are marked by '.

I. Aerodynamic Coefficients

The piecewise polynomial models of the aerodynamic coefficients are given

$$C_{\odot}(\alpha, \beta, \dots) = \begin{cases} C_{\odot}^{pre}(\alpha, \beta, \dots) & \text{if } \alpha \le \alpha_0, \\ C_{\odot}^{post}(\alpha, \beta, \dots) & \text{else,} \end{cases}$$
(1)

where $C_{\odot} \in \{C_{\rm X}, C_{\rm Y}, C_{\rm Z}, C_{\rm l}, C_{\rm m}, C_{\rm n}\}$ are polynomials in angle of attack, side-slip, surface deflections, and normalized body rates; and the boundary is found at

$$\alpha_0 = 16.111^{\circ}.$$
 (2)

The polynomials in low and high angle of attack, C_{\odot}^{pre} , C_{\odot}^{post} , are sums

$$C_{\odot}^{pre} = C_{\odot\alpha}^{pre}(\alpha) + C_{\odot\beta}^{pre}(\alpha,\beta) + C_{\odot\xi}^{pre}(\alpha,\beta,\xi) + C_{\odot\eta}^{pre}(\alpha,\beta,\eta) + C_{\odot\zeta}^{pre}(\alpha,\beta,\zeta) + C_{\odot p}^{pre}(\alpha,\hat{p}) + C_{\odot q}^{pre}(\alpha,\hat{q}) + C_{\odot r}^{pre}(\alpha,\hat{r});$$

$$(3)$$

$$C_{\odot}^{post} = C_{\odot\alpha}^{post}(\alpha) + C_{\odot\beta}^{post}(\alpha,\beta) + C_{\odot\xi}^{post}(\alpha,\beta,\xi) + C_{\odot\eta}^{post}(\alpha,\beta,\eta) + C_{\odot\zeta}^{post}(\alpha,\beta,\zeta) + C_{\odot p}^{post}(\alpha,\hat{p}) + C_{\odot q}^{post}(\alpha,\hat{q}) + C_{\odot r}^{post}(\alpha,\hat{r}) .$$

$$\tag{4}$$

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In the following subsections, we present the polynomial terms obtained using the pwpfit toolbox. Coefficients of absolute value lower than 10^{-2} have been omitted for readability.

A. Domain of low angle of attack

Polynomials in angle of attack:

$$C_{X\alpha}^{pre} = -0.039 + 0.244\alpha + 4.453\alpha^2 - 17.398\alpha^3;$$
(5)

$$C_{Z\alpha}^{pre} = -0.017 - 5.241\alpha - 1.865\alpha^2 + 28.463\alpha^3; \tag{6}$$

$$C_{\rm m\alpha}^{pre} = 0.119 - 1.465\alpha + 8.130\alpha^2 - 31.986\alpha^3; \tag{7}$$

 $C_{\mathrm{Y}\alpha}^{pre},\,C_{\mathrm{l}\alpha}^{pre},\,C_{\mathrm{n}\alpha}^{pre}$ are zero by definition.

Polynomials in angle of attack and side-slip:

$$C_{\rm X\beta}^{pre} = 0.012 - 0.048\alpha - 1.433\alpha^2 + 0.035\alpha\beta + 0.033\beta^2 + 5.481\alpha^3 - 0.135\alpha^2\beta;$$
(8)

$$C_{Y\beta}^{pre} = -1.086\beta - 0.185\alpha\beta + 0.734\alpha^2\beta + 0.213\beta^3;$$
(9)

$$C_{Z\beta}^{pre} = -0.033 + 0.204\alpha + 1.730\alpha^2 + 0.065\beta^2 - 9.930\alpha^3 + 0.073\alpha^2\beta + 2.857\alpha\beta^2;$$
(10)

$$C_{1\beta}^{pre} = -0.066\beta - 0.298\alpha\beta + 1.191\alpha^2\beta;$$
(11)

$$C_{\rm m\beta}^{pre} = -0.221\alpha - 3.304\alpha^2 - 0.025\alpha\beta - 0.725\beta^2 + 13.192\alpha^3 + 0.199\alpha^2\beta + 0.462\alpha\beta^2 - 0.016\beta^3;$$
(12)

(13)

$$C_{n\beta}^{pre} = 0.116\beta - 0.022\alpha\beta - 0.363\alpha^2\beta + 0.056\beta^3.$$

Polynomials in angle of attack, side-slip, and aileron deflections:

$$C_{X\xi}^{pre} = 0.013\beta\xi - 0.012\xi^2 - 0.071\alpha\beta^2 - 0.148\alpha\beta\xi + 0.063\alpha\xi^2;$$
(14)

$$C_{Y\xi}^{pre} = 0.323\beta - 0.020\xi - 0.410\alpha\beta + 0.015\alpha\xi + 3.141\alpha^2\beta + 0.022\alpha^2\xi - 0.532\beta^3 - 0.703\beta\xi^2;$$
(15)

$$C_{Z\xi}^{pre} = -0.088\beta\xi - 0.010\xi^2 - 0.323\alpha\beta^2 + 0.446\alpha\beta\xi - 0.095\alpha\xi^2;$$
(16)

$$C_{l\xi}^{pre} = 0.013\beta - 0.070\xi + 0.036\alpha\xi + 0.286\alpha^2\beta + 0.230\alpha^2\xi - 0.047\beta^3 + 0.027\beta^2\xi - 0.043\beta\xi^2 + 0.039\xi^3;$$
(17)

$$C_{\mathrm{m}\xi}^{pre} = 0.321\beta^2 + 0.031\beta\xi - 0.096\xi^2 - 0.931\alpha\beta^2 - 0.471\alpha\xi^2;$$
(18)

$$C_{n\xi}^{pre} = 0.067\beta - 0.058\alpha\beta + 0.344\alpha^2\beta + 0.043\alpha^2\xi - 0.110\beta^3 - 0.094\beta\xi^2 + 0.016\xi^3.$$
(19)

Polynomials in angle of attack, side-slip, and elevator deflections:

$$C_{X\eta}^{pre} = -0.011\beta - 0.011\eta + 0.012\alpha\beta + 0.262\alpha\eta - 0.161\eta^2 - 0.778\alpha^2\eta + 0.097\alpha\beta^2 - 0.022\alpha\beta\eta - 0.012\alpha\eta^2 + 0.017\beta^3 - 0.070\eta^3;$$
(20)
$$C_{X\eta}^{pre} = -0.323\beta + 0.410\alpha\beta - 3.141\alpha^2\beta + 0.532\beta^3;$$
(21)

$$C_{Y\eta}^{pre} = -0.323\beta + 0.410\alpha\beta - 3.141\alpha^2\beta + 0.532\beta^3;$$

$$C_{Z\eta}^{pre} =$$
(21)

 $-0.033\beta - 1.087\eta + 0.148\alpha\beta + 0.029\beta^{2} + 0.019\beta\eta + 0.020\eta^{2} - 0.120\alpha^{2}\beta + 1.726\alpha^{2}\eta + 0.036\alpha\beta^{2} - 0.055\alpha\beta\eta + 0.194\alpha\eta^{2} - 0.018\beta^{3} + 0.616\beta^{2}\eta + 0.024\beta\eta^{2} + 1.518\eta^{3};$ (22)

$$C_{1\eta}^{pre} = -0.013\beta - 0.286\alpha^2\beta + 0.047\beta^3;$$
⁽²³⁾

$$C_{\mathrm{m}\eta}^{pre} =$$

 $-0.107\beta - 3.706\eta + 0.412\alpha\beta - 0.144\alpha\eta + 0.061\beta^{2} + 0.053\beta\eta - 0.481\eta^{2} - 0.136\alpha^{2}\beta + 10.402\alpha^{2}\eta + 0.434\alpha\beta^{2} - 0.045\alpha\beta\eta + 2.857\alpha\eta^{2} + 0.013\beta^{3} + 1.376\beta^{2}\eta + 0.221\beta\eta^{2} + 2.544\eta^{3};$ (24)

$$C_{n\eta}^{pre} = -0.067\beta + 0.058\alpha\beta - 0.344\alpha^2\beta + 0.110\beta^3.$$
⁽²⁵⁾

Polynomials in angle of attack, side-slip, and rudder deflections:

$$C_{X\zeta}^{pre} = 0.011\beta - 0.012\alpha\beta + 0.014\beta^2 + 0.039\beta\zeta - 0.054\zeta^2 - 0.197\alpha\beta^2 - 0.141\alpha\beta\zeta + 0.064\alpha\zeta^2 - 0.017\beta^3;$$
(26)

$$C_{Y\zeta}^{pre} = -0.013\beta + 0.041\alpha\beta + 0.080\alpha\zeta - 0.284\alpha^2\beta - 0.595\alpha^2\zeta + 0.089\zeta^3;$$
(27)

$$C_{Z\zeta}^{pre} = 0.033\beta - 0.148\alpha\beta - 0.024\beta^2 - 0.024\beta\zeta + 0.022\zeta^2 + 0.120\alpha^2\beta + 0.017\alpha\beta^2 + 0.085\alpha\beta\zeta - 0.055\alpha\zeta^2 + 0.018\beta^3;$$
(28)

$$C_{1\zeta}^{pre} = -0.016\beta - 0.081\zeta + 0.191\alpha\beta + 0.069\alpha\zeta - 1.012\alpha^{2}\beta - 0.121\alpha^{2}\zeta + 0.061\beta^{3} + 0.042\beta^{2}\zeta + 0.124\zeta^{3};$$
(29)

$$C_{m\zeta}^{pre} = 0.107\beta - 0.412\alpha\beta - 0.265\beta^{2} - 0.191\beta\zeta + 0.156\zeta^{2} + 0.136\alpha^{2}\beta + 0.337\alpha\beta^{2} + 0.794\alpha\beta\zeta - 0.260\alpha\zeta^{2} - 0.013\beta^{3};$$
(30)

$$C_{n\zeta}^{pre} = -0.122\zeta + 0.094\alpha\beta + 0.160\alpha\zeta + 0.393\alpha^{2}\beta - 0.493\alpha^{2}\zeta + 0.108\beta^{3} - 0.029\beta^{2}\zeta + 0.022\beta\zeta^{2}.$$
(31)

Polynomials in angle of attack and normalized body *p*-rate:

$$C_{\rm Y\hat{p}}^{pre} = 2.281\hat{p} - 7.166\alpha\hat{p} + 39.769\hat{p}^2 - 54.568\alpha^2\hat{p} + 689.390\alpha\hat{p}^2 + 8193.600\hat{p}^3; \tag{32}$$

$$C_{1\hat{p}}^{pre} = -14.046\hat{p} - 13.426\alpha\hat{p} + 25.305\hat{p}^2 + 175.810\alpha^2\hat{p} + 1247.500\alpha\hat{p}^2 - 988\,450\hat{p}^3; \tag{33}$$

$$C_{n\hat{p}}^{pre} = -2.106\hat{p} - 1.812\alpha\hat{p} - 135.930\hat{p}^2 + 64.789\alpha^2\hat{p} - 296.100\alpha\hat{p}^2 + 4450.500\hat{p}^3;$$
(34)

 $C_{{\rm X}\hat{p}}^{pre},\,C_{{\rm Z}\hat{p}}^{pre},\,C_{{\rm m}\hat{p}}^{pre}$ are zero due to lack of GTM measurement data.

Polynomials in angle of attack and normalized body q-rate:

$$C_{X\hat{q}}^{pre} = 63.167\hat{q} + 0.076\alpha^2 + 677.000\alpha\hat{q} + 440\,640\hat{q}^2 + 0.126\alpha^3 + 1193.100\alpha^2\hat{q} + 2\,281\,300\alpha\hat{q}^2 - 1\,043\,400\hat{q}^3;$$
(35)

$$C_{Z\hat{q}}^{pre} = 0.091\alpha - 1875.100\hat{q} - 0.203\alpha^2 - 1872.400\alpha\hat{q} + 4\,243\,400\hat{q}^2 - 0.283\alpha^3 - 4745.800\alpha^2\hat{q} - 15\,335\,000\alpha\hat{q}^2 - 166\,980\hat{q}^3;$$
(36)

$$C_{\mathrm{m}\hat{a}}^{pre} =$$

 $-0.021 - 0.033\alpha - 2383.500\hat{q} + 0.496\alpha^2 - 199.420\alpha\hat{q} + 1\,792\,400\hat{q}^2 + 0.908\alpha^3 + 1574.400\alpha^2\hat{q} + 7\,267\,100\alpha\hat{q}^2 - 2\,980\,200\,000\hat{q}^3;$ (37)

 $C_{{\rm Y}\hat{q}}^{pre},\,C_{{\rm l}\hat{q}}^{pre},\,C_{{\rm n}\hat{q}}^{pre}$ are zero due to lack of GTM measurement data.

Polynomials in angle of attack and normalized body *r*-rate:

$$C_{\mathbf{v}\hat{r}}^{pre} = 44.179\hat{r} + 49.371\alpha\hat{r} + 2891.700\hat{r}^2 + 92.222\alpha^2\hat{r} - 5041.500\alpha\hat{r}^2 + 10\,357\hat{r}^3; \tag{38}$$

 $C_{l\hat{r}}^{pre} = 9.679\hat{r} + 43.079\alpha\hat{r} - 15.899\hat{r}^2 + 48.546\alpha^2\hat{r} + 243.490\alpha\hat{r}^2 - 1593\,100\hat{r}^3;$ (39)

 $C_{n\hat{r}}^{pre} = -9.646\hat{r} - 14.456\alpha\hat{r} - 1548.100\hat{r}^2 - 53.131\alpha^2\hat{r} + 3188.800\alpha\hat{r}^2 + 4313.400\hat{r}^3;$ (40)

 $C_{\mathbf{X}\hat{r}}^{pre}, C_{\mathbf{Z}\hat{r}}^{pre}, C_{\mathbf{m}\hat{r}}^{pre}$ are zero due to lack of GTM measurement data.

B. Domain of high angle of attack

Polynomials in angle of attack:

$$C_{X\alpha}^{post} = 0.019 - 0.130\alpha + 0.169\alpha^2 - 0.022\alpha^3; \tag{41}$$

$$C_{Z\alpha}^{post} = -0.365 - 2.711\alpha + 1.647\alpha^2 - 0.369\alpha^3;$$
(42)

$$C_{\rm m\alpha}^{post} = 0.247 - 2.847\alpha + 2.748\alpha^2 - 1.105\alpha^3; \tag{43}$$

 $C_{\rm Y\alpha}^{post},\,C_{\rm l\alpha}^{post},\,C_{\rm n\alpha}^{post}$ are zero by definition.

Polynomials in angle of attack and side-slip:

$$C_{\rm X\beta}^{post} = 0.016\alpha - 0.023\alpha^2 + 0.053\beta^2 - 0.061\alpha\beta^2; \tag{44}$$

$$C_{Y\beta}^{post} = -0.887\beta - 0.867\alpha\beta + 0.637\alpha^2\beta + 0.213\beta^3;$$
(45)

$$C_{Z\beta}^{post} = -0.219 + 0.690\alpha + 0.018\beta - 0.452\alpha^2 - 0.068\alpha\beta + 0.939\beta^2 + 0.029\alpha^3 + 0.055\alpha^2\beta - 0.251\alpha\beta^2;$$
(46)

$$C_{I\beta}^{post} = 0.014\beta - 0.277\alpha\beta + 0.103\alpha^2\beta;$$
(47)

$$C_{m\beta}^{post} = -0.247 + 1.291\alpha + 0.036\beta - 1.970\alpha^2 - 0.087\alpha\beta - 1.023\beta^2 + 0.838\alpha^3 + 0.028\alpha^2\beta + 1.520\alpha\beta^2 - 0.016\beta^3;$$
(48)

$$C_{n\beta}^{post} = 0.150\beta - 0.279\alpha\beta + 0.129\alpha^2\beta + 0.056\beta^3.$$
⁽⁴⁹⁾

Polynomials in angle of attack, side-slip, and aileron deflections:

$$C_{\chi\xi}^{post} = -0.068\beta^2 - 0.036\beta\xi + 0.032\xi^2 + 0.140\alpha\beta^2 + 0.024\alpha\beta\xi - 0.095\alpha\xi^2;$$
(50)

$$C_{Y\xi}^{post} = 1.026\beta - 0.020\xi - 2.635\alpha\beta + 0.026\alpha\xi + 2.152\alpha^2\beta - 0.016\alpha^2\xi - 0.532\beta^3 - 0.703\beta\xi^2;$$
(51)

$$C_{7\varepsilon}^{post} = -0.112\beta^2 + 0.061\beta\xi - 0.124\xi^2 + 0.093\alpha\beta^2 - 0.086\alpha\beta\xi + 0.309\alpha\xi^2;$$
(52)

$$C_{l\xi}^{post} = 0.078\beta - 0.046\xi - 0.195\alpha\beta + 0.013\alpha\xi + 0.152\alpha^2\beta - 0.047\beta^3 + 0.027\beta^2\xi - 0.043\beta\xi^2 + 0.039\xi^3;$$
(53)

$$C_{m\xi}^{post} = 0.201\beta^2 + 0.041\beta\xi - 0.205\xi^2 - 0.505\alpha\beta^2 - 0.032\alpha\beta\xi - 0.082\alpha\xi^2;$$
(54)

$$C_{n\xi}^{post} = 0.130\beta - 0.237\alpha\beta + 0.024\alpha\xi + 0.187\alpha^2\beta - 0.017\alpha^2\xi - 0.110\beta^3 - 0.094\beta\xi^2 + 0.016\xi^3.$$
(55)

Polynomials in angle of attack, side-slip, and elevator deflections:

$$C_{X\eta}^{post} = -0.023\eta - 0.016\alpha\beta + 0.123\alpha\eta + 0.075\beta^2 - 0.154\eta^2 + 0.013\alpha^2\beta - 0.126\alpha^2\eta - 0.164\alpha\beta^2 - 0.037\alpha\eta^2 + 0.017\beta^3 - 0.070\eta^3;$$
(56)
(56)
$$C_{Y\eta}^{post} = -1.026\beta + 2.635\alpha\beta - 2.152\alpha^2\beta + 0.532\beta^3;$$
(57)

$$C_{Z\eta}^{post} =$$

 $-0.013\beta - 1.307\eta + 0.058\alpha\beta + 1.429\alpha\eta + 0.032\beta^2 - 0.260\eta^2 - 0.048\alpha^2\beta - 0.583\alpha^2\eta + 0.026\alpha\beta^2 + 1.188\alpha\eta^2 - 0.018\beta^3 + 0.616\beta^2\eta + 0.024\beta\eta^2 + 1.518\eta^3;$

(58)

$$C_{l\eta}^{post} = -0.078\beta + 0.195\alpha\beta - 0.152\alpha^2\beta + 0.047\beta^3;$$

$$C_{l\eta}^{post} = -0.078\beta + 0.0152\alpha^2\beta + 0.047\beta^3;$$
(59)

$$C_{m\eta}^{post} =$$

 $-3.589\eta + 2.488\alpha\eta + 0.268\beta^2 + 0.038\beta\eta + 0.148\eta^2 - 0.441\alpha^2\eta - 0.303\alpha\beta^2 + 0.622\alpha\eta^2 + 0.013\beta^3 + 1.376\beta^2\eta + 0.221\beta\eta^2 + 2.544\eta^3;$ (60)

$$C_{n\eta}^{post} = -0.130\beta + 0.237\alpha\beta - 0.187\alpha^2\beta + 0.110\beta^3.$$
(61)

Polynomials in angle of attack, side-slip, and rudder deflections:

$$C_{X\zeta}^{post} = 0.016\alpha\beta - 0.097\beta^2 - 0.020\beta\zeta - 0.040\zeta^2 - 0.013\alpha^2\beta + 0.198\alpha\beta^2 + 0.068\alpha\beta\zeta + 0.015\alpha\zeta^2 - 0.017\beta^3;$$
(62)

$$C_{X\zeta}^{post} = -0.099\beta - 0.076\zeta + 0.333\alpha\beta + 0.221\alpha\zeta - 0.237\alpha^2\beta - 0.177\alpha^2\zeta + 0.089\zeta^3;$$
(63)

$$C_{7c}^{post} = 0.013\beta - 0.058\alpha\beta - 0.047\beta^2 + 0.048\alpha^2\beta + 0.101\alpha\beta^2 + 0.031\alpha\beta\zeta + 0.045\alpha\zeta^2 + 0.018\beta^3;$$
(64)

$$C_{Z\zeta}^{post} = -0.069\beta = 0.104\zeta + 0.118\alpha\beta + 0.165\alpha\zeta = 0.079\alpha^2\beta = 0.175\alpha^2\zeta + 0.061\beta^3 + 0.042\beta^2\zeta + 0.124\zeta^3.$$
(65)

$$C_{1\zeta}^{post} = -0.316\beta^2 + 0.190\beta\zeta + 0.096\zeta^2 + 0.518\alpha\beta^2 - 0.559\alpha\beta\zeta - 0.048\alpha\zeta^2 - 0.013\beta^3;$$
(66)

$$C_{n\zeta}^{post} = 0.451\beta - 0.304\zeta - 1.755\alpha\beta + 0.791\alpha\zeta + 1.304\alpha^2\beta - 0.434\alpha^2\zeta + 0.108\beta^3 - 0.029\beta^2\zeta + 0.022\beta\zeta^2.$$
(67)

Polynomials in angle of attack and normalized body *p*-rate:

$$C_{Y\hat{p}}^{post} = 2.714\hat{p} - 33.368\alpha\hat{p} + 3086.500\hat{p}^2 + 33.135\alpha^2\hat{p} - 10\,146\alpha\hat{p}^2 + 8193.600\hat{p}^3;$$
(68)

$$C_{l\hat{p}}^{post} = 3.365\hat{p} - 33.324\alpha\hat{p} + 346.110\hat{p}^2 + 26.371\alpha^2\hat{p} + 106.590\alpha\hat{p}^2 - 988\,450\hat{p}^3;\tag{69}$$

$$C_{\mathbf{n}\hat{p}}^{post} = 8.850\hat{p} - 28.449\alpha\hat{p} - 879.480\hat{p}^2 + 20.942\alpha^2\hat{p} + 2348.200\alpha\hat{p}^2 + 4450.500\hat{p}^3;$$
(70)

 $C_{X\hat{p}}^{post}, C_{Z\hat{p}}^{post}, C_{m\hat{p}}^{post}$ are zero due to lack of GTM measurement data.

Polynomials in angle of attack and normalized body q-rate:

$$C_{\mathbf{X}\hat{q}}^{post} =$$

 $\begin{array}{l} 0.038 - 0.176\alpha + 1260.000 \hat{q} + 0.245 \alpha^2 - 4151.300 \alpha \hat{q} + 1\,750\,800 \hat{q}^2 - 0.097 \alpha^3 + 3226.500 \alpha^2 \hat{q} - 2\,378\,300 \alpha \hat{q}^2 - 1\,043\,400 \hat{q}^3; \\ (71) \end{array}$

$$C_{\mathbf{Z}\hat{a}}^{post} =$$

$$0.050 - 0.411\alpha - 5274.900\hat{q} + 0.977\alpha^2 + 11\,599\alpha\hat{q} - 3\,051\,200\hat{q}^2 - 0.677\alpha^3 - 9654.600\alpha^2\hat{q} + 10\,607\,000\alpha\hat{q}^2 - 166\,980\hat{q}^3;$$
(72)

$$C_{\mathrm{m}\hat{q}}^{post} =$$

$$0.115 - 0.412\alpha - 662.240\hat{q} + 0.431\alpha^2 - 8186.500\alpha\hat{q} + 6\,062\,800\hat{q}^2 - 0.172\alpha^3 + 8209.000\alpha^2\hat{q} - 7\,919\,900\alpha\hat{q}^2 - 2\,980\,200\,000\hat{q}^3;$$
(73)

 $C_{{\rm Y}\hat{q}}^{post},\,C_{{\rm l}\hat{q}}^{post},\,C_{{\rm n}\hat{q}}^{post}$ are zero due to lack of GTM measurement data.

Polynomials in angle of attack and normalized body r-rate:

$$C_{Y\hat{r}}^{post} = 222.670\hat{r} - 676.410\alpha\hat{r} + 5458.500\hat{r}^2 + 415.860\alpha^2\hat{r} - 14\,170\alpha\hat{r}^2 + 10\,357\hat{r}^3;$$
(74)

$$C_{l\hat{r}}^{post} = -7.843\hat{r} + 181.470\alpha\hat{r} + 14.963\hat{r}^2 - 222.030\alpha^2\hat{r} + 133.730\alpha\hat{r}^2 - 1593\,100\hat{r}^3;$$
(75)

$$C_{n\hat{r}}^{post} = -27.260\hat{r} + 41.592\alpha\hat{r} - 837.820\hat{r}^2 - 29.673\alpha^2\hat{r} + 662.790\alpha\hat{r}^2 + 4313.400\hat{r}^3;$$
(76)

 $C_{{\rm X}\hat{r}}^{post},\,C_{{\rm Z}\hat{r}}^{post},\,C_{{\rm m}\hat{r}}^{post}$ are zero due to lack of GTM measurement data.

II. Equations of Motion

We have the aerodynamic forces and moments in body axis

$$\begin{bmatrix} X^{\mathrm{A}} \\ Y^{\mathrm{A}} \\ Z^{\mathrm{A}} \end{bmatrix}_{\mathrm{f}} = \frac{1}{2} \rho S V_{\mathrm{A}}^{2} \begin{bmatrix} C_{\mathrm{X}} \\ C_{\mathrm{Y}} \\ C_{\mathrm{Z}} \end{bmatrix}; \qquad \begin{bmatrix} L^{\mathrm{A}} \\ M^{\mathrm{A}} \\ N^{\mathrm{A}} \end{bmatrix}_{\mathrm{f}} = \frac{1}{2} \rho S V_{\mathrm{A}}^{2} \begin{bmatrix} b C_{\mathrm{l}} \\ c_{\mathrm{a}} C_{\mathrm{m}} \\ b C_{\mathrm{n}} \end{bmatrix} + \begin{bmatrix} X^{\mathrm{A}} \\ Y^{\mathrm{A}} \\ Z^{\mathrm{A}} \end{bmatrix}_{\mathrm{f}} \times \left(\mathbf{x}_{\mathrm{cg}} - \mathbf{x}_{\mathrm{cg}}^{\mathrm{ref}} \right); \tag{77}$$

and the resulting forces by rotation into the air-path axis system

$$X_{\rm a} = \left(X_{\rm f}^{\rm A}\cos\alpha + Z_{\rm f}^{\rm A}\sin\alpha + X_{\rm f}^{\rm F}\cos\alpha\right)\cos\beta + Y_{\rm f}^{\rm A}\sin\beta;$$

$$V_{\rm c} = -\left(X_{\rm f}^{\rm A}\cos\alpha + Z_{\rm f}^{\rm A}\sin\alpha + X_{\rm f}^{\rm F}\cos\alpha\right)\sin\beta + V_{\rm f}^{\rm A}\cos\beta;$$
(78)

$$Y_{\rm a} = -\left(X_{\rm f}^{\rm A}\cos\alpha + Z_{\rm f}^{\rm A}\sin\alpha + X_{\rm f}^{\rm F}\cos\alpha\right)\sin\beta + Y_{\rm f}^{\rm A}\cos\beta;\tag{79}$$

$$Z_{\rm a} = -X_{\rm f}^{\rm A} \sin \alpha + Z_{\rm f}^{\rm A} \cos \alpha - X_{\rm f}^{\rm F} \sin \alpha; \tag{80}$$

with the thrust $X_{\rm f}^{\rm F} = F$ (engines aligned with the $x_{\rm f}$ -axis). The resulting forces lead to changes in air speed, side-slip, air-path inclination, and azimuth by

$$\dot{V}_{\rm A} = \frac{1}{m} (X_{\rm a} - mg\sin\gamma_{\rm A}); \qquad (81)$$

$$\dot{\beta} = \frac{1}{mV_{\rm A}} Y_{\rm a};\tag{82}$$

$$\dot{\gamma}_{\rm A} = -\frac{1}{mV_{\rm A}} \left(Z_{\rm a} \cos \mu_{\rm A} + mg \cos \gamma_{\rm A} \right); \tag{83}$$

$$\dot{\chi}_{\rm A} = -\frac{1}{mV_{\rm A}} Z_{\rm a} \sin \mu_{\rm A}. \tag{84}$$

For a symmetric plane $(I_{xy} = I_{uz} = 0)$, the resulting moments in body axis are given as

$$L_{\rm f} = L_{\rm f}^{\rm A} - q \, r \, (I_z - I_y) + p \, q \, I_{zx}; \tag{85}$$

$$M_{\rm f} = M_{\rm f}^{\rm A} + M_{\rm f}^{\rm F} - p \, r \left(I_x - I_z \right) - \left(p^2 - r^2 \right) I_{zx}; \tag{86}$$

$$N_{\rm f} = N_{\rm f}^{\rm A} - p \, q \, (I_y - I_x) - q \, r \, I_{zx}; \tag{87}$$

with $M_{\rm f}^{\rm F} = l_{\rm t}F$ (engines symmetric to the $x_{\rm f}$ - $y_{\rm f}$ -plane and shifted vertically from the origin by $l_{\rm t}$) and the inertias I_x, I_y, I_z, I_{zx} . The changes of angular body rates are then given as

$$\dot{p} = \frac{1}{I_x I_z - I_{zx}^{(2)}} \left(I_z L_f + I_{zx} N_f \right); \tag{88}$$

$$\dot{q} = \frac{1}{I_y} M_{\rm f};\tag{89}$$

$$\dot{r} = \frac{1}{I_x I_z - I_{zx}^{(2)}} \left(I_{zx} L_{\rm f} + I_x N_{\rm f} \right).$$
(90)

Here, the normalized body rates have been used with

$$\begin{bmatrix} \hat{p} \\ \hat{q} \\ \hat{r} \end{bmatrix} = \frac{1}{2V_{\rm A}} \begin{bmatrix} b \ p \\ c_{\rm a} \ q \\ b \ r \end{bmatrix} \Longleftrightarrow \begin{bmatrix} p \\ q \\ r \end{bmatrix} = 2V_{\rm A} \begin{bmatrix} b^{-1} \ \hat{p} \\ c_{\rm a}^{-1} \ \hat{q} \\ b^{-1} \ \hat{r} \end{bmatrix}$$
(91)

and

$$\begin{bmatrix} \dot{\hat{p}} \\ \dot{\hat{q}} \\ \dot{\hat{r}} \end{bmatrix} = \frac{1}{V_{\rm A}} \left(\frac{1}{2} \begin{bmatrix} b \, \dot{p} \\ c_{\rm a} \, \dot{q} \\ b \, \dot{r} \end{bmatrix} - \dot{V}_{\rm A} \begin{bmatrix} \hat{p} \\ \hat{q} \\ \hat{r} \end{bmatrix} \right). \tag{92}$$

The change of attitude is finally obtained by rotation into normal earth-fixed axis system:

$$\Phi = p + q \sin \Phi \tan \Theta + r \cos \Phi \tan \Theta; \tag{93}$$

$$\dot{\Theta} = q\cos\Phi - r\sin\Phi; \tag{94}$$

$$\dot{\Psi} = q\sin\Phi\cos^{-1}\Theta + r\cos\Phi\cos^{-1}\Theta. \tag{95}$$

III. LONGITUDINAL MODEL

The longitudinal model is restricted to the x_a - z_a -plane, assuming $\beta = \mu_A = \chi_A = 0$.

A. Aerodynamic Coefficients

The longitudinal aerodynamic coefficients, $C_{\rm L}, C_{\rm D}, C_{\rm m}$, are obtained as

$$C_{\rm L}(\alpha,\eta) = C_{\rm L\alpha}(\alpha) + C_{\rm L\eta}(\alpha,\eta) \quad \text{with} \\ C_{\rm L\alpha}(\alpha) = \begin{cases} 0.017 + 5.234\alpha + 1.985\alpha^2 - 30.060\alpha^3 & \text{if } \alpha \le 16.634^\circ \\ 0.279 + 3.251\alpha - 3.235\alpha^2 + 0.708\alpha^3 & \text{olso} \end{cases},$$
(96)

$$C_{L\eta}(\alpha,\eta) = -0.000 + 0.003\alpha + 0.521\eta - 0.072\alpha^2 - 0.416\alpha\eta$$

$$+ 0.089\eta^2 + 0.051\alpha^3 + 0.039\alpha^2\eta - 0.293\alpha\eta^2 - 0.479\eta^3;$$
(97)

$$C_{\rm D}(\alpha, \eta) = C_{\rm D\alpha}(\alpha) + C_{\rm D\eta}(\alpha, \eta) \quad \text{with}$$

$$\int_{\alpha} 0.029 - 0.110\alpha + 2.364\alpha^2 + 3.948\alpha^3 \quad \text{if } \alpha \le 16.634^\circ$$

$$C_{\mathrm{D}\alpha}(\alpha) = \begin{cases} -0.029 - 0.110\alpha + 2.304\alpha + 3.948\alpha & \text{if } \alpha \le 10.034 \\ -0.170 + 1.427\alpha + 0.719\alpha^2 - 0.486\alpha^3 & \text{else} \end{cases},$$
(98)

$$C_{\mathrm{D}\eta}(\alpha,\eta) = +0.008 - 0.012\alpha + 0.112\eta + 0.040\alpha^2 + 0.183\alpha\eta - 0.069\eta^2 - 0.053\alpha^3 - 0.043\alpha^2\eta - 0.070\alpha\eta^2 - 0.628\eta^3;$$
(99)

$$C_{\rm m}(\alpha,\eta) = C_{\rm m\alpha}(\alpha) + C_{\rm m\eta}(\alpha,\eta) \quad \text{with} \\ C_{\rm m\alpha}(\alpha) = \begin{cases} 0.117 - 1.475\alpha + 8.475\alpha^2 - 32.729\alpha^3 & \text{if } \alpha \le 16.634^\circ \\ 0.144 - 2.456\alpha + 2.304\alpha^2 - 0.950\alpha^3 & \text{else} \end{cases},$$
(100)

$$C_{m\eta}(\alpha,\eta) = +0.014 + 0.165\alpha - 1.968\eta - 0.410\alpha^2 + 1.365\alpha\eta -0.415\eta^2 + 0.186\alpha^3 - 0.144\alpha^2\eta + 0.948\alpha\eta^2 + 1.356\eta^3.$$
(101)

B. Equations of motion

The longitudinal equations of motion are given as

$$\dot{V}_{\rm A} = \frac{1}{m} \left(F \cos \alpha - \frac{1}{2} \rho S V_{\rm A}^2 C_{\rm D}(\alpha, \eta, q) - mg \sin \gamma_{\rm A} \right),\tag{102}$$

$$\dot{\gamma}_{\rm A} = \frac{1}{mV_{\rm A}} \left(F \sin \alpha + \frac{1}{2} \rho S V_{\rm A}^2 C_{\rm L}(\alpha, \eta, q) - mg \cos \gamma_{\rm A} \right),\tag{103}$$

$$\dot{q} = \frac{1}{I_y} \left(l_t F + \frac{1}{2} \rho S c_a V_A^2 C_m(\alpha, \eta, q) - \frac{1}{2} \rho S V_A^2 C_Z(\alpha, \eta, q) \left(x_{cg}^{ref} - x_{cg} \right) + \frac{1}{2} \rho S V_A^2 C_X(\alpha, \eta, q) \left(z_{cg}^{ref} - z_{cg} \right) \right); \quad (104)$$

with

$$\Theta = \alpha + \gamma. \tag{105}$$

MATLAB SOURCE CODE

The source code for the aerodynamic coefficients and the equations of motion can be found at:

https://github.com/pwpfit/GTMpw

Appendix

A. Spline-based Longitudinal Coefficients

The purpose of this model is to provide an application example of a spline-based longitudinal aircraft model. It has neither been designed nor evaluated for engineering purposes. For the longitudinal equations of motion, refer to Section III-B and note

$$C_{\rm D}(\alpha,\ldots) = -C_{\rm X}(\alpha,\ldots)\cos\alpha - C_{\rm Z}(\alpha,\ldots)\sin\alpha$$
(106)

$$C_{\rm L}(\alpha,\ldots) = C_{\rm X}(\alpha,\ldots)\sin\alpha - C_{\rm Z}(\alpha,\ldots)\cos\alpha$$
(107)

The longitudinal aerodynamic coefficients are obtained as

$$C_{\odot}(\alpha,\eta,\hat{q}) = C_{\odot\alpha}(\alpha) + C_{\odot\eta}(\alpha,\eta) + C_{\odot\hat{q}}(\alpha,\hat{q}), \qquad (108)$$

where $C_{\odot} \in \{C_{\rm X}, C_{\rm Z}, C_{\rm m}\}, \, \hat{q} = c_{\rm a}q/(2V_{\rm A}), \, \text{and}$

$$C_{\odot\alpha}(\alpha,\eta) = \begin{cases} C_{\odot\alpha}^{(1)} & \text{if } \alpha \in (-\infty;\alpha_1), \\ C_{\odot\alpha}^{(2)} & \text{if } \alpha \in [\alpha_1;\alpha_2), \\ C_{\odot\alpha}^{(3)} & \text{if } \alpha \in [\alpha_2;\alpha_3), \\ C_{\odot\alpha}^{(4)} & \text{if } \alpha \in [\alpha_3;\alpha_3), \\ C_{\odot\alpha}^{(5)} & \text{if } \alpha \in [\alpha_4;\infty); \end{cases}$$
(109)

$$C_{\odot\eta}(\alpha,\eta) = \begin{cases} C_{\odot\eta}^{(1)} & \text{if } \alpha \in (-\infty;\alpha_1), \\ C_{\odot\eta}^{(2)} & \text{if } \alpha \in [\alpha_1;\alpha_2), \\ C_{\odot\eta}^{(3)} & \text{if } \alpha \in [\alpha_2;\alpha_3), \\ C_{\odot\eta}^{(4)} & \text{if } \alpha \in [\alpha_3;\alpha_3), \\ C_{\odot\eta}^{(5)} & \text{if } \alpha \in [\alpha_4;\infty); \end{cases}$$
(110)

$$C_{\odot\hat{q}}(\alpha,\hat{q}) = \begin{cases} C_{\odot\hat{q}}^{(1)} & \text{if } \hat{q} \in (-\infty; \hat{q}_1), \\ C_{\odot\hat{q}}^{(2)} & \text{if } \hat{q} \in [\hat{q}_1; \hat{q}_2), \\ C_{\odot\hat{q}}^{(3)} & \text{if } \hat{q} \in [\hat{q}_2; \hat{q}_3), \\ C_{\odot\hat{q}}^{(4)} & \text{if } \hat{q} \in [\hat{q}_3; \hat{q}_3), \\ C_{\odot\hat{q}}^{(5)} & \text{if } \hat{q} \in [\hat{q}_4; \infty); \end{cases}$$
(111)

with

$$\begin{array}{ll}
\alpha_1 = 5^\circ, & \alpha_2 = 15^\circ, & \alpha_3 = 25^\circ, & \alpha_4 = 45^\circ; \\
\hat{q}_1 = -0.200^\circ, & \hat{q}_2 = -0.075^\circ, & \hat{q}_3 = 0.075^\circ, & \hat{q}_4 = 0.200^\circ; \\
\end{array} \tag{112}$$

and

$C_{\mathbf{X}\alpha}^{(1)}(\alpha) = -0.025 - 0.002\alpha + 0.827\alpha^2;$	(114)
$C_{\mathbf{X}\alpha}^{(2)}(\alpha) = -0.204 + 2.778\alpha - 7.493\alpha^2;$	(115)
$C_{\mathbf{X}\alpha}^{(3)}(\alpha) = 0.217 - 1.218\alpha + 1.628\alpha^2;$	(116)
$C_{\mathbf{X}\alpha}^{(4)}(\alpha) = 0.022 - 0.110\alpha + 0.114\alpha^2;$	(117)
$C_{X\alpha}^{(5)}(\alpha) = -0.052 + 0.024\alpha + 0.063\alpha^2;$	(118)
$C_{Z\alpha}^{(1)}(\alpha) = -0.028 - 4.949\alpha + 0.837\alpha^2;$	(119)
$C_{Z\alpha}^{(2)}(\alpha) = 0.155 - 8.239\alpha + 14.537\alpha^2;$	(120)
$C_{Z\alpha}^{(3)}(\alpha) = -0.815 - 0.298\alpha - 1.648\alpha^2;$	(121)
$C_{Z\alpha}^{(4)}(\alpha) = -0.467 - 2.158\alpha + 0.786\alpha^2;$	(122)
$C_{\mathbf{Z}\alpha}^{(5)}(\alpha) = -1.052 - 0.996\alpha + 0.254\alpha^2;$	(123)

$$C_{m\alpha}^{(1)}(\alpha) = 0.157 - 1.724\alpha + 1.806\alpha^{2} + 11.969\alpha^{3};$$

$$C_{m\alpha}^{(2)}(\alpha) = 0.565 - 10.419\alpha + 59.277\alpha^{2} - 118.320\alpha^{3};$$

$$C_{m\alpha}^{(3)}(\alpha) = 7.543 - 64.304\alpha + 174.300\alpha^{2} - 160.370\alpha^{3};$$
(126)

$$C_{m\alpha}^{(4)}(\alpha) = -0.866 + 1.176\alpha - 1.875\alpha^2 + 0.681\alpha^3;$$
(127)

$$C_{m\alpha}^{(5)}(\alpha) = -1.053 + 1.752\alpha - 2.210\alpha^2 + 0.561\alpha^3;$$
(128)

$$C_{X\eta}^{(1)}(\alpha,\eta) = -0.010\eta + 0.195\alpha\eta - 0.082\eta^2 + 0.628\alpha^2\eta + 0.213\alpha\eta^2 - 0.036\eta^3;$$
(129)

$$C_{X\eta}^{(2)}(\alpha,\eta) = 0.011\eta - 0.009\alpha\eta - 0.060\eta^2 + 0.165\alpha^2\eta - 0.043\alpha\eta^2 - 0.036\eta^3;$$
(130)

$$C_{X\eta}^{(3)}(\alpha,\eta) = 0.060\eta - 0.175\alpha\eta - 0.043\eta^2 + 0.087\alpha^2\eta - 0.106\alpha\eta^2 - 0.036\eta^3;$$
(131)

$$C_{X\eta}^{(4)}(\alpha,\eta) = 0.027\eta - 0.079\alpha\eta - 0.056\eta^2 + 0.042\alpha^2\eta - 0.076\alpha\eta^2 - 0.036\eta^3;$$
(132)

$$C_{X\eta}^{(5)}(\alpha,\eta) = -0.281\eta + 0.586\alpha\eta - 0.133\eta^2 - 0.305\alpha^2\eta + 0.021\alpha\eta^2 - 0.036\eta^3;$$
(133)

$$C_{Z\eta}^{(1)}(\alpha,\eta) = -0.595\eta + 0.058\alpha\eta + 0.039\eta^2 + 0.045\alpha^2\eta + 0.023\alpha\eta^2 + 1.142\eta^3;$$
(134)

$$C_{Z\eta}^{(2)}(\alpha,\eta) = -0.626\eta + 0.461\alpha\eta + 0.012\eta^2 - 0.452\alpha^2\eta + 0.332\alpha\eta^2 + 1.142\eta^3;$$
(135)

$$C_{Z\eta}^{(3)}(\alpha,\eta) = -0.631\eta + 0.299\alpha\eta + 0.051\eta^2 + 0.224\alpha^2\eta + 0.183\alpha\eta^2 + 1.142\eta^3;$$
(136)

$$C_{Z\eta}^{(4)}(\alpha,\eta) = -0.666\eta + 0.516\alpha\eta - 0.337\eta^2 - 0.084\alpha^2\eta + 1.074\alpha\eta^2 + 1.142\eta^3;$$
(137)

$$C_{Z\eta}^{(5)}(\alpha,\eta) = -1.116\eta + 1.625\alpha\eta + 0.312\eta^2 - 0.768\alpha^2\eta + 0.247\alpha\eta^2 + 1.142\eta^3;$$
(138)

$$C_{2\eta}^{(1)}(\alpha,\eta) = -\frac{1870\pi}{1.110\eta} + \frac{0.047}{1.020\eta} + \frac{0.012\eta}{0.000} + \frac{0.0247\eta}{1.000\eta} + \frac{0.224\eta}{1.112\eta},$$
(130)

$$C_{m\eta}^{(1)}(\alpha,\eta) = -1.879\eta - 0.047\alpha\eta - 0.227\eta^2 - 0.845\alpha^2\eta + 0.378\alpha\eta^2 + 1.409\eta^3;$$
(139)

$$C_{m\eta}^{(2)}(\alpha,\eta) = -2.006\eta + 1.410\alpha\eta - 0.260\eta^2 - 0.807\alpha^2\eta + 0.756\alpha\eta^2 + 1.409\eta^3;$$
(140)

$$C_{m\eta}^{(3)}(\alpha,\eta) = -1.916\eta - 0.071\alpha\eta - 0.704\eta^2 + 3.530\alpha^2\eta + 2.449\alpha\eta^2 + 1.409\eta^3;$$
(141)

$$C_{m\eta}^{(\alpha)}(\alpha,\eta) = -1.916\eta - 0.071\alpha\eta - 0.704\eta^2 + 3.530\alpha^2\eta + 2.449\alpha\eta^2 + 1.409\eta^3;$$
(141)

$$C_{m\eta}^{(4)}(\alpha,\eta) = -1.612\eta + 0.765\alpha\eta + 0.802\eta^2 + 0.017\alpha^2\eta - 1.002\alpha\eta^2 + 1.409\eta^3;$$
(142)

$$C_{m\eta}^{(5)}(\alpha,\eta) = -1.555\eta + 0.535\alpha\eta - 0.777\eta^2 + 0.219\alpha^2\eta + 1.009\alpha\eta^2 + 1.409\eta^3;$$
(143)
as well as

$$C_{\hat{\mathbf{X}}\hat{q}}^{(1)}(\alpha,\hat{q}) = -0.003 - 1.776\hat{q} - 0.010\alpha - 276.480\hat{q}^{(2)} - 2.319\hat{q}\alpha - 0.005\alpha^2;$$
(144)

$$C_{X\hat{q}}^{(2)}(\alpha,\hat{q}) = 0.001 + 0.689\hat{q} + 0.004\alpha + 120.080\hat{q}^{(2)} + 1.492\hat{q}\alpha - 0.005\alpha^{2};$$
(145)

$$C_{X\hat{q}}^{(3)}(\alpha,\hat{q}) = 0.001 + 1.338\hat{q} + 0.003\alpha + 232.350\hat{q}^{(2)} + 0.558\hat{q}\alpha - 0.005\alpha^{2};$$
(146)

$$C_{X\hat{q}}^{(4)}(\alpha,\hat{q}) = 0.001 + 1.897\hat{q} + 0.004\alpha + 144.900\hat{q}^{(2)} - 0.699\hat{q}\alpha - 0.005\alpha^{2};$$

$$(147)$$

$$C_{X\hat{q}}^{(5)}(\alpha,\hat{q}) = 0.001 + 0.251\hat{q} + 0.004\alpha + 144.900\hat{q}^{(2)} - 0.699\hat{q}\alpha - 0.005\alpha^{2};$$

$$(147)$$

$$C_{\mathbf{X}\hat{q}}^{(5)}(\alpha,\hat{q}) = 0.001 + 2.271\hat{q} - 0.009\alpha - 7.040\hat{q}^{(2)} + 2.981\hat{q}\alpha - 0.005\alpha^2;$$
(148)

$$C_{Z\hat{q}}^{(1)}(\alpha,\hat{q}) = -0.008 - 25.814\hat{q} + 0.138\alpha + 2806.400\hat{q}^{(2)} + 22.164\hat{q}\alpha + 0.004\alpha^{2};$$

$$C_{Z\hat{q}}^{(2)}(\alpha,\hat{q}) = -0.010 - 22.148\hat{q} + 0.010\alpha + 1120.800\hat{q}^{(2)} - 11.021\hat{q}\alpha + 0.004\alpha^{2};$$
(149)
$$C_{Z\hat{q}}^{(2)}(\alpha,\hat{q}) = -0.010 - 22.148\hat{q} + 0.010\alpha + 1120.800\hat{q}^{(2)} - 11.021\hat{q}\alpha + 0.004\alpha^{2};$$
(150)

$$C_{Z\hat{q}}^{(2)}(\alpha,\hat{q}) = -0.010 - 32.148\hat{q} + 0.019\alpha + 1120.800\hat{q}^{(2)} - 11.921\hat{q}\alpha + 0.004\alpha^2;$$
(150)

$$C_{Z\hat{q}}^{(3)}(\alpha,\hat{q}) = -0.014 - 36.128\hat{q} + 0.029\alpha + 507.060\hat{q}^{(2)} - 3.943\hat{q}\alpha + 0.004\alpha^2;$$
(151)

$$C_{Z\hat{q}}^{(4)}(\alpha,\hat{q}) = -0.010 - 40.109\hat{q} + 0.019\alpha + 1120.800\hat{q}^{(2)} + 4.036\hat{q}\alpha + 0.004\alpha^2;$$
(152)

$$C_{\mathbf{Z}\hat{q}}^{(5)}(\alpha,\hat{q}) = -0.008 - 46.443\hat{q} + 0.138\alpha + 2806.400\hat{q}^{(2)} - 30.049\hat{q}\alpha + 0.004\alpha^{2};$$
(153)

$$C_{\mathrm{m}\hat{q}}^{(1)}(\alpha,\hat{q}) = 0.008 - 41.631\hat{q} - 0.013\alpha + 300.350\hat{q}^{(2)} - 10.716\hat{q}\alpha - 0.081\alpha^{2};$$
(154)

$$C_{\mathbf{m}\hat{q}}^{(2)}(\alpha,\hat{q}) = 0.009 - 40.268\hat{q} + 0.009\alpha + 632.510\hat{q}^{(2)} - 4.284\hat{q}\alpha - 0.081\alpha^{2};$$
⁽³⁾

$$C_{\mathrm{m}\hat{q}}^{(3)}(\alpha,\hat{q}) = 0.009 - 40.445\hat{q} + 0.012\alpha + 674.850\hat{q}^{(2)} - 2.169\hat{q}\alpha - 0.081\alpha^2;$$
(156)

$$C_{m\hat{q}}^{(4)}(\alpha,\hat{q}) = 0.009 - 39.916\hat{q} + 0.009\alpha + 381.400\hat{q}^{(2)} - 0.193\hat{q}\alpha - 0.081\alpha^2;$$

$$C_{m\hat{q}}^{(5)}(\alpha,\hat{q}) = 0.001 - 35.950\hat{q} + 0.009\alpha + 381.400\hat{q}^{(2)} - 0.193\hat{q}\alpha - 0.081\alpha^2;$$
(157)
$$C_{m\hat{q}}^{(5)}(\alpha,\hat{q}) = 0.001 - 35.950\hat{q} + 0.009\alpha + 381.400\hat{q}^{(2)} - 0.193\hat{q}\alpha - 0.081\alpha^2;$$
(157)

$$C_{\mathbf{m}\hat{q}}^{(5)}(\alpha,\hat{q}) = -0.001 - 35.258\hat{q} + 0.008\alpha - 208.640\hat{q}^{(2)} + 0.192\hat{q}\alpha - 0.081\alpha^2;$$
(158)

Nomenclature

$ \begin{aligned} a_0 &= \text{Low-angle of attack boundary (°); \\ &= \text{Side-Sip angle (rad); } \\ &= \text{Nide-Sip angle (rad); angative if leading to positive yaw moment; } \\ &= \text{Riduder deflection (rad), negative if leading to positive pitch moment; } \\ &= \text{Air-path bank angle (rad); } \\ &= \text{Air-path bank angle (rad); } \\ &= \text{Air density } (g=1.200 \text{ kg m}^{-3}); \\ &= \text{X} \text{A} = \text{Air-path azimuth angle (rad); } \\ &= \text{Air density } (g=1.200 \text{ kg m}^{-3}); \\ &= \text{X} = \text{Air density } (g=1.200 \text{ kg m}^{-3}); \\ &= \text{X} = \text{Air density } (g=1.200 \text{ kg m}^{-3}); \\ &= \text{X} = \text{Air density } (g=1.200 \text{ kg m}^{-3}); \\ &= \text{X} = \text{Arrodynamic mean chord } (c_n = 0.280 \text{ m}); \\ &= \text{C} = \text{Cordynamic mean chord } (c_n = 0.280 \text{ m}); \\ &= \text{C} = \text{Cordynamic mean chord } (c_n = 0.280 \text{ m}); \\ &= \text{C} = \text{Standard gravitational acceleration } (g \approx 9.810 \text{ ms}^{-2}); \\ &= \text{Logine vertical displacement, positive along } s_r-axis (l_t = 0.100 \text{ m}); \\ &= \text{Mir ardi mass } (m = 26.190 \text{ kg}); \\ &= \text{Pitch rate (rad s^{-1}); } \\ &= \text{T} = \text{Mir ardi mass } (m = 26.190 \text{ kg}); \\ &= \text{Pitch rate (rad s^{-1}); } \\ &= \text{C} = \text{Aerodynamic coefficient moment body } s_r-axis (\cdot); \\ &= \text{Aerodynamic coefficient moment body } s_r-axis (\cdot); \\ &= \text{Aerodynamic coefficient moment body } s_r-axis (\cdot); \\ &= \text{Aerodynamic coefficient force body } s_r-axis (\cdot); \\ &= \text{Aerodynamic coefficient force body } s_r-axis (\cdot); \\ &= \text{Aerodynamic coefficient force body } s_r-axis (\cdot); \\ &= \text{Aerodynamic coefficient force body } s_r-axis (\cdot); \\ &= \text{Aerodynamic coefficient force body } s_r-axis (\cdot); \\ &= \text{Aerodynamic coefficient force body } s_r-axis (\cdot); \\ &= \text{C} = \text{Aerodynamic coefficient force body } s_r-axis (I = -X_n^A, N); \\ &= \text{C} = \text{Aerodynamic coefficient force body } s_r-axis (I = -X_n^A, N); \\ &= \text{C} = \text{Aerodynamic coefficient force body } s_r-axis (I = -X_n^A, N); \\ &= \text{C} = \text{Aerodynamic coefficient force body } s_r-axis (I = -X_n^A, N); \\ &= \text{C} = \text{Aerodynamic coefficient force body } s_r-axis $	α	=	Angle of attack (rad);
$ \begin{array}{llllllllllllllllllllllllllllllllllll$	$lpha_0$	=	Low-angle of attack boundary (°);
$\begin{array}{rcl} \gamma_A & = & \operatorname{Air-path} \operatorname{Inclination} \operatorname{angle} (rad); \\ \zeta & = & \operatorname{Rudder} deflection (rad), negative if leading to positive yaw moment; \\ \eta & = & \operatorname{Lievator} deflection (rad), negative if leading to positive pilch moment; \\ \mu_A & = & \operatorname{Air-path} bank angle (rad); \\ \xi & = & \operatorname{Air-path} azimuth angle (rad); \\ \Theta & = & \operatorname{Bank} angle (rad); \\ \Theta & = & \operatorname{Bank} angle (rad); \\ \Psi & = & \operatorname{Aaimuth} angle (rad); \\ g & = & \operatorname{Standard} gravitational acceleration (\varphi \approx 9.810 m s^{-2}); \\ l_i & = & \operatorname{Reigne vertical displacement, positive along z_r \operatorname{axis} (l_i = 0.100 \text{ m}); \\ \pi & = & \operatorname{Aircraft} mass (m = 26.190 \text{ kg}); \\ g & = & \operatorname{Standard} gravitational acceleration (\varphi \approx 9.810 m s^{-2}); \\ l_i & = & \operatorname{Roignawic coefficient moment body } z_r \operatorname{axis} (.); \\ g & = & \operatorname{Pitch} \operatorname{argi} (rad s^{-1}); \\ g & = & \operatorname{Pitch} \operatorname{rads} (rad s^{-1}); \\ g & = & \operatorname{Pitch} \operatorname{rads} (rad s^{-1}); \\ \pi^{aing}_{1,2}, \pi^{aing}_{2,4} & = & \operatorname{Longitudinal position cetter of gravity} (x_{eing}^{eing} = -1.460 \text{ m}, x_{eing}^{eing} = -0.290 \text{ m}); \\ G_m & & \operatorname{Aerodynamic coefficient moment body } x_r \operatorname{axis} (.); \\ C_m & & \operatorname{Aerodynamic coefficient moment body x_r - \operatorname{axis} (.); \\ C_L & & \operatorname{Aerodynamic coefficient moment body x_r - \operatorname{axis} (.); \\ C_L & & \operatorname{Aerodynamic darg coefficient force negative air-path} x_a - \operatorname{axis} (.); \\ C_X & & & \operatorname{Aerodynamic coefficient force body x_r - \operatorname{axis} (.); \\ C_X & & & & \operatorname{Aerodynamic coefficient force body x_r - \operatorname{axis} (.); \\ C_X & & & & & & & & & & & & & & & & & & &$	β	=	Side-slip angle (rad);
$ \begin{array}{llllllllllllllllllllllllllllllllllll$	$\gamma_{ m A}$	=	Air-path inclination angle (rad);
$ \begin{array}{llllllllllllllllllllllllllllllllllll$	ζ	=	Rudder deflection (rad), negative if leading to positive yaw moment;
$\begin{array}{llllllllllllllllllllllllllllllllllll$	η	=	Elevator deflection (rad), negative if leading to positive pitch moment;
$ \begin{array}{llllllllllllllllllllllllllllllllllll$	$\mu_{ m A}$	=	Air-path bank angle (rad);
$\begin{array}{llllllllllllllllllllllllllllllllllll$	ξ	=	Aileron deflection (rad), negative if leading to positive roll moment;
$\begin{array}{llllllllllllllllllllllllllllllllllll$	ϱ	=	Air density $(\varrho = 1.200 \mathrm{kg m^{-3}});$
$\begin{array}{llllllllllllllllllllllllllllllllllll$	χ_A	=	Air-path azimuth angle (rad);
$ \begin{aligned} $	Θ	=	Pitch angle (rad);
$ \begin{array}{llllllllllllllllllllllllllllllllllll$	Φ	=	Bank angle (rad);
b = Reference aerodynamic span $(b = 2.088 \text{ m});$ c_{A} = Aerodynamic mean chord $(c_{A} = 0.280 \text{ m});$ g = Standard gravitational acceleration $(g \approx 9.810 \text{ ms}^{-2});$ l_{t} = Engine vertical displacement, positive along z_{t} -axis $(l_{t} = 0.100 \text{ m});$ m = Aircraft mass $(m = 26.190 kg);p = Roll rate (\text{rad s}^{-1});q = Pitch rate (\text{rad s}^{-1});r = Yaw rate (\text{rad s}^{-1});r = Vaw rate (\text{rad s}^{-1});r = Longitudinal position center of gravity (x_{cg} = -1.450 \text{ m}, z_{cg} = -0.300 \text{ m});x_{cg}^{ref}, z_{cg}^{ref} = Longitudinal position center of gravity (x_{cg}^{ref} = -1.460 \text{ m}, z_{cg}^{ref} = -0.290 \text{ m});C_{I} = Aerodynamic coefficient moment body x_{r}-axis (\cdot);C_{m} = Aerodynamic coefficient moment body z_{r}-axis (\cdot);C_{n} = Aerodynamic coefficient force negative air-path x_{a}-axis (\cdot);C_{L} = Aerodynamic if coefficient, force negative air-path z_{a}-axis (\cdot);C_{L} = Aerodynamic coefficient force body y_{r}-axis (\cdot);C_{X} = Aerodynamic coefficient force body y_{r}-axis (L = -X_{a}^{\Lambda}, N);F = Thrust force (N), positive along body x_{r}-axis (L = -X_{a}^{\Lambda}, N);F = Thrust force (N), positive along body x_{r}-axis (L = -Z_{a}^{\Lambda}, N);F = Thrust force (N), mathematically positive around x_{r}-axis;M_{f} = Pitch moment (N m), mathematically positive around x_{r}-axis;N_{f} = Yaw moment (N m), mathematically positive around x_{r}-axis;N_{f} = Aerodynamic force along body x_{r}-axis (N);X_{f}^{\Lambda} = Resulting force along body x_{r}-axis (N);X_{f}^{\Lambda} = Resulting force along body x_{r}-axis (N);X_{f}^{\Lambda} = Resulting force along body x_{r}-axis (N);Z_{A}^{\Lambda} = Resulting force along body x_{r}-axis (N);Z_{A}^{\Lambda$	Ψ	=	Azimuth angle (rad);
$\begin{array}{rcl} c_{\rm A} &=& {\rm Aerodynamic mean chord } (c_{\rm A}=0.280{\rm m}); \\ g &=& {\rm Standard gravitational acceleration } (g\approx 9.810{\rm ms^{-2}}); \\ l_{\rm t} &=& {\rm Engine vertical displacement, positive along } z_{\rm f} {\rm -axis} \ (l_{\rm t}=0.100{\rm m}); \\ m &=& {\rm Aircraft mass} \ (m=26.190{\rm kg}); \\ p &=& {\rm Roll rate (rad {\rm s}^{-1}); \\ q &=& {\rm Pitch rate (rad {\rm s}^{-1}); \\ r &=& {\rm Yaw rate (rad {\rm s}^{-1}); \\ r &=& {\rm Yaw rate (rad {\rm s}^{-1}); \\ r &=& {\rm Yaw rate (rad {\rm s}^{-1}); \\ r &=& {\rm Aerodynamic coefficient moment body } x_{\rm r} {\rm -axis} \ (\cdot); \\ C_{\rm f} &=& {\rm Aerodynamic coefficient moment body } x_{\rm r} {\rm -axis} \ (\cdot); \\ C_{\rm m} &=& {\rm Aerodynamic coefficient moment body } x_{\rm r} {\rm -axis} \ (\cdot); \\ C_{\rm L} &=& {\rm Aerodynamic coefficient moment body } x_{\rm r} {\rm -axis} \ (\cdot); \\ C_{\rm L} &=& {\rm Aerodynamic coefficient moment body } x_{\rm r} {\rm -axis} \ (\cdot); \\ C_{\rm L} &=& {\rm Aerodynamic coefficient moment body } x_{\rm r} {\rm -axis} \ (\cdot); \\ C_{\rm L} &=& {\rm Aerodynamic coefficient force negative air-path } z_{\rm a} {\rm -axis} \ (\cdot); \\ C_{\rm X} &=& {\rm Aerodynamic coefficient force body } x_{\rm r} {\rm -axis} \ (\cdot); \\ C_{\rm X} &=& {\rm Aerodynamic coefficient force body } x_{\rm r} {\rm -axis} \ (\cdot); \\ C_{\rm X} &=& {\rm Aerodynamic coefficient force body } x_{\rm r} {\rm -axis} \ (\cdot); \\ C_{\rm X} &=& {\rm Aerodynamic coefficient force body } x_{\rm r} {\rm -axis} \ (\cdot); \\ C_{\rm X} &=& {\rm Aerodynamic coefficient force body } x_{\rm r} {\rm -axis} \ (\cdot); \\ C_{\rm X} &=& {\rm Aerodynamic coefficient force body } x_{\rm r} {\rm -axis} \ (\cdot); \\ D &=& {\rm Drag force, positive along negative air-path } Z_{\rm a} {\rm -axis} \ (L=-Z_{\rm a}^{\rm A}, {\rm N}); \\ F &=& {\rm Thrust force} ({\rm N}), {\rm positive along body } x_{\rm r} {\rm -axis}; \ (L=-Z_{\rm a}^{\rm A}, {\rm N}); \\ L_{\rm f} &=& {\rm Roll moment} \ ({\rm Nm}), {\rm mathematically positive around } x_{\rm r} {\rm -axis}; \\ S &=& {\rm Wing area} \ (S=0.550{\rm m}^2); \\ V_{\rm A} \ {\rm N} &=& {\rm Resulting force along body } x_{\rm r} {\rm -axis} \ ({\rm N}); \\ X_{\rm A}^{\rm A} &=& {\rm Resoulting force along body } x_{\rm r} {\rm -axis} \ ({\rm N$	b	=	Reference aerodynamic span $(b = 2.088 \text{ m});$
$\begin{array}{llllllllllllllllllllllllllllllllllll$	c_{A}	=	Aerodynamic mean chord $(c_{\rm A} = 0.280 \mathrm{m});$
$ \begin{array}{llllllllllllllllllllllllllllllllllll$	g	=	Standard gravitational acceleration $(g \approx 9.810 \mathrm{m s^{-2}});$
$\begin{array}{llllllllllllllllllllllllllllllllllll$	$l_{ m t}$	=	Engine vertical displacement, positive along $z_{\rm f}$ -axis ($l_{\rm t} = 0.100 {\rm m}$);
$\begin{array}{llllllllllllllllllllllllllllllllllll$	m	=	Aircraft mass $(m = 26.190 \text{ kg});$
$\begin{array}{llllllllllllllllllllllllllllllllllll$	p	=	Roll rate $(rad s^{-1})$;
$\begin{array}{rcl} r & = & \operatorname{Yaw} \operatorname{rate} (\operatorname{rad} \operatorname{s}^{-1});\\ x_{cg}, z_{cg}, z_{cg} & = & \operatorname{Longitudinal position center of gravity } (x_{cg}^{cef} = -1.450 \mathrm{m}, z_{cg} = -0.300 \mathrm{m});\\ x_{cg}^{ref}, z_{cg}^{ref} & = & \operatorname{Longitudinal position center of gravity } (x_{cg}^{ref} = -1.460 \mathrm{m}, z_{cg}^{ref} = -0.290 \mathrm{m});\\ C_{1} & = & \operatorname{Aerodynamic coefficient moment body } x_{r} \operatorname{axis}(\cdot);\\ C_{m} & = & \operatorname{Aerodynamic coefficient moment body } x_{r} \operatorname{axis}(\cdot);\\ C_{1} & = & \operatorname{Aerodynamic coefficient, moment body } x_{r} \operatorname{axis}(\cdot);\\ C_{L} & = & \operatorname{Aerodynamic coefficient, force negative air-path } x_{a} \operatorname{axis}(\cdot);\\ C_{X} & = & \operatorname{Aerodynamic coefficient force body } x_{r} \operatorname{axis}(\cdot);\\ C_{X} & = & \operatorname{Aerodynamic coefficient force body } y_{r} \operatorname{axis}(\cdot);\\ C_{Z} & = & \operatorname{Aerodynamic coefficient force body } y_{r} \operatorname{axis}(\cdot);\\ C_{Z} & = & \operatorname{Aerodynamic coefficient force body } y_{r} \operatorname{axis}(\cdot);\\ D & = & \operatorname{Drag} \ force, \ positive \ along \ negative \ air-path } X_{a} \operatorname{axis}(L = -X_{a}^{\Lambda}, N);\\ F & = & \operatorname{Thrust} \ force \ (N), \ positive \ along \ negative \ arrout } X_{a} \operatorname{axis}(L = -Z_{a}^{\Lambda}, N);\\ L_{f} & = & \operatorname{Roll} \ moment \ (N m), \ mathematically \ positive \ around } y_{r} \operatorname{axis};\\ M_{f} & = & \operatorname{Pitch} \ moment \ (N m), \ mathematically \ positive \ around } y_{r} \operatorname{axis};\\ S & = & \operatorname{Wing} \operatorname{area}(S = 0.550 \mathrm{m}^{2});\\ V_{A}, \mathbf{V}_{A} & = & \operatorname{Aerodynamic} \ force \ along \ body } x_{r} \operatorname{axis}(N);\\ X_{f}^{F} & = & \operatorname{Thrust} \ force \ along \ body } x_{r} \operatorname{axis}(N);\\ X_{f}^{F} & = & \operatorname{Thrust} \ force \ along \ body \\ x_{r} \operatorname{axis}(N);\\ X_{f}^{F} & = & \operatorname{Thrust} \ force \ along \ body \\ x_{r} \operatorname{axis}(N);\\ Y^{A} & = & \operatorname{Resulting} \ force \ along \ body \\ x_{r} \operatorname{axis}(N);\\ X_{f}^{F} & = & \operatorname{Thrust} \ force \ along \ body \\ x_{r} \operatorname{axis}(N);\\ Z^{A} & = & \operatorname{Resulting} \ force \ along \ body \\ x_{r} \operatorname{axis}(N);\\ Z^{A} & = & \operatorname{Resulting} \ force \ along \ body \\ x_{r} \operatorname{axis}(N);\\ Z^{A} & = & \operatorname{Aerodynamic} \ force \ along \ body \\ x_{r} \operatorname{axis}(N);\\ Z^{A} & = & \operatorname{Resulting} \ force \ along \ body \\ x_{r}$	q	=	Pitch rate $(rad s^{-1});$
$ \begin{array}{llllllllllllllllllllllllllllllllllll$	r	=	Yaw rate (rad s ⁻¹);
$ \begin{array}{llllllllllllllllllllllllllllllllllll$	x_{cg}, z_{cg}	=	Longitudinal position center of gravity ($x_{cg} = -1.450 \text{ m}, z_{cg} = -0.300 \text{ m}$);
$\begin{array}{rcl} C_1 & = & \operatorname{Aerodynamic coefficient moment body x_{Γ}-axis (\cdot); \\ C_m & = & \operatorname{Aerodynamic coefficient moment body x_{Γ}-axis (\cdot); \\ C_n & = & \operatorname{Aerodynamic coefficient moment body x_{Γ}-axis (\cdot); \\ C_L & = & \operatorname{Aerodynamic coefficient, force negative air-path x_a-axis (·); \\ C_L & = & \operatorname{Aerodynamic coefficient, force negative air-path x_a-axis (·); \\ C_X & = & \operatorname{Aerodynamic coefficient force body x_{Γ}-axis (·); \\ C_Z & = & \operatorname{Aerodynamic coefficient force body x_{Γ}-axis (·); \\ C_Z & = & \operatorname{Aerodynamic coefficient force body x_{Γ}-axis (·); \\ D & = & \operatorname{Drag force, positive along negative air-path x_a-axis ($L = -X_a^A, N); \\ F & = & \operatorname{Thrust force (N), positive along body x_{Γ}-axis; \\ L & = & \operatorname{Lift force, positive along negative air-path Z_a-axis ($L = -Z_a^A, N); \\ L_f & = & \operatorname{Roll moment (N m), mathematically positive around x_{Γ}-axis; \\ M_f & = & \operatorname{Pitch moment (N m), mathematically positive around x_{Γ}-axis; \\ S & = & Wing area ($S = 0.550 m^2$); \\ V_A, \mathbf{V}_A & = & \operatorname{Aircraft speed and velocity relative to air ($V_A = \ \mathbf{V}_A\ _2$, ms^{-1}); \\ X_A^A & = & \operatorname{Resulting force along body x_{Γ}-axis (N); \\ X_I^F & = & \operatorname{Thrust force along body x_{Γ}-axis (N); \\ X_A^T & = & \operatorname{Aerodynamic force along body x_{Γ}-axis (N); \\ Y^A & = & \operatorname{Resulting force along body x_{Γ}-axis (N); \\ Y_A^A & = & \operatorname{Resulting force along body x_{Γ}-axis (N); \\ Z_A^F & = & \operatorname{Aerodynamic force along body x_{Γ}-axis (N); \\ Z_A^A & = & \operatorname{Resulting force along body x_{Γ}-axis (N); \\ Z_A^A & = & \operatorname{Resulting force along body x_{Γ}-axis (N); \\ Z_A^F & = & \operatorname{Aerodynamic force along body x_{Γ}-axis (N); \\ Z_A^A & = & \operatorname{Resulting force along body x_{Γ}-axis (N); \\ Z_A^F & = & \operatorname{Aerodynamic force along body x_{Γ}-axis (N); \\ Z_A^F & = & \operatorname{Aerodynamic force along body x_{Γ}-axis (N); \\ Z_A^F & = & \operatorname{Aerodynamic force along body x_{Γ}-axis (N); \\ Z_A^F & = & \operatorname{Aerodynamic force along body x_{Γ}-axis (N); \\ Z_A^F & = & \operatorname{Aerodynamic force along body x_{Γ}-axis (N); \\ Z_A^F & = & Aer$	$x_{\rm cg}^{\rm ref}, z_{\rm cg}^{\rm ref}$	=	Longitudinal position reference center of gravity $(x_{cg}^{ref} = -1.460 \text{ m}, z_{cg}^{ref} = -0.290 \text{ m});$
$\begin{array}{rcl} C_{\rm m} &=& {\rm Aerodynamic coefficient moment body } y_{\rm f} {\rm axis} (\cdot);\\ C_{\rm n} &=& {\rm Aerodynamic coefficient moment body } z_{\rm f} {\rm axis} (\cdot);\\ C_{\rm D} &=& {\rm Aerodynamic drag coefficient, force negative air-path } x_{\rm a} {\rm -axis} (\cdot);\\ C_{\rm L} &=& {\rm Aerodynamic lift coefficient, force negative air-path } z_{\rm a} {\rm -axis} (\cdot);\\ C_{\rm X} &=& {\rm Aerodynamic coefficient force body } y_{\rm f} {\rm -axis} (\cdot);\\ C_{\rm Y} &=& {\rm Aerodynamic coefficient force body } y_{\rm f} {\rm -axis} (\cdot);\\ C_{\rm Z} &=& {\rm Aerodynamic coefficient force body } y_{\rm f} {\rm -axis} (\cdot);\\ C_{\rm Z} &=& {\rm Aerodynamic coefficient force body } y_{\rm f} {\rm -axis} (\cdot);\\ C_{\rm Z} &=& {\rm Aerodynamic coefficient force body } y_{\rm f} {\rm -axis} (\cdot);\\ D &=& {\rm Drag force, positive along negative air-path } Z_{\rm a} {\rm -axis} (L = -X_{\rm a}^{\rm A}, {\rm N});\\ F &=& {\rm Thrust force} ({\rm N}), {\rm positive along negative air-path } Z_{\rm a} {\rm -axis} (L = -Z_{\rm a}^{\rm A}, {\rm N});\\ L_{\rm f} &=& {\rm Roll moment} ({\rm Nm}), {\rm mathematically positive around } x_{\rm f} {\rm -axis};\\ M_{\rm f} &=& {\rm Pitch moment} ({\rm Nm}), {\rm mathematically positive around } y_{\rm f} {\rm -axis};\\ S &=& {\rm Wing area} (S = 0.550 {\rm m}^2);\\ V_{\rm A}, {\rm V}_{\rm A} &=& {\rm Resulting force along air-path } x_{\rm a} {\rm -axis} ({\rm N});\\ X_{\rm f}^{\rm A} &=& {\rm Aerodynamic foree along body } x_{\rm f} {\rm -axis} ({\rm N});\\ X_{\rm f}^{\rm A} &=& {\rm Aerodynamic force along body } x_{\rm f} {\rm -axis} ({\rm N});\\ Y_{\rm A}^{\rm A} &=& {\rm Resulting force along air-path } x_{\rm a} {\rm -axis} ({\rm N});\\ X_{\rm f}^{\rm A} &=& {\rm Aerodynamic force along body } x_{\rm f} {\rm -axis} ({\rm N});\\ Z_{\rm f}^{\rm A} &=& {\rm Aerodynamic force along body } y_{\rm f} {\rm -axis} ({\rm N});\\ Z_{\rm f}^{\rm A} &=& {\rm Aerodynamic force along body } y_{\rm f} {\rm -axis} ({\rm N});\\ Z_{\rm f}^{\rm A} &=& {\rm Aerodynamic force along body } y_{\rm f} {\rm -axis} ({\rm N});\\ Z_{\rm f}^{\rm A} &=& {\rm Aerodynamic force along body } y_{\rm f} {\rm -axis} ({\rm N});\\ Z_{\rm f}^{\rm A} &=& {\rm Aerodynamic force along body } y_{\rm f} {\rm -axis} ({\rm N});\\ Z_{\rm f}^{\rm A} &=& {\rm Aerodynamic force along body$	C_{l}	=	Aerodynamic coefficient moment body x_{f} -axis (·);
$\begin{array}{rcl} C_{n} & = & \operatorname{Aerodynamic coefficient moment body } z_{r}\operatorname{axis}\left(\cdot\right);\\ C_{D} & = & \operatorname{Aerodynamic drag coefficient, force negative air-path } x_{a}\operatorname{-axis}\left(\cdot\right);\\ C_{L} & = & \operatorname{Aerodynamic coefficient force body } x_{t}\operatorname{-axis}\left(\cdot\right);\\ C_{X} & = & \operatorname{Aerodynamic coefficient force body } x_{t}\operatorname{-axis}\left(\cdot\right);\\ C_{Y} & = & \operatorname{Aerodynamic coefficient force body } x_{t}\operatorname{-axis}\left(\cdot\right);\\ C_{Z} & = & \operatorname{Aerodynamic coefficient force body } x_{t}\operatorname{-axis}\left(\cdot\right);\\ D & = & \operatorname{Drag force, positive along negative air-path } X_{a}\operatorname{-axis}\left(L = -X_{a}^{A}, N\right);\\ F & = & \operatorname{Thrust force}\left(N\right), \text{ positive along body } x_{t}\operatorname{-axis}\left(L = -Z_{a}^{A}, N\right);\\ L & = & \operatorname{Lift force, positive along negative air-path } Z_{a}\operatorname{-axis}\left(L = -Z_{a}^{A}, N\right);\\ L_{f} & = & \operatorname{Roll moment}\left(N \operatorname{m}\right), \operatorname{mathematically positive around } x_{t}\operatorname{-axis};\\ S & = & \operatorname{Wing area}\left(S = 0.550 \mathrm{m}^{2}\right);\\ V_{A}, \mathbf{V}_{A} & = & \operatorname{Aircraft speed and velocity relative to air (V_{A} = \ \mathbf{V}_{A}\ _{2}, \operatorname{m s}^{-1});\\ X_{A}^{A} & = & \operatorname{Resulting force along air-path } x_{a}\operatorname{-axis}\left(N\right);\\ X_{f}^{A} & = & \operatorname{Aerodynamic force along body } x_{t}\operatorname{-axis}\left(N\right);\\ Y_{A}^{A} & = & \operatorname{Resulting force along body } x_{t}\operatorname{-axis}\left(N\right);\\ Y_{A}^{A} & = & \operatorname{Resulting force along air-path } x_{a}\operatorname{-axis}\left(N\right);\\ Y_{A}^{A} & = & \operatorname{Resulting force along air-path } x_{a}\operatorname{-axis}\left(N\right);\\ Z_{A}^{A} & = & \operatorname{Resulting force along air-path } x_{a}\operatorname{-axis}\left(N\right);\\ Z_{A}^{A} & = & \operatorname{Resulting force along air-path } x_{a}\operatorname{-axis}\left(N\right);\\ Z_{A}^{A} & = & \operatorname{Resulting force along air-path } x_{a}\operatorname{-axis}\left(N\right);\\ Z_{A}^{A} & = & \operatorname{Resulting force along air-path } x_{a}\operatorname{-axis}\left(N\right);\\ Z_{A}^{A} & = & \operatorname{Resulting force along body } x_{t}\operatorname{-axis}\left(N\right);\\ Z_{A}^{A} & = & \operatorname{Resulting force along body } x_{t}\operatorname{-axis}\left(N\right);\\ Z_{A}^{A} & = & \operatorname{Resulting force along body } x_{t}\operatorname{-axis}\left(N\right);\\ Z_{P}^{Post} & = & \operatorname{Domain of high angle of attack};\\ (\cdot)^{pros} & = & \operatorname{Domain of low angle of attack};\\ (\cdot)^{pros} & = & \operatorname{Domain of low angle of attack};\\ x_{x}, y_{x}, z_{a} & = & \operatorname{Air-path axis system};\\ x_{x},$	$C_{\rm m}$	=	Aerodynamic coefficient moment body $y_{\rm f}$ -axis (·);
$\begin{array}{rcl} C_{\rm D} &=& {\rm Aerodynamic drag coefficient, force negative air-path $x_{\rm a}$-axis (·);}\\ C_{\rm L} &=& {\rm Aerodynamic lift coefficient, force negative air-path $x_{\rm a}$-axis (·);}\\ C_{\rm X} &=& {\rm Aerodynamic coefficient force body $x_{\rm f}$-axis (·);}\\ C_{\rm Y} &=& {\rm Aerodynamic coefficient force body $x_{\rm f}$-axis (·);}\\ C_{\rm Z} &=& {\rm Aerodynamic coefficient force body $x_{\rm f}$-axis (·);}\\ D &=& {\rm Drag force, positive along negative air-path $X_{\rm a}$-axis ($L=-X_{\rm a}^{\rm A}$, ${\rm N}$);}\\ F &=& {\rm Thrust force (N), positive along body $x_{\rm f}$-axis;}\\ L &=& {\rm Lift force, positive along negative air-path $Z_{\rm a}$-axis ($L=-Z_{\rm a}^{\rm A}$, ${\rm N}$);}\\ L_{\rm f} &=& {\rm Roll moment (Nm), mathematically positive around $x_{\rm f}$-axis;}\\ N_{\rm f} &=& {\rm Pitch moment (Nm), mathematically positive around $x_{\rm f}$-axis;}\\ S &=& {\rm Wing area ($S=0.550{\rm m}^2$);}\\ V_{\rm A}, {\bf V}_{\rm A} &=& {\rm Aircraft speed and velocity relative to air (V_{\rm A}=\ {\bf V}_{\rm A}\ _2,{\rm ms}^{-1}$);}\\ X_{\rm A}^{\rm A} &=& {\rm Resulting force along air-path $x_{\rm a}$-axis (N);}\\ X_{\rm f}^{\rm F} &=& {\rm Thrust force along body $x_{\rm f}$-axis (N);}\\ X_{\rm f}^{\rm A} &=& {\rm Aerodynamic force along body $x_{\rm f}$-axis (N);}\\ Y_{\rm A}^{\rm A} &=& {\rm Resulting force along air-path $x_{\rm a}$-axis (N);}\\ Z_{\rm f}^{\rm A} &=& {\rm Aerodynamic force along body $x_{\rm f}$-axis (N);}\\ Z_{\rm f}^{\rm A} &=& {\rm Aerodynamic force along body $x_{\rm f}$-axis (N);}\\ Z_{\rm f}^{\rm A} &=& {\rm Aerodynamic force along body $x_{\rm f}$-axis (N);}\\ Z_{\rm f}^{\rm A} &=& {\rm Aerodynamic force along body $x_{\rm f}$-axis (N);}\\ Z_{\rm f}^{\rm A} &=& {\rm Aerodynamic force along body $x_{\rm f}$-axis (N);}\\ Z_{\rm f}^{\rm A} &=& {\rm Aerodynamic force along body $x_{\rm f}$-axis (N);}\\ Z_{\rm f}^{\rm A} &=& {\rm Aerodynamic force along body $x_{\rm f}$-axis (N);}\\ Z_{\rm f}^{\rm A} &=& {\rm Aerodynamic force along body $x_{\rm f}$-axis (N);}\\ Z_{\rm f}^{\rm a} &=& {\rm Aerodynamic force along body $x_{\rm f}$-axis (N);}\\ Z_{\rm f}^{\rm a} &=& {\rm Aerodynamic force along body $x_{\rm f}$-axis (N);}\\ Z_{\rm f}^{\rm a} &=& {\rm Aerodynamic force a$	C_{n}	=	Aerodynamic coefficient moment body $z_{\rm f}$ -axis (·);
$\begin{array}{rcl} C_{\rm L} & = & {\rm Aerodynamic int coefficient, force negative air-path $z_{\rm a}$-axis (·);}\\ C_{\rm X} & = & {\rm Aerodynamic coefficient force body $x_{\rm f}$-axis (·);}\\ C_{\rm Y} & = & {\rm Aerodynamic coefficient force body $y_{\rm f}$-axis (·);}\\ C_{\rm Z} & = & {\rm Aerodynamic coefficient force body $z_{\rm f}$-axis (·);}\\ D & = & {\rm Drag force, positive along negative air-path $X_{\rm a}$-axis ($L = -X_{\rm a}^{\rm A}, {\rm N}$);}\\ F & = & {\rm Thrust force (N), positive along body $x_{\rm f}$-axis;}\\ L & = & {\rm Lift force, positive along negative air-path $Z_{\rm a}$-axis ($L = -Z_{\rm a}^{\rm A}, {\rm N}$);}\\ L_{\rm f} & = & {\rm Roll moment (Nm), mathematically positive around $x_{\rm f}$-axis;}\\ M_{\rm f} & = & {\rm Pitch moment (Nm), mathematically positive around $x_{\rm f}$-axis;}\\ S & = & {\rm Wing area (}S = 0.550 {\rm m}^2$);\\ V_{\rm A}, {\rm V}_{\rm A} & = & {\rm Aerodynamic force along body $x_{\rm f}$-axis (N);}\\ X_{\rm A}^{\rm A} & = & {\rm Resulting force along air-path $x_{\rm a}$-axis (N);}\\ X_{\rm f}^{\rm F} & = & {\rm Thrust force along body $x_{\rm f}$-axis (N);}\\ X_{\rm f}^{\rm F} & = & {\rm Resulting force along body $x_{\rm f}$-axis (N);}\\ Y^{\rm A} & = & {\rm Resulting force along body $x_{\rm f}$-axis (N);}\\ Y_{\rm A}^{\rm F} & = & {\rm Aerodynamic force along body $x_{\rm f}$-axis (N);}\\ Y_{\rm f}^{\rm A} & = & {\rm Aerodynamic force along body $x_{\rm f}$-axis (N);}\\ Z_{\rm f}^{\rm A} & = & {\rm Aerodynamic force along body $x_{\rm f}$-axis (N);}\\ Z_{\rm f}^{\rm A} & = & {\rm Aerodynamic force along body $x_{\rm f}$-axis (N);}\\ Z_{\rm f}^{\rm A} & = & {\rm Aerodynamic force along body $x_{\rm f}$-axis (N);}\\ Z_{\rm f}^{\rm A} & = & {\rm Aerodynamic force along body $x_{\rm f}$-axis (N);}\\ Z_{\rm f}^{\rm A} & = & {\rm Aerodynamic force along body $x_{\rm f}$-axis (N);}\\ C_{\rm f}^{\rm post} & = & {\rm Domain of high angle of attack;}\\ C_{\rm f}^{\rm post} & = & {\rm Domain of high angle of attack;}\\ x_{\rm a}, y_{\rm a}, z_{\rm a} & & {\rm Air-path axis system;}\\ x_{\rm f}, y_{\rm f}, z_{\rm g} & = & {\rm Normal earth-fixed axis system;}\\ \end{array}$	$C_{\rm D}$	=	Aerodynamic drag coefficient, force negative air-path x_a -axis (·);
$\begin{array}{rcl} C_{\rm X} & = & {\rm Aerodynamic coefficient force body } x_{\rm f} {\rm -axis (\cdot)}; \\ C_{\rm Y} & = & {\rm Aerodynamic coefficient force body } y_{\rm f} {\rm -axis (} \cdot); \\ C_{\rm Z} & = & {\rm Aerodynamic coefficient force body } z_{\rm f} {\rm -axis (} \cdot); \\ D & = & {\rm Drag force, positive along negative air-path } X_{\rm a} {\rm -axis (} L = -X_{\rm a}^{\rm A}, {\rm N}); \\ F & = & {\rm Thrust force (N), positive along pody } x_{\rm f} {\rm -axis}; \\ L & = & {\rm Lift force, positive along negative air-path } Z_{\rm a} {\rm -axis (} L = -Z_{\rm a}^{\rm A}, {\rm N}); \\ L_{\rm f} & = & {\rm Roll moment (N m), mathematically positive around } x_{\rm f} {\rm -axis}; \\ M_{\rm f} & = & {\rm Pitch moment (N m), mathematically positive around } y_{\rm f} {\rm -axis}; \\ S & = & {\rm Wing area (} S = 0.550 {\rm m}^2); \\ V_{\rm A}, {\rm V}_{\rm A} & = & {\rm Aerodynamic force along air-path } x_{\rm a} {\rm -axis (N)}; \\ X_{\rm f}^{\rm A} & = & {\rm Resulting force along air-path } x_{\rm a} {\rm -axis (N)}; \\ X_{\rm f}^{\rm F} & = & {\rm Thrust force along air-path } y_{\rm a} {\rm -axis (N)}; \\ Y^{\rm A} & = & {\rm Resulting force along air-path } y_{\rm a} {\rm -axis (N)}; \\ Y_{\rm f}^{\rm A} & = & {\rm Aerodynamic force along body } x_{\rm f} {\rm -axis (N)}; \\ Z_{\rm f}^{\rm A} & = & {\rm Resulting force along air-path } x_{\rm a} {\rm -axis (N)}; \\ Z_{\rm f}^{\rm A} & = & {\rm Aerodynamic force along body } y_{\rm f} {\rm -axis (N)}; \\ Z_{\rm f}^{\rm A} & = & {\rm Resulting force along air-path } x_{\rm a} {\rm -axis (N)}; \\ Z_{\rm f}^{\rm A} & = & {\rm Aerodynamic force along body } y_{\rm f} {\rm -axis (N)}; \\ Z_{\rm f}^{\rm A} & = & {\rm Aerodynamic force along body } y_{\rm f} {\rm -axis (N)}; \\ Z_{\rm f}^{\rm A} & = & {\rm Aerodynamic force along body } y_{\rm f} {\rm -axis (N)}; \\ C_{\rm post} & = & {\rm Domain of high angle of attack}; \\ c)^{post} & = & {\rm Domain of high angle of attack}; \\ c)^{post} & = & {\rm Domain of high angle of attack}; \\ x_{\rm a}, y_{\rm a}, z_{\rm a} & & {\rm Air-path axis system}; \\ x_{\rm f}, y_{\rm f}, z_{\rm f} & = & {\rm Body axis system}; \\ x_{\rm g}, y_{\rm g}, z_{\rm g} & = & {\rm Normal earth-fixed axis system}; \\ \end{array}$	$C_{\rm L}$	=	Aerodynamic lift coefficient, force negative air-path z_a -axis (·);
$\begin{array}{llllllllllllllllllllllllllllllllllll$	$C_{\rm X}$	=	Aerodynamic coefficient force body x_{f} -axis (·);
$\begin{array}{llllllllllllllllllllllllllllllllllll$	$C_{\rm Y}$	=	Aerodynamic coefficient force body $y_{\rm f}$ -axis (·);
$\begin{array}{llllllllllllllllllllllllllllllllllll$	C _Z	=	Aerodynamic coefficient force body $z_{\rm f}$ -axis (·);
$\begin{array}{llllllllllllllllllllllllllllllllllll$		=	Drag force, positive along negative air-path A_a -axis $(L = -A_a^{-1}, N)$;
$\begin{array}{llllllllllllllllllllllllllllllllllll$	Г Т	=	I infust force (N), positive along body $x_{\rm f}$ -axis;
$\begin{split} & M_{\rm f} &= \text{Non moment (Nm), mathematically positive around } x_{\rm f}\text{-axis;} \\ & M_{\rm f} &= \text{Pitch moment (Nm), mathematically positive around } z_{\rm f}\text{-axis;} \\ & S &= \text{Wing area } (S = 0.550 \mathrm{m}^2); \\ & V_{\rm A}, \mathbf{V}_{\rm A} &= \text{Aircraft speed and velocity } relative to air (V_{\rm A} = \ \mathbf{V}_{\rm A}\ _2, \mathrm{ms}^{-1}); \\ & X^{\rm A} &= \text{Resulting force along air-path } x_{\rm a}\text{-axis (N);} \\ & X^{\rm A}_{\rm f} &= \text{Aerodynamic force along body } x_{\rm f}\text{-axis (N);} \\ & X^{\rm F}_{\rm f} &= \text{Thrust force along body } x_{\rm f}\text{-axis (N);} \\ & Y^{\rm A} &= \text{Resulting force along body } x_{\rm f}\text{-axis (N);} \\ & Y^{\rm A}_{\rm f} &= \text{Aerodynamic force along body } y_{\rm f}\text{-axis (N);} \\ & Y^{\rm A}_{\rm f} &= \text{Resulting force along body } y_{\rm f}\text{-axis (N);} \\ & Z^{\rm A}_{\rm f} &= \text{Resulting force along body } y_{\rm f}\text{-axis (N);} \\ & Z^{\rm A}_{\rm f} &= \text{Aerodynamic force along body } y_{\rm f}\text{-axis (N);} \\ & (\cdot)^{post} &= \text{Domain of high angle of attack;} \\ & (\cdot)^{pre} &= \text{Domain of high angle of attack;} \\ & (\cdot)^{pre} &= \text{Domain of low angle of attack;} \\ & x_{\rm a}, y_{\rm a}, z_{\rm a} &= \text{Air-path axis system;} \\ & x_{\rm g}, y_{\rm g}, z_{\rm g} &= \text{Normal earth-fixed axis system;} \\ \end{aligned}$		_	Lift force, positive along negative air-path Z_a -axis ($L = -Z_a$, N); Roll moment (Nm), mathematically positive around x_a axis:
$\begin{split} M_{\rm f} &= \operatorname{Picch moment (ivm), mathematically positive around y_{\rm f}-axis;\begin{aligned} N_{\rm f} &= \operatorname{Yaw moment (N m), mathematically positive around z_{\rm f}-axis;\begin{aligned} S &= \operatorname{Wing area} \left(S = 0.550 \mathrm{m}^2\right); \\ V_{\rm A}, \mathbf{V}_{\rm A} &= \operatorname{Aircraft speed and velocity relative to air (V_{\rm A} = \ \mathbf{V}_{\rm A}\ _2, \mathrm{ms}^{-1}); \\ X^{\rm A} &= \operatorname{Resulting force along air-path } x_{\rm a}-axis (N);\begin{aligned} X^{\rm A}_{\rm f} &= \operatorname{Aerodynamic force along body } x_{\rm f}-axis (N);\begin{aligned} X^{\rm F}_{\rm f} &= \operatorname{Thrust force along body } x_{\rm f}-axis (N);\begin{aligned} Y^{\rm A} &= \operatorname{Resulting force along air-path } y_{\rm a}-axis (N);\begin{aligned} Y^{\rm A} &= \operatorname{Resulting force along air-path } y_{\rm a}-axis (N);\begin{aligned} Z^{\rm A} &= \operatorname{Resulting force along air-path } z_{\rm a}-axis (N);\begin{aligned} Z^{\rm A} &= \operatorname{Resulting force along air-path } z_{\rm a}-axis (N);\begin{aligned} Z^{\rm A} &= \operatorname{Resulting force along air-path } z_{\rm a}-axis (N);(\cdot) ^{post} &= \operatorname{Domain of high angle of attack; } (N); \\ (\cdot)^{pre} &= \operatorname{Domain of high angle of attack; } (X_{\rm a}, y_{\rm a}, z_{\rm a}) &= \operatorname{Air-path axis system; } X_{\rm a}, y_{\rm a}, z_{\rm g} &= \operatorname{Normal earth-fixed axis system; } X_{\rm g}, y_{\rm g}, z_{\rm g} &= \operatorname{Normal earth-fixed axis system; } (N) \\ \end{array}$	$L_{\rm f}$ $M_{\rm c}$	_	Pitch moment (Nm) , mathematically positive around $u_{\rm f}$ -axis,
$\begin{aligned} & \mathcal{N}_{\mathrm{f}} & = & \text{Taw moment (Nm), mathematically positive around } z_{\mathrm{f}}^{-\mathrm{axis}}, \\ & S & = & \text{Wing area } (S = 0.550 \mathrm{m}^2); \\ & V_{\mathrm{A}}, \mathbf{V}_{\mathrm{A}} & = & \text{Aircraft speed and velocity } relative to air (V_{\mathrm{A}} = \ \mathbf{V}_{\mathrm{A}}\ _{2}, \mathrm{ms^{-1}}); \\ & X^{\mathrm{A}} & = & \text{Resulting force along air-path } x_{\mathrm{a}}\text{-axis (N)}; \\ & X^{\mathrm{F}}_{\mathrm{f}} & = & \text{Aerodynamic force along body } x_{\mathrm{f}}\text{-axis (N)}; \\ & X^{\mathrm{F}}_{\mathrm{f}} & = & \text{Thrust force along body } x_{\mathrm{f}}\text{-axis (N)}; \\ & Y^{\mathrm{A}} & = & \text{Resulting force along air-path } y_{\mathrm{a}}\text{-axis (N)}; \\ & Y^{\mathrm{A}} & = & \text{Resulting force along body } x_{\mathrm{f}}\text{-axis (N)}; \\ & Z^{\mathrm{A}} & = & \text{Resulting force along air-path } z_{\mathrm{a}}\text{-axis (N)}; \\ & (\cdot)^{Post} & = & \text{Aerodynamic force along body } z_{\mathrm{f}}\text{-axis (N)}; \\ & (\cdot)^{pre} & = & \text{Domain of high angle of attack}; \\ & (\cdot)^{pre} & = & \text{Domain of high angle of attack}; \\ & x_{\mathrm{a}}, y_{\mathrm{a}}, z_{\mathrm{a}} & = & \text{Air-path axis system}; \\ & x_{\mathrm{f}}, y_{\mathrm{f}}, z_{\mathrm{f}} & = & \text{Body axis system}; \\ & x_{\mathrm{g}}, y_{\mathrm{g}}, z_{\mathrm{g}} & = & \text{Normal earth-fixed axis system}; \\ \end{aligned}$	N ₁	_	Vaw moment (Nm), mathematically positive around z_{t} axis,
$\begin{array}{llllllllllllllllllllllllllllllllllll$	S S	_	Wing area $(S = 0.550 \text{ m}^2)$:
$\begin{array}{llllllllllllllllllllllllllllllllllll$	V_{Λ} V	_	Aircraft speed and velocity relative to air $(V_{\star} - \mathbf{V}_{\star} - ms^{-1})$:
$\begin{array}{llllllllllllllllllllllllllllllllllll$	X_{A}^{A}, Y_{A}^{A}	_	Resulting force along air-path x_{-} -axis (N):
$\begin{array}{rcl} X_{\rm f}^{\rm r} & = & \mbox{Altrodynamic force using body } x_{\rm f} \mbox{ and } (N), \\ X_{\rm f}^{\rm F} & = & \mbox{Thrust force along body } x_{\rm f} \mbox{-axis } (N); \\ Y^{\rm A} & = & \mbox{Resulting force along air-path } y_{\rm a} \mbox{-axis } (N); \\ Z^{\rm A} & = & \mbox{Resulting force along air-path } z_{\rm a} \mbox{-axis } (N); \\ Z^{\rm A} & = & \mbox{Resulting force along air-path } z_{\rm a} \mbox{-axis } (N); \\ Z^{\rm A} & = & \mbox{Resulting force along air-path } z_{\rm a} \mbox{-axis } (N); \\ (\cdot)^{post} & = & \mbox{Domain of righ angle of attack;} \\ (\cdot)^{pre} & = & \mbox{Domain of high angle of attack;} \\ x_{\rm a}, y_{\rm a}, z_{\rm a} & = & \mbox{Air-path axis system;} \\ x_{\rm f}, y_{\rm f}, z_{\rm f} & = & \mbox{Body axis system;} \\ x_{\rm g}, y_{\rm g}, z_{\rm g} & = & \mbox{Normal earth-fixed axis system;} \end{array}$	X^{A}	_	Aerodynamic force along body r_{c-} axis (N):
$\begin{array}{rcl} Y^{A} & = & \operatorname{Pinustric force along body } y_{\mathrm{f}} \operatorname{takk}\left(\mathbf{N} \right); \\ Y^{A} & = & \operatorname{Resulting force along air-path } y_{\mathrm{a}}\operatorname{-axis}\left(\mathbf{N} \right); \\ Z^{A} & = & \operatorname{Resulting force along air-path } z_{\mathrm{a}}\operatorname{-axis}\left(\mathbf{N} \right); \\ Z^{A}_{\mathrm{f}} & = & \operatorname{Aerodynamic force along body } z_{\mathrm{f}}\operatorname{-axis}\left(\mathbf{N} \right); \\ (\cdot)^{post} & = & \operatorname{Domain of high angle of attack;} \\ (\cdot)^{pre} & = & \operatorname{Domain of low angle of attack;} \\ (\cdot)^{pre} & = & \operatorname{Domain of low angle of attack;} \\ x_{\mathrm{a}}, y_{\mathrm{a}}, z_{\mathrm{a}} & = & \operatorname{Air-path axis system;} \\ x_{\mathrm{f}}, y_{\mathrm{f}}, z_{\mathrm{f}} & = & \operatorname{Body axis system;} \\ x_{\mathrm{g}}, y_{\mathrm{g}}, z_{\mathrm{g}} & = & \operatorname{Normal earth-fixed axis system;} \end{array}$	$X_{\rm f}^{\rm F}$	_	Thrust force along body x_{r} -axis (N):
$\begin{array}{llllllllllllllllllllllllllllllllllll$	$Y^{\rm f}_{\rm A}$	_	Resulting force along air-path y_{c} -axis (N):
$Z^{A} = \text{Resulting force along air-path } z_{a}\text{-axis (N)};$ $Z^{A}_{f} = \text{Aerodynamic force along body } z_{f}\text{-axis (N)};$ $(\cdot)^{post} = \text{Domain of high angle of attack};$ $(\cdot)^{pre} = \text{Domain of low angle of attack};$ $x_{a}, y_{a}, z_{a} = \text{Air-path axis system};$ $x_{f}, y_{f}, z_{f} = \text{Body axis system};$ $x_{g}, y_{g}, z_{g} = \text{Normal earth-fixed axis system};$	Y_{c}^{A}	=	Aerodynamic force along body u_{c} -axis (N):
$ \begin{array}{llllllllllllllllllllllllllllllllllll$	Z^{A}	=	Resulting force along air-path z_{a} -axis (N):
$\begin{array}{llllllllllllllllllllllllllllllllllll$	Z_{ϵ}^{A}	=	Aerodynamic force along body z_{e} -axis (N):
$\begin{array}{llllllllllllllllllllllllllllllllllll$	$(\cdot)^{post}$	_	Domain of high angle of attack:
$x_{a}, y_{a}, z_{a} = Air-path axis system;$ $x_{f}, y_{f}, z_{f} = Body axis system;$ $x_{g}, y_{g}, z_{g} = Normal earth-fixed axis system;$	$(\cdot)^{pre}$	=	Domain of low angle of attack:
$x_{\rm f}, y_{\rm f}, z_{\rm f} = { m Body axis system;} x_{\rm g}, y_{\rm g}, z_{\rm g} = { m Normal earth-fixed axis system;}$	x_2, y_2, z_2	=	Air-path axis system:
$x_{\rm g}, y_{\rm g}, z_{\rm g}$ = Normal earth-fixed axis system;	x_{f}, y_{f}, z_{f}	=	Body axis system;
	$x_{\mathrm{g}}, y_{\mathrm{g}}, z_{\mathrm{g}}$	=	Normal earth-fixed axis system;