Design Report 04: Twin Sea Lion

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Nomenclature

AAA	=	Advanced Aircraft Analysis Program
AR_W	=	Wind aspect ratio
b_w	=	Wing span
c_w	=	Wing chord
D_{t_n}	=	Nosewheel tire diameter
D_{t_M}	=	Main gear tire diameter
d_{ns}	=	Nose strut diameter
d_{ms}	=	Main strut diameter
$d_{retract}$	=	Gear bogey diameter while retracted
i_W	=	Wing incidence angle
l_f	=	Fuselage length
l_m	=	Length from x_{cg} to main gear
l_n	=	Length from x_{cg} to nose gear
n_m	=	Number of main gear
P_n	=	Maximum static load per nose bogey
P_m	=	Maximum static load per main bogey
S_W	=	Wing area
S_h	=	Horizontal stabilizer area
S_v	=	Vertical stabilizer area
$TDPF$	=	Tail Damping Power Factor
W_{TO}	=	Takeoff weight
$w_{retract}$	=	Gear bogey width while retracted
X	=	Distance of a component from the nose of the aircraft
Y	=	Distance of a component from the centerline of the aircraft
Z	=	Distance of a component from the belly of the aircraft
λ_W	=	Wing sweep angle

$\Lambda_{c/4w}$ = Quarter chord sweep angle

Γ_W = Wing dihedral angle

ϵ_W = Wing twist angle

I. Introduction

This is the final report on development progress of the Twin Sea Lion. This report covers landing gear configuration, ground clearance and tipover calculations, spin characteristics and the flying qualities of the Twin Sea Lion.

II. Addendum to Report 3

Fuel x_{cg} was incorrectly placed at 22 ft while the wing x_{cg} was at 23 ft. Since the fuel cannot be before the wing, the fuel had to be moved back. This correction also improved the stability from 44% to 41%.

III. Landing Gear Layout Design

Tables 1, 2, and 3 summarize the results of the gear layout section.

Table 1 Summary of main gear and tire dimensions

D_{t_m} [in]	b_{t_m} [in]	n_{mt}	l_m [ft]	P_m [lb]	P_m [%]	d_{ms} [ft]	$L_{S_m}[ft]$
30	9	2	3	16,152	42.86	0.3587	6.15

Table 2 Summary of nose gear and tire dimensions

D_{t_n} [in]	b_{t_n} [in]	n_{nt}	l_n [ft]	P_n [lb]	P_n [%]	d_{ns} [ft]	$L_{S_n}[ft]$
23.4	6.5	2	18	5384.1	14.29	0.2244	5.36

Table 3 Summary and clearance and tip-over requirements

Requirement	Sea Lion Value [deg]	Relation	Requirement [deg]	Satisfaction
Longitudinal Ground Clearance	14.9	$\ngtr$	15	F
Lateral Ground Clearance	15.68	$>$	5	T
Longitudinal Tip-Over	12.86	$\ngtr$	15	F
Lateral Tip-Over	51.8	$<$	55	T

A. Sizing of the Landing Gear

Designers chose a tricycle configuration as it allows the most passenger comfort while the plane is on the ground. A tricycle configuration also makes the plane easier to steer on the ground. These gears will be retractable, with three total struts. The nose gear and main gear each have two tires per strut. Tires were selected to be similar to other regional turboprops of a similar weight. These tires will have a dual arrangement. Definitions of P_n (Equation 1) and P_m(Equation 2) come from Presentation 26[8]. For the Twin Sea Lion, l_n = 18 ft l_m = 3 ft, so $P_n = 5384.1\ lb = 14.29\%$

and $P_m = 16152\ lb = 42.86\%$.

$$P_n = \frac{W_{TO} l_m}{l_m + l_n} \tag{1}$$

$$P_m = \frac{W_{TO} l_n}{n_m(l_m + l_n)} \tag{2}$$

B. Location of the Landing Gear

Locations were originally chosen in order to put 10% of the weight on the nose gear with the main gear slightly behind the aircraft cg. Changes made in order to meet longitudinal ground clearance requirements took the nose gear loading up to 14.28%. This placed the main gear 3 ft behind the aircraft cg and the nose gear 18 ft in front of the aircraft cg.

1. Longitudinal Ground Clearance

The nose struts are 17 feet ahead of the apex of the wing and the empennage begins to sweep upwards 21 feet behind the main gear. The height above the ground of this corner is determined by the length of the struts so these struts were designed to ensure the required 15 degrees of clearance[8]. Clearance from the belly is calculated in Equation 3 as 5.36 feet. The belly is 9.5 inches below where the struts will begin, so the main landing gear struts are 6.15 feet long.

$$h = 21 \tan(\alpha) = 21 \tan(15\ deg) = 5.36\ ft \tag{3}$$

2. Lateral Ground Clearance

With 5.36 feet of clearance below the belly at the main landing gear, 32 feet from the main landing gear to the wingtip, and a wingtip height of 8.94 feet, the wingtips have a clearance of 15.68 degrees from the ground location of the main gear. This is greater than the 5 degrees required[8]. Propeller strikes are not a risk because the propellers are directly above the main gear.

3. Longitudinal Tip-Over

Longitudinal tip-over depends on the gear placement and tire separation as input to AAA in Figure 2. Nose strut diameter is 0.2244 feet and main strut diameter is 0.3587 feet as determined from Equations 4 and 5 respectively. As determined from the longitudinal clearance requirement, the main gear struts are 5.36 feet + 9.5 in = 6.15 ft long. The nose gear strut is 5.36 feet long.

$$d_{ns} = (0.041 + 0.0025\sqrt{P_n}) = 0.2244 \tag{4}$$

$$d_{ms} = (0.041 + 0.0025\sqrt{P_m}) = 0.3587 \tag{5}$$

With two wheels on each strut align in the y direction, lateral tip-over depends on the y separation of the wheels. This separation needs to be slightly more than the sum of two half thicknesses of the tires and the strut diameter as seen in Equation 6.

$$Styn = 1.05(t_n + d_{ns}) = 0.8044 \tag{6}$$

$$Stym = 1.05(t_m + d_{ms}) = 1.1642 \tag{7}$$

Table 9.1 Typical Landing Gear Wheel Data (n_s = 2)

Type	W_{TO}	Main Gear				Nose Gear			
		$D_t x b_t$	$2P_m/W_{TO}$	PSI	n_{mt}	$D_t x b_t$	P_n/W_{TO}	PSI	n_{nt}
	lbs	in.xin.				in.xin.			
Homebuilts	600	13x5	0.80	25	1	9x3.4	0.17	25	1
	1,200	12x5	0.78	45	1	12x5	0.22	45	1
	3,300	16x6	0.87	45	1	16x6	0.13	45	1
Single Engine Prop. Driven	1,600	15x6	0.80	18	1	15x5	0.20	28	1
	2,400	17x6	0.84	19	1	12.5x5	0.16	22	1
	3,800	16.5x6	0.84	55	1	14x5	0.16	49	1
Twin Engine Prop. Driven	5,000	16x6	0.83	55	1	16x6	0.17	40	1
	8,000	22x6.5	0.88	75	1	17x6	0.12	40	1
	12,000	26.6x7	0.84	82	1	19.3x6.6	0.16	82	1
Agricultural	3,000	22x8	0.95	35	1	9x3.5*	0.05*	55*	1*
	7,000	24x8.5	0.92	35	1	12.4x4.5*	0.08*	50*	1*
					*Note: these are tailwheel data				
	10,000	29x7.5	0.85	35	1	25x7	0.15	35	1
Regional Turbo-propeller Driven Airplanes	12,500	18x5.5	0.89	105	2	22x6.75	0.11	57	1
	21,000	24x7.25	0.90	85	2	18x5.5	0.10	65	2
	26,000	36x11	0.92	40	1	20x7.5	0.08	40	1
	44,000	30x9	0.93	107	2	23.4x6.5	0.07	77	2
Business Jets	12,000	22x6.3	0.93	90	1	18x5.7	0.07	120	1
	23,000	27.6x9.3	0.95	155	1	17x5.5	0.05	50	2
	39,000	26x6.6	0.92	208	2	14.5x5.5	0.08	130	2
	68,000	34x9.25	0.93	174	2	21x7.25	0.07	113	2

Fig. 1 Landing gear of similar airplanes

With all this input into AAA, Figure 2 gives $\phi_{gear_{cg}} = 12.86$ deg. The requirement for longitudinal tip-over is that $\phi_{gear_{cg}} > 15$[8]. This requirement is not met but is close enough to accept for the first round of design.

$$\phi = 12.86\ deg \ngtr 15\ deg \tag{8}$$

4. Lateral Tip-Over

Lateral tip-over is determined by the same AAA module as longitudinal tip-over. Figure 2 gives $\psi = 51.8$ deg. In order to pass this requirement $\psi \leq 55$ deg[8]. This requirement is easily satisfied. The Sea Lion will not tip-over laterally.

$$\psi = 51.8\ deg < 55\ deg \tag{9}$$

Landing Gear Geometry: Flight Condition 1

Input Parameters

X_{cg}	24.32	ft	Y_{cg}	-0.11	ft	Z_{cg}	2.95	ft
X_{cg_E}	24.80	ft	Z_{cg_E}	3.47	ft			

Output Parameters

$X_{gear_{forw}}$	6.00	ft	$Z_{gear_{forw}}$	-6.33	ft	$Y_{gear_{aft}}$	9.10	ft
$Y_{gear_{forw}}$	0.00	ft	$X_{gear_{aft}}$	26.50	ft	$Z_{gear_{aft}}$	-6.60	ft
Ψ	51.8	deg	$Z_{gear_{crit}}$	-6.60	ft	$\phi_{gear_{cg\ e}}$	9.58	deg
$X_{gear_{crit}}$	26.50	ft	$\phi_{gear_{cg}}$	12.86	deg	Coordinates Defined		

Landing Gear Table

#	Landing Gear	$N_{side\text{-}by\text{-}side}$	N_{inline}	D_{wheel} ft	w_{wheel} ft	X_{wheel} ft	Y_{wheel} ft	Z_{wheel} ft	$S_{B_{wheel}}$ ft	$S_{T_{wheel}}$ ft
1	Nose Gear: Down	2	1	1.95	0.54	6.00	0.00	-5.35	0.00	0.80
2	Main Gear: Down	2	1	2.50	0.75	26.50	9.10	-5.35	0.00	1.16
3	Main Gear: Down	2	1	2.50	0.75	26.50	-9.10	-5.35	0.00	1.16

Fig. 2 AAA results for tip-over conditions

C. Gear Retraction Volume

Expansions of the tires in inches are given by Equations 10 and 11 for tire width and diameter respectively[8]. Total retraction volume is estimated using these new dimensions and modeling the set of tires as a cylinder.

$$w_{retract} = w + 0.04w + 3 \tag{10}$$

$$d_{retract} = d + 0.1d + 3 \tag{11}$$

Based on the above, each main gear tire was assumed to expand to a diameter of 36 inches and width of 12.36 inches

Table 4 Expanded gear dimensions.

Gear	Individual D [in]	Individual W [in]	Total D [ft]	Total W [ft]	Volume [ft^3]
Nose	26.634	9.76	2.2195	1.851	7.1616
Main	36	12.36	3	2.4187	17.0967

in cruise. By approximating the two tires and the diameter of the gear strut as a cylinder with length equal to twice the width of the wheel plus the strut diameter and a diameter equal to the tire's expanded diameter, the retracted volume of the main gear is calculated to be the following on each side and is tabulated in Table 4.

$$V_{h_main} = 17.0967\ ft^3 \tag{12}$$

From Report 02[2], the Twin Sea Lion requires 10,679 pounds of fuel and the wings have room for 20,559 pounds or 407.76 ft^3 of fuel. This leaves 195.96 ft^3 across both wings or 97.98 ft^3 in each wing for things other than fuel. The retracted gear would take up 17.4% of the remaining gear volume, leaving a very reasonable 82.6% of the non-fuel wing volume for other materials like tanks, wires, and hydraulics.

The nose gear expands in a similar manner. Each expanded tire was calculated as 26.634 inches in diameter and 9.76 inches in width. Again accounting for both tires and the diameter of the nose gear strut, the retracted volume of the nose gear is as follows.

$$V_{h_nose} = 7.1615\ ft^3 \tag{13}$$

The total diameter of the nose gear cylinder is 2.2195 ft and the total length is 1.851 ft. From Report 02[2], the back half of the cockpit has 17.55 in or 1.4625 ft from the floor to the outer shell. This is too small for the nose gear to fit either way so the gear will be retracted as far as possible and a clam shell used to cover the remaining.

IV. Aircraft Dimensions and Three-View

A. Geometric Summary

Wing design variables and fuselage length were determined in Report 02[2], and tail areas were determined in Report 03[3].

Table 5 Geometric design variables

S_W $[ft^2]$	b_w [ft]	AR_W	c_w[ft]	λ_W	$\Lambda_{c/4w}[°]$	$\Gamma_W[°]$	$i_W[°]$	$\epsilon_W[°]$	l_f $[ft]$	S_h $[ft^2]$	S_v $[ft^2]$
837	81.8	8	10.16	0.6	0	5	-1	0	47.58	190.0	137.0

B. Aircraft Three-View

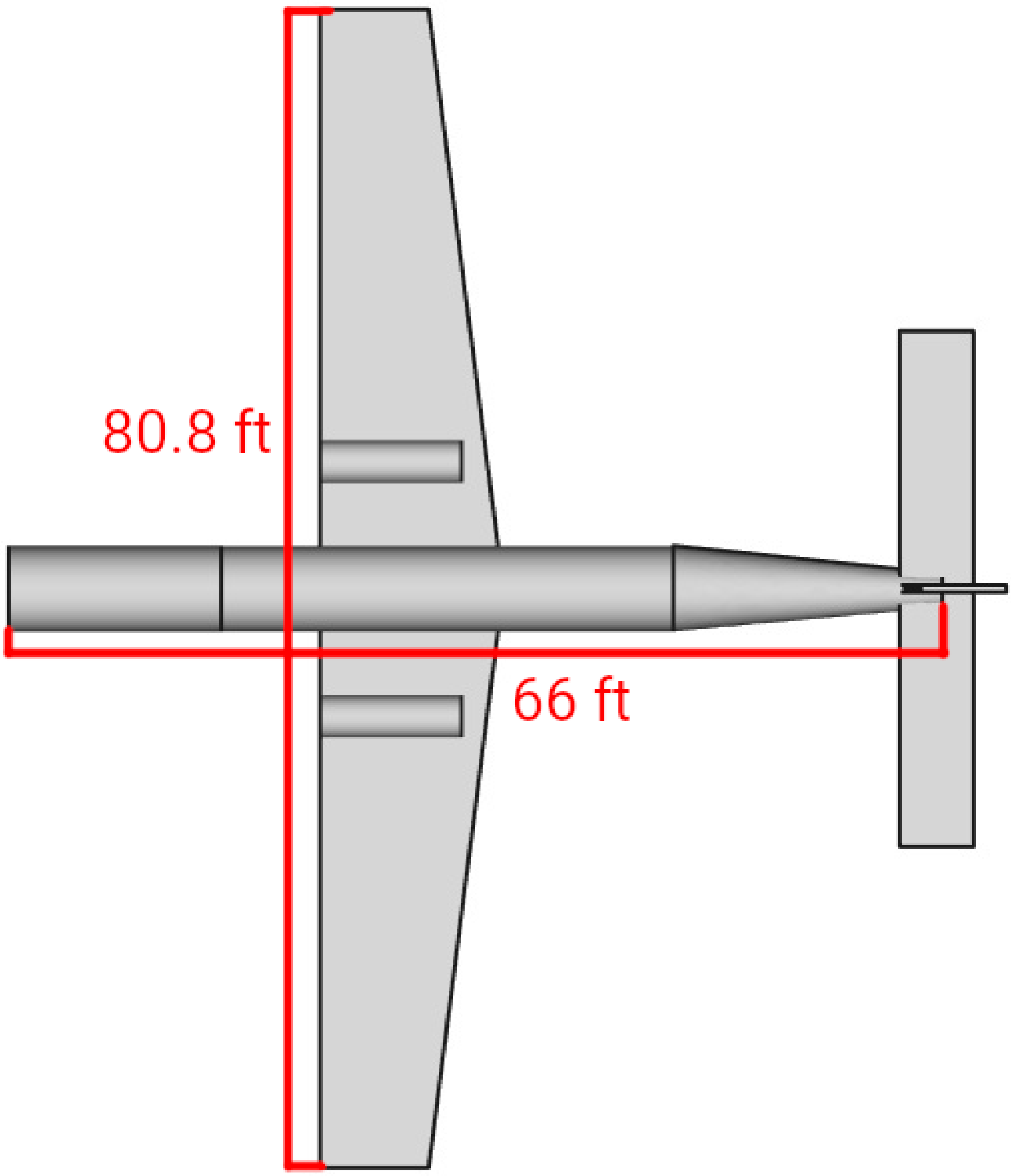


Fig. 3 Top view of the Twin Sea Lion

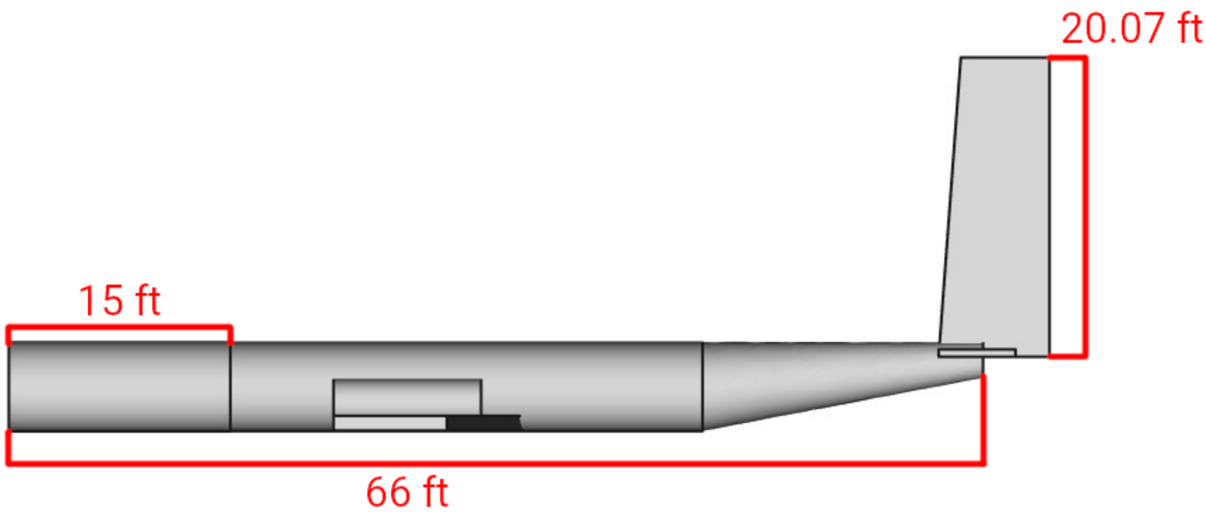


Fig. 4 Side view of the Twin Sea Lion

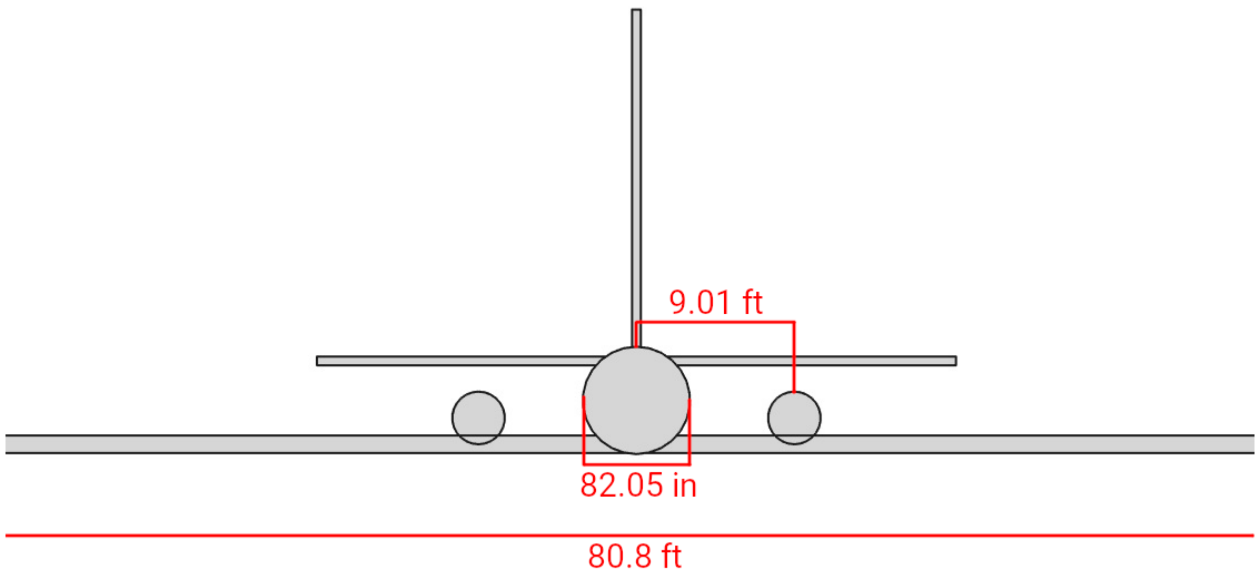


Fig. 5 Front view of the Twin Sea Lion

Note that while the length of the cockpit has been included in this model, the precise details are not included and it is simply replaced with a cylinder.

V. Moments of Inertia and Spin Characteristics

A. Moments of Inertia

The empty weight table seen in Figure 6 was populated with all empty weight groups and supplemented with the aircraft load split as much as possible with the available boxes. Note that the component names in the table were ignored in order to fit as many parts of the aircraft into the table as possible.

The actual names associated with each item are as follows.

1) Furnishings
2) Other fixed equipment
3) Engine 1
4) Engine 2
5) Propeller 1
6) Propeller 2
7) Wing 1
8) Wing 2
9) Fuselage
10) Horizontal Stabilizer
11) Vertical Stabilizer
12) Nose gear
13) Main gear 1
14) Main gear 2
15) Fuel 1
16) Fuel 2
17) Cargo
18) Baggage
19) Crew
20) Trapped fuel and oil
21) Passenger group 1
22) Passenger group 2

Items split into groups 1 and 2 denote equipment that is on the right and left side of the aircraft respectively.

Class II Empty Weight Moment of Inertia: Flight Condition 1

Input Parameters

X_{cg_E} 24.80 ft	Y_{cg_E} 0.00 ft	Z_{cg_E} 3.47 ft

Output Parameters

$I_{xx_{e_B}}$ 200121.1 slug-ft^2	$I_{yy_{e_B}}$ 51880.2 slug-ft^2	$I_{zz_{e_B}}$ 245693.0 slug-ft^2	$I_{xz_{e_B}}$ 4375.6 slug-ft^2

Class II Empty Weight Moment of Inertia Table

Component	Weight lb	I_{xx_B} slug-ft^2	I_{yy_B} slug-ft^2	I_{zz_B} slug-ft^2	I_{xz_B} slug-ft^2	X_{cg} ft	Y_{cg} ft	Z_{cg} ft
Wing	83.4					41.63	1.96	4.21
Horizontal Tail	5192.0					21.41	0.00	3.50
Vertical Tail	1896.3					23.80	9.00	3.80
Fuselage	1896.3					23.80	-9.00	3.80
Nose Landing Gear	901.8					20.00	9.00	3.80
Main Landing Gear	901.8					20.00	-9.00	3.80
Propeller	1693.1					23.00	18.75	3.50
Turboprop Engine	1693.1					23.00	-18.75	3.50
Fuel System	4455.6					21.41	0.00	3.50
Air Induction System	445.6					62.00	0.00	6.00
Propulsion System	267.3					62.00	0.00	16.00
Flight Control System	245.9					6.00	0.00	0.98
Hydraulic and Pneumatic System	696.9					27.00	9.10	2.38
Instruments/Avionics/Electronics	696.9					27.00	-9.10	2.38
Electrical System	5348.6					23.00	18.75	2.00
Air Cond./Press./Icing System	5348.6					23.00	-18.75	2.00
Oxygen System	2020.0					33.00	-2.00	0.00
Auxiliary Power Unit	605.0					28.92	0.00	3.00
Furnishings	525.0					12.05	-0.56	5.00
Cargo Handling Equipment	188.4					21.41	0.00	3.50
Operational Items	875.0					28.92	21.57	5.00
Other Items	875.0					28.92	-21.57	5.00

Fig. 6 AAA inertia inputs

B. Spin Characteristics

The spin recovery criterion is described in Equation 14. S_{R_1} is the usable area of the rudder above the horizontal stabilizer. L_1 is the length from aircraft cg to the center of S_{R_1}. S_{R_2} and L_2 are similarly related. These parameters are taken from Presentation 27[9]

$$SRC = \frac{I_x - I_y}{b^2(W/g)} \tag{14}$$

$$TDPF = (TDR)(URVC) \tag{15}$$

$$TDR = \frac{S_F L^2}{S_W (b/2)^2} \tag{16}$$

$$URVC = \frac{S_{R_1} L_1 + S_{R_2} L_2}{S_w (b/2)} \tag{17}$$

$$\mu = \frac{W/S}{\rho g b} \tag{18}$$

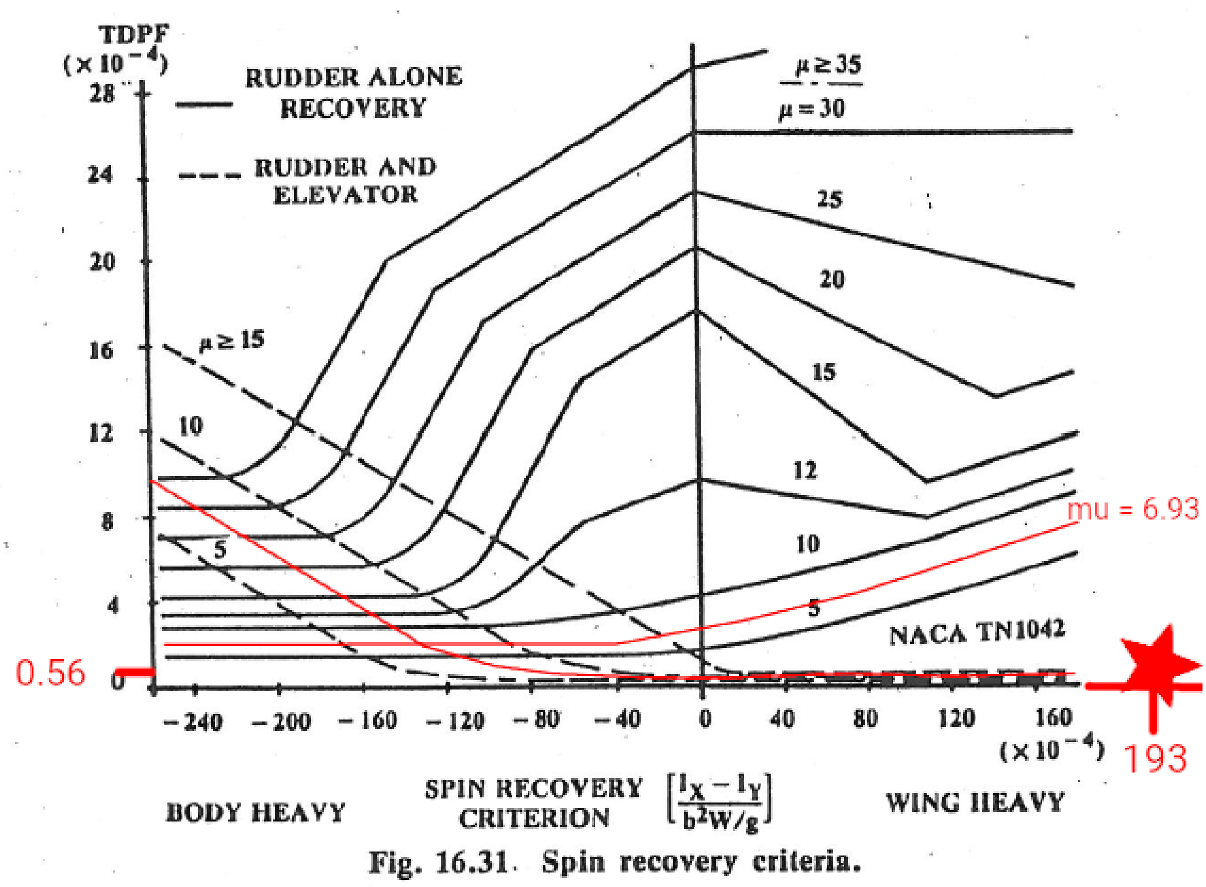


Fig. 7 Spin recoverability prediction, with the Twin Sea Lion's location marked

Thanks to the tall, single vertical stabilizer, $S_R = 8.19 ft^2$ and $L_R = 42 ft$ at most aft CG. A small amount of the vertical stabilizer aside from the rudder is not blanketed, so $S_F = 5 ft^2$ and $L_f = 39 ft$. From these, $TDPF = 0.566 \times 10^{-4}$, $\mu = 6.93$ at sea level, and $SRC = 193 \times 10^{-4}$. From the above graphic, it is a apparent that the Twin Sea Lion is very wing heavy and because its rudder is blanketed almost entirely by dirty air, it has next to no chance of recovery if a spin is encountered. However, this is acceptable for a FAR 25 certified aircraft.

In addition, the authors note that while no testing is planned, it may be possible to arrest a spin with differential thrust.

VI. Stability and Control Derivative

A. Longitudinal Stability Derivatives

All longitudinal stability derivatives and coefficients where determined from AAA using handout #2[5] and results from handout #1[4]. AAA printouts for this section can be found in Figures 33 through 54, with background calculations in Figures 12 through 32.

Table 6 All longitudinal stability derivatives

Steady State Coefficients	C_{L_1}	C_{D_1}	$C_{T_{x_1}}$	$C_{m_{T_1}}$	C_{m_1}
	0.1076	0.0177	0.0177	-0.0013	0.0013
Aerodynamic Speed Derivatives	C_{D_u}	C_{L_u}	C_{m_u}	$C_{T_{xu}}$	$C_{m_{T_u}}$
	0	0.0586	0.0106	-0.0531	0.0038
Angle of Attack Derivatives	C_{D_α}	C_{L_α}	C_{m_α}	$C_{m_{T_\alpha}}$	
	0.0972	6.1586	-3.5082	-0.0251	
Change of Angle of Attack Derivatives	$C_{D'_\alpha}$	$C_{L'_\alpha}$	$C_{m'_\alpha}$		
	0	3.6077	-12.7779		
Pitch Rate Derivatives	C_{D_q}	C_{L_q}	C_{m_q}		
	0	14.1354	-32.5032		

B. Lateral-Directional Stability Derivatives

Calculations for lateral-directional stability derivatives were done in AAA as described in handout #2 with printouts from Figures 55 through 71.

Table 7 All lateral stability derivatives

Aerodynamic sideslip derivatives	C_{y_β}	C_{l_β}	C_{n_β}	$C_{Y_{T_\beta}}$	$C_{n_{T_\beta}}$
	-0.9179	-0.3025	0.3995	0	0
Sideslip rate derivatives	$C_{y'_\beta}$	$C_{l'_\beta}$	$C_{n'_\beta}$		
	-0.0066	-0.0017	-0.0029		
Roll rate derivatives	C_{y_p}	C_{l_p}	C_{n_p}		
	-0.1342	-0.5259	-0.0193		
Yaw rate derivatives	C_{y_r}	C_{l_r}	C_{n_r}		
	0.7794	0.2663	-0.3678		

C. Longitudinal Control Derivatives

Table 8 All longitudinal control derivatives

Longitudinal control derivatives were calculated in AAA, resulting in Figures 72 through 75.

Longitudinal control derivatives	$C_{D_{\delta_e}}$	$C_{L_{\delta_e}}$	$C_{M_{\delta_e}}$
	0.0087	0.5482	-1.9416

D. Lateral-Directional Control Derivatives

Lateral-directional control derivatives were calculated in AAA as shown in Figures 76 through 81.

Table 9 All lateral control derivatives

Aileron control derivatives	$C_{y_{\delta_a}}$	$C_{L_{\delta_a}}$	$C_{n_{\delta_a}}$
	0	0.1629	-0.0044
Rudder control derivatives	$C_{y_{\delta_r}}$	$C_{L_{\delta_r}}$	$C_{n_{\delta_r}}$
	0.2717	0.0726	-0.1380

VII. Static Stability and One Engine Inoperative Analyses

A. Static Longitudinal Stability

With the updates from Handouts #1 through #4, the Twin Sea Lion now has a static margin $SM = 56\%$. This is far in excess of the typical 10% to 15% that most aircraft have. The most forward cg in cruise comes directly after adding baggage when the airplane takes off. This gives 24.27 ft. The most aft cg in cruise comes after unloaded fuel and gives 24.83 ft. The initial calculations were done at 24.32 ft. The static margin at the most forward cg is then 57.44% and the is 52.07%. All of these are stable but none of of them are acceptable for controllability. Static margin could be improved by a revised horizontal stabilizer or a complete overhaul of fuselage design.

B. Static Lateral-Directional Stability

From Table 7, $C_{n_\beta} = 0.3995$. This is suitably positive for positive stability and so is an acceptable value for lateral directional stability.

C. One Engine Inoperative Stability Analysis

Thanks to substantial rudder area, the Twin Sea Lion appears to have no issues with an engine out. As seen in Figures 85 and 86, the Twin Sea Lion needs to only deflect its rudder by 0.28 degrees at cruise altitude and speed, or 0.82 degrees at takeoff speed and altitude. However, V_{mc} is 420 knots at cruise and 168 knots at takeoff. Both these numbers are above the normal flying speeds of the aircraft. This is something of a contradiction, because the rudder deflections given are not anywhere near their maximums. This indicates that in reality the rudder could be more useful than AAA is calculating.

VIII. Transfer Function and Flying Quality Analyses

A. Transfer Function Analysis

1. Longitudinal Transfer Functions

Longitudinal transfer functions were determined through AAA in Figure 87. The following printouts, Figures 8 through 10 through the actual transfer functions as produced by AAA.

Longitudinal Transfer Function

Polynomial Form:

$$\frac{u(S)}{\delta_e(S)} = \frac{-565\ 5055\ S^3 - 6591\ 7688\ S^2 + 867350\ 4462\ S + 924232\ 6193}{594\ 2409\ S^4 + 6860\ 1311\ S^3 + 58549\ 8487\ S^2 + 595\ 4493\ S + 164\ 2356}$$

Factored Form:

$$\frac{u(S)}{\delta_e(S)} = \frac{-565\ 5055\ (S - 34\ 3625)(S + 44\ 9610)(S + 1\ 0578)}{594\ 2409\ (S^2 + 11\ 5345\ S + 98\ 4123)(S^2 + 0\ 0099\ S + 0\ 0028)}$$

$$K_{gain} = 5627\ \ 480478$$

Fig. 8 Airspeed response to elevator deflection transfer function

Longitudinal Transfer Function

Polynomial Form:

$$\frac{\alpha(S)}{\delta_e(S)} = \frac{-60\ 3020\ S^3 - 29782\ 3990\ S^2 - 294\ 5643\ S - 83\ 8327}{594\ 2409\ S^4 + 6860\ 1311\ S^3 + 58549\ 8487\ S^2 + 595\ 4493\ S + 164\ 2356}$$

Factored Form:

$$\frac{\alpha(S)}{\delta_e(S)} = \frac{-60\ 3020\ (S + 493\ 8772)(S^2 + 0\ 0099\ S + 0\ 0028)}{594\ 2409\ (S^2 + 11\ 5345\ S + 98\ 4123)(S^2 + 0\ 0099\ S + 0\ 0028)}$$

$$K_{gain} = -0\ \ 510442$$

Fig. 9 Angle of attack response to elevator deflect transfer function

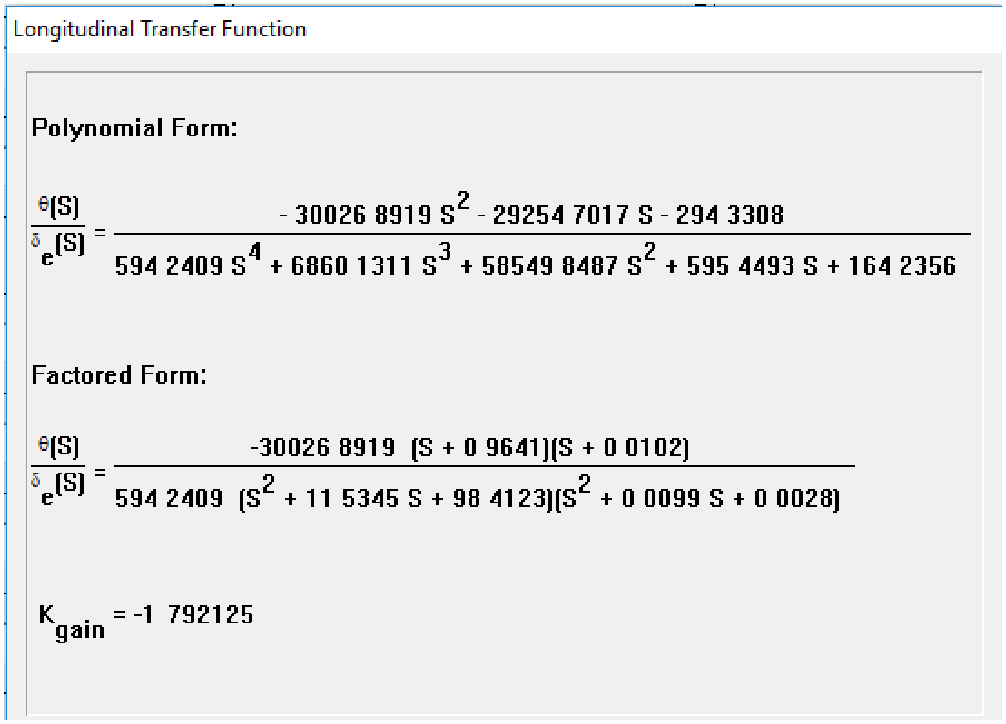


Fig. 10 Flight path angle response to elevator deflection transfer function

2. Lateral-Directional Transfer Functions

Lateral transfer functions were determined through AAA in Figure 88 for aileron and 89 for rudder.

3. Aileron Transfer Functions

4. Rudder Transfer Functions

B. Flying Qualities Analysis

1. Longitudinal Flying Qualities

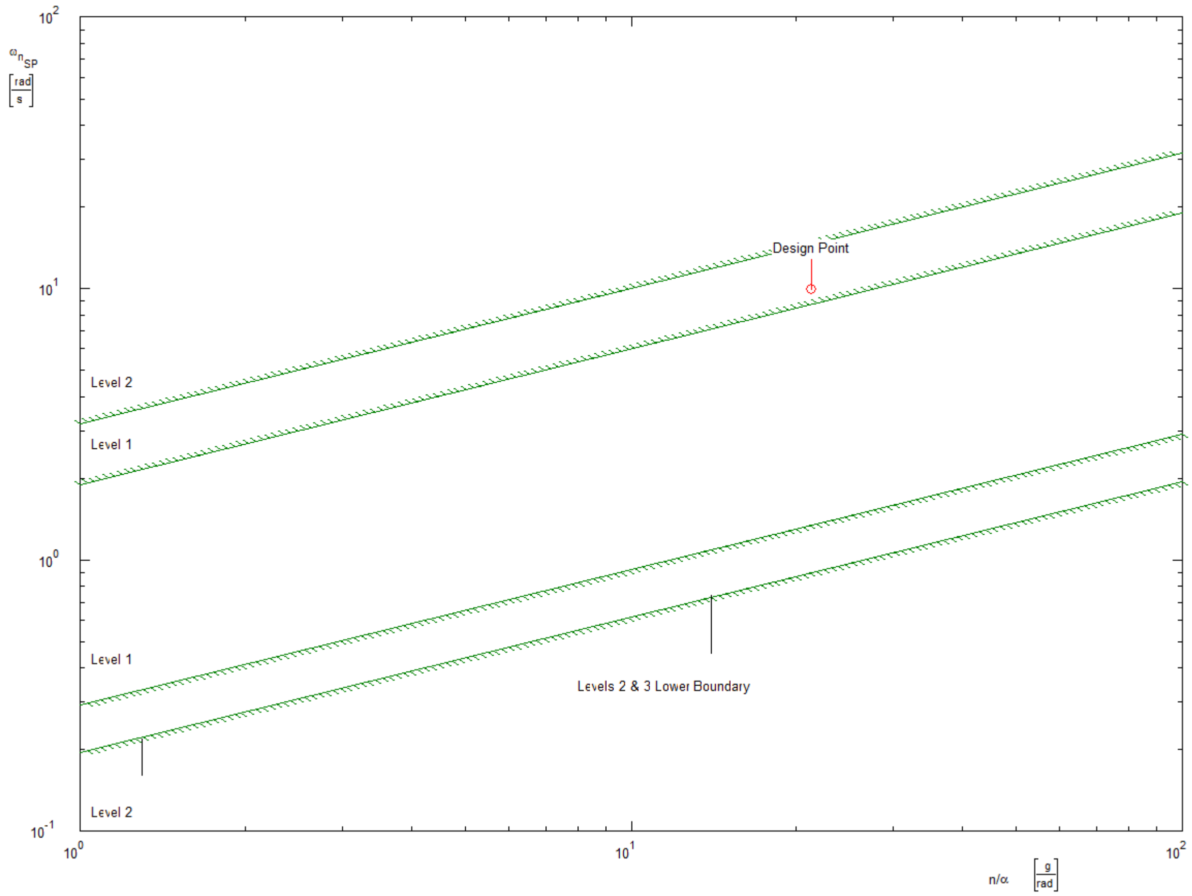


Fig. 11 Short period response is slightly outside level 1 requirements

AAA predicts that the Twin Sea Lion will have excellent flying qualities. AAA lists the relevant coefficients in Figure 87. In the phugoid mode, $\omega_P = 0.053s^{-1}$ and $\zeta_P = 0.093$. Short period has $\omega_{SP} = 9.92s^{-1}$ and $\zeta_{SP} = 0.581$. The detailed transfer functions are in Figures 8, 9, and 10.

With the exception of short period frequency, all the flying qualities of the Twin Sea Lion are considered Level 1, indicating that they are acceptable without further modification. Short period frequency is considered Level 2. This means that it can probably be corrected. The abnormally high short period frequency is consistent with the abnormally high static margin of the Twin Sea Lion. Future revisions can probably correct both issues simultaneously by redesigning the horizontal stabilizer.

2. Lateral-Directional Flying Qualities

Notably, the Twin Sea Lion is stable in spiral and dutch roll modes. This is unusual as most aircraft are either stable in dutch roll or spiral, but the unusual weight configuration distribution of the Twin Sea Lion, along with substantial dihedral and a very large tail mean that it manages stability in both modes.

IX. Design Changes Needed to Meet Mission Requirements or Improve Mission Performance

A. Conclusions

The Twin Sea Lion has begun to embody its name quite well. It is large, heavy, and likely quite loud. While its handling qualities are predicted to be quite fair, they are not perfect and many parts of the plane are perhaps over specialized. It has fallen short of its original range and payload requirements in order to maintain high cruising altitude and top speed. Whether this is a fair tradeoff is a decision for the pilot or operator, but the designers think they may have missed the mark. Nevertheless, the Twin Sea Lion represents a unique set of capabilities based around speed and altitude not normally seen in the turboprop class.

B. Recommended Design Changes

Large design changes ought to be considered for the Twin Sea Lion. Chief among them is whether the performance targets are feasible with current technology. In an effort to fly far, fast, and high, the aircraft has mostly become wing and engine at the expense of cargo and payload space. By flying shorter missions, more weight could be moved towards cargo and passengers instead of fuel. By altitude requirements, the wings and control surface sizes could be reduced. Finally, takeoff altitude and speed requirements would allow for reductions to maximum engine power. In addition, reworking the horizontal stabilizer could reduce pitch stiffness and make the plane more flyable overall.

However, these are all substantial and require significant extra work. Smaller changes might include moving to composite construction. An all carbon fiber aircraft would have savings not only from reduced structural weight, but all the efficiencies that follow as fuel and powerplant requirements also decrease. That room could be used for cargo, stronger landing gear, and better high lift devices to maintain the original goals of STOL performance and long range. In addition, fewer rivets would decrease drag moderately.

In either case, the authors believe that the first changes should be made to the empennage. The high aspect ratios of the horizontal and vertical stabilizers make the aircraft excessively stiff in pitch and yaw and smaller surfaces would likely suffice. If the elevator and rudder authorities are insufficient, the elevators and rudders could be made into all-moving tailplanes in order to keep adequate area for the aerodynamic surfaces.

References

[1] Junker and Killelea, "Design Report 01: Twin Sea Lion."

[2] Junker and Killelea, "Design Report 02: Twin Sea Lion."

[3] Junker and Killelea, "Design Report 03: Twin Sea Lion."

[4] Gerren, "Handout #1", `https://canvas.colorado.edu`

[5] Gerren, "Handout #2", `https://canvas.colorado.edu`

[6] Gerren, "Handout #3", `https://canvas.colorado.edu`

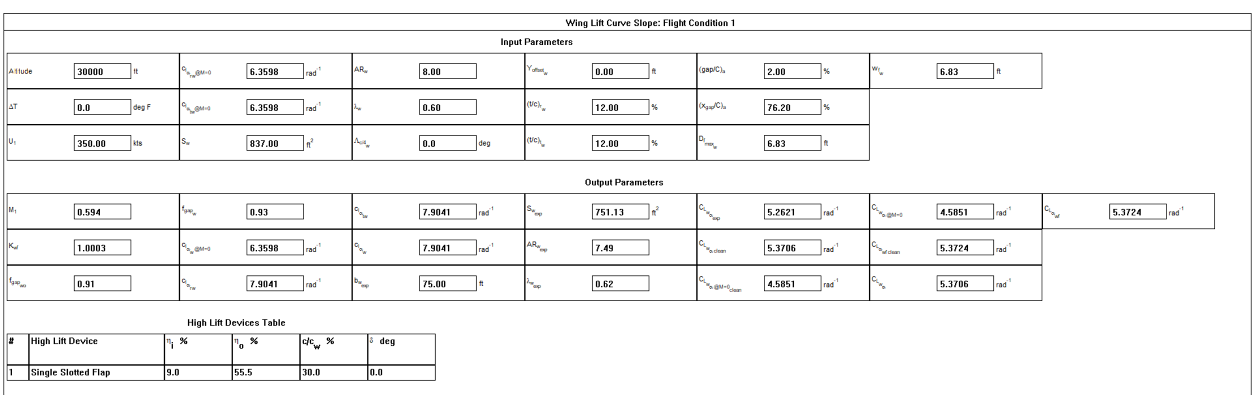
[7] Gerren, "Handout #4", `https://canvas.colorado.edu`

[8] Gerren, "Presentation 26", `https://canvas.colorado.edu`

[9] Gerren, "Presentation 27", `https://canvas.colorado.edu`

X. Appendix

A. AAA: Stability and Control Derivatives



Wing Lift Curve Slope: Flight Condition 1

Input Parameters

Altitude	30000 ft	$c_{l_{\alpha_{rw}}@M=0}$	6.3598 rad^{-1}	AR_w	8.00	Y_{offset_w}	0.00 ft	$(gap/C)_a$	2.00 %	w_{f_w}	6.83 ft
ΔT	0.0 deg F	$c_{l_{\alpha_{tw}}@M=0}$	6.3598 rad^{-1}	λ_w	0.60	$(t/c)_{r_w}$	12.00 %	$(x_{gap}/C)_a$	76.20 %		
U_1	350.00 kts	S_w	837.00 ft^2	$\Lambda_{c/4_w}$	0.0 deg	$(t/c)_{t_w}$	12.00 %	$D_{f_{max_w}}$	6.83 ft		

Output Parameters

M_1	0.594	f_{gap_w}	0.93	$c_{l_{\alpha_{tw}}}$	7.9041 rad^{-1}	$S_{w_{exp}}$	751.13 ft^2	$C_{L_{w_{\alpha_{exp}}}}$	5.2621 rad^{-1}	$C_{L_{w_{\alpha}@M=0}}$	4.5851 rad^{-1}	$C_{L_{\alpha_{wf}}}$	5.3724 rad^{-1}
K_{wf}	1.0003	$c_{l_{\alpha_w}@M=0}$	6.3598 rad^{-1}	$c_{l_{\alpha_w}}$	7.9041 rad^{-1}	$AR_{w_{exp}}$	7.49	$C_{L_{w_{\alpha\ clean}}}$	5.3706 rad^{-1}	$C_{L_{\alpha_{wf\ clean}}}$	5.3724 rad^{-1}		
$f_{gap_{wo}}$	0.91	$c_{l_{\alpha_{rw}}}$	7.9041 rad^{-1}	$b_{w_{exp}}$	75.00 ft	$\lambda_{w_{exp}}$	0.62	$C_{L_{w_{\alpha}@M=0_{clean}}}$	4.5851 rad^{-1}	$C_{L_{w_{\alpha}}}$	5.3706 rad^{-1}		

High Lift Devices Table

#	High Lift Device	η_i %	η_o %	c/c_w %	δ deg
1	Single Slotted Flap	9.0	55.5	30.0	0.0

Fig. 12 Wing lift curve slope

Wing Lift Coefficient at Alpha = 0 deg: Flight Condition 1

Input Parameters

Altitude 30000 ft	S_w 837.00 ft^2	$\Lambda_{c/4_w}$ 0.0 deg	$C_{L_{\alpha_{wf\,clean}}}$ 5.3724 rad^{-1}	$c_{l_{\alpha_{tw}}@M=0}$ 6.3598 rad^{-1}	i_w -1.0 deg	$(t/c)_{t_w}$ 12.00 %
ΔT 0.0 deg F	AR_w 8.00	$C_{L_{w_{\alpha}\,clean}}$ 5.3706 rad^{-1}	$C_{L_{\alpha_{wf}}}$ 5.3724 rad^{-1}	$\alpha_{o_{rw\,M=0}}$ -3.0 deg	ε_{g_w} 0.0 deg	
U_1 350.00 kts	λ_w 0.60	$C_{L_{w_{\alpha}}}$ 5.3706 rad^{-1}	$c_{l_{\alpha_{rw}}@M=0}$ 6.3598 rad^{-1}	$\alpha_{o_{tw\,M=0}}$ -3.0 deg	$(t/c)_{r_w}$ 12.00 %	

Output Parameters

M_1 0.594	ε_w 0.0 deg	$c_{l_{\alpha_w}@M=0}$ 6.3598 rad^{-1}	$\alpha_{w_{o\,clean}}$ -3.0 deg	$\Delta C_{L_{w_{o\,hld}}}$ 0.0000	$C_{L_{w_o}}$ 0.2812
$\alpha_{o_{rw}}$ -3.0 deg	$c_{l_{\alpha_{rw}}}$ 7.9041 rad^{-1}	$c_{l_{\alpha_w}}$ 7.9041 rad^{-1}	α_{w_o} -3.0 deg	$\Delta C_{L_{wf_{o\,hld}}}$ 0.0000	$C_{L_{o_{wf\,clean}}}$ 0.1875
$\alpha_{o_{tw}}$ -3.0 deg	$c_{l_{\alpha_{tw}}}$ 7.9041 rad^{-1}	$\alpha_{o_{1_w}}$ -0.4	$\alpha_{o_{wf}}$ -2.0 deg	$C_{L_{w_{o\,clean}}}$ 0.2812	$C_{L_{o_{wf}}}$ 0.1875

High Lift Devices Table

#	High Lift Device	η_i %	η_o %	c/c_w %	δ deg	$\Delta C_{L_{w_o}}$
		Input	Input	Input	Input	Output
1	Single Slotted Flap	9.0	55.5	30.0	0.0	0.0000

Fig. 13 Wing lift coefficient at zero angle of attack

Horizontal Tail Lift Curve Slope: Flight Condition 1

Input Parameters

Altitude 30000 ft	$c_{l_{\alpha_{rh}}@M=0}$ 6.2504 rad^{-1}	AR_h 7.00	Y_{offset_h} 0.00 ft	w_{f_h} 2.00 ft
ΔT 0.0 deg F	$c_{l_{\alpha_{th}}@M=0}$ 6.2504 rad^{-1}	λ_h 1.00	$(t/c)_{r_h}$ 12.0 %	$(gap/C)_e$ 0.00 %
U_1 350.00 kts	S_h 190.00 ft^2	$\Lambda_{c/4_h}$ 0.0 deg	$(t/c)_{t_h}$ 12.0 %	$(x_{gap}/C)_e$ 70.00 %

Output Parameters

M_1 0.594	$AR_{h_{exp}}$ 6.62	$b_{h_{exp}}$ 34.47 ft	$C_{L_{h_{\alpha_{exp}}}}$ 5.3897 rad^{-1}	f_{gap_h} 1.00	$c_{l_{\alpha_{rh}}}$ 7.7681 rad^{-1}	$c_{l_{\alpha_h}}$ 7.7681 rad^{-1}
$S_{h_{exp}}$ 179.58 ft^2	$\lambda_{h_{exp}}$ 1.00	$K_{h(b)} + K_{b(h)}$ 1.12	$f_{gap_{ho}}$ 1.00	$c_{l_{\alpha_h}@M=0}$ 6.2504 rad^{-1}	$c_{l_{\alpha_{th}}}$ 7.7681 rad^{-1}	$C_{L_{h_{\alpha}}}$ 5.7070 rad^{-1}

Fig. 14 Horizontal stabilizer lift curve slope

Horizontal Tail Downwash Gradient: Flight Condition 1

Input Parameters

S_w 837.00 ft^2	$\Lambda_{c/4_w}$ 0.0 deg	$Z_{c_r/4_w}$ 2.00 ft	$C_{L_{w_{\alpha}@M=0_{clean}}}$ 4.5851 rad^{-1}	AR_h 7.00	Γ_h 0.0 deg	$Z_{c_r/4_h}$ 6.00 ft
AR_w 8.00	X_{apex_w} 23.00 ft	i_w -1.0 deg	$C_{L_{w_{\alpha}}}$ 5.3706 rad^{-1}	λ_h 1.00	X_{apex_h} 60.00 ft	
λ_w 0.60	Y_{offset_w} 0.00 ft	$C_{L_{w_{\alpha}\,clean}}$ 5.3706 rad^{-1}	S_h 190.00 ft^2	$\Lambda_{c/4_h}$ 0.0 deg	Y_{offset_h} 0.00 ft	

Output Parameters

Z_{ac_h} 6.00 ft	l_h 35.11 ft	$(d\varepsilon/d\alpha)_\infty$ 0.4274	$(d\varepsilon_h/d\alpha)_{M=0}$ 0.3356	$(d\varepsilon_h/d\alpha)_{p.off}$ 0.3931	$d\varepsilon_h/d\alpha_{clean}$ 0.3931	$d\varepsilon_h/d\alpha$ 0.3931

High Lift Devices Table

#	High Lift Device	η_i %	η_o %
1	Single Slotted Flap	9.0	55.5

Fig. 15 Horizontal stabilizer downwash gradient

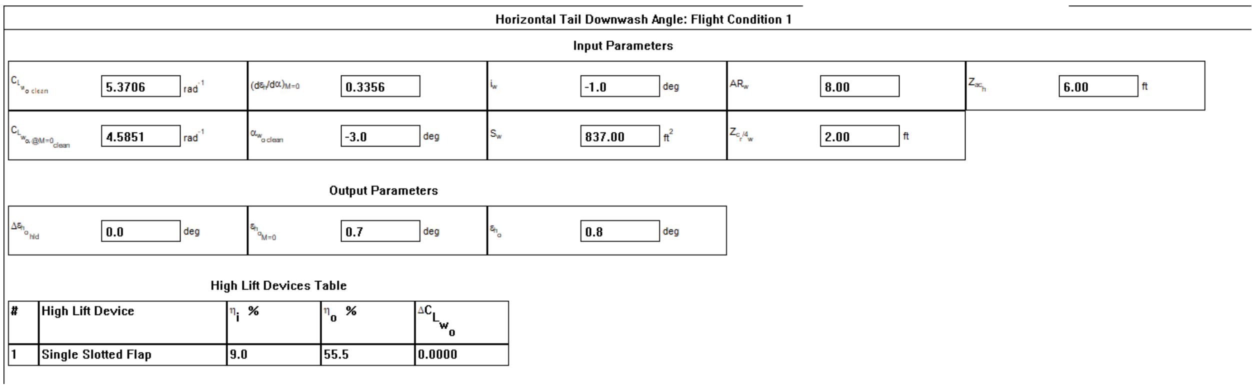


Fig. 16 Horizontal stabilizer downwash angle

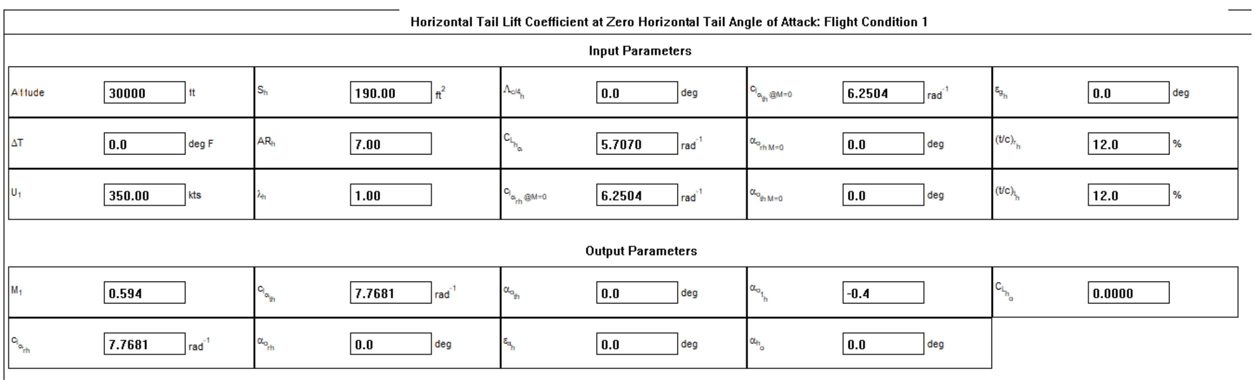


Fig. 17 Horizontal stabilizer lift coefficient at zero angle of attack

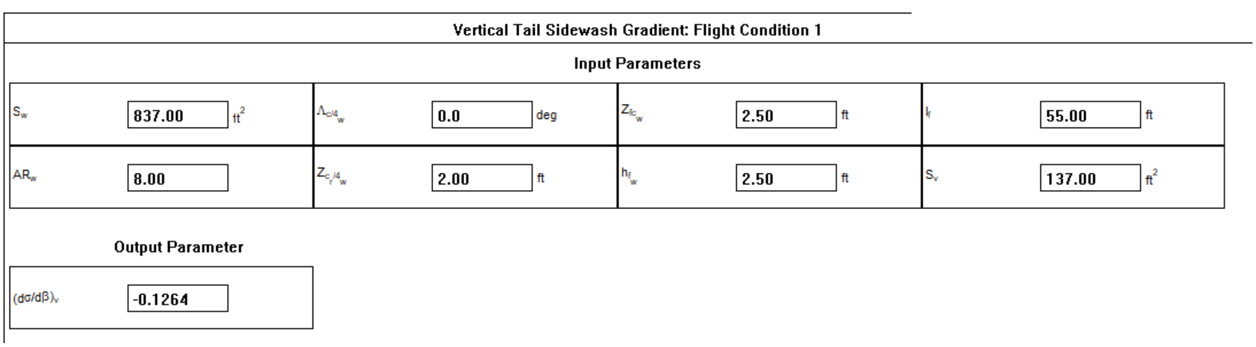


Fig. 18 Vertical stabilizer sidewash gradient

Vertical Tail Downwash Gradient: Flight Condition 1

Input Parameters

S_w	837.00	ft^2	$\Lambda_{c/4_w}$	0.0	deg	$Z_{c_r/4_w}$	2.00	ft	$C_{L_{w_{\alpha\,@M=0_{clean}}}}$	4.5851	rad^{-1}	AR_v	3.00		Γ_v	90.0	deg
AR_w	8.00		X_{apex_w}	23.00	ft	i_w	-1.0	deg	$C_{L_{w_\alpha}}$	5.3706	rad^{-1}	λ_v	0.80		X_{apex_v}	60.00	ft
λ_w	0.60		Y_{offset_w}	0.00	ft	$C_{L_{w_{\alpha\,clean}}}$	5.3706	rad^{-1}	S_v	137.00	ft^2	$\Lambda_{c/4_v}$	5.0	deg	Z_{apex_v}	15.00	ft

Output Parameters

Z_{ac_v}	24.76	ft	l_v	36.53	ft	$(d\varepsilon/d\alpha)_{M=0}$	0.2379		$(d\varepsilon/d\alpha)_{p.off}$	0.2787		$d\varepsilon/d\alpha_{clean}$	0.2787		$d\varepsilon/d\alpha$	0.2787	

High Lift Devices Table

#	High Lift Device	η_i %	η_o %
1	Single Slotted Flap	9.0	55.5

Fig. 19 Vertical stabilizer downwash gradient

Vertical Tail Downwash Angle: Flight Condition 1

Input Parameters

$C_{L_{w_{\alpha\,clean}}}$	5.3706	rad^{-1}	$(d\varepsilon/d\alpha)_{M=0}$	0.2379		i_w	-1.0	deg	AR_w	8.00		Z_{ac_v}	24.76	ft
$C_{L_{w_{\alpha\,@M=0_{clean}}}}$	4.5851	rad^{-1}	$\alpha_{w_{o\,clean}}$	-3.0	deg	S_w	837.00	ft^2	$Z_{c_r/4_w}$	2.00	ft			

Output Parameters

$\Delta\varepsilon_{v_{\alpha_f}}$	0.0	deg	$\varepsilon_{v_{o_{M=0}}}$	0.5	deg	ε_{v_o}	0.6	deg

High Lift Devices Table

#	High Lift Device	η_i %	η_o %	$\Delta C_{L_{w_o}}$
1	Single Slotted Flap	9.0	55.5	0.0000

Fig. 20 Vertical stabilizer downwash angle

Wing Lift Coefficient for Given Angle of Attack: Linear Range: Flight Condition 1

Input Parameters

α	0.00	deg	α_{w_o}	-3.0	deg	$C_{L_{w_{\alpha\,clean}}}$	5.3706	rad^{-1}	$C_{L_{o_{no\,emp\,clean}}}$	0.1875		$C_{L_{\alpha_{no\,emp\,clean}}}$	5.3724	rad^{-1}
$\alpha_{w_{o\,clean}}$	-3.0	deg	i_w	-1.0	deg	$C_{L_{w_\alpha}}$	5.3706	rad^{-1}	$C_{L_{o_{no\,empen}}}$	0.1875		$C_{L_{\alpha_{no\,empen}}}$	5.3724	rad^{-1}

Output Parameters

$\alpha_{w_{p.off}}$	-1.0	deg	$C_{L_{w\,clean}}$	0.1875		$C_{L_{wf\,cln\,p.off}}$	0.1875		$C_{L_{wf}}$	0.1875		$\Delta C_{L_{hld}}$	0.0000	
$C_{L_{w\,cln\,p.off}}$	0.1875		C_{L_w}	0.1875		$C_{L_{wf\,clean}}$	0.1875		$\Delta C_{L_{w_{o_{hld}}}}$	0.0000				

Fig. 21 Wing lift coefficient

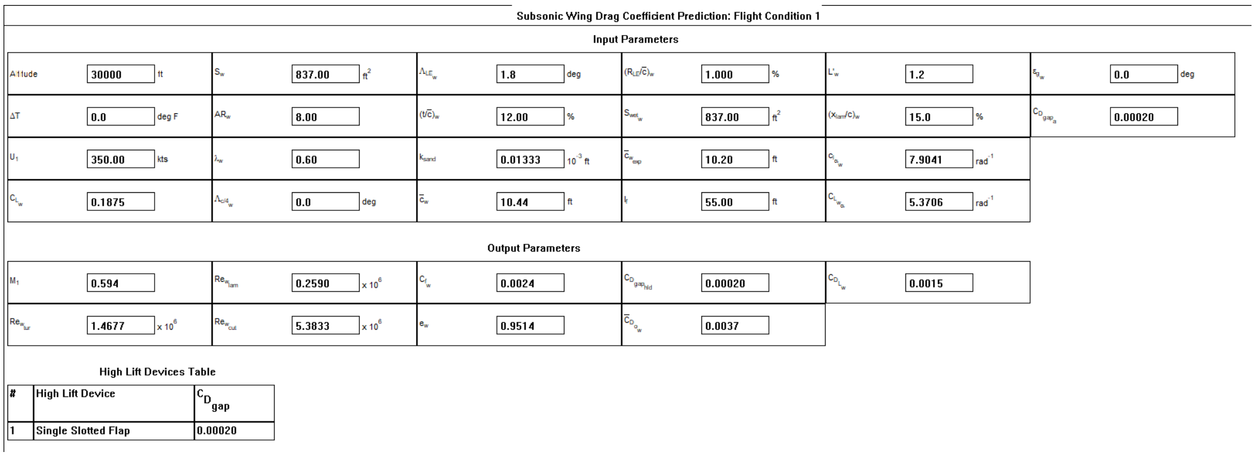


Fig. 22 Wing drag coefficients

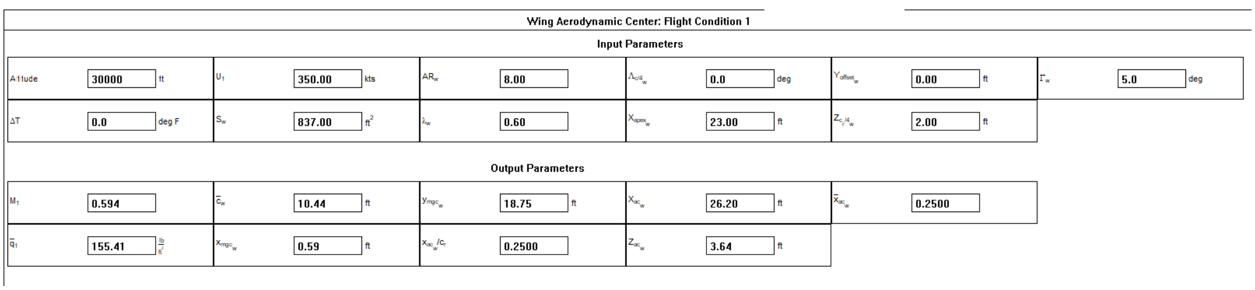


Fig. 23 Wing aerodynamic center

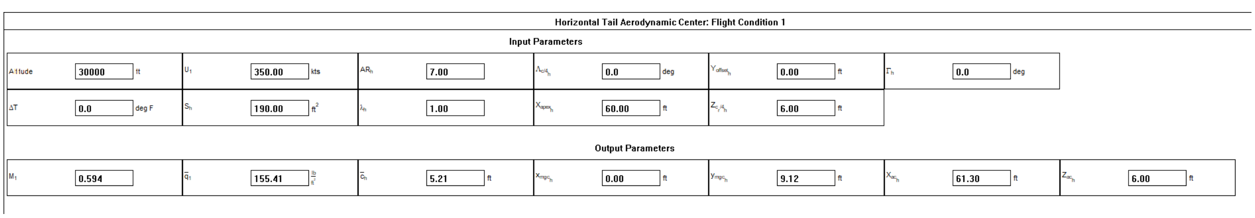


Fig. 24 Horizontal stabilizer aerodynamic center

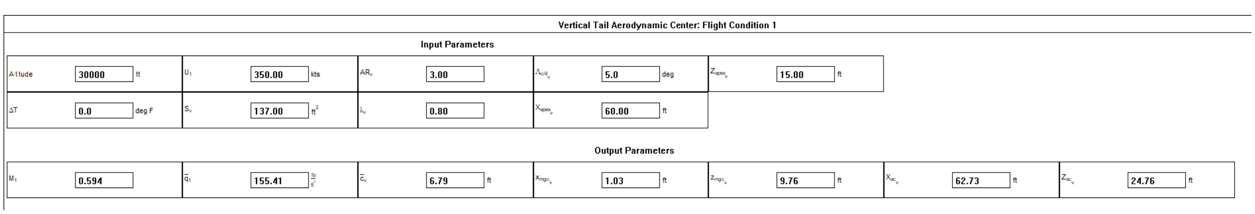


Fig. 25 Vertical stabilizer aerodynamic center

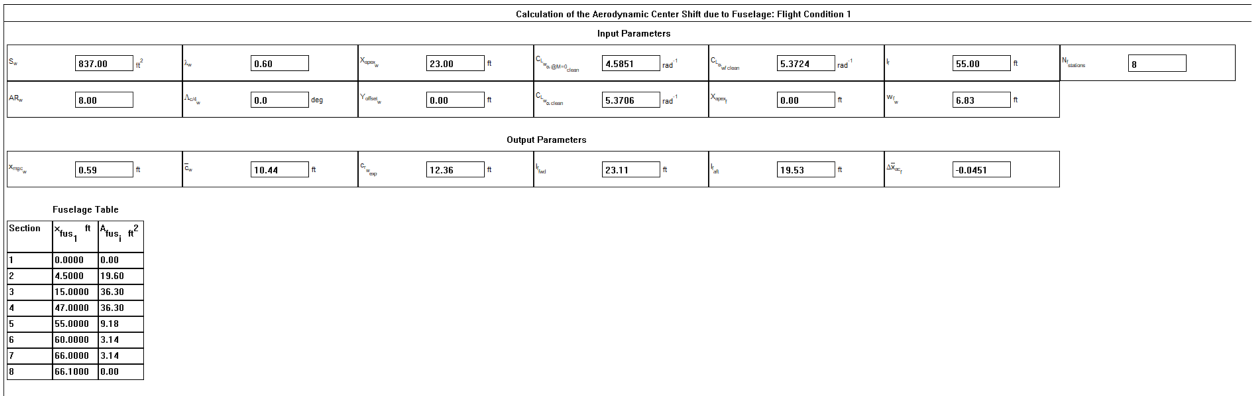


Fig. 26 Aerodynamic center shift due to fuselage effects

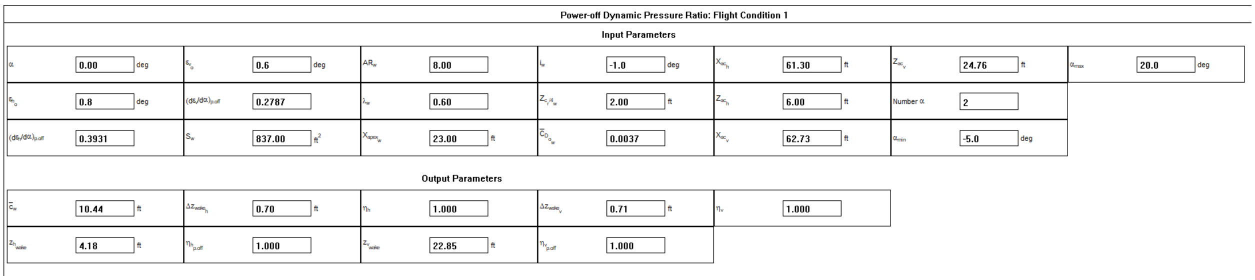


Fig. 27 Power-off dynamic pressure ratio

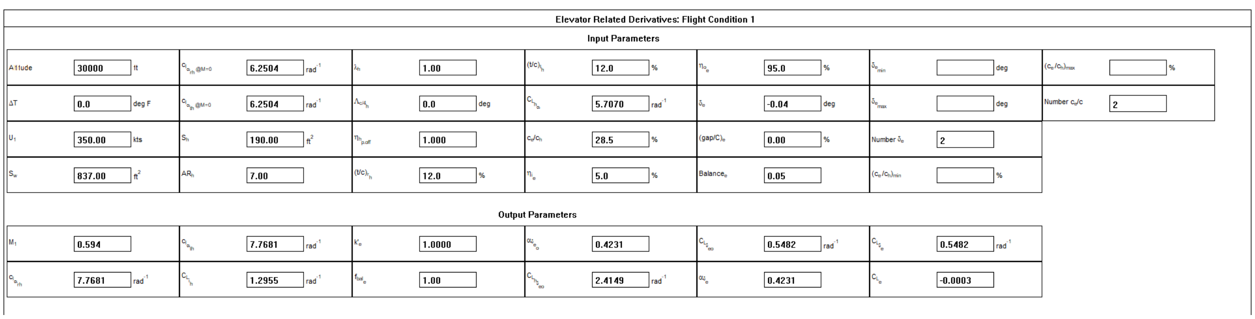


Fig. 28 Elevator related derivatives

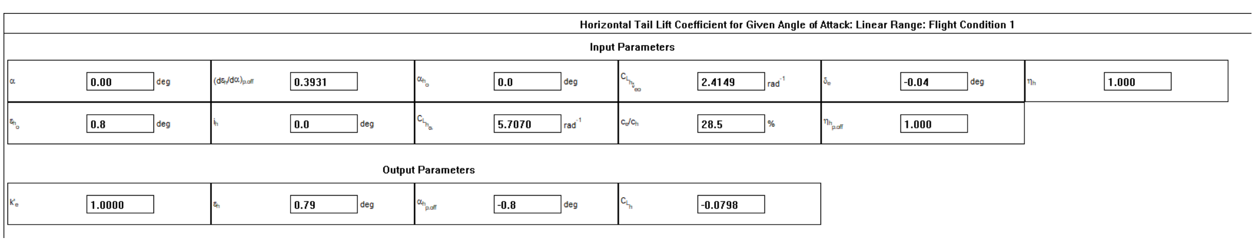


Fig. 29 Horizontal tail lift coefficient

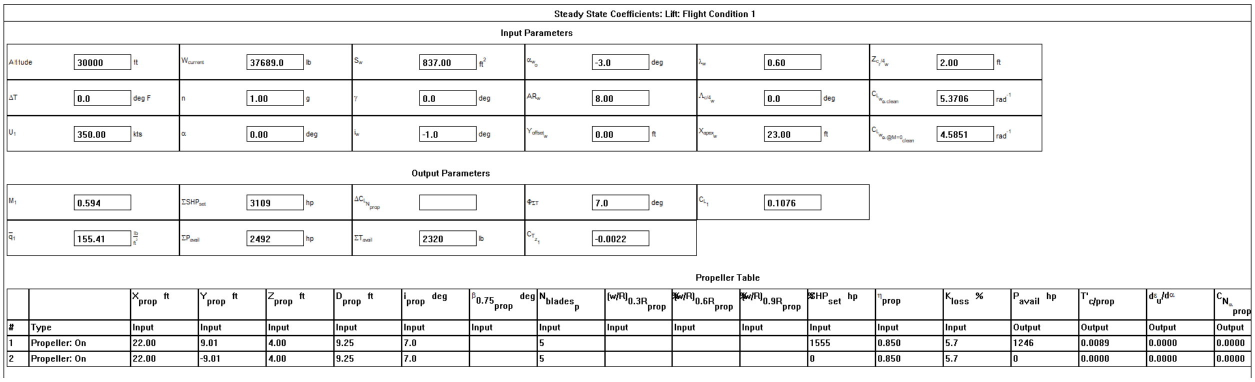


Fig. 30   Steady state lift coefficients

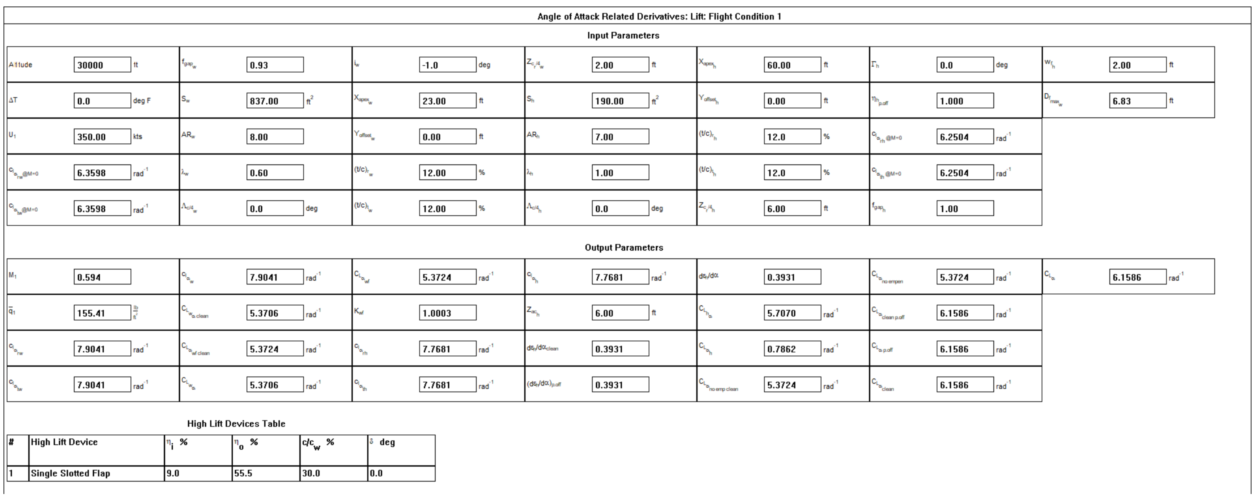


Fig. 31   Angle of attack related derivatives

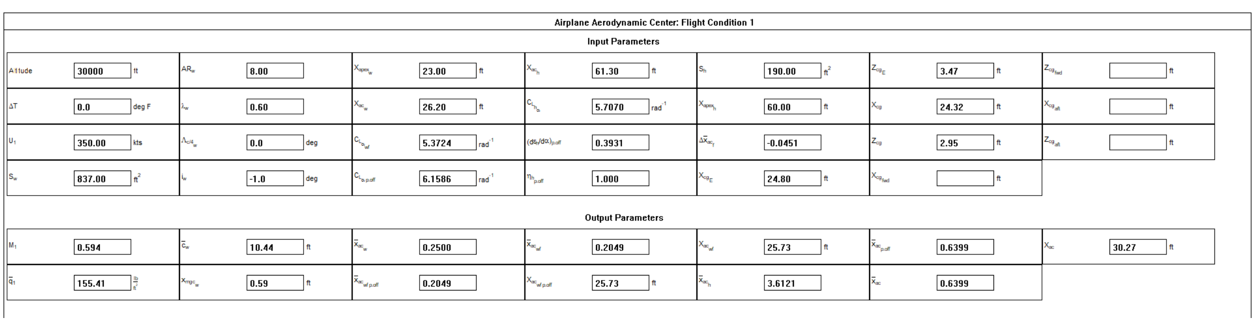


Fig. 32   Aircraft aerodynamic center

Steady State Coefficients: Lift: Flight Condition 1

Input Parameters

Altitude	30000	ft	$W_{current}$	37689.0	lb	S_w	837.00	ft^2	α_{w_0}	-3.0	deg	λ_w	0.60		$Z_{c_r/4_w}$	2.00	ft
ΔT	0.0	deg F	n	1.00	g	γ	0.0	deg	AR_w	8.00		$\Lambda_{c/4_w}$	0.0	deg	$C_{L_{w_{\alpha,clean}}}$	5.3706	rad^{-1}
U_1	350.00	kts	α	0.00	deg	i_w	-1.0	deg	Y_{offset_w}	0.00	ft	X_{apex_w}	23.00	ft	$C_{L_{w_{\alpha,@M=0_{clean}}}}$	4.5851	rad^{-1}

Output Parameters

M_1	0.594		ΣSHP_{set}	3109	hp	$\Delta C_{L_{N_{prop}}}$			$\Phi_{\Sigma T}$	7.0	deg	C_{L_1}	0.1076	
$\bar{q}_1$	155.41	lb/ft^2	ΣP_{avail}	2492	hp	ΣT_{avail}	2320	lb	$C_{T_{z_1}}$	-0.0022				

Propeller Table

		X_{prop} ft	Y_{prop} ft	Z_{prop} ft	D_{prop} ft	i_{prop} deg	$\beta_{0.75_{prop}}$ deg	N_{blades_p}	$(w/R)_{0.3R_{prop}}$	$(w/R)_{0.6R_{prop}}$	$(w/R)_{0.9R_{prop}}$	SHP_{set} hp	η_{prop}	K_{loss} %	P_{avail} hp	$T'_{c/prop}$	$d\varepsilon_u/d\alpha$	$C_{N_{\alpha_{prop}}}$
#	Type	Input	Input	Input	Input	Input	Input	Input	Input	Input	Input	Input	Input	Input	Output	Output	Output	Output
1	Propeller: On	22.00	9.01	4.00	9.25	7.0		5				1555	0.850	5.7	1246	0.0089	0.0000	0.0000
2	Propeller: On	22.00	-9.01	4.00	9.25	7.0		5				0	0.850	5.7	0	0.0000	0.0000	0.0000

Fig. 33 Steady state lift coefficient

Steady State Coefficients: Drag: Flight Condition 1

Input Parameters

C_{L_1}	0.1076	$\bar{C}_{D_0}$		$B_{C_{D_1}}$		$B_{C_{D_2}}$		$B_{C_{D_3}}$		$B_{C_{D_4}}$		$B_{C_{D_5}}$	

Output Parameters

C_{D_1}	0.0177	L/D	6.08

Fig. 34 Steady state flight coefficients

Class I Current Flight Condition Drag Polar: Flight Condition 1

Input Parameters

W_{TO}	37689.0	lb	AR_w	8.00		a	-2.3010	c	-0.0866	$\Delta\bar{C}_{D_0}$	0.0005	$C_{L_{plot_{max}}}$	3.0000	
S_w	837.00	ft^2	λ_w	0.60		b	1.0000	d	0.8099	$C_{L_{plot_{min}}}$	0.0000			

Output Parameters

e	0.8560		f	20.83	ft^2	$\bar{C}_{D_{0_1}}$	0.0254	B_{DP}	0.0465	$C_{L_{@C_{D_{min}}}}$	0.0000
S_{wet}	4165.58	ft^2	$\bar{C}_{D_{0_{clean}}}$	0.0249		A_{DP}	0.0000	$C_{D_{min}}$	0.0254		

Fig. 35 Steady state drag polar calculations

Steady State Coeffcient due to Thrust in X-direction: Flight Condition 1

Input Parameters

Altitude	30000	ft	ΔT	0.0	deg F	U_1	350.00	kts	α	0.00	deg	S_w	837.00	ft^2

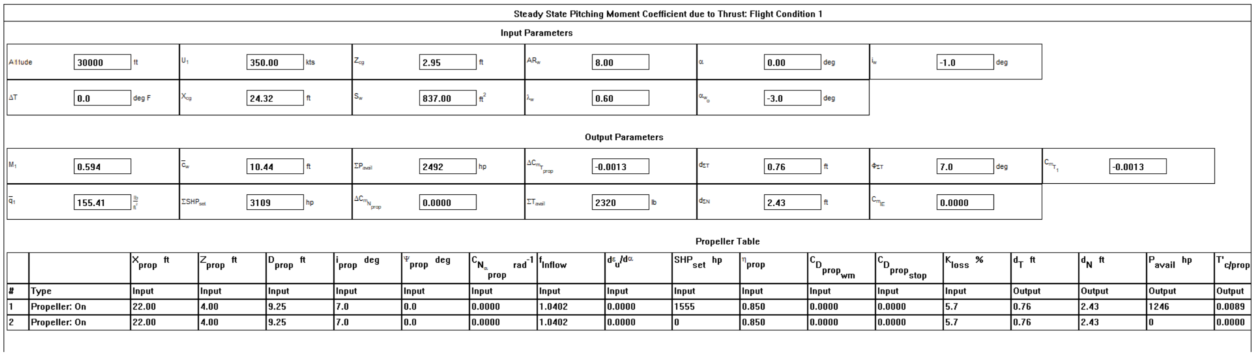
Output Parameters

M_1	0.594		$\Phi_{T_{\Sigma prop}}$	7.0	deg	ΣP_{avail}	2492	hp	$\Phi_{\Sigma T}$	7.0	deg
$\bar{q}_1$	155.41	lb/ft^2	ΣSHP_{set}	3109	hp	ΣT_{avail}	2320	lb	$C_{T_{x_1}}$	0.0177	

Propeller Table

		SHP_{set} hp	η_{prop}	i_{prop} deg	Ψ_{prop} deg	K_{loss} %	P_{avail} hp	T_{avail} lb	$T'_{c/prop}$	$C_{T_{x_1}}$
#	Type	Input	Input	Input	Input	Input	Output	Output	Output	Output
1	Propeller: On	1555	0.850	7.0	0.0	5.7	1246	1160	0.0089	0.0089
2	Propeller: On	0	0.850	7.0	0.0	5.7	0	0	0.0000	0.0089

Fig. 36 Steady state thrust



#	Type	X_{prop} ft	Z_{prop} ft	D_{prop} ft	i_{prop} deg	Ψ_{prop} deg	$C_{N_{\alpha_{prop}}}$ rad^{-1}	f_{Inflow}	$d\varepsilon_u/d\alpha$	SHP_{set} hp	η_{prop}	$C_{D_{prop_{wm}}}$	$C_{D_{prop_{stop}}}$	K_{loss} %	d_T ft	d_N ft	P_{avail} hp	$T'_{c/prop}$
		Input	Input	Input	Input	Input	Input	Input	Input	Input	Input	Input	Input	Input	Output	Output	Output	Output
1	Propeller: On	22.00	4.00	9.25	7.0	0.0	0.0000	1.0402	0.0000	1555	0.850	0.0000	0.0000	5.7	0.76	2.43	1246	0.0089
2	Propeller: On	22.00	4.00	9.25	7.0	0.0	0.0000	1.0402	0.0000	0	0.850	0.0000	0.0000	5.7	0.76	2.43	0	0.0000

Fig. 37 Steady state pitching moment

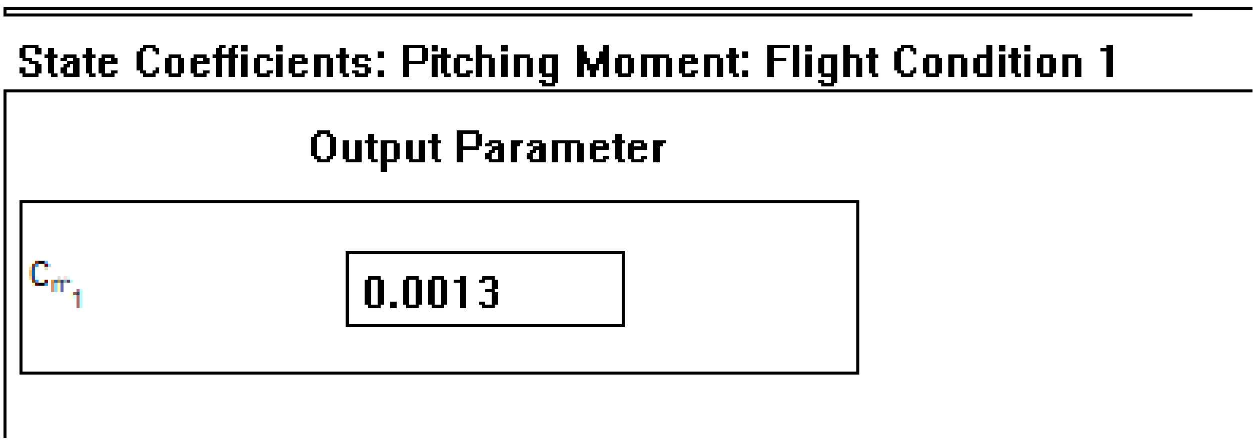


Fig. 38 Steady state pitching moment

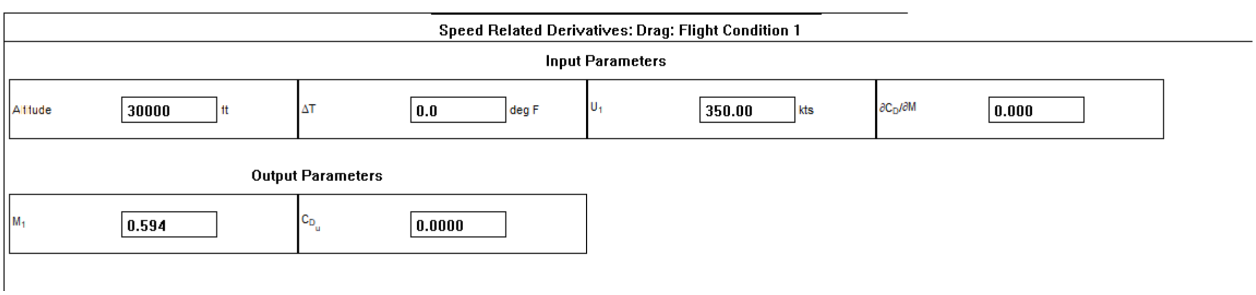


Fig. 39 Speed related derivatives

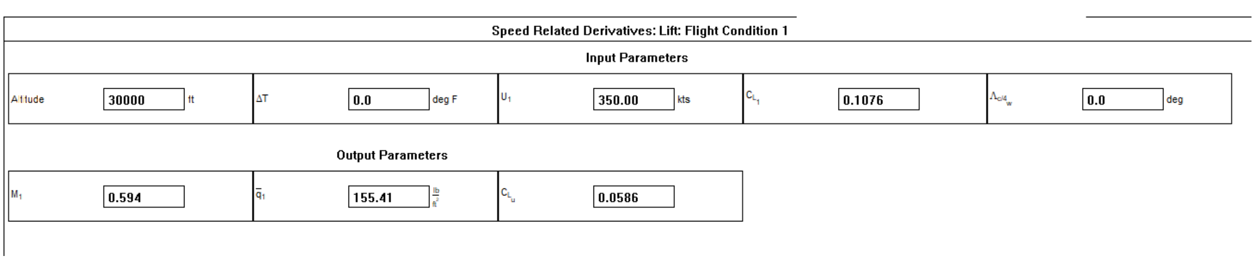


Fig. 40 Speed related derivatives

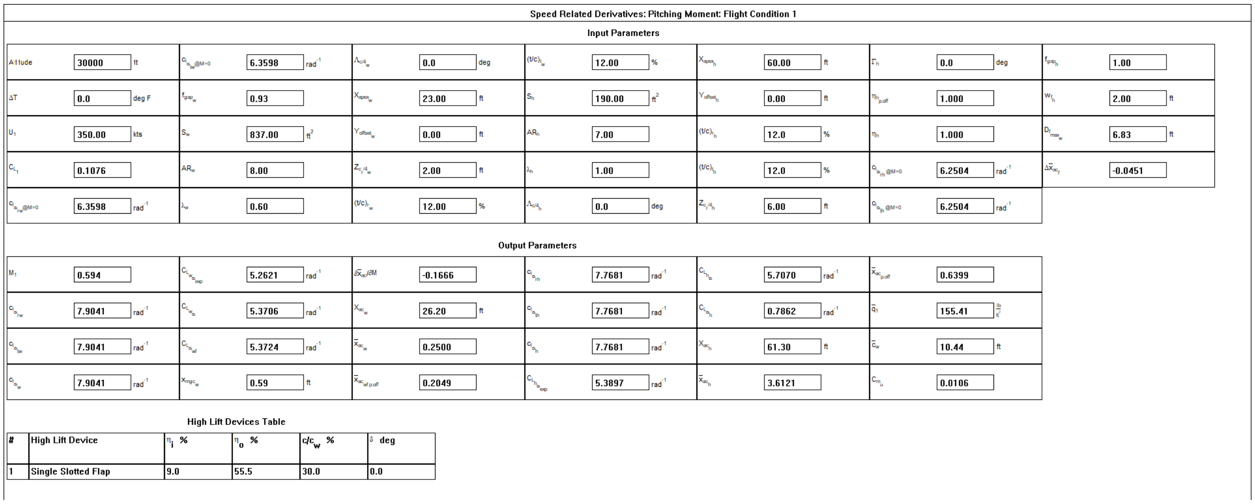


Fig. 41 Speed related derivatives

Speed Related Derivatives: Thrust: Flight Condition 1

Input Parameter

$C_{T_{x_1}}$	0.0177

Output Parameter

$C_{T_{x_u}}$	-0.0531

Propeller Table

		$C_{T_{x_1}}$	$C_{T_{x_u}}$
#	Type	Input	Output
1	Propeller: On	0.0089	-0.0266
2	Propeller: On	0.0089	-0.0266

Fig. 42 Speed related derivatives

Speed Related Derivatives: Pitching Moment due to Thrust: Flight Condition 1

Input Parameters

S_w	837.00 ft^2	AR_w	8.00	λ_w	0.60	X_{cg}	24.32 ft	Z_{cg}	2.95 ft

Output Parameters

$d_{\Sigma T_{prop}}$	0.76 ft	$\Phi_{T_{\Sigma prop}}$	7.0 deg	$d_{\Sigma N}$	2.43 ft	$\bar{c}_w$	10.44 ft
$d_{\Sigma N_{prop}}$	2.43 ft	$d_{\Sigma T}$	0.76 ft	$\Phi_{\Sigma T}$	7.0 deg	$C_{m_{T_u}}$	0.0038

Propeller Table

		X_{prop} ft	Z_{prop} ft	i_{prop} deg	$C_{T_{x_u}}$	$C_{m_{T_u}}$
#	Type	Input	Input	Input	Input	Output
1	Propeller: On	22.00	4.00	7.0	-0.0266	0.0019
2	Propeller: On	22.00	4.00	7.0	-0.0266	0.0019

Fig. 43 Speed related derivatives

Angle of Attack Related Derivatives: Drag: Flight Condition 1

Input Parameters

Altitude	30000 ft	M_1	0.594	$\bar{C}_{D_0}$	0.0254	B_{DP}	0.0465	$C_{L_{\alpha\ p.off}}$	6.1586 rad^{-1}
ΔT	0.0 deg F	α	0.00 deg	A_{DP}	0.0000	$C_{L_{0\ p.off}}$	0.1698		

Output Parameter

C_{D_α}	0.0972 rad^{-1}

Fig. 44 Angle of attack related derivatives

Angle of Attack Related Derivatives: Lift: Flight Condition 1

Input Parameters

Altitude	30000 ft	f_{gap_w}	0.93	i_w	-1.0 deg	$Z_{c_r/4_w}$	2.00 ft	X_{apex_h}	60.00 ft	Γ_h	0.0 deg	w_{f_h}	2.00 ft
ΔT	0.0 deg F	S_w	837.00 ft^2	X_{apex_w}	23.00 ft	S_h	190.00 ft^2	Y_{offset_h}	0.00 ft	$\eta_{h_{p.off}}$	1.000	$D_{f_{max_w}}$	6.83 ft
U_1	350.00 kts	AR_w	8.00	Y_{offset_w}	0.00 ft	AR_h	7.00	$(t/c)_{r_h}$	12.0 %	$c_{l_{\alpha_{rh}}@M=0}$	6.2504 rad^{-1}		
$c_{l_{\alpha_{rw}}@M=0}$	6.3598 rad^{-1}	λ_w	0.60	$(t/c)_{r_w}$	12.00 %	λ_h	1.00	$(t/c)_{t_h}$	12.0 %	$c_{l_{\alpha_{th}}@M=0}$	6.2504 rad^{-1}		
$c_{l_{\alpha_{tw}}@M=0}$	6.3598 rad^{-1}	$\Lambda_{c/4_w}$	0.0 deg	$(t/c)_{t_w}$	12.00 %	$\Lambda_{c/4_h}$	0.0 deg	$Z_{c_r/4_h}$	6.00 ft	f_{gap_h}	1.00		

Output Parameters

M_1	0.594	$c_{l_{\alpha_w}}$	7.9041 rad^{-1}	$C_{L_{\alpha_{wf}}}$	5.3724 rad^{-1}	$c_{l_{\alpha_h}}$	7.7681 rad^{-1}	$d\varepsilon_h/d\alpha$	0.3931	$C_{L_{\alpha_{no\ empen}}}$	5.3724 rad^{-1}	C_{L_α}	6.1586 rad^{-1}
$\bar{q}_1$	155.41 lb/ft^2	$C_{L_{w_{\alpha\ clean}}}$	5.3706 rad^{-1}	K_{wf}	1.0003	Z_{ac_h}	6.00 ft	$C_{L_{h_\alpha}}$	5.7070 rad^{-1}	$C_{L_{\alpha_{clean\ p.off}}}$	6.1586 rad^{-1}		
$c_{l_{\alpha_{rw}}}$	7.9041 rad^{-1}	$C_{L_{\alpha_{wf\ clean}}}$	5.3724 rad^{-1}	$c_{l_{\alpha_{rh}}}$	7.7681 rad^{-1}	$d\varepsilon_h/d\alpha_{clean}$	0.3931	$C_{L_{\alpha_h}}$	0.7862 rad^{-1}	$C_{L_{\alpha\ p.off}}$	6.1586 rad^{-1}		
$c_{l_{\alpha_{tw}}}$	7.9041 rad^{-1}	$C_{L_{w_\alpha}}$	5.3706 rad^{-1}	$c_{l_{\alpha_{th}}}$	7.7681 rad^{-1}	$(d\varepsilon_h/d\alpha)_{p.off}$	0.3931	$C_{L_{\alpha_{no\ emp\ clean}}}$	5.3724 rad^{-1}	$C_{L_{\alpha_{clean}}}$	6.1586 rad^{-1}		

High Lift Devices Table

#	High Lift Device	η_i %	η_o %	c/c_w %	δ deg
1	Single Slotted Flap	9.0	55.5	30.0	0.0

Fig. 45 Angle of attack related derivatives

Angle of Attack Related Derivatives: Pitching Moment: Flight Condition 1

Input Parameters

Altitude	30000 ft	f_{gap_w}	0.93	X_{apex_w}	23.00 ft	S_h	190.00 ft^2	Y_{offset_h}	0.00 ft	$\eta_{h_{p.off}}$	1.000	$D_{f_{max_w}}$	6.83 ft
ΔT	0.0 deg F	S_w	837.00 ft^2	Y_{offset_w}	0.00 ft	AR_h	7.00	$(t/c)_{r_h}$	12.0 %	$c_{l_{\alpha_{rh}}@M=0}$	6.2504 rad^{-1}	$\Delta\bar{x}_{ac_f}$	-0.0451
U_1	350.00 kts	AR_w	8.00	$(t/c)_{r_w}$	12.00 %	λ_h	1.00	$(t/c)_{t_h}$	12.0 %	$c_{l_{\alpha_{th}}@M=0}$	6.2504 rad^{-1}	X_{cg}	24.32 ft
$c_{l_{\alpha_{rw}}@M=0}$	6.3598 rad^{-1}	λ_w	0.60	$(t/c)_{t_w}$	12.00 %	$\Lambda_{c/4_h}$	0.0 deg	$Z_{c_r/4_h}$	6.00 ft	f_{gap_h}	1.00		
$c_{l_{\alpha_{tw}}@M=0}$	6.3598 rad^{-1}	$\Lambda_{c/4_w}$	0.0 deg	$Z_{c_r/4_w}$	2.00 ft	X_{apex_h}	60.00 ft	Γ_h	0.0 deg	w_{f_h}	2.00 ft		

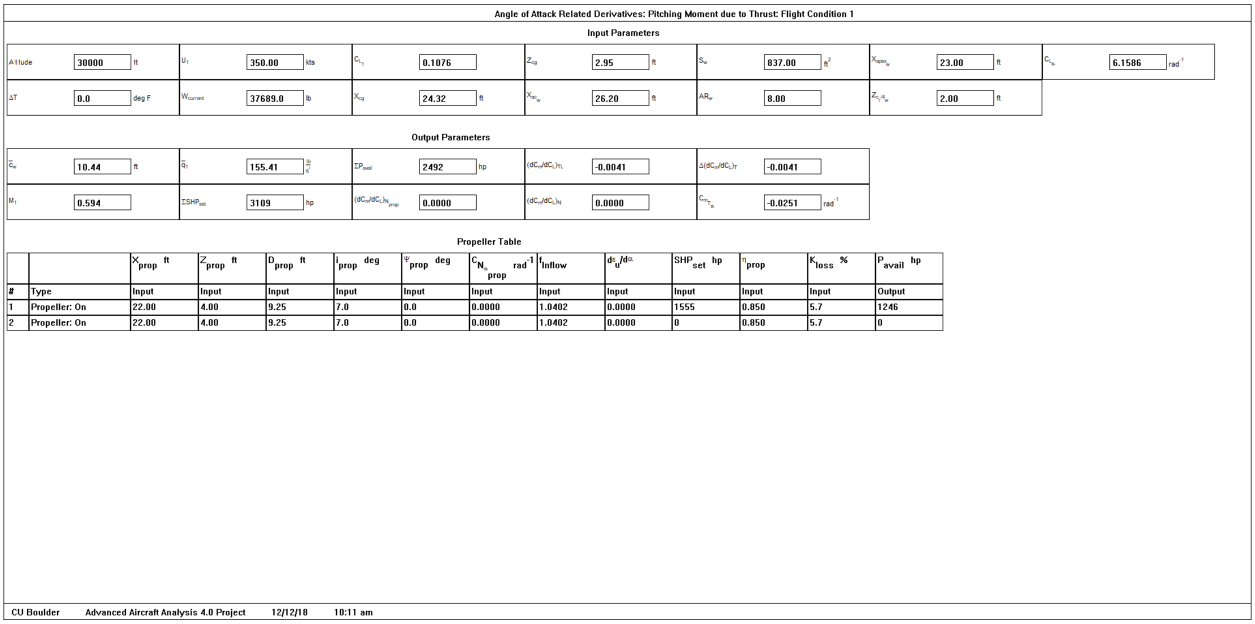
Output Parameters

M_1	0.594	$c_{l_{\alpha_{rw}}}$	7.9041 rad^{-1}	$C_{L_{w_\alpha}}$	5.3706 rad^{-1}	$\bar{x}_{ac_{wf\ p.off}}$	0.2049	$\bar{x}_{ac_h}$	3.6121	$d\varepsilon_h/d\alpha$	0.3931	SM	56.96 %
$\bar{q}_1$	155.41 lb/ft^2	$c_{l_{\alpha_{tw}}}$	7.9041 rad^{-1}	$C_{L_{\alpha_{wf}}}$	5.3724 rad^{-1}	$c_{l_{\alpha_{rh}}}$	7.7681 rad^{-1}	$C_{L_{h_\alpha}}$	5.7070 rad^{-1}	$\bar{V}_h$	0.8040	$C_{L_{\alpha\ p.off}}$	6.1586 rad^{-1}
$\bar{x}_{cg}$	0.0702	$c_{l_{\alpha_w}}$	7.9041 rad^{-1}	X_{ac_w}	26.20 ft	$c_{l_{\alpha_{th}}}$	7.7681 rad^{-1}	$C_{L_{\alpha_h}}$	0.7862 rad^{-1}	X_{ac}	30.27 ft	C_{L_α}	6.1586 rad^{-1}
$\bar{c}_w$	10.44 ft	$C_{L_{w_{\alpha\ clean}}}$	5.3706 rad^{-1}	$\bar{x}_{ac_w}$	0.2500	$c_{l_{\alpha_h}}$	7.7681 rad^{-1}	Z_{ac_h}	6.00 ft	$\bar{x}_{ac_{p.off}}$	0.6399	$C_{m_{\alpha\ p.off}}$	-3.5082 rad^{-1}
x_{mgc_w}	0.59 ft	$C_{L_{\alpha_{wf\ clean}}}$	5.3724 rad^{-1}	$X_{ac_{wf\ p.off}}$	25.73 ft	X_{ac_h}	61.30 ft	$(d\varepsilon_h/d\alpha)_{p.off}$	0.3931	$\bar{x}_{ac}$	0.6399	C_{m_α}	-3.5082 rad^{-1}

High Lift Devices Table

#	High Lift Device	η_i %	η_o %	c/c_w %	δ deg
1	Single Slotted Flap	9.0	55.5	30.0	0.0

Fig. 46 Angle of attack related derivatives



Angle of Attack Related Derivatives: Pitching Moment due to Thrust: Flight Condition 1

Input Parameters

Altitude 30000 ft	U_1 350.00 kts	C_{L_1} 0.1076	Z_{cg} 2.95 ft	S_w 837.00 ft^2	X_{apex_w} 23.00 ft	C_{L_α} 6.1586 rad^{-1}
ΔT 0.0 deg F	$W_{current}$ 37689.0 lb	X_{cg} 24.32 ft	X_{ac_w} 26.20 ft	AR_w 8.00	$Z_{c_r/4_w}$ 2.00 ft	

Output Parameters

$\bar{c}_w$ 10.44 ft	$\bar{q}_1$ 155.41 lb/ft^2	ΣP_{avail} 2492 hp	$(dC_m/dC_L)_{TL}$ -0.0041	$\Delta(dC_m/dC_L)_T$ -0.0041
M_1 0.594	ΣSHP_{set} 3109 hp	$(dC_m/dC_L)_{N_{prop}}$ 0.0000	$(dC_m/dC_L)_N$ 0.0000	$C_{m_{T_\alpha}}$ -0.0251 rad^{-1}

Propeller Table

		X_{prop} ft	Z_{prop} ft	D_{prop} ft	i_{prop} deg	Ψ_{prop} deg	$C_{N_{\alpha_{prop}}}$ rad^{-1}	f_{Inflow}	$d\varepsilon_u/d\alpha$	SHP_{set} hp	η_{prop}	K_{loss} %	P_{avail} hp
#	Type	Input	Input	Input	Input	Input	Input	Input	Input	Input	Input	Input	Output
1	Propeller: On	22.00	4.00	9.25	7.0	0.0	0.0000	1.0402	0.0000	1555	0.850	5.7	1246
2	Propeller: On	22.00	4.00	9.25	7.0	0.0	0.0000	1.0402	0.0000	0	0.850	5.7	0

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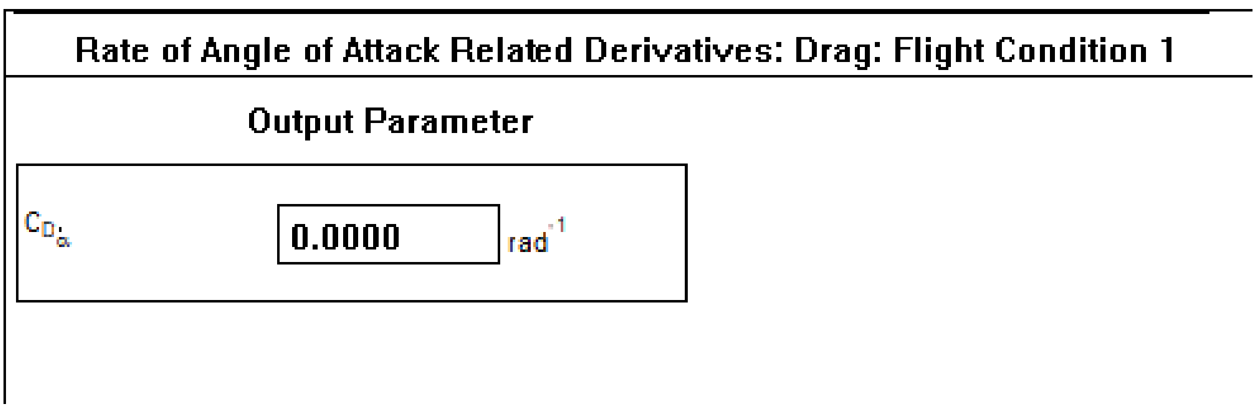
Fig. 47 Angle of attack related derivatives



Rate of Angle of Attack Related Derivatives: Drag: Flight Condition 1

Output Parameter

$C_{D_{\dot{\alpha}}}$ 0.0000 rad^{-1}

Fig. 48 Angle of attack rate related derivatives

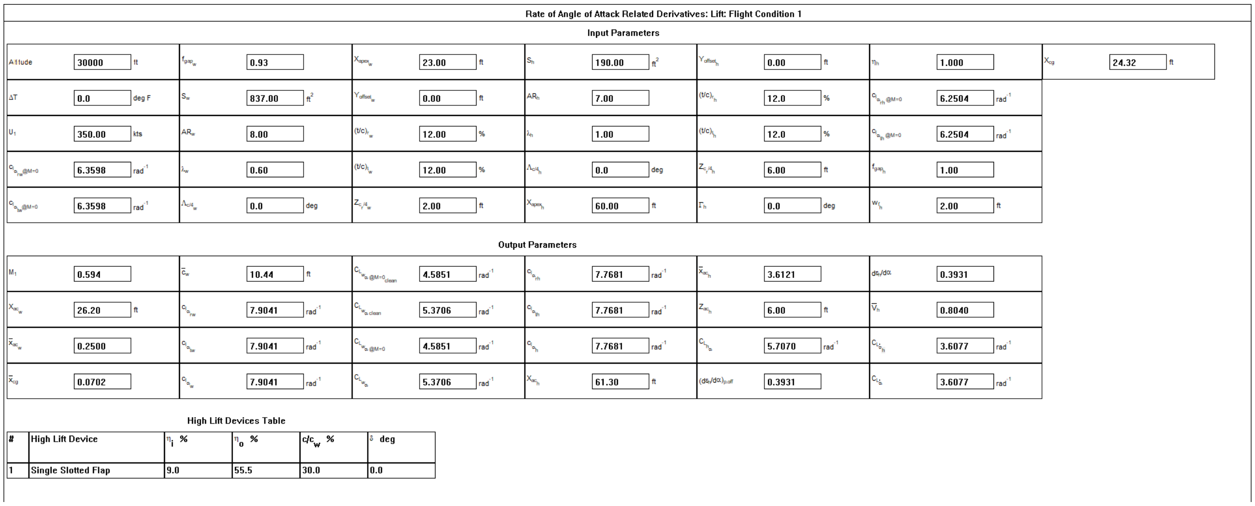


Fig. 49 Angle of attack rate related derivatives

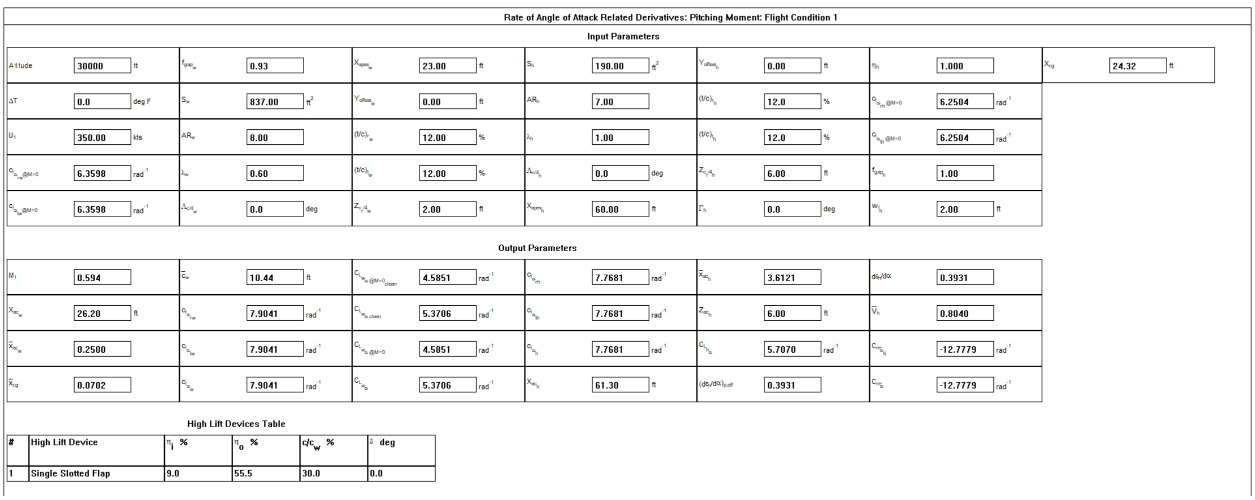


Fig. 50 Angle of attack rate related derivatives

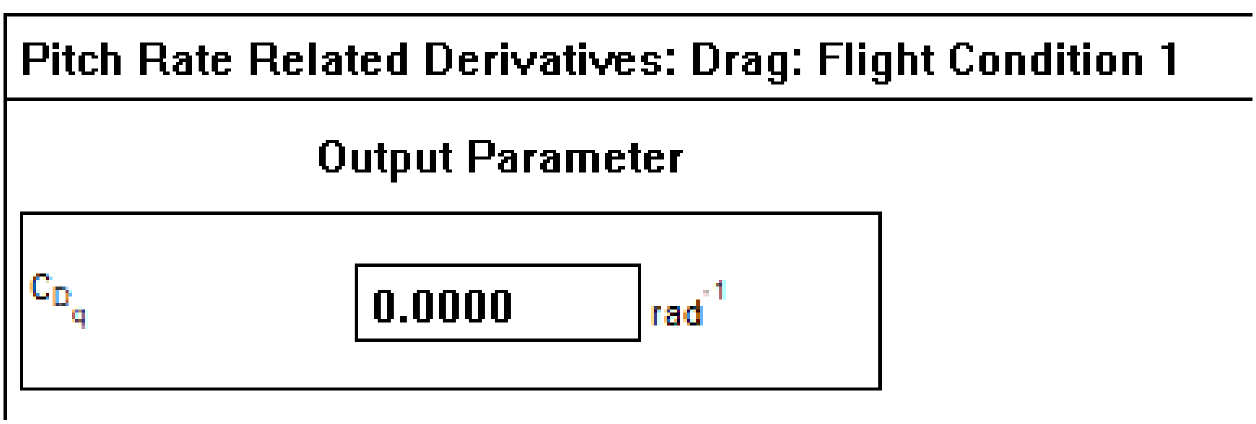


Fig. 51 Pitch rate related derivatives

Pitch Rate Related Derivatives: Lift: Flight Condition 1

Input Parameters

Altitude	30000 ft	$c_{l_{\alpha_{tw}}@M=0}$	6.3598 rad^{-1}	$\Lambda_{c/4_w}$	0.0 deg	S_h	190.00 ft^2	Y_{offset_h}	0.00 ft	η_h	1.000	X_{apex_f}	0.00 ft
ΔT	0.0 deg F	f_{gap_w}	0.93	X_{apex_w}	23.00 ft	AR_h	7.00	$(t/c)_{r_h}$	12.0 %	$c_{l_{\alpha_{rh}}@M=0}$	6.2504 rad^{-1}	l_f	55.00 ft
U_1	350.00 kts	S_w	837.00 ft^2	Y_{offset_w}	0.00 ft	λ_h	1.00	$(t/c)_{t_h}$	12.0 %	$c_{l_{\alpha_{th}}@M=0}$	6.2504 rad^{-1}	$D_{f_{max_w}}$	6.83 ft
X_{cg}	24.32 ft	AR_w	8.00	$(t/c)_{r_w}$	12.00 %	$\Lambda_{c/4_h}$	0.0 deg	$Z_{c_r/4_h}$	6.00 ft	f_{gap_h}	1.00	w_{f_w}	6.83 ft
$c_{l_{\alpha_{rw}}@M=0}$	6.3598 rad^{-1}	λ_w	0.60	$(t/c)_{t_w}$	12.00 %	X_{apex_h}	60.00 ft	Γ_h	0.0 deg	w_{f_h}	2.00 ft	S_o	20.49 ft^2

Output Parameters

M_1	0.594	$c_{l_{\alpha_w}@M=0}$	6.3598 rad^{-1}	$C_{L_{w_{\alpha_{exp}}}}$	5.2621 rad^{-1}	$\bar{x}_{ac_w}$	0.2500	$\bar{x}_{ac_h}$	3.6121	$C_{L_{q_h}}$	9.1769 rad^{-1}
$\bar{x}_{cg}$	0.0702	$c_{l_{\alpha_w}}$	7.9041 rad^{-1}	$k_2 - k_1$	0.913	$c_{l_{\alpha_{rh}}}$	7.7681 rad^{-1}	$C_{L_{h_\alpha}}$	5.7070 rad^{-1}	$C_{L_{q_w}}$	4.6958 rad^{-1}
$\bar{c}_w$	10.44 ft	$S_{w_{exp}}$	751.13 ft^2	$C_{L_{\alpha_f}}$	0.0447 rad^{-1}	$c_{l_{\alpha_{th}}}$	7.7681 rad^{-1}	$\bar{V}_h$	0.8040	$C_{L_{q_f}}$	0.2628 rad^{-1}
$c_{l_{\alpha_{rw}}}$	7.9041 rad^{-1}	$\bar{c}_{w_{exp}}$	10.20 ft	$K_{w(b)} + K_{b(w)}$	1.18	$c_{l_{\alpha_h}}$	7.7681 rad^{-1}	$\bar{c}_h$	5.21 ft	$C_{L_{q_{wf}}}$	4.9586 rad^{-1}
$c_{l_{\alpha_{tw}}}$	7.9041 rad^{-1}	$C_{L_{w_\alpha}@M=0}$	4.5851 rad^{-1}	X_{ac_w}	26.20 ft	X_{ac_h}	61.30 ft	$C_{L_{h_q}}$	81.0235 rad^{-1}	C_{L_q}	14.1354 rad^{-1}

High Lift Devices Table

#	High Lift Device	η_i %	η_o %	c/c_w %	δ deg
1	Single Slotted Flap	9.0	55.5	30.0	0.0

Fig. 52 Pitch rate related derivatives

Pitch Rate Related Derivatives: Pitching Moment: Flight Condition 1

Input Parameters

Altitude	30000 ft	$f_{gap_{wo}}$	0.91	X_{apex_w}	23.00 ft	S_h	190.00 ft^2	$(t/c)_{r_h}$	12.0 %	$c_{l_{\alpha_{th}}@M=0}$	6.2504 rad^{-1}	X_{c_f}	ft
ΔT	0.0 deg F	f_{gap_w}	0.93	Y_{offset_w}	0.00 ft	AR_h	7.00	$(t/c)_{t_h}$	12.0 %	f_{gap_h}	1.00	S_{b_f}	ft^2
U_1	350.00 kts	S_w	837.00 ft^2	$(t/c)_{r_w}$	12.00 %	λ_h	1.00	$Z_{c_r/4_h}$	6.00 ft	w_{f_h}	2.00 ft	V_f	ft^3
X_{cg}	24.32 ft	AR_w	8.00	$(t/c)_{t_w}$	12.00 %	$\Lambda_{c/4_h}$	0.0 deg	Γ_h	0.0 deg	X_{apex_f}	0.00 ft		
$c_{l_{\alpha_{rw}}@M=0}$	6.3598 rad^{-1}	λ_w	0.60	w_{f_w}	6.83 ft	X_{apex_h}	60.00 ft	η_h	1.000	l_f	55.00 ft		
$c_{l_{\alpha_{tw}}@M=0}$	6.3598 rad^{-1}	$\Lambda_{c/4_w}$	0.0 deg	$C_{L_{\alpha_{wf}}}$	5.3724 rad^{-1}	Y_{offset_h}	0.00 ft	$c_{l_{\alpha_{rh}}@M=0}$	6.2504 rad^{-1}	$\Delta\bar{x}_{ac_f}$	-0.0451		

Output Parameters

M_1	0.594	$c_{l_{\alpha_{tw}}}$	7.9041 rad^{-1}	$\bar{c}_{w_{exp}}$	10.20 ft	$\bar{x}_{ac_w}$	0.2500	X_{ac_h}	61.30 ft	$\bar{c}_h$	5.21 ft	$C_{m_{q_f}}$	rad^{-1}
$\bar{x}_{cg}$	0.0702	$c_{l_{\alpha_w}@M=0}$	6.3598 rad^{-1}	$C_{m_{\alpha_f}}$	0.2422 rad^{-1}	$c_{l_{\alpha_{rh}}}$	7.7681 rad^{-1}	$\bar{x}_{ac_h}$	3.6121	$C_{m_{h_q}}$	-143.1850 rad^{-1}	$C_{m_{q_{wf}}}$	rad^{-1}
$\bar{c}_w$	10.44 ft	$c_{l_{\alpha_w}}$	7.9041 rad^{-1}	$K_{w(b)} + K_{b(w)}$	1.18	$c_{l_{\alpha_{th}}}$	7.7681 rad^{-1}	$C_{L_{h_\alpha}}$	5.7070 rad^{-1}	$C_{m_{q_h}}$	-32.5032 rad^{-1}	C_{m_q}	-32.5032 rad^{-1}
$c_{l_{\alpha_{rw}}}$	7.9041 rad^{-1}	$S_{w_{exp}}$	751.13 ft^2	X_{ac_w}	26.20 ft	$c_{l_{\alpha_h}}$	7.7681 rad^{-1}	$\bar{V}_h$	0.8040	$C_{m_{q_w}}$	-1.3600 rad^{-1}		

Fig. 53 Pitch rate related derivatives

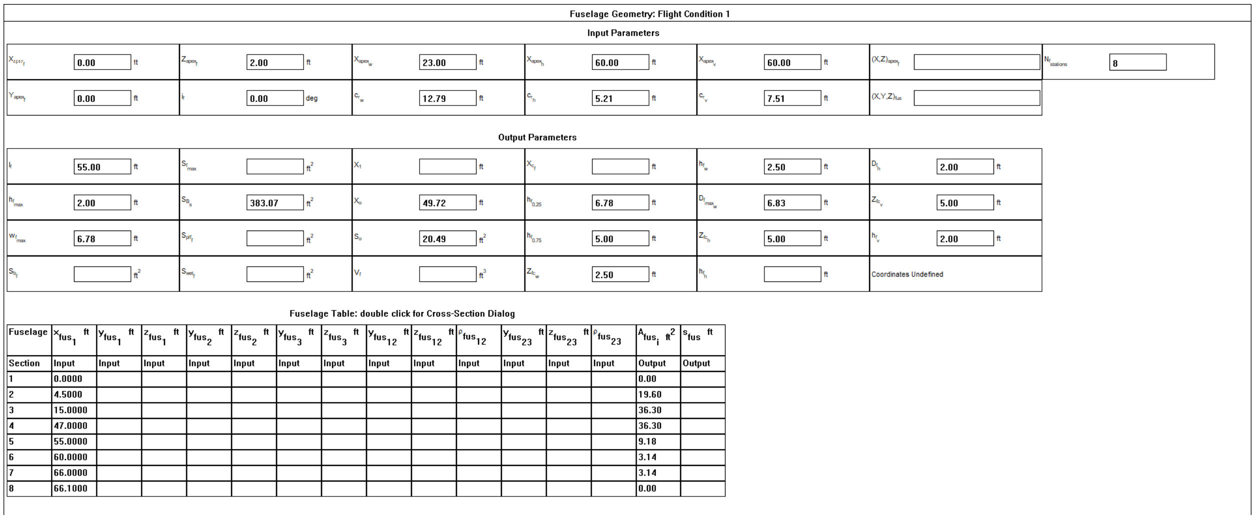


Fig. 54   Fuselage geometry

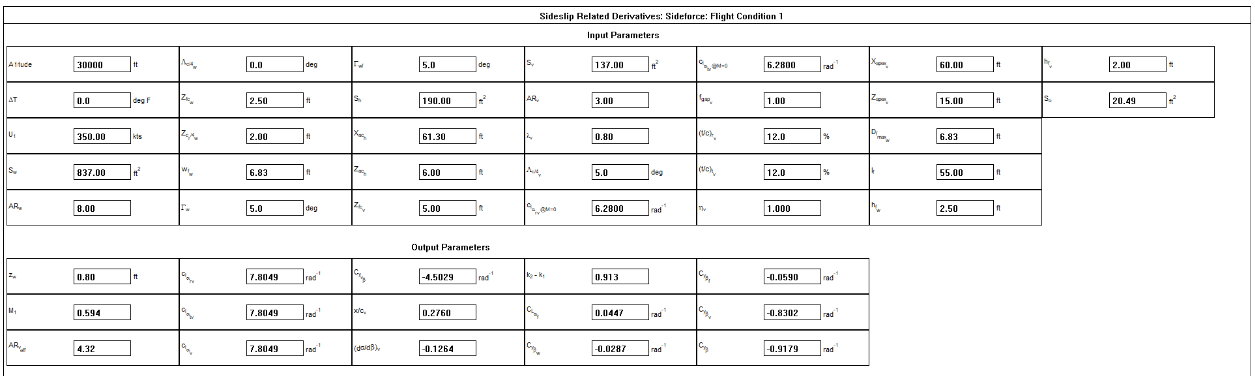


Fig. 55   Sideslip related derivatives

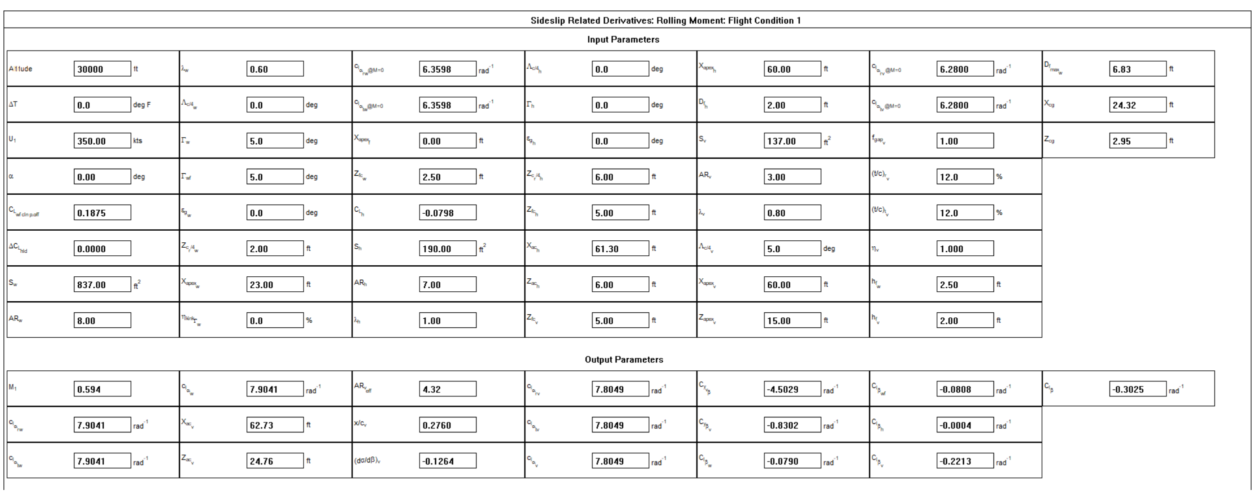


Fig. 56   Sideslip related derivatives

Sideslip Related Derivatives: Yawing Moment: Flight Condition 1

Input Parameters

Altitude 30000 ft	λ_w 0.60	Z_{ac_h} 6.00 ft	X_{apex_v} 60.00 ft	$(t/c)_{t_v}$ 12.0 %	Z_{cg} 2.95 ft	X_{apex_f} 0.00 ft
ΔT 0.0 deg F	$\Lambda_{c/4_w}$ 0.0 deg	Z_{fc_v} 5.00 ft	Z_{apex_v} 15.00 ft	η_v 1.000	S_{B_s} 383.07 ft^2	
U_1 350.00 kts	$Z_{c_r/4_w}$ 2.00 ft	S_v 137.00 ft^2	$c_{l_{\alpha_{rv}}}$ @M=0 6.2800 rad^{-1}	l_f 55.00 ft	$h_{f_{0.25}}$ 6.78 ft	
α 0.00 deg	Z_{fc_w} 2.50 ft	AR_v 3.00	$c_{l_{\alpha_{tv}}}$ @M=0 6.2800 rad^{-1}	h_{f_w} 2.50 ft	$h_{f_{0.75}}$ 5.00 ft	
S_w 837.00 ft^2	S_h 190.00 ft^2	λ_v 0.80	f_{gap_v} 1.00	h_{f_v} 2.00 ft	$h_{f_{max}}$ 2.00 ft	
AR_w 8.00	X_{ac_h} 61.30 ft	$\Lambda_{c/4_v}$ 5.0 deg	$(t/c)_{r_v}$ 12.0 %	X_{cg} 24.32 ft	$w_{f_{max}}$ 6.78 ft	

Output Parameters

M_1 0.594	Z_{ac_v} 24.76 ft	$c_{l_{\alpha_{tv}}}$ 7.8049 rad^{-1}	x/c_v 0.2760	$K_{N_{fus}}$ -0.00029	$C_{n_{\beta_v}}$ 0.3897 rad^{-1}
Re_f 93.1248 x 10^6	$AR_{v_{eff}}$ 4.32	$c_{l_{\alpha_v}}$ 7.8049 rad^{-1}	$(d\sigma/d\beta)_v$ -0.1264	$K_{R_{l_{fus}}}$ 1.92878	C_{n_β} 0.3995 rad^{-1}
X_{ac_v} 62.73 ft	$c_{l_{\alpha_{rv}}}$ 7.8049 rad^{-1}	C_{y_β} -4.5029 rad^{-1}	$C_{y_{\beta_v}}$ -0.8302 rad^{-1}	$C_{n_{\beta_f}}$ 0.0098 rad^{-1}	

Fig. 57 Sideslip related derivatives

Sideslip Related Derivatives: Sideforce due to Thrust: Flight Condition 1

Input Parameter

S_w 837.00 ft^2

Output Parameter

$C_{y_{T_\beta}}$ 0.0000 rad^{-1}

Propeller Table

#	Type	D_{prop} ft	f_{Inflow}	$C_{N_{\alpha_{prop}}}$ rad^{-1}
1	Propeller: On	9.25	1.0402	0.0000
2	Propeller: On	9.25	1.0402	0.0000

Fig. 58 Sideslip related derivatives

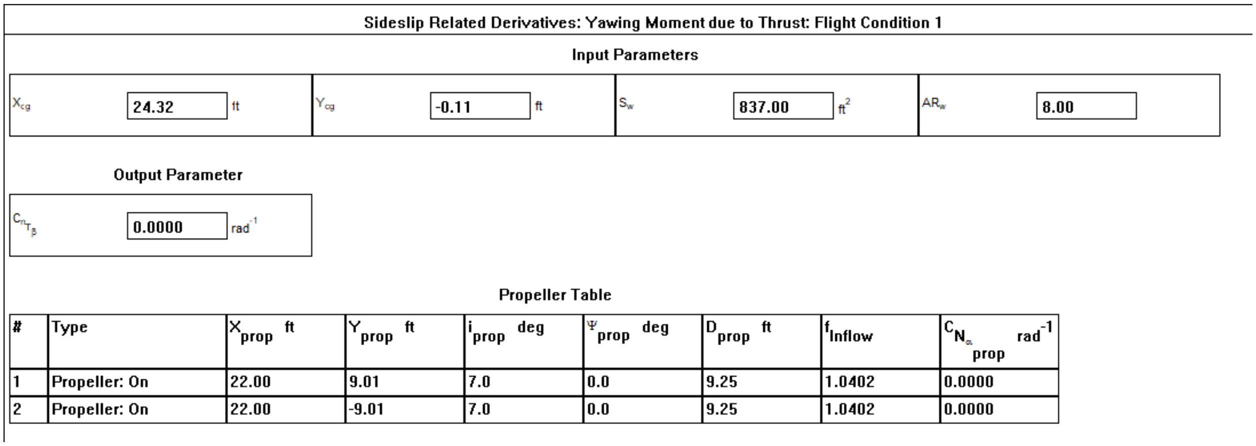


Fig. 59   Sideslip related derivatives

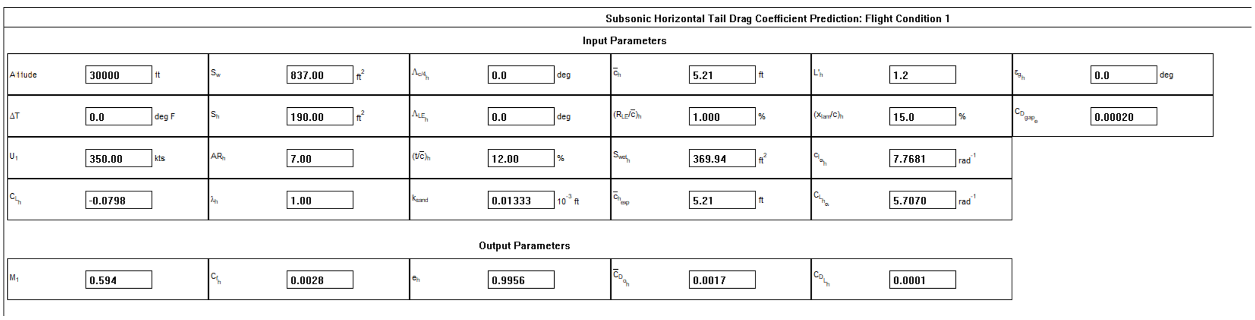


Fig. 60   Horizontal stabilizer drag coefficient

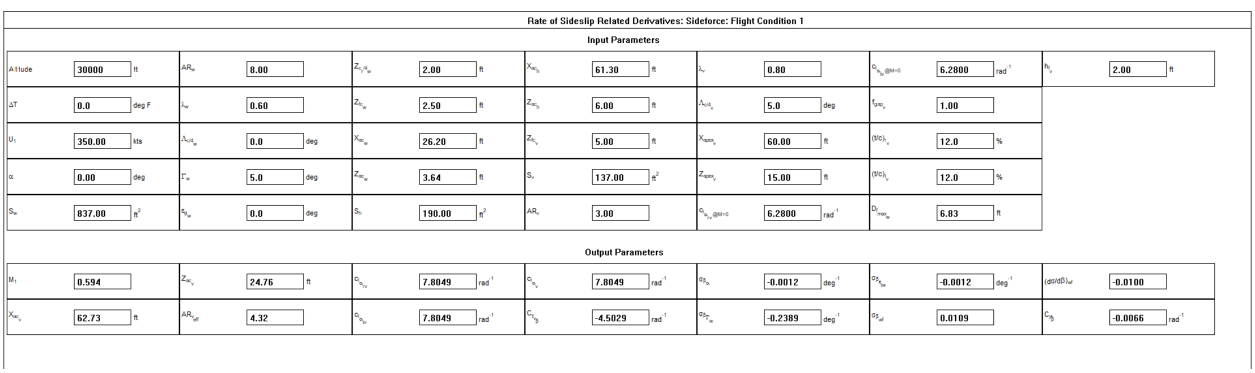


Fig. 61   Sideslip rate related derivatives

Rate of Sideslip Related Derivatives: Rolling Moment: Flight Condition 1

Input Parameters

Altitude	30000 ft	AR_w	8.00	$Z_{c_r/4_w}$	2.00 ft	X_{ac_h}	61.30 ft	λ_v	0.80	$c_{l_{\alpha_{tv}}}$ @M=0	6.2800 rad^{-1}	h_{f_v}	2.00 ft
ΔT	0.0 deg F	λ_w	0.60	Z_{fc_w}	2.50 ft	Z_{ac_h}	6.00 ft	$\Lambda_{c/4_v}$	5.0 deg	f_{gap_v}	1.00		
U_1	350.00 kts	$\Lambda_{c/4_w}$	0.0 deg	X_{ac_w}	26.20 ft	Z_{fc_v}	5.00 ft	X_{apex_v}	60.00 ft	$(t/c)_{r_v}$	12.0 %		
α	0.00 deg	Γ_w	5.0 deg	Z_{ac_w}	3.64 ft	S_v	137.00 ft^2	Z_{apex_v}	15.00 ft	$(t/c)_{t_v}$	12.0 %		
S_w	837.00 ft^2	ε_{g_w}	0.0 deg	S_h	190.00 ft^2	AR_v	3.00	$c_{l_{\alpha_{rv}}}$ @M=0	6.2800 rad^{-1}	$D_{f_{max_w}}$	6.83 ft		

Output Parameters

M_1	0.594	$AR_{v_{eff}}$	4.32	$c_{l_{\alpha_v}}$	7.8049 rad^{-1}	$\sigma_{\beta_{\Gamma_w}}$	-0.2389 deg^{-1}	$(d\sigma/d\beta)_{wf}$	-0.0100
X_{ac_v}	62.73 ft	$c_{l_{\alpha_{rv}}}$	7.8049 rad^{-1}	$C_{y_{v_\beta}}$	-4.5029 rad^{-1}	$\sigma_{\beta_{\varepsilon_{tw}}}$	-0.0012 deg^{-1}	$C_{y_{\dot\beta}}$	-0.0066 rad^{-1}
Z_{ac_v}	24.76 ft	$c_{l_{\alpha_{tv}}}$	7.8049 rad^{-1}	σ_{β_α}	-0.0012 deg^{-1}	$\sigma_{\beta_{wf}}$	0.0109	$C_{l_{\dot\beta}}$	-0.0017 rad^{-1}

Fig. 62 Sideslip rate related derivatives

Rate of Sideslip Related Derivatives: Yawing Moment: Flight Condition 1

Input Parameters

Altitude	30000 ft	AR_w	8.00	$Z_{c_r/4_w}$	2.00 ft	X_{ac_h}	61.30 ft	λ_v	0.80	$c_{l_{\alpha_{tv}}}$ @M=0	6.2800 rad^{-1}	h_{f_v}	2.00 ft
ΔT	0.0 deg F	λ_w	0.60	Z_{fc_w}	2.50 ft	Z_{ac_h}	6.00 ft	$\Lambda_{c/4_v}$	5.0 deg	f_{gap_v}	1.00		
U_1	350.00 kts	$\Lambda_{c/4_w}$	0.0 deg	X_{ac_w}	26.20 ft	Z_{fc_v}	5.00 ft	X_{apex_v}	60.00 ft	$(t/c)_{r_v}$	12.0 %		
α	0.00 deg	Γ_w	5.0 deg	Z_{ac_w}	3.64 ft	S_v	137.00 ft^2	Z_{apex_v}	15.00 ft	$(t/c)_{t_v}$	12.0 %		
S_w	837.00 ft^2	ε_{g_w}	0.0 deg	S_h	190.00 ft^2	AR_v	3.00	$c_{l_{\alpha_{rv}}}$ @M=0	6.2800 rad^{-1}	$D_{f_{max_w}}$	6.83 ft		

Output Parameters

M_1	0.594	$AR_{v_{eff}}$	4.32	$c_{l_{\alpha_v}}$	7.8049 rad^{-1}	$\sigma_{\beta_{\Gamma_w}}$	-0.2389 deg^{-1}	$(d\sigma/d\beta)_{wf}$	-0.0100
X_{ac_v}	62.73 ft	$c_{l_{\alpha_{rv}}}$	7.8049 rad^{-1}	$C_{y_{v_\beta}}$	-4.5029 rad^{-1}	$\sigma_{\beta_{\varepsilon_{tw}}}$	-0.0012 deg^{-1}	$C_{y_{\dot\beta}}$	-0.0066 rad^{-1}
Z_{ac_v}	24.76 ft	$c_{l_{\alpha_{tv}}}$	7.8049 rad^{-1}	σ_{β_α}	-0.0012 deg^{-1}	$\sigma_{\beta_{wf}}$	0.0109	$C_{n_{\dot\beta}}$	-0.0029 rad^{-1}

Fig. 63 Sideslip rate related derivatives

Sideslip Related Derivatives: Sideforce due to Thrust: Flight Condition 1

Input Parameter

S_w	837.00	ft^2

Output Parameter

$C_{y_{T_\beta}}$	0.0000	rad^{-1}

Propeller Table

#	Type	D_{prop} ft	f_{Inflow}	$C_{N_{\alpha_{prop}}}$ rad^{-1}
1	Propeller: On	9.25	1.0402	0.0000
2	Propeller: On	9.25	1.0402	0.0000

Fig. 64 Sideslip related derivatives

Sideslip Related Derivatives: Yawing Moment due to Thrust: Flight Condition 1

Input Parameters

X_{cg}	24.32	ft	Y_{cg}	-0.11	ft	S_w	837.00	ft^2	AR_w	8.00

Output Parameter

$C_{n_{T_\beta}}$	0.0000	rad^{-1}

Propeller Table

#	Type	X_{prop} ft	Y_{prop} ft	i_{prop} deg	Ψ_{prop} deg	D_{prop} ft	f_{Inflow}	$C_{N_{\alpha_{prop}}}$ rad^{-1}
1	Propeller: On	22.00	9.01	7.0	0.0	9.25	1.0402	0.0000
2	Propeller: On	22.00	-9.01	7.0	0.0	9.25	1.0402	0.0000

Fig. 65 Sideslip related derivatives

Roll Rate Related Derivatives: Sideforce: Flight Condition 1

Input Parameters

Altitude	30000 ft	α	0.00 deg	$Z_{f_{c_w}}$	2.50 ft	$f_{gap_{wo}}$	0.91	S_v	137.00 ft^2	Z_{apex_v}	15.00 ft	$(t/c)_{t_v}$	12.0 %
ΔT	0.0 deg F	S_w	837.00 ft^2	λ_w	0.60	S_h	190.00 ft^2	AR_v	3.00	$c_{l_{\alpha_{rv}}@M=0}$	6.2800 rad^{-1}	η_v	1.000
U_1	350.00 kts	AR_w	8.00	Γ_w	5.0 deg	X_{ac_h}	61.30 ft	λ_v	0.80	$c_{l_{\alpha_{tv}}@M=0}$	6.2800 rad^{-1}	h_{f_w}	2.50 ft
X_{cg}	24.32 ft	$\Lambda_{c/4_w}$	0.0 deg	$c_{l_{\alpha_{rw}}@M=0}$	6.3598 rad^{-1}	Z_{ac_h}	6.00 ft	$\Lambda_{c/4_v}$	5.0 deg	f_{gap_v}	1.00	h_{f_v}	2.00 ft
Z_{cg}	2.95 ft	$Z_{c_r/4_w}$	2.00 ft	$c_{l_{\alpha_{tw}}@M=0}$	6.3598 rad^{-1}	$Z_{f_{c_v}}$	5.00 ft	X_{apex_v}	60.00 ft	$(t/c)_{r_v}$	12.0 %		

Output Parameters

M_1	0.594	$c_{l_{\alpha_w}}$	7.9041 rad^{-1}	$AR_{v_{eff}}$	4.32	$c_{l_{\alpha_v}}$	7.8049 rad^{-1}	$(d\sigma/d\beta)_v$	-0.1264
$c_{l_{\alpha_{rw}}}$	7.9041 rad^{-1}	X_{ac_v}	62.73 ft	$c_{l_{\alpha_{rv}}}$	7.8049 rad^{-1}	$C_{y_{\beta}}$	-4.5029 rad^{-1}	$C_{y_{\beta_v}}$	-0.8302 rad^{-1}
$c_{l_{\alpha_{tw}}}$	7.9041 rad^{-1}	Z_{ac_v}	24.76 ft	$c_{l_{\alpha_{tv}}}$	7.8049 rad^{-1}	x/c_v	0.2760	C_{y_p}	-0.1342 rad^{-1}

Fig. 66 Roll rate related derivatives

Roll Rate Related Derivatives: Rolling Moment: Flight Condition 1

Input Parameters

Altitude	30000 ft	AR_w	8.00	$c_{l_{\alpha_{tw}}@M=0}$	6.3598 rad^{-1}	λ_h	1.00	f_{gap_h}	1.00	$\Lambda_{c/4_v}$	5.0 deg	h_{f_w}	2.50 ft
ΔT	0.0 deg F	λ_w	0.60	$f_{gap_{wo}}$	0.91	$\Lambda_{c/4_h}$	0.0 deg	$f_{gap_{ho}}$	1.00	X_{apex_v}	60.00 ft	h_{f_v}	2.00 ft
U_1	350.00 kts	$\Lambda_{c/4_w}$	0.0 deg	f_{gap_w}	0.93	Γ_h	0.0 deg	$C_{L_{h_{\alpha}}}$	5.7070 rad^{-1}	Z_{apex_v}	15.00 ft	X_{cg}	24.32 ft
α	0.00 deg	Γ_w	5.0 deg	$C_{L_{w_{\alpha}}}$	5.3706 rad^{-1}	$Z_{c_r/4_h}$	6.00 ft	X_{ac_h}	61.30 ft	$c_{l_{\alpha_{rv}}@M=0}$	6.2800 rad^{-1}	Z_{cg}	2.95 ft
$\alpha_{w_{0\,clean}}$	-3.0 deg	$Z_{c_r/4_w}$	2.00 ft	$\bar{C}_{D_{0_w}}$	0.0037	w_{f_h}	2.00 ft	Z_{ac_h}	6.00 ft	$c_{l_{\alpha_{tv}}@M=0}$	6.2800 rad^{-1}		
i_w	-1.0 deg	$(t/c)_{r_w}$	12.00 %	$\bar{C}_{D_{0_{\Sigma hld}}}$	0.0000	$(t/c)_{r_h}$	12.0 %	$\bar{C}_{D_{0_h}}$	0.0017	f_{gap_v}	1.00		
$C_{L_{w_{\alpha\,clean}}}$	5.3706 rad^{-1}	$(t/c)_{t_w}$	12.00 %	C_{L_h}	-0.0798	$(t/c)_{t_h}$	12.0 %	S_v	137.00 ft^2	$(t/c)_{r_v}$	12.0 %		
$\Delta C_{L_{hld}}$	0.0000	$Z_{f_{c_w}}$	2.50 ft	S_h	190.00 ft^2	$c_{l_{\alpha_{rh}}@M=0}$	6.2504 rad^{-1}	AR_v	3.00	$(t/c)_{t_v}$	12.0 %		
S_w	837.00 ft^2	$c_{l_{\alpha_{rw}}@M=0}$	6.3598 rad^{-1}	AR_h	7.00	$c_{l_{\alpha_{th}}@M=0}$	6.2504 rad^{-1}	λ_v	0.80	η_v	1.000		

Output Parameters

M_1	0.594	$c_{l_{\alpha_w}@M=0}$	6.3598 rad^{-1}	$c_{l_{\alpha_h}@M=0}$	6.2504 rad^{-1}	$AR_{v_{eff}}$	4.32	$c_{l_{\alpha_v}}$	7.8049 rad^{-1}	$C_{y_{\beta_v}}$	-0.8302 rad^{-1}	C_{l_p}	-0.5259 rad^{-1}
$C_{L_{w\,cln\,p.off}}$	0.1875	$c_{l_{\alpha_w}}$	7.9041 rad^{-1}	$c_{l_{\alpha_h}}$	7.7681 rad^{-1}	$c_{l_{\alpha_{rv}}}$	7.8049 rad^{-1}	$C_{y_{\beta}}$	-4.5029 rad^{-1}	$C_{l_{p_w}}$	-0.5141 rad^{-1}		
$c_{l_{\alpha_{rw}}}$	7.9041 rad^{-1}	$c_{l_{\alpha_{rh}}}$	7.7681 rad^{-1}	X_{ac_v}	62.73 ft	$c_{l_{\alpha_{tv}}}$	7.8049 rad^{-1}	x/c_v	0.2760	$C_{l_{p_h}}$	-0.0118 rad^{-1}		
$c_{l_{\alpha_{tw}}}$	7.9041 rad^{-1}	$c_{l_{\alpha_{th}}}$	7.7681 rad^{-1}	Z_{ac_v}	24.76 ft	$c_{l_{\alpha_v}@M=0}$	6.2800 rad^{-1}	$(d\sigma/d\beta)_v$	-0.1264	$C_{l_{p_v}}$	0.0000 rad^{-1}		

High Lift Devices Table

#	High Lift Device	c/c_w %	$S_{w_{hld}}/S_w$	δ deg
1	Single Slotted Flap	30.0	0.506	0.0

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Fig. 67 Roll rate related derivatives

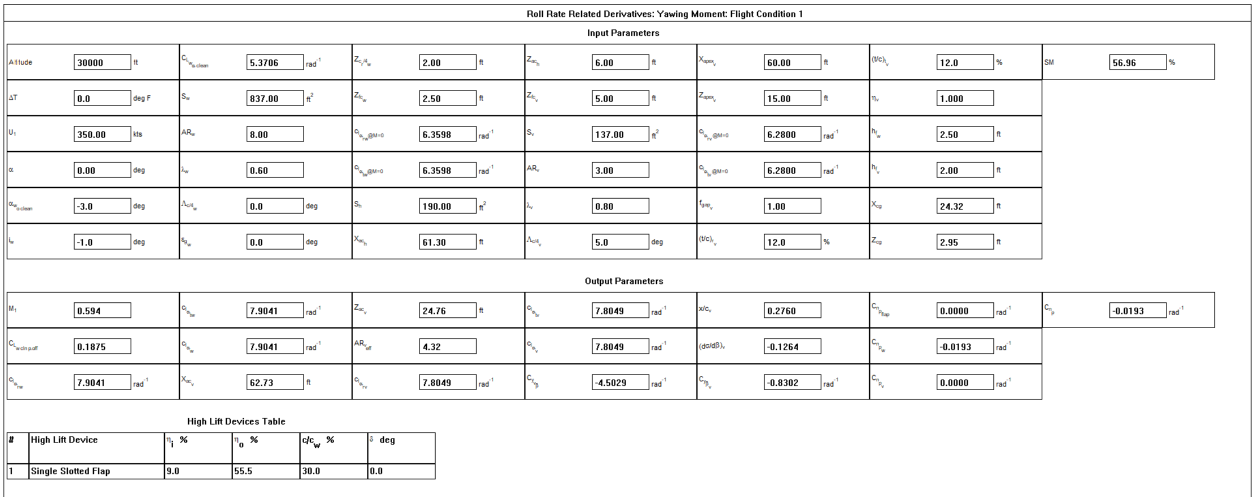

Fig. 68   Roll rate related derivatives

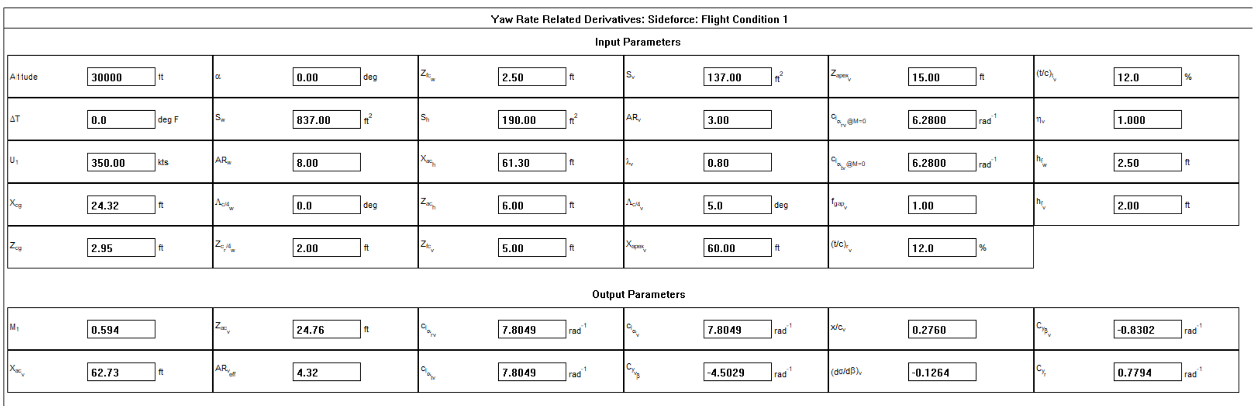

Fig. 69   Yaw rate related derivatives

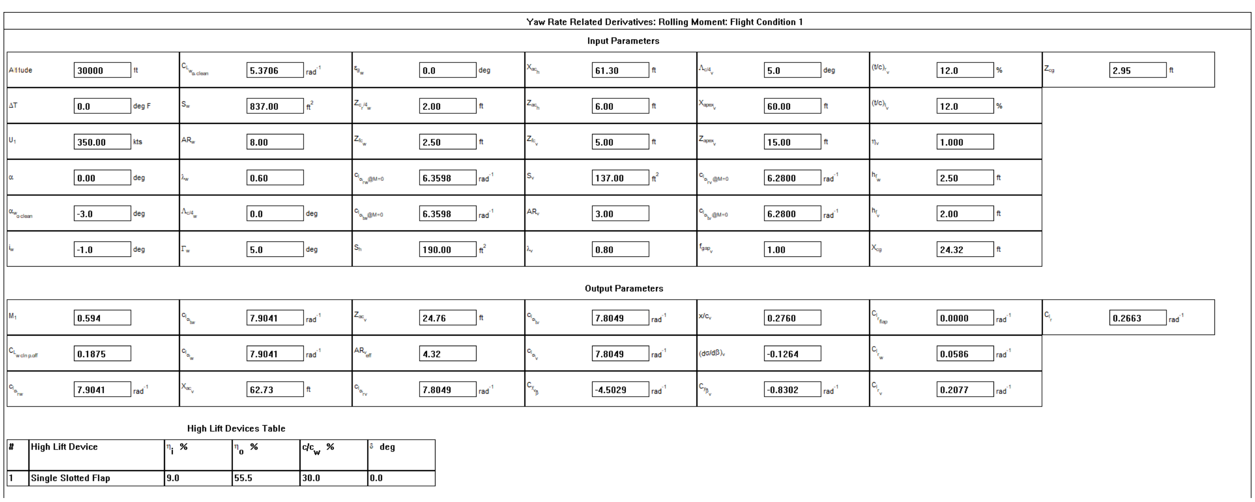

Fig. 70   Yaw rate related derivatives

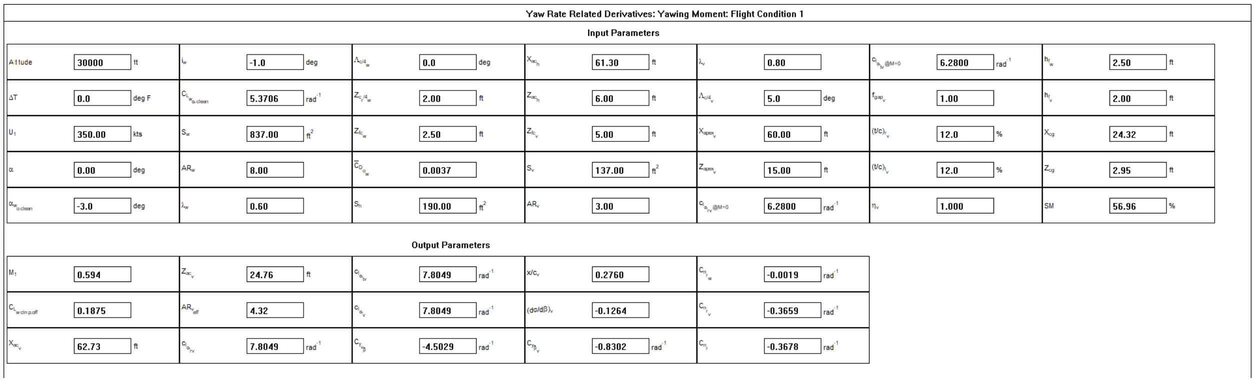

Fig. 71 Yaw rate related derivatives

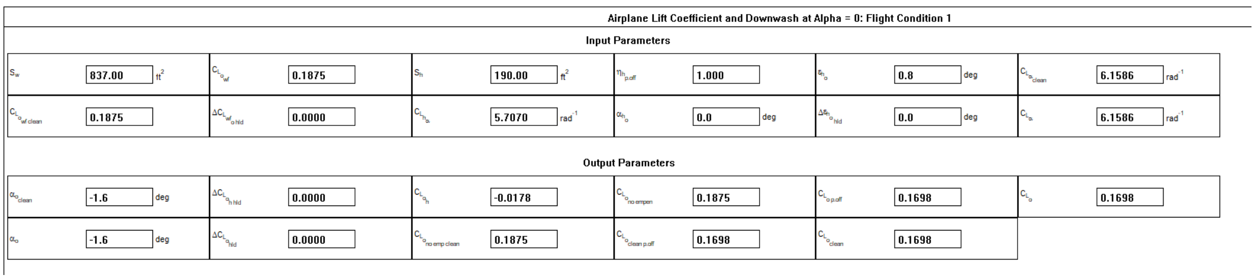

Fig. 72 Angle of attack related derivatives

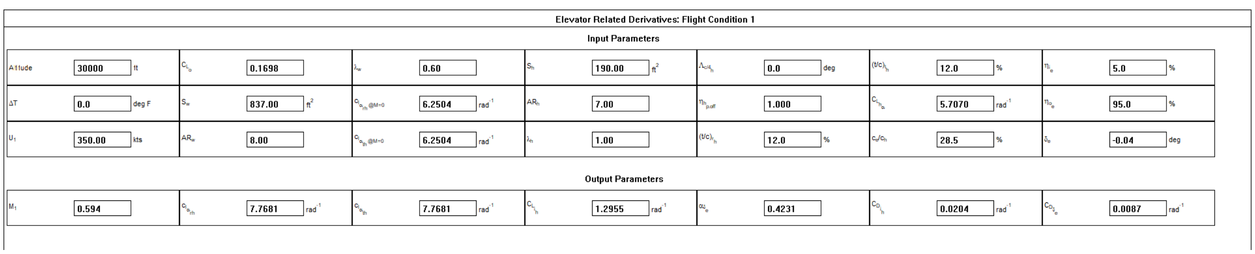

Fig. 73 Elevator related derivatives

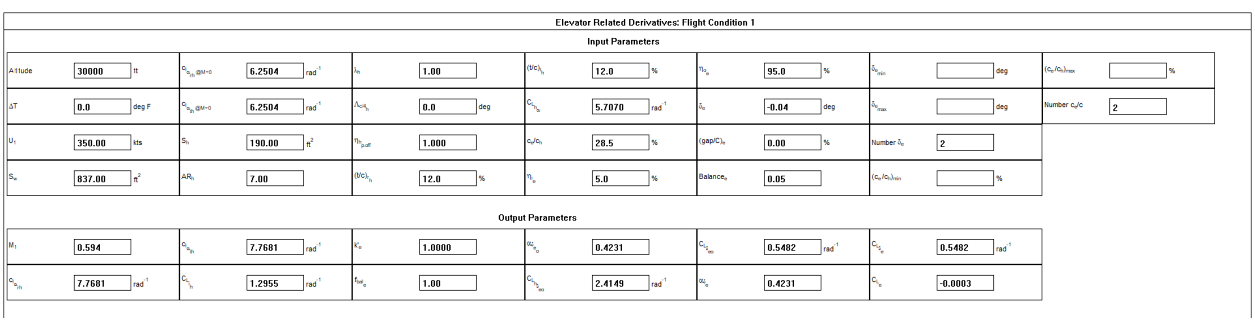

Fig. 74 Elevator related derivatives

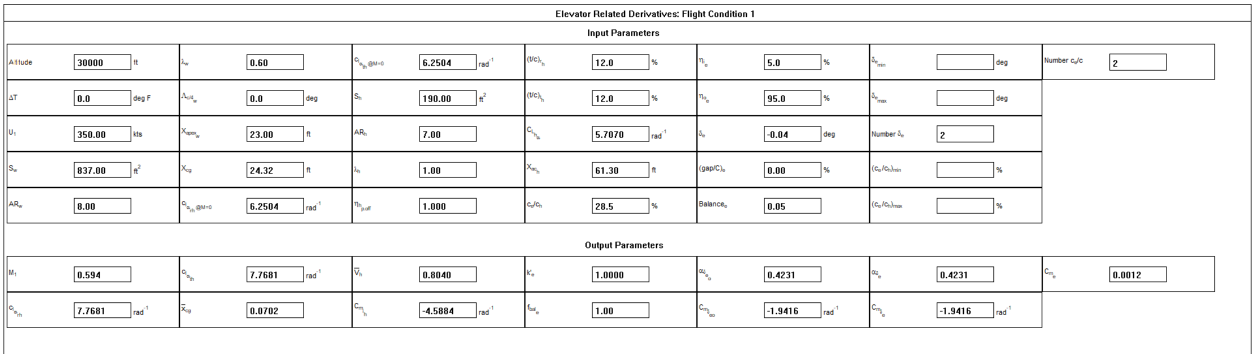

Fig. 75 Elevator related derivatives

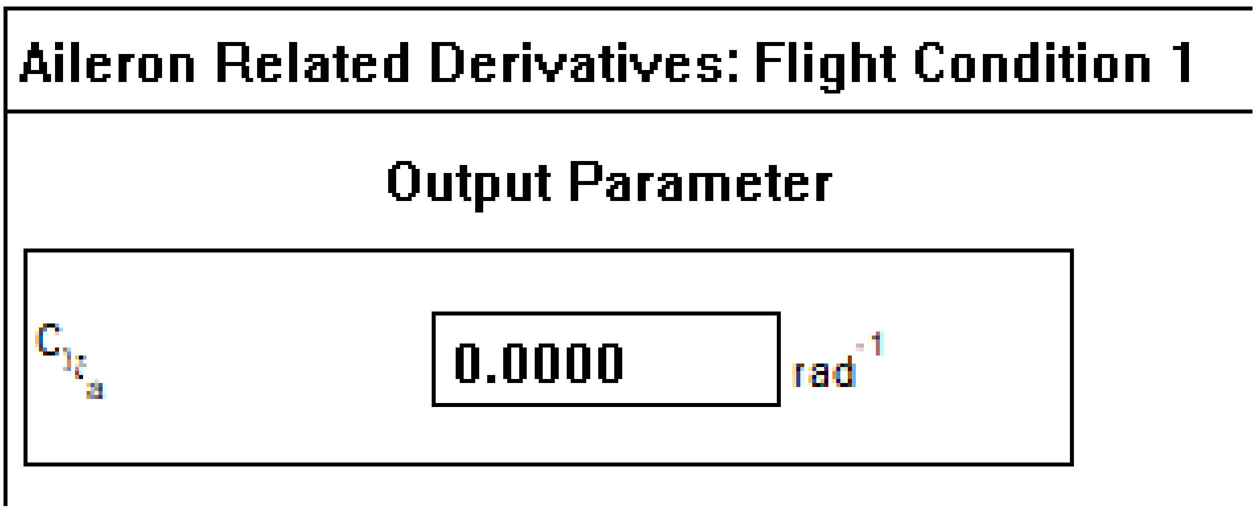

Fig. 76 Aileron related derivatives

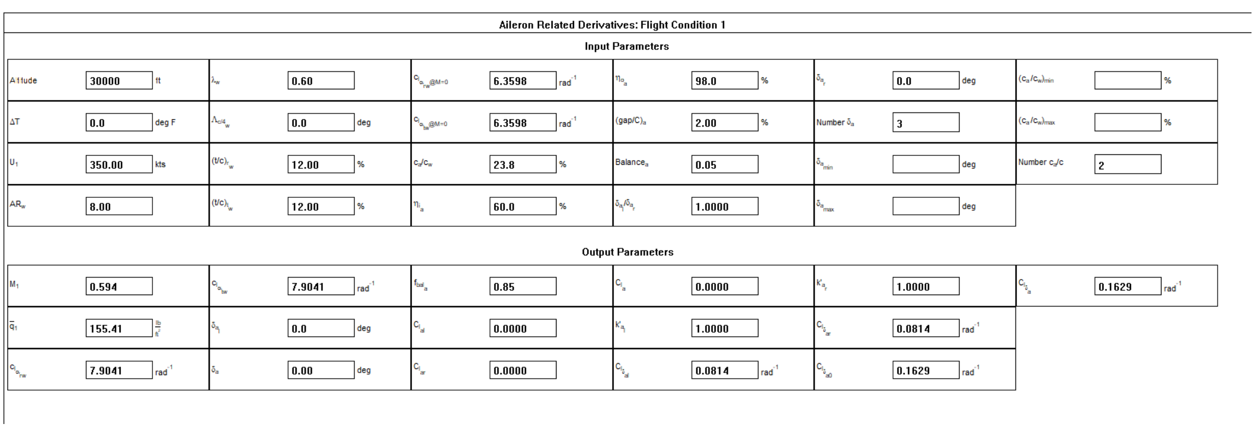

Fig. 77 Aileron related derivatives

Aileron Related Derivatives: Flight Condition 1

Input Parameters

Altitude	30000	ft	$\alpha_{w_{o\,clean}}$	-3.0	deg	AR_w	8.00		$(t/c)_{t_w}$	12.00	%	η_{i_a}	60.0	%	$\delta_{a_l}/\delta_{a_r}$	1.0000		$\delta_{a_{min}}$		deg
ΔT	0.0	deg F	i_w	-1.0	deg	λ_w	0.60		$c_{l_{\alpha_{rw}}@M=0}$	6.3598	rad^{-1}	η_{o_a}	98.0	%	δ_{a_r}	0.0	deg	$\delta_{a_{max}}$		deg
U_1	350.00	kts	$C_{L_{w_{\alpha\,clean}}}$	5.3706	rad^{-1}	$\Lambda_{c/4_w}$	0.0	deg	$c_{l_{\alpha_{tw}}@M=0}$	6.3598	rad^{-1}	$(gap/C)_a$	2.00	%	$K_{N_{\delta_a}}$	1.0				
α	0.00	deg	S_w	837.00	ft^2	$(t/c)_{r_w}$	12.00	%	c_a/c_w	23.8	%	$Balance_a$	0.05		Number δ_a	3				

Output Parameters

M_1	0.594		$c_{l_{\alpha_{tw}}}$	7.9041	rad^{-1}	δ_a	0.00	deg	$C_{D_{P_{ar}}}$	0.0000		$C_{n_{al_p}}$	0.0000		$C_{n_{a_i}}$	0.0000		$C_{n_{\delta_{aDi}}}$	-0.0044	rad^{-1}
$\bar{q}_1$	155.41	$\frac{lb}{ft^2}$	$C_{L_{w\,cln\,p.off}}$	0.1875		f_{bal_a}	0.85		$C_{n_{al_i}}$	0.0000		$C_{n_{ar_p}}$	0.0000		C_{n_a}	0.0000		$C_{n_{\delta_a}}$	-0.0044	rad^{-1}
$c_{l_{\alpha_{rw}}}$	7.9041	rad^{-1}	δ_{a_l}	0.0	deg	$C_{D_{P_{al}}}$	0.0000		$C_{n_{ar_i}}$	0.0000		$C_{n_{a_p}}$	0.0000		$C_{n_{\delta_{aDp}}}$	0.0000	rad^{-1}			

Fig. 78 Aileron related derivatives

Rudder Related Derivatives: Flight Condition 1

Input Parameters

Altitude	30000	ft	S_h	190.00	ft^2	AR_v	3.00		f_{gap_v}	1.00		h_{f_v}	2.00	ft	δ_r	0.82	deg	$\delta_{r_{max}}$		deg
ΔT	0.0	deg F	X_{ac_h}	61.30	ft	λ_v	0.80		$(t/c)_{r_v}$	12.0	%	η_v	1.000		$(gap/C)_r$	2.00	%			
U_1	350.00	kts	Z_{ac_h}	6.00	ft	$\Lambda_{c/4_v}$	5.0	deg	$(t/c)_{t_v}$	12.0	%	c_r/c_v	28.5	%	$Balance_r$	0.05				
S_w	837.00	ft^2	Z_{fc_v}	5.00	ft	$c_{l_{\alpha_{rv}}@M=0}$	6.2800	rad^{-1}	X_{apex_v}	60.00	ft	η_{i_r}	5.0	%	Number δ_r	2				
AR_w	8.00		S_v	137.00	ft^2	$c_{l_{\alpha_{tv}}@M=0}$	6.2800	rad^{-1}	Z_{apex_v}	15.00	ft	η_{o_r}	95.0	%	$\delta_{r_{min}}$		deg			

Output Parameters

M_1	0.594		$c_{l_{\alpha_{rv}}}$	7.8049	rad^{-1}	$C_{y_{v_\beta}}$	-4.5029	rad^{-1}	f_{bal_r}	0.85		β_{δ_r}	-0.4356	
$\bar{q}_1$	155.41	$\frac{lb}{ft^2}$	$c_{l_{\alpha_{tv}}}$	7.8049	rad^{-1}	x/c_v	0.2760		$\beta_{\delta_{r_o}}$	-0.4356		$C_{y_{\delta_r}}$	0.2717	rad^{-1}
$AR_{v_{eff}}$	4.32		$c_{l_{\alpha_v}}$	7.8049	rad^{-1}	K'_r	1.0000		$C_{y_{\delta_{ro}}}$	0.2717	rad^{-1}	$C_{y_{rudder}}$	0.0000	

Fig. 79 Rudder related derivatives

Rudder Related Derivatives: Flight Condition 1

Input Parameters

α	0.00	deg	$C_{y_{\delta_{ro}}}$	0.2717	rad^{-1}	AR_w	8.00		λ_v	0.80		Z_{apex_v}	15.00	ft	η_{o_r}	95.0	%	Number δ_r	2	
X_{cg}	24.32	ft	$C_{y_{\delta_r}}$	0.2717	rad^{-1}	S_v	137.00	ft^2	$\Lambda_{c/4_v}$	5.0	deg	c_r/c_v	28.5	%	δ_r	0.82	deg	$\delta_{r_{min}}$		deg
Z_{cg}	2.95	ft	S_w	837.00	ft^2	AR_v	3.00		X_{apex_v}	60.00	ft	η_{i_r}	5.0	%	$Balance_r$	0.05		$\delta_{r_{max}}$		deg

Output Parameters

$C_{l_{\delta_{ro}}}$	0.0726	rad^{-1}	$C_{l_{\delta_r}}$	0.0726	rad^{-1}	$C_{l_{rudder}}$	0.0000	

Fig. 80 Rudder related derivatives

Rudder Related Derivatives: Flight Condition 1

Input Parameters

α	0.00	deg	$C_{y_{\delta_{ro}}}$	0.2717	rad^{-1}	AR_w	8.00		λ_v	0.80		Z_{apex_v}	15.00	ft	η_{o_r}	95.0	%	Number δ_r	2	
X_{cg}	24.32	ft	$C_{y_{\delta_r}}$	0.2717	rad^{-1}	S_v	137.00	ft^2	$\Lambda_{c/4_v}$	5.0	deg	c_r/c_v	28.5	%	δ_r	0.82	deg	$\delta_{r_{min}}$		deg
Z_{cg}	2.95	ft	S_w	837.00	ft^2	AR_v	3.00		X_{apex_v}	60.00	ft	η_{i_r}	5.0	%	$Balance_r$	0.05		$\delta_{r_{max}}$		deg

Output Parameters

$C_{n_{\delta_{ro}}}$	-0.1380	rad^{-1}	$C_{n_{\delta_r}}$	-0.1380	rad^{-1}	$C_{n_{rudder}}$	0.0000	

Fig. 81 Rudder related derivatives

B. AAA: Static Stability and One Engine Inoperative Analyses

Angle of Attack Related Derivatives: Pitching Moment: Flight Condition 1

Input Parameters

Altitude	30000 ft	f_{gap_w}	0.93	X_{apex_w}	23.00 ft	S_h	190.00 ft^2	Y_{offset_h}	0.00 ft	$\eta_{h_{p.off}}$	1.000	$D_{f_{max_w}}$	6.83 ft
ΔT	0.0 deg F	S_w	837.00 ft^2	Y_{offset_w}	0.00 ft	AR_h	7.00	$(t/c)_{r_h}$	12.0 %	$c_{l_{\alpha_{rh}}@M=0}$	6.2504 rad^{-1}	$\Delta\bar{x}_{ac_f}$	-0.0451
U_1	350.00 kts	AR_w	8.00	$(t/c)_{r_w}$	12.00 %	λ_h	1.00	$(t/c)_{t_h}$	12.0 %	$c_{l_{\alpha_{th}}@M=0}$	6.2504 rad^{-1}	X_{cg}	24.32 ft
$c_{l_{\alpha_{rw}}@M=0}$	6.3598 rad^{-1}	λ_w	0.60	$(t/c)_{t_w}$	12.00 %	$\Lambda_{c/4_h}$	0.0 deg	$Z_{c_r/4_h}$	6.00 ft	f_{gap_h}	1.00		
$c_{l_{\alpha_{tw}}@M=0}$	6.3598 rad^{-1}	$\Lambda_{c/4_w}$	0.0 deg	$Z_{c_r/4_w}$	2.00 ft	X_{apex_h}	60.00 ft	Γ_h	0.0 deg	w_{f_h}	2.00 ft		

Output Parameters

M_1	0.594	$c_{l_{\alpha_{rw}}}$	7.9041 rad^{-1}	$C_{L_{w_\alpha}}$	5.3706 rad^{-1}	$\bar{x}_{ac_{wf\,p.off}}$	0.2049	$\bar{x}_{ac_h}$	3.6121	$d\varepsilon_h/d\alpha$	0.3931	SM	56.96 %
$\bar{q}_1$	155.41 lb/ft^2	$c_{l_{\alpha_{tw}}}$	7.9041 rad^{-1}	$C_{L_{\alpha_{wf}}}$	5.3724 rad^{-1}	$c_{l_{\alpha_{rh}}}$	7.7681 rad^{-1}	$C_{L_{h_\alpha}}$	5.7070 rad^{-1}	$\bar{V}_h$	0.8040	$C_{L_{\alpha\,p.off}}$	6.1586 rad^{-1}
$\bar{x}_{cg}$	0.0702	$c_{l_{\alpha_w}}$	7.9041 rad^{-1}	X_{ac_w}	26.20 ft	$c_{l_{\alpha_{th}}}$	7.7681 rad^{-1}	$C_{L_{\alpha_h}}$	0.7862 rad^{-1}	X_{ac}	30.27 ft	C_{L_α}	6.1586 rad^{-1}
$\bar{c}_w$	10.44 ft	$C_{L_{w_\alpha\,clean}}$	5.3706 rad^{-1}	$\bar{x}_{ac_w}$	0.2500	$c_{l_{\alpha_h}}$	7.7681 rad^{-1}	Z_{ac_h}	6.00 ft	$\bar{x}_{ac_{p.off}}$	0.6399	$C_{m_{\alpha\,p.off}}$	-3.5082 rad^{-1}
x_{mgc_w}	0.59 ft	$C_{L_{\alpha_{wf\,clean}}}$	5.3724 rad^{-1}	$X_{ac_{wf\,p.off}}$	25.73 ft	X_{ac_h}	61.30 ft	$(d\varepsilon_h/d\alpha)_{p.off}$	0.3931	$\bar{x}_{ac}$	0.6399	C_{m_α}	-3.5082 rad^{-1}

High Lift Devices Table

#	High Lift Device	η_i %	η_o %	c/c_w %	δ deg
1	Single Slotted Flap	9.0	55.5	30.0	0.0

Fig. 82 Angle of attack related derivatives

Sideslip Related Derivatives: Yawing Moment: Flight Condition 1

Input Parameters

Altitude	30000 ft	λ_w	0.60	Z_{ac_h}	6.00 ft	X_{apex_v}	60.00 ft	$(t/c)_{t_v}$	12.0 %	Z_{cg}	2.95 ft	X_{apex_f}	0.00 ft
ΔT	0.0 deg F	$\Lambda_{c/4_w}$	0.0 deg	Z_{fc_v}	5.00 ft	Z_{apex_v}	15.00 ft	η_v	1.000	S_{B_s}	383.07 ft^2		
U_1	350.00 kts	$Z_{c_r/4_w}$	2.00 ft	S_v	137.00 ft^2	$c_{l_{\alpha_{rv}}@M=0}$	6.2800 rad^{-1}	l_f	55.00 ft	$h_{f_{0.25}}$	6.78 ft		
α	0.00 deg	Z_{fc_w}	2.50 ft	AR_v	3.00	$c_{l_{\alpha_{tv}}@M=0}$	6.2800 rad^{-1}	h_{f_w}	2.50 ft	$h_{f_{0.75}}$	5.00 ft		
S_w	837.00 ft^2	S_h	190.00 ft^2	λ_v	0.80	f_{gap_v}	1.00	h_{f_v}	2.00 ft	$h_{f_{max}}$	2.00 ft		
AR_w	8.00	X_{ac_h}	61.30 ft	$\Lambda_{c/4_v}$	5.0 deg	$(t/c)_{r_v}$	12.0 %	X_{cg}	24.32 ft	$w_{f_{max}}$	6.78 ft		

Output Parameters

M_1	0.594	Z_{ac_v}	24.76 ft	$c_{l_{\alpha_{tv}}}$	7.8049 rad^{-1}	x/c_v	0.2760	$K_{N_{fus}}$	-0.00029	$C_{n_{\beta_v}}$	0.3897 rad^{-1}
Re_f	93.1248 x 10^6	$AR_{v_{eff}}$	4.32	$c_{l_{\alpha_v}}$	7.8049 rad^{-1}	$(d\sigma/d\beta)_v$	-0.1264	$K_{R_{l_{fus}}}$	1.92878	C_{n_β}	0.3995 rad^{-1}
X_{ac_v}	62.73 ft	$c_{l_{\alpha_{rv}}}$	7.8049 rad^{-1}	$C_{y_{v_\beta}}$	-4.5029 rad^{-1}	$C_{y_{\beta_v}}$	-0.8302 rad^{-1}	$C_{n_{\beta_f}}$	0.0098 rad^{-1}		

Fig. 83 Sideslip related derivatives

Rudder Related Derivatives: Flight Condition 1

Input Parameters

α	0.00 deg	$C_{y_{\delta_{ro}}}$	0.2717 rad^{-1}	AR_w	8.00	λ_v	0.80	Z_{apex_v}	15.00 ft	η_{o_r}	95.0 %	Number δ_r	2
X_{cg}	24.32 ft	$C_{y_{\delta_r}}$	0.2717 rad^{-1}	S_v	137.00 ft^2	$\Lambda_{c/4_v}$	5.0 deg	c_r/c_v	28.5 %	δ_r	0.82 deg	$\delta_{r_{min}}$	deg
Z_{cg}	2.95 ft	S_w	837.00 ft^2	AR_v	3.00	X_{apex_v}	60.00 ft	η_{i_r}	5.0 %	$Balance_r$	0.05	$\delta_{r_{max}}$	deg

Output Parameters

$C_{n_{\delta_{ro}}}$	-0.1380 rad^{-1}	$C_{n_{\delta_r}}$	-0.1380 rad^{-1}	$C_{n_{rudder}}$	0.0000

Fig. 84 Rudder related derivatives

Engine Out Control: Flight Condition 1

Input Parameters

Altitude	30000	ft	ΔT	0.0	deg F	S_w	837.00	ft^2	AR_w	8.00		V_S	350.00	kts	$C_{n_{\delta_r}}$	-0.1380	rad^{-1}

Output Parameters

V_{mc}	420.00	kts	δ_r	0.28	deg

Propeller Table

		SHP_{set} hp	X_{prop} ft	Y_{prop} ft	Z_{prop} ft	i_{prop} deg	Ψ_{prop} deg	η_{prop}	K_{loss} %	$C_{D_{prop_{wm}}}$	$C_{D_{prop_{stop}}}$	P_{avail} hp	T_{avail} lb
#	Type	Input	Input	Input	Input	Input	Input	Input	Input	Input	Input	Output	Output
1	Propeller: On	1555	22.00	9.01	4.00	7.0	0.0	0.850	5.7	0.0000	0.0000	1246	1160
2	Propeller: On	0	22.00	-9.01	4.00	7.0	0.0	0.850	5.7	0.0000	0.0000	0	0

Fig. 85 One engine out at cruise altitude and speed

Engine Out Control: Flight Condition 1

Input Parameters

Altitude	7000	ft	ΔT	0.0	deg F	S_w	837.00	ft^2	AR_w	8.00		V_S	140.00	kts	$C_{n_{\delta_r}}$	-0.1380	rad^{-1}

Output Parameters

V_{mc}	168.00	kts	δ_r	0.82	deg

Propeller Table

		SHP_{set} hp	X_{prop} ft	Y_{prop} ft	Z_{prop} ft	i_{prop} deg	Ψ_{prop} deg	η_{prop}	K_{loss} %	$C_{D_{prop_{wm}}}$	$C_{D_{prop_{stop}}}$	P_{avail} hp	T_{avail} lb
#	Type	Input	Input	Input	Input	Input	Input	Input	Input	Input	Input	Output	Output
1	Propeller: On	1555	22.00	9.01	4.00	7.0	0.0	0.850	5.7	0.0000	0.0000	1246	1160
2	Propeller: On	0	22.00	-9.01	4.00	7.0	0.0	0.850	5.7	0.0000	0.0000	0	0

Fig. 86 One engine out at takeoff altitude and speed

C. AAA: Transfer Function and Flying Quality Analyses

Computation of Longitudinal Transfer Functions: Flight Condition 1

Input Parameters

Altitude	30000	ft	α	0.00	deg	C_{m_u}	0.0106		$C_{m_{T_u}}$	0.0038		$C_{L_{\dot{\alpha}}}$	3.6077	rad^{-1}	$C_{T_{x_1}}$	0.0177	
ΔT	0.0	deg F	γ	0.0	deg	C_{m_α}	-3.5082	rad^{-1}	$C_{m_{T_\alpha}}$	-0.0251	rad^{-1}	C_{L_q}	14.1354	rad^{-1}	$C_{T_{x_u}}$	-0.0531	
U_1	350.00	kts	$\bar{c}_w$	10.44	ft	$C_{m_{\dot{\alpha}}}$	-12.7779	rad^{-1}	C_{L_1}	0.1076		C_{D_1}	0.0177		$C_{L_{\delta_e}}$	0.5482	rad^{-1}
$W_{current}$	37689.0	lb	I_{yy_B}	51880.2	slug-ft^2	C_{m_q}	-32.5032	rad^{-1}	C_{L_u}	0.0586		C_{D_α}	0.0972	rad^{-1}	$C_{D_{\delta_e}}$	0.0087	rad^{-1}
S_w	837.00	ft^2	C_{m_1}	0.0013		$C_{m_{T_1}}$	-0.0013		C_{L_α}	6.1586	rad^{-1}	C_{D_u}	0.0000		$C_{m_{\delta_e}}$	-1.9416	rad^{-1}

Output Parameters

M_1	0.594		X_α	1.1436	ft/s^2	M_{T_u}	0.0001	$1/(ft\,s)$	B_{long}	6860.1		ζ_{SP}	0.581		TC_{long_2}		s
$\bar{q}_1$	155.41	lb/ft^2	Z_u	-0.0510	s^{-1}	M_α	-91.8437	s^{-2}	C_{long}	58549.8		$\omega_{n_{P_{long}}}$	0.0530	rad/s	TC_{long_3}		s
W/S	45.03	lb/ft^2	Z_α	-679.4278	ft/s^2	M_{T_α}	-0.6576	s^{-2}	D_{long}	595.4		$\zeta_{P_{long}}$	0.093		TC_{long_4}		s
Θ	0.0	deg	$Z_{\dot{\alpha}}$	-3.5074	ft/s	$M_{\dot{\alpha}}$	-2.9565	s^{-1}	E_{long}	164.2		ω_{n_3}		rad/s	X_{δ_e}	-0.9516	ft/s^2
X_u	-0.0066	s^{-1}	Z_q	-13.7427	ft/s	M_q	-7.5205	s^{-1}	RH_{long}	231228114880.2		ζ_3			Z_{δ_e}	-60.3020	ft/s^2
X_{T_u}	-0.0033	s^{-1}	M_u	0.0006	$1/(ft\,s)$	A_{long}	594.2		$\omega_{n_{SP}}$	9.9203	rad/s	TC_{long_1}		s	M_{δ_e}	-50.8298	s^{-2}

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Fig. 87 Longitudinal transfer functions, frequencies, and damping

Lateral-Directional Transfer Functions: Flight Condition 1

Input Parameters

$W_{current}$	37689.0 lb	S_w	837.00 ft^2	I_{xx_B}	200121.1 slug-ft^2	C_{l_p}	-0.5259 rad^{-1}	C_{n_p}	-0.0193 rad^{-1}	C_{y_p}	-0.1342 rad^{-1}	$C_{n_{\delta_a}}$	-0.0044 rad^{-1}
Altitude	30000 ft	Θ	0.0 deg	I_{zz_B}	245693.0 slug-ft^2	C_{l_r}	0.2663 rad^{-1}	C_{n_r}	-0.3678 rad^{-1}	C_{y_r}	0.7794 rad^{-1}		
ΔT	0.0 deg F	α	0.00 deg	I_{xz_B}	4375.6 slug-ft^2	C_{n_β}	0.3995 rad^{-1}	C_{y_β}	-0.9179 rad^{-1}	$C_{y_{\delta_a}}$	0.0000 rad^{-1}		
U_1	350.00 kts	b_w	81.83 ft	C_{l_β}	-0.3025 rad^{-1}	$C_{n_{T_\beta}}$	0.0000 rad^{-1}	$C_{y_{T_\beta}}$	0.0000 rad^{-1}	$C_{l_{\delta_a}}$	0.1629 rad^{-1}		

Output Parameters

M_1	0.594	Y_β	-100.9699 ft/s^2	L_r	0.9809 s^{-1}	$B_{lat\text{-}dir}$	1887.7	ζ_D	0.138	$TC_{lateral_2}$	s
$\bar{q}_1$	155.41 lb/ft^2	Y_{T_β}	0.0000 ft/s^2	N_β	17.3067 s^{-2}	$C_{lat\text{-}dir}$	11539.0	$\omega_{n_{P_{lateral}}}$	rad/s	$TC_{lateral_3}$	s
W/S	45.03 lb/ft^2	Y_p	-1.0227 ft/s	N_{T_β}	0.0000 s^{-2}	$D_{lat\text{-}dir}$	20872.2	$\zeta_{P_{lateral}}$		$TC_{lateral_4}$	s
I_{xx_S}	200121.1 slug-ft^2	Y_r	5.9385 ft/s	N_p	-0.0578 s^{-1}	$E_{lat\text{-}dir}$	24.8	T_S	839.642 s	Y_{δ_a}	0.0000 ft/s^2
I_{zz_S}	245693.0 slug-ft^2	L_β	-16.0899 s^{-2}	N_r	-1.1036 s^{-1}	$RH_{lat\text{-}dir}$	197293681276.6	T_R	0.487 s	L_{δ_a}	8.6636 s^{-2}
I_{xz_S}	4375.6 slug-ft^2	L_p	-1.9372 s^{-1}	$A_{lat\text{-}dir}$	590.5	ω_{n_D}	4.1464 rad/s	$TC_{lateral_1}$	s	N_{δ_a}	-0.1923 s^{-2}

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Fig. 88 Lateral-directional transfer functions, frequencies, and damping response to ailerons

Lateral-Directional Transfer Functions: Flight Condition 1

Input Parameters

$W_{current}$	37689.0 lb	S_w	837.00 ft^2	I_{xx_B}	200121.1 slug-ft^2	C_{l_p}	-0.5259 rad^{-1}	C_{n_p}	-0.0193 rad^{-1}	C_{y_p}	-0.1342 rad^{-1}	$C_{n_{\delta_r}}$	-0.1380 rad^{-1}
Altitude	30000 ft	Θ	0.0 deg	I_{zz_B}	245693.0 slug-ft^2	C_{l_r}	0.2663 rad^{-1}	C_{n_r}	-0.3678 rad^{-1}	C_{y_r}	0.7794 rad^{-1}		
ΔT	0.0 deg F	α	0.00 deg	I_{xz_B}	4375.6 slug-ft^2	C_{n_β}	0.3995 rad^{-1}	C_{y_β}	-0.9179 rad^{-1}	$C_{y_{\delta_r}}$	0.2717 rad^{-1}		
U_1	350.00 kts	b_w	81.83 ft	C_{l_β}	-0.3025 rad^{-1}	$C_{n_{T_\beta}}$	0.0000 rad^{-1}	$C_{y_{T_\beta}}$	0.0000 rad^{-1}	$C_{l_{\delta_r}}$	0.0726 rad^{-1}		

Output Parameters

M_1	0.594	Y_β	-100.9699 ft/s^2	L_r	0.9809 s^{-1}	$B_{lat\text{-}dir}$	1887.7	ζ_D	0.138	$TC_{lateral_2}$	s
$\bar{q}_1$	155.41 lb/ft^2	Y_{T_β}	0.0000 ft/s^2	N_β	17.3067 s^{-2}	$C_{lat\text{-}dir}$	11539.0	$\omega_{n_{P_{lateral}}}$	rad/s	$TC_{lateral_3}$	s
W/S	45.03 lb/ft^2	Y_p	-1.0227 ft/s	N_{T_β}	0.0000 s^{-2}	$D_{lat\text{-}dir}$	20872.2	$\zeta_{P_{lateral}}$		$TC_{lateral_4}$	s
I_{xx_S}	200121.1 slug-ft^2	Y_r	5.9385 ft/s	N_p	-0.0578 s^{-1}	$E_{lat\text{-}dir}$	24.8	T_S	839.642 s	Y_{δ_r}	29.8864 ft/s^2
I_{zz_S}	245693.0 slug-ft^2	L_β	-16.0899 s^{-2}	N_r	-1.1036 s^{-1}	$RH_{lat\text{-}dir}$	197293681276.6	T_R	0.487 s	L_{δ_r}	3.8637 s^{-2}
I_{xz_S}	4375.6 slug-ft^2	L_p	-1.9372 s^{-1}	$A_{lat\text{-}dir}$	590.5	ω_{n_D}	4.1464 rad/s	$TC_{lateral_1}$	s	N_{δ_r}	-5.9794 s^{-2}

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Fig. 89 Lateral-directional transfer functions, frequencies, and damping response to rudder

Longitudinal Mode Checking Flight Phase Category B: Flight Condition 1

Input Parameters

$\omega_{n_{SP}}$	9.9203 rad/s	ζ_{SP}	0.581	$\omega_{n_{P_{long}}}$	0.0530 rad/s	$\zeta_{P_{long}}$	0.093	Z_α	-679.4278 ft/s^2	Altitude	30000 ft

Output Parameters

n/α	21.316 g/rad	T_{2_P}	s	$T_{1/2_P}$	140.700 s	Level$_P$ = 1		Level ζ_{SP} = 1		Level $\omega_{n_{SP}}$ = 2	

Fig. 90 Longitudinal mode frequencies, phugoid and short period flying quality levels

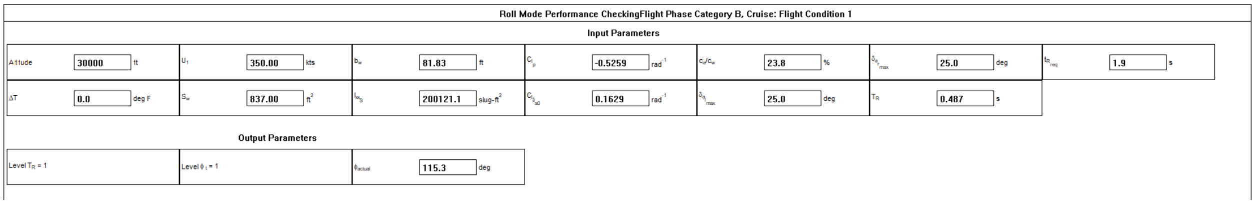

Fig. 91 Roll mode performance and flying quality level

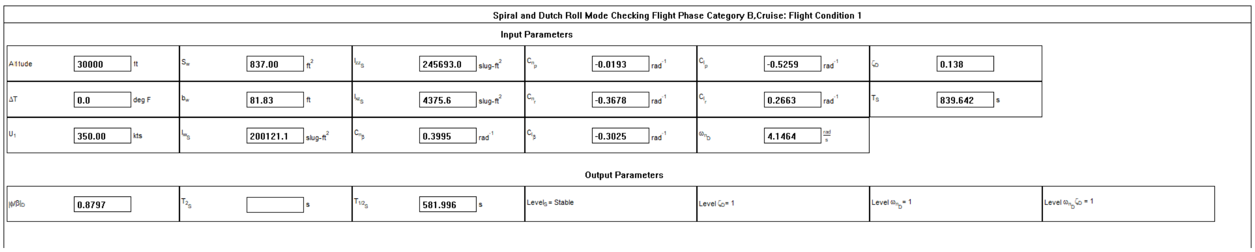

Fig. 92 Spiral and dutch roll fling quality levels

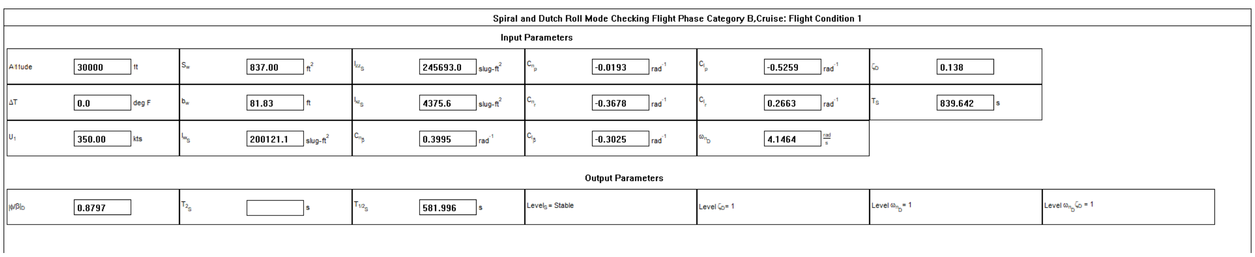

Fig. 93 Spiral and dutch roll fling quality levels