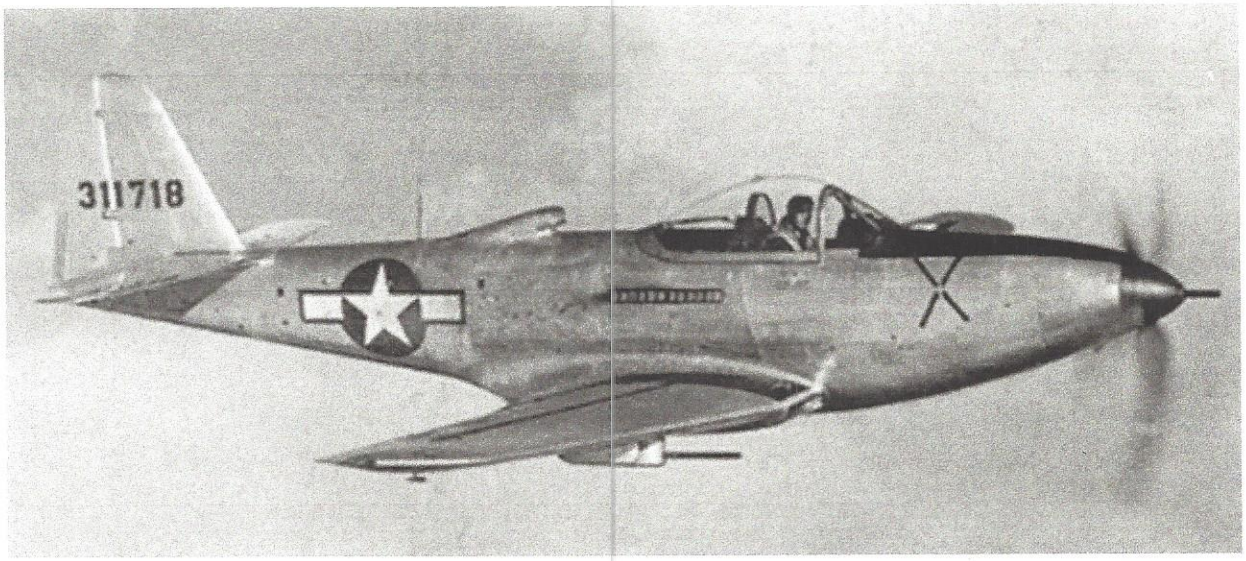
Drag Prediction Project

Aircraft #1 – Bell P-63 D-1 Kingcobra



Only one P-63D was built with a bubble canopy. It was the fastest version of the P-63.

Despite being heavier, the P-63D was the fastest version of the P-63 reaching 437 mph at 30,000 feet. The wing was lengthened by 10 inches and it was powered by an Allison V-1710-109 engine producing 1,425 hp. A major change was the removal of the automobile-type doors and the installation of a bubble canopy. The performance of the P-63D put it on par with the P-51 Mustang and P-47 Thunderbolt, but it was destroyed during diving tests.

Wing span:	Length:	Height:	Empty:	Max T/O:	Maximum Speed:	Service Ceiling:	Normal Range:	Max. Range:	Powerplant
39 ft 2 in (11.94 m)	32 ft 8 in (9.96 m)	11 ft 2 in (3.40 m)	7,076 lb (3,210 kg)	11,100 lb (5,035 kg)	437 mph (703 km/h) at 30,000 ft (9,144 m)	39,000 ft (11,887 m)	950 miles (1,529 km)	2,000 miles (3,219 km)	One Allison V-1710-109 1,425 hp (1,062 kW) V-12, liquid cooled engine.

Using the data above and the drawings provided, estimate the C_{Do} of the aircraft for the following configurations: (scale drawings according to published lengths)

a) Clean
b) with just gear down for takeoff, and
c) with gear and flaps (at 30°) for landing

Assume the cruise altitude is 25,000 feet and the cruise velocity is 370 mph. Neglect all guns, gun pods and antennas. Include the cooling drag of the radiators.

[redacted]

P-63 D			GW =	11,000	ESHP =	1,425	Allison V-1710-109A			
Item	Planform	($A_{wet\ net/}$		Interference						
Lifting Surfaces	Area (ft^2)	$A_{wet\ gross}$)	C_D	factor (%)	δf_e	Δf_e	**Misc**	Δf_e	(see component calcs)	
Wing	250.8	0.929	0.008		1.864	2.237	Main Gear	6.237		
Wing/Fuse fair int				10	0.186		Nose Gear	3.802		
3D & roughness				5	0.093		Flaps @ 30°	3.010		
cntrl surf,gaps etc.				5	0.093					
							SUMMARY		(ft^2)	
Horz Tail	52.5	0.967	0.010		0.508		Components		4.652	
Vert Tail int				10	0.051	0.610	Protuberances	10	0.465	
3D & roughness				5	0.025		Trim		0.30	
cntrl surf,gaps etc.				5	0.025		Momentum		0.23	
							Airplane cruise mode		5.645	
Vert Tail	35.13	1.000	0.010		0.351					
Horz Tail int				5	0.018	0.422	**Airplane cruise mode**		5.65	(ft^2)
Fuse int				5	0.018					
3D & roughness				5	0.018		**Airplane T/O mode**		15.68	(ft^2)
cntrl surf,gaps etc.				5	0.018					
							Airplane LNDG mode		18.69	(ft^2)
Bodies of Rev	Aw_{net}/A_f	C_d/C_f		Interference						
Fuselage	(ft^2)	(N/D)	δf_e'	factor (%)	δf_e					
skin friction	270.26	0.002287	0.618		0.681	Δf_e	C_{do} =	0.0225		
frontal	9.52	0.078153	0.744			0.852				
Wing/fuse fairing int				10	0.068		C_{do} =	0.0625		
Vert tail int				5	0.034					
3D & roughness				5	0.034		C_{do} =	0.0745		
doors,gaps etc.				5	0.034					
Canopy	(ft^2)	(N/D)	δf_e'	factor (%)	δf_e					
skin friction	26.32	0.005805	0.153		0.156	Δf_e				
frontal	4.06	0.039211	0.159			0.326				
canopy/fuse				10	0.068					
Vert tail int				5	0.034					
3D & roughness				5	0.034					
doors,gaps etc.				5	0.034					
Carb Inlet	(ft^2)	(N/D)	δf_e'	factor (%)	δf_e					
skin friction	4.19	0.007109	0.030		0.070	Δf_e				
frontal	2.48	0.044550	0.111			0.206				
carb/fuse				10	0.068					
3D & roughness				5	0.034					
doors,gaps etc.				5	0.034					
			Component sub total			4.652				

$V_{dsgn\ cr}$ (ktas) = **370** h_{alt} (ft) = **25,000** ρ = 0.001065293 ν = 0.0003047

Lifting Surfaces	Ref L (in)	Ref L (ft)	log Re	C_{FB}
Wing	**85.8**	7.15	7.1661	0.0028274
Horz Tail	**46.8**	3.90	6.9028	0.0031140
Vert Tail	**62.4**	5.20	7.0277	0.0029732

Bodies of Rev	Ref L (in)	Ref L (ft)	log Re	C_{FB}	Maximum Perimeter (ft)	$A_{wet\ gross}$ (ft^2)	$Awet_{net}$ (ft^2)	A_{front} (ft^2)	Dia_{hyd} (ft)	l/d	d/l	$C_{D\ WET}$	C_{Df}
Fuselage	**476.0**	39.67	7.9104	0.0021911	**10.94**	312.45	270.26	9.52	3.48	11.39	0.08779	**0.002287**	**0.078153**
Carb Inlet	**44.5**	3.71	6.8816	0.0031389	**5.58**	7.46	4.19	2.48	1.78	2.09	0.47873	**0.007109**	**0.04455**
Canopy	**86.9**	7.24	7.1716	0.0028218	**10.10**	26.32	26.32	8.12	3.21	2.25	0.44412	**0.005805**	**0.039211**

$V_{dsgn\ gear\ speed}$ (ktas) = **120** halt (ft) = **3000** ρ = **0.002175257** ν = **0.000171**

MISC	Ref L (ft)	log Re	C_{FB}	Awet	q	Drag	δf_e
main gear doors	0.974	6.3007	0.0039408	4.501	44.679	0.793	0.018
nose gear doors	6.496	7.1246	0.0028700	7.234	44.679	0.928	0.021
wing fairing	4.919	7.0038	0.0029995	1.585	44.679	0.212	0.005

	$A_{frontal}$	C_{DF}	δf_e
main gear oleos, etc.	8.407	0.50	4.204
main gear wheels	4.031	0.50	2.016
nose gear oleos, etc.	5.237	0.50	2.619
nose gear wheels	2.326	0.50	1.163
	20.002		

flaps @ 30°

flap/chord ratio	0.109
$\delta\alpha_o/\Delta\delta$	0.25
ΔC_D	0.05
b_f/b	0.24
δf_e	3.010

Atmosphere

alt.$_{press}$ =	25,000	(ft)	$\delta T(\Delta^{\circ}C)$		or $T_{amb}(^{\circ}F)$		or assume STD Day	
	(Input either δ or amb temp value, but not both for non std day. Input "0" in both for a std day calc.)							

Atm data			**STD**							
h_{press}=	25000	(ft)	25000	(ft)						
T_{amb}=	-34.528	($^{\circ}$C)	-30.150	($^{\circ}$F)	**SLS**					
δ	0.3711	(N/D)	0.3711	(N/D)	P_o	2116.22	(lb/ft^2)	P	785.41	(lb/ft^2)
θ	0.8281	(N/D)	0.8281	(N/D)	T_o	518.688	(deg R)	T	429.539	(deg R)
σ'	0.4482	(N/D)	0.4481	(N/D)	ρ_o	0.002377	(slugs/ft^3)	ρ	0.0010653	(slugs/ft^3)
					μ_o	3.7846E-07	(slug/ft-sec)	μ	3.2459E-07	(slug/ft-sec)
					ν_o	1.5922E-04	(ft^2/sec)	ν	3.0470E-04	(ft^2/sec)

Dimensional data from drawings.

TOP/FRONT VIEW				(scale factor= 5.3872 mm/ft)	
Wing					
T_W		mm	ft		
	C_R	48	8.910	area=	114.447
	C_T	25	4.641	cx=	3.548
	L	91	16.892	cy=	7.559
E_{W1}		c =	0.087		
	a	13	2.413	area=	5.277
	b	15	2.784	cx=	5.517
E_{W2}				cy=	6.366
	a	14	2.599	area=	5.683
	b	15	2.784	cx=	5.942
Λ_{LE}	5	degrees		cy=	6.366
HT					
T_{HT}					
	C_R	28	5.197	area=	23.215
	C_T	10.5	1.949	cx=	2.059
	L	35	6.497	cy=	2.756
E_{HT1}		c =	0.259		
	a	7.5	1.392	area=	1.522
	b	7.5	1.392	cx=	3.183
E_{HT2}				cy=	3.183
	a	7.5	1.392	area=	1.522
	b	7.5	1.392	cx=	3.183
Λ_{LE}	15	degrees		cy=	3.183
HT/F int "c"	c	26.5	4.919	area=	2.741
	t	3.8	0.705		
CARB INLET					
	w	6	1.114		

MG		mm	ft		
oleo-1	d	7	1.299	area=	2.412
	l	10	1.856		
oleo-2	d	7	1.299	area=	2.412
	l	10	1.856		
fork-1	w	5	0.928	area=	0.689
	l	4	0.742		
fork-2	w	2	0.371	area=	1.447
	l	21	3.898		
scissors	w	2	0.371	area=	1.447
	l	21	3.898		
wheel	w	9	1.671	area=	4.031
	d	13	2.413		
NG					
oleo	d	3	0.557	area=	2.067
	l	20	3.712		
fork-1	w	2.5	0.464	area=	1.723
	l	20	3.712		
scissors	w	2	0.371	area=	1.447
	l	21	3.898		
wheel	w	7.5	1.392	area=	2.326
	d	9	1.671		

COOLING INLETS		mm	ft		
Preston	w	7	1.299	area=	2.412
	h	10	1.856	total =	4.824
oil	w	10	1.856	area=	1.723
	h	10	1.856	total =	3.446
W fairing/w int					
	c	46	8.539	area=	1.585
	w	2	0.371		
W/F int					
	c	46	8.539	area=	12.679
	w	16	2.970		
F/HT int					
	c1	8	1.485	area=	3.721
	c2	4	0.742		
	l	18	3.341		

SIDE VIEW (scale factor= 5.3878 mm/ft)

VT

		mm	ft		
T_{VT1}					
	C_R	11	2.042	area=	11.368
	C_T	9	1.670	cx=	0.931
	L	33	6.125	cy=	2.960
Λ_{LE}	35	degrees			
T_{VT2}					
	C_R	32	5.939	area=	18.887
	C_T	11	2.042	cx=	2.154
	L	25.5	4.733	cy=	0.807
Λ_{LE}	0	degrees			
E_{VT1}					
	a	9	1.670	area=	2.679
	b	11	2.042	cx=	3.820
E_{VT2}				cy=	4.669
	a	9	1.670	area=	2.192
	b	9	1.670	cx=	3.820
				cy=	3.820

CARB INLET

L	20	3.712	
h	6	1.114	

CANOPY

L	39	7.239	
h	10	1.856	
w	14	2.598	

W fairing int

c	26.5	4.919	area=	2.741
t	3.8	0.705		

HT/F int

	mm	ft		
c	26.5	4.919	area=	2.741
t	3.8	0.705		

VT/F int

c	32	5.939	area=	2.177
t	2.5	0.464		

CARB INLET/F int

L	20	3.712	area=	3.266
w	6	1.114		

CANOPY/F int

L	39	7.239	area=	14.859
w	14	2.598		

W fairing/F int

c	26.5	4.919	area=	2.741
t	3.8	0.705		

MG

strut door	w	4.5	0.835	area=	0.735
	l	6	1.114		
wheel door	w	32	5.939	area=	2.177
	l	2.5	0.464		

NG

wheel door	w1	4	0.742	area=	3.617
	w2	2	0.371		
	l	35	6.496		

FUSELAGE MAX PERIMETER

E_{F1}				
a	8	1.485	area=	2.597
b	12	2.227		
E_{F2}				
a	8	1.485	area=	2.165
b	10	1.856		

total area = 9.524
D_{HYD} = 3.482
P_{MAX} = 10.940

CANOPY MAX PERIMETER

E_{C1}				
a	7.5	1.392	area=	2.029
b	10	1.856		

total frontal area = 4.058
extended BofR frontal area = 8.117
D_{HYD} = 3.215
P_{MAX} = 10.100

CARB INLET MAX PERIMETER

E_{CI1}				
a	6	1.114	area=	1.240
b	6	1.114		

total frontal area = 2.480
extended BofR frontal area = 2.480
D_{HYD} = 1.777
P_{MAX} = 5.583

REFERENCE AREAS & CENTROIDS

Lifting Surfaces

Wing

					mm	(ft)	Gross Wetted Area=	541.757
Area=	250.8135	(ft^2)		mgc=	38.5	7.147	Intersection areas =	38.463
Cy =	7.455	(ft)	40.160			85.758	Net Wetted Area =	503.295
Cx =	3.739	(ft)					A_N/A_G =	0.929

HT

							Gross Wetted Area=	113.441
Area=	52.519	(ft^2)			mm	(ft)	Intersection areas =	3.721
Cy =	2.806	(ft)	15.115	mgc=	21	3.898	Net Wetted Area =	109.720
Cx =	2.189	(ft)				46.777	A_N/A_G =	0.967

VT

							Gross Wetted Area=	75.871
Area=	35.126	(ft^2)			mm	(ft)	Intersection areas =	0.000
Cy =	1.986	(ft)	10.703	mgc=	28	5.197	Net Wetted Area =	75.871
Cx =	1.989	(ft)				62.364	A_N/A_G =	1.000

Bodies of Revolution

Fuselage

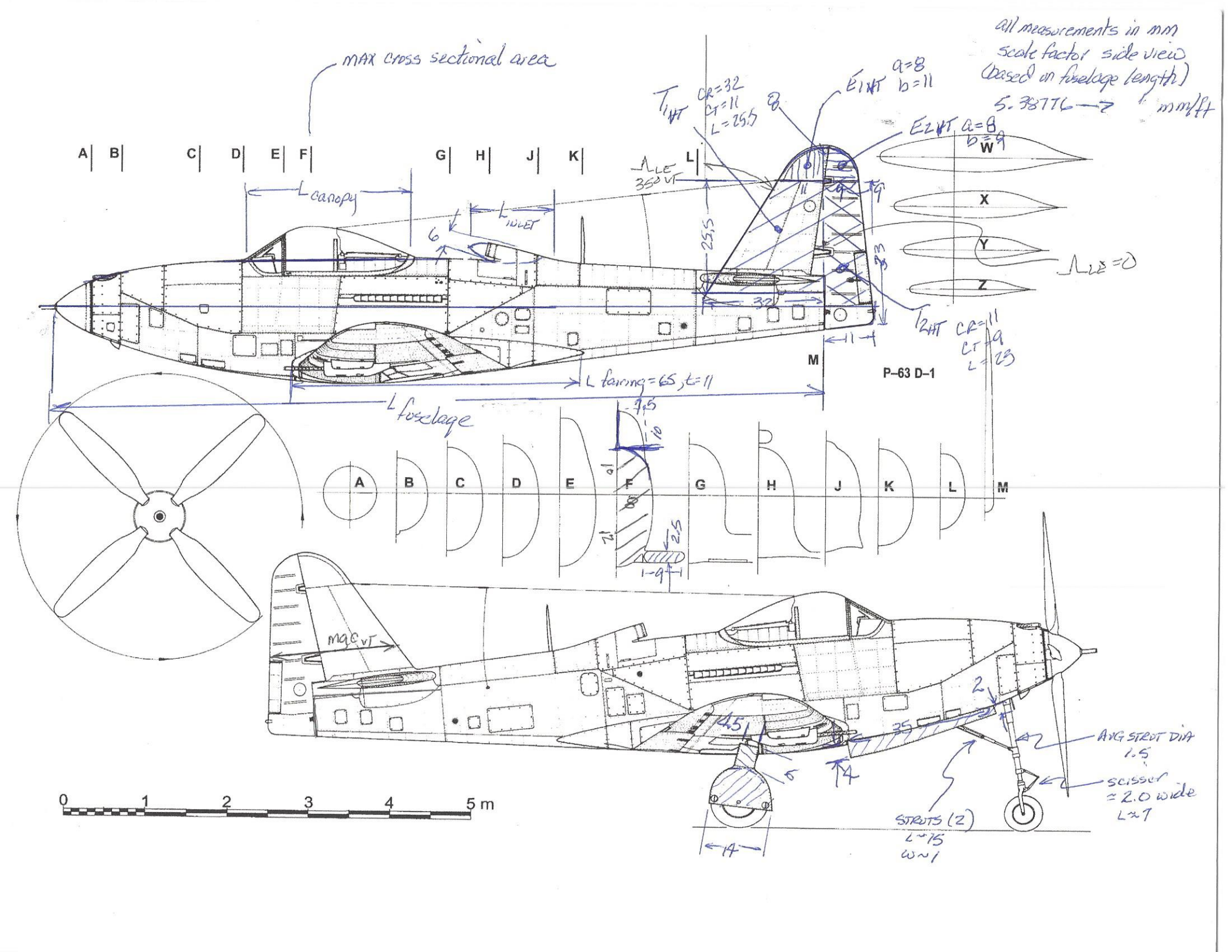
length =	39.667	(ft)	Gross Wetted Area=	312.446
max P =	10.940	(ft)	Intersection areas =	42.183
	476.004		Net Wetted Area =	270.262
			A_N/A_G =	0.865

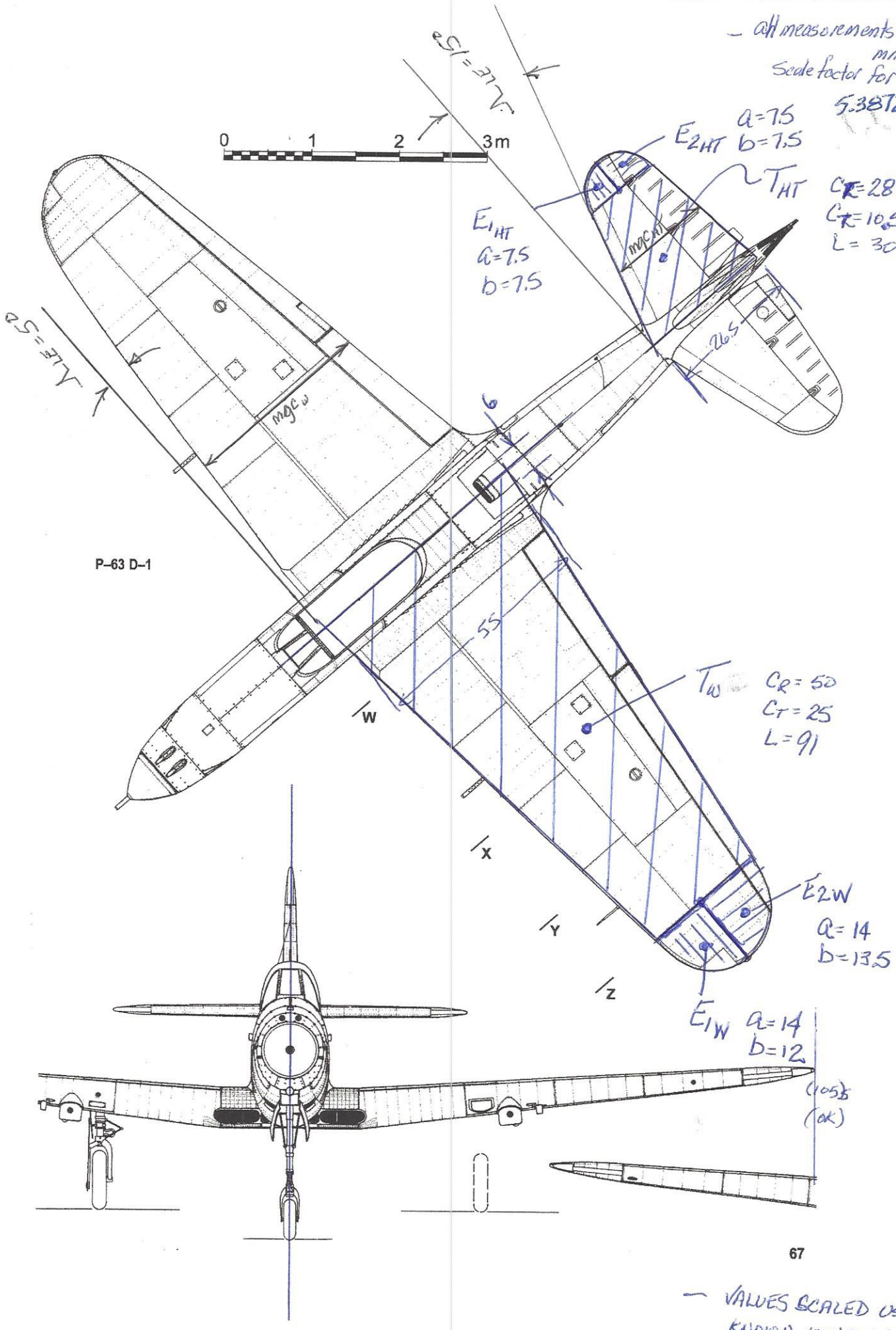
CARB INLET

length =	3.712	(ft)	Gross Wetted Area=	7.461
max P =	5.583	(ft)	Intersection areas =	3.266
	44.545		Net Wetted Area =	4.195
			A_N/A_G =	0.562

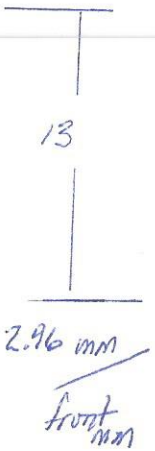
Canopy

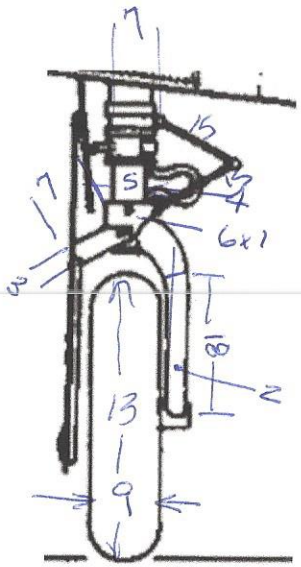
length =	7.239	(ft)	Gross Wetted Area=	26.318
max P =	10.100	(ft)	Intersection areas =	0.000
	86.864		Net Wetted Area =	26.318
			A_N/A_G =	1.000


all measurements in mm
scale factor side view
(based on fuselage length)
5.3877L → 1 mm/ft
MAX cross sectional area
A B C D E F G H J K L M
L canopy
L inlet
L fairing = 65, t = 11
L fuselage
P-63 D-1
T HT CR=32 CT=11 L=25.5
E1 HT a=8 b=11
E2 HT a=8 b=9
Λ LE 35° VT
Λ LE = 0
W X Y Z
I2 HT CR=11 CT=9 L=23
MAC VT
AVG STRUT DIA 1.5
scisser ≈ 2.0 wide L≈7
STRUTS (2) L≈15 W≈1
0 1 2 3 4 5 m

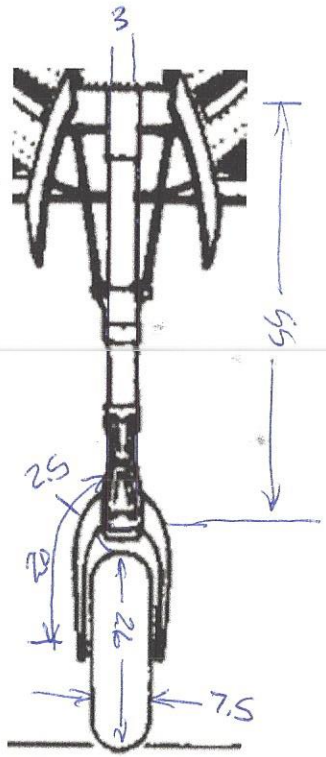


- VALUES SCALED USING KNOWN WING SPAN.

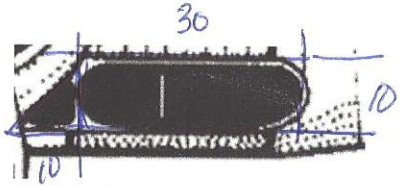




main landing gear

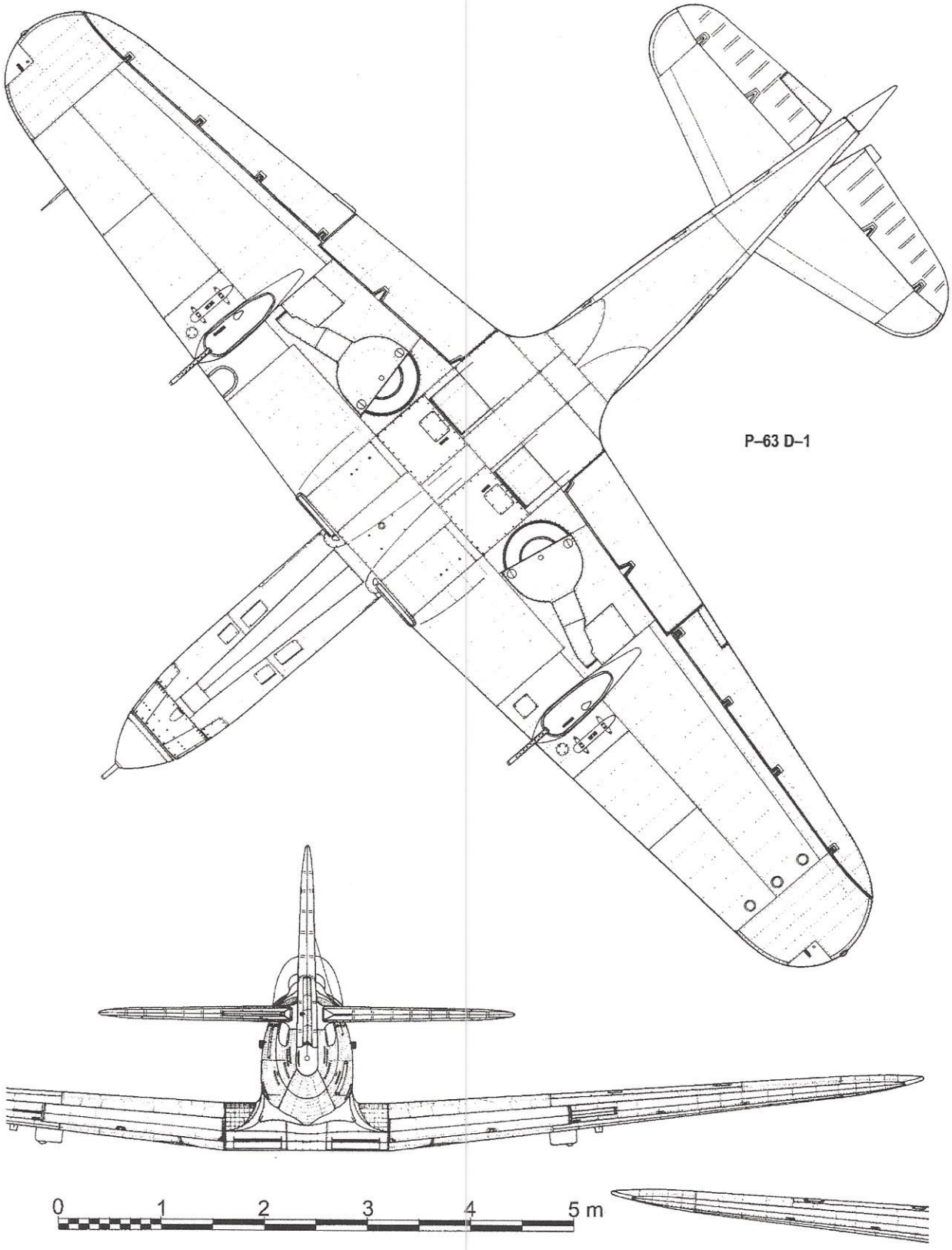


nose landing gear

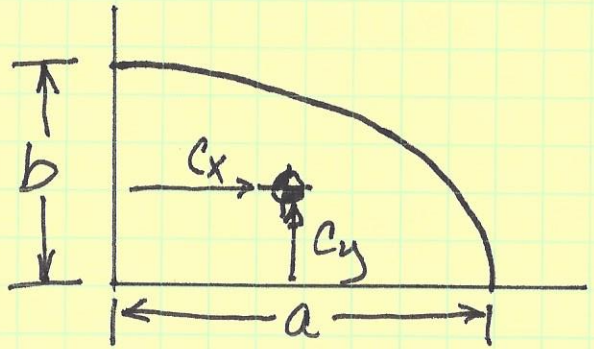


Preston & oil cooler inlet

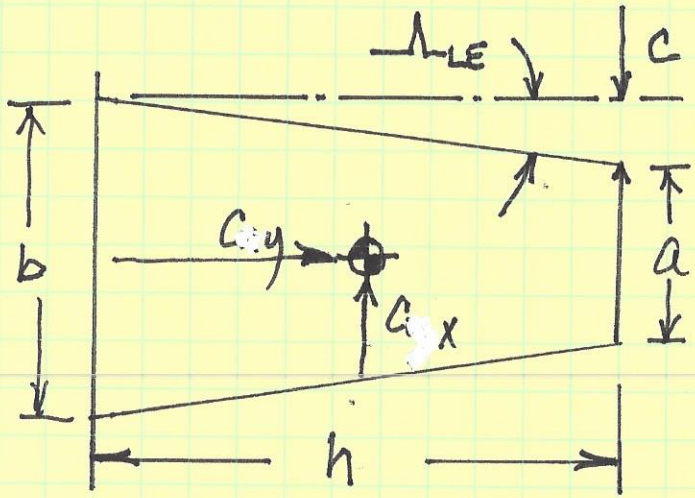
scaled up by ≈ 3x to measure



not used



	CENTROID	
AREA	$\bar{x}$	$\bar{y}$
$\text{area} = \frac{\pi a b}{4}$	$\frac{4a}{3\pi}$	$\frac{4b}{3\pi}$



AREA

$$\text{area} = \frac{h(a+b)}{2}$$

$$\bar{c}_x = \frac{2ac + a^2 + cb + ab + b^2}{3(a+b)}$$

$$\bar{c}_y = \frac{h(2a+b)}{3(a+b)}$$

$$c = h \sin \Lambda_{LE}$$

check: if $b = a$ [rectangle] $\equiv 1 \Rightarrow \Lambda_{LE} = 0°$ let $h = 2$

then $c = h \sin \Lambda_{LE} = h(0) = 0$

$$\bar{c}_x = \frac{(2)(1)(0) + (1)^2 + (0)(1) + (1)(1) + (1)^2}{3(1+1)} = \frac{3}{3(2)} = \frac{1}{2} \quad \checkmark$$

$$\bar{c}_y = \frac{(2)[(2)(0)+1]}{3(1+1)} = \frac{6}{6} = 1 \quad \checkmark$$