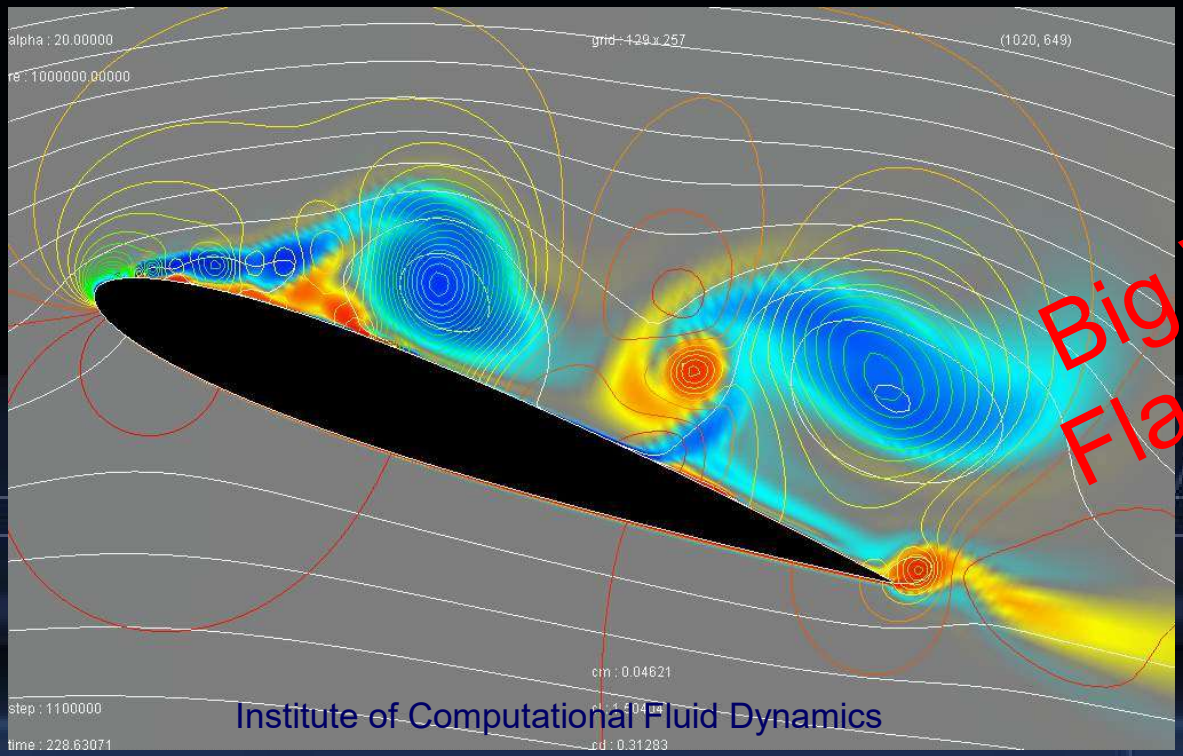
Why Airplanes Fly

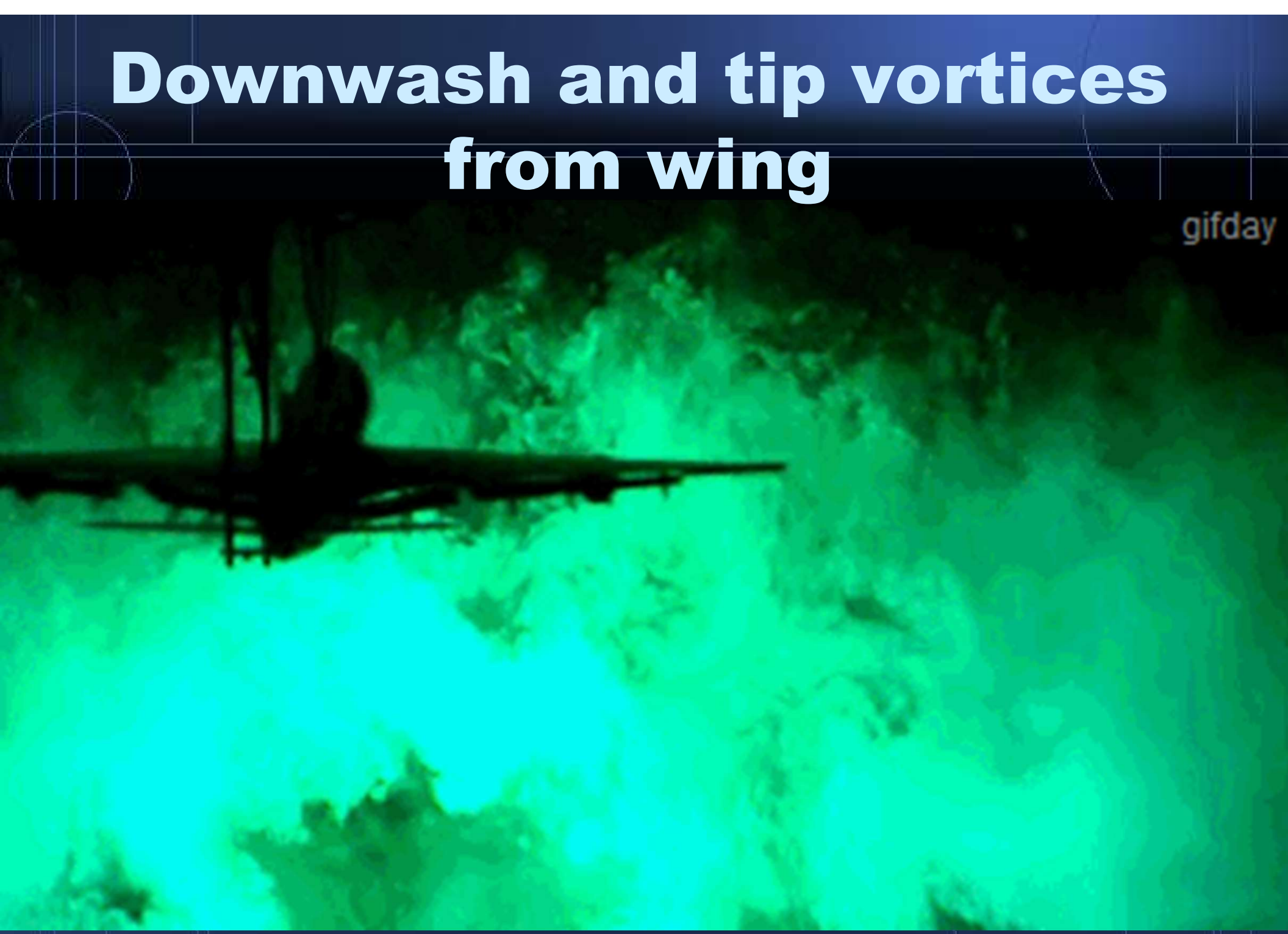
Aerodynamics, Part 2 Stability and more …



Big Warbirds,
Flaps, Speeds,
Tail Sizing

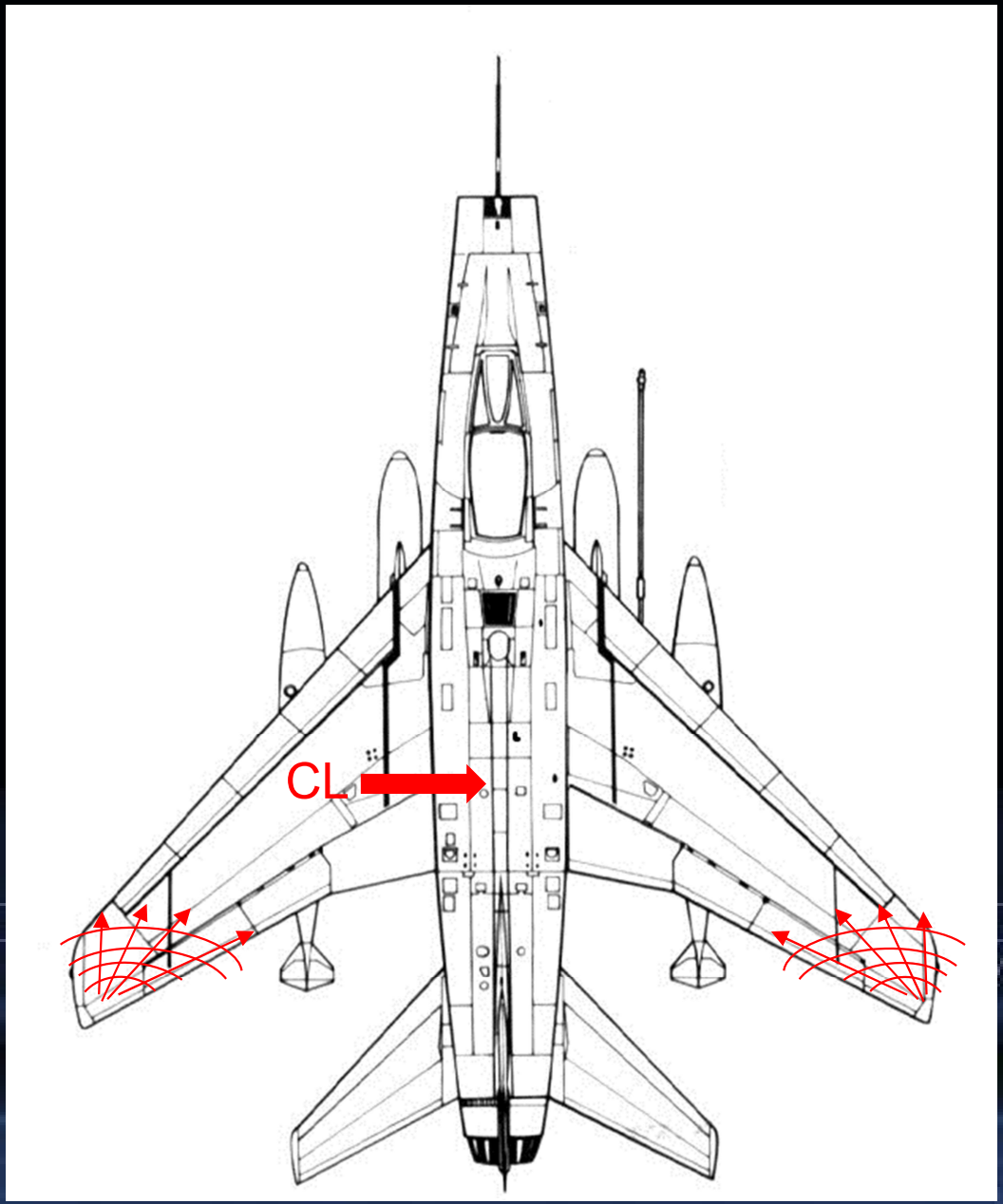
Institute of Computational Fluid Dynamics

Downwash and tip vortices from wing



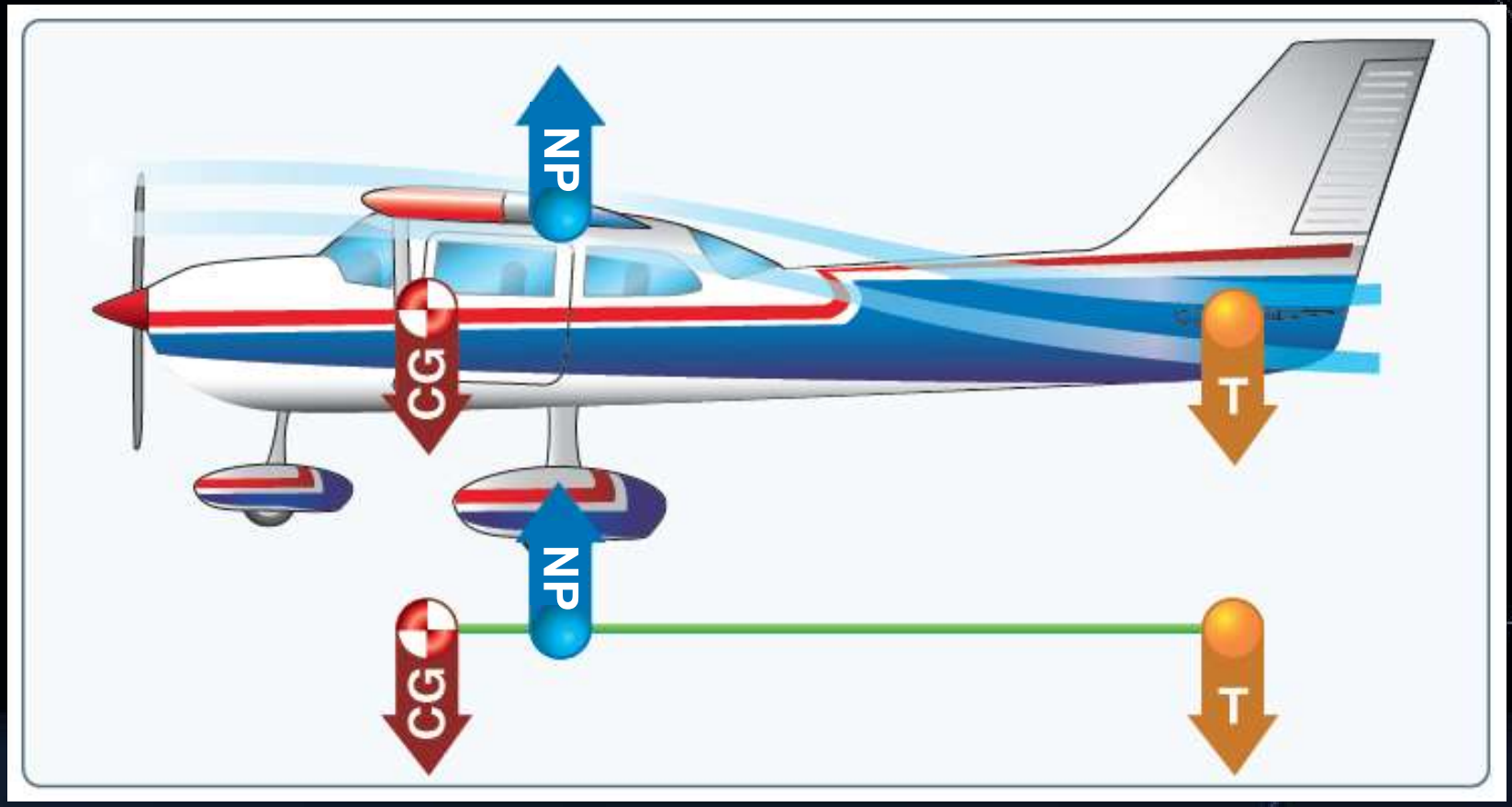
Center of Gravity

Swept Wing Stalls
A special case



Saber Dance

CG and Stability

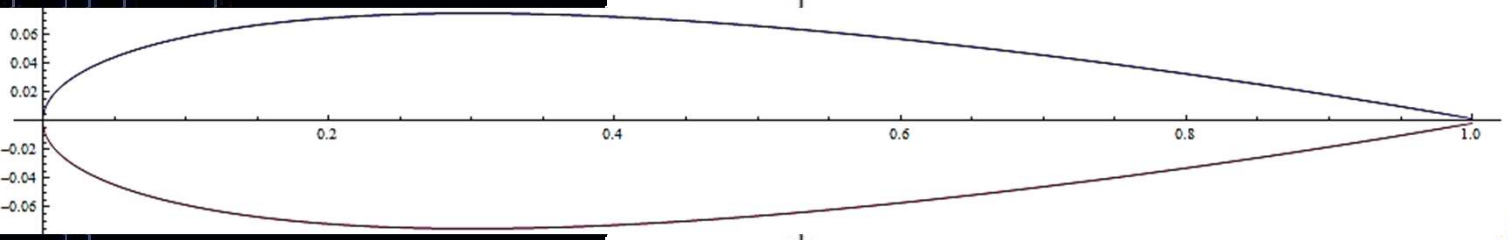


CG and Stability

Figure 1

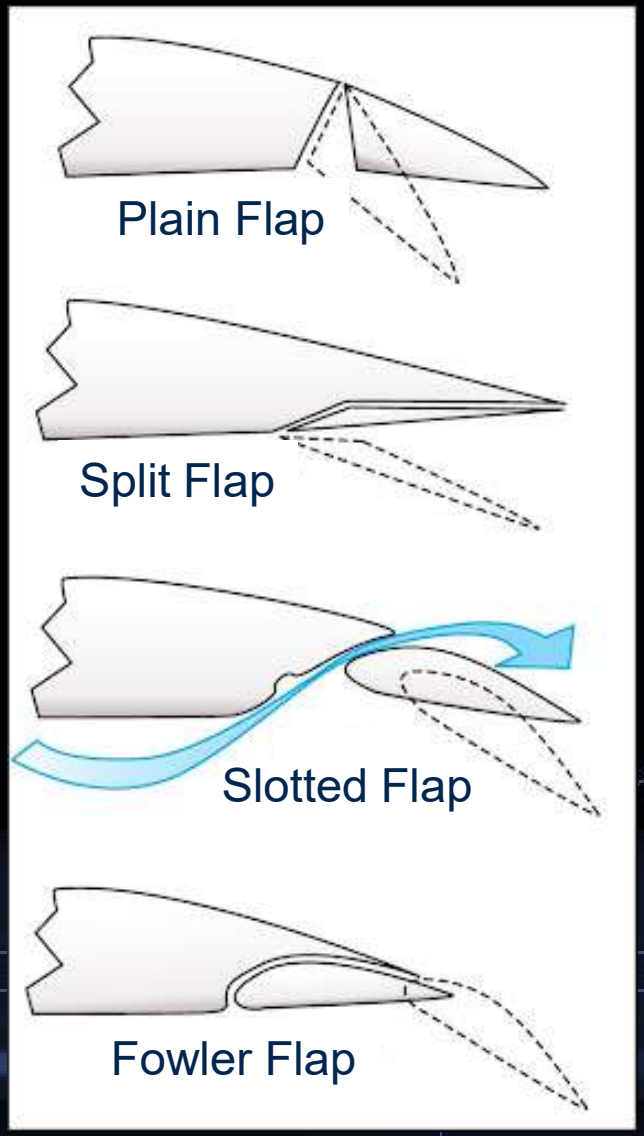
Figure 2

NACA 0015 Lift Curve

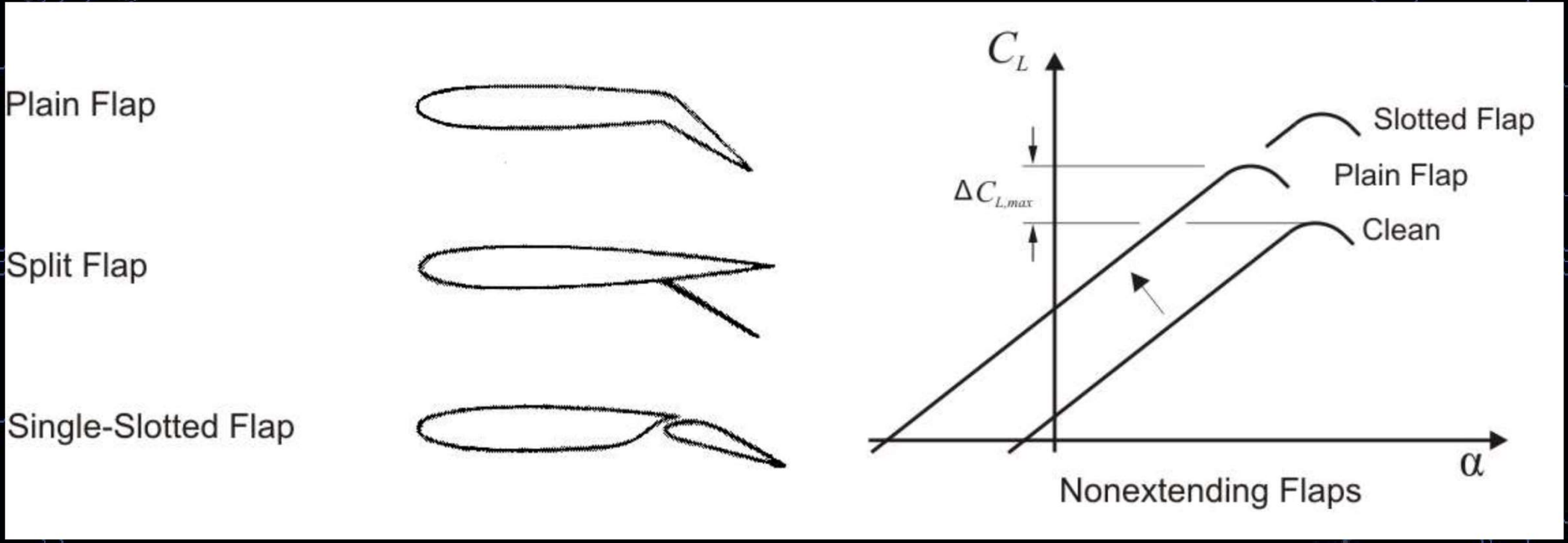


Flaps

Flaps allow for an increase in the angle of decent, without an increase in the rate of decent.



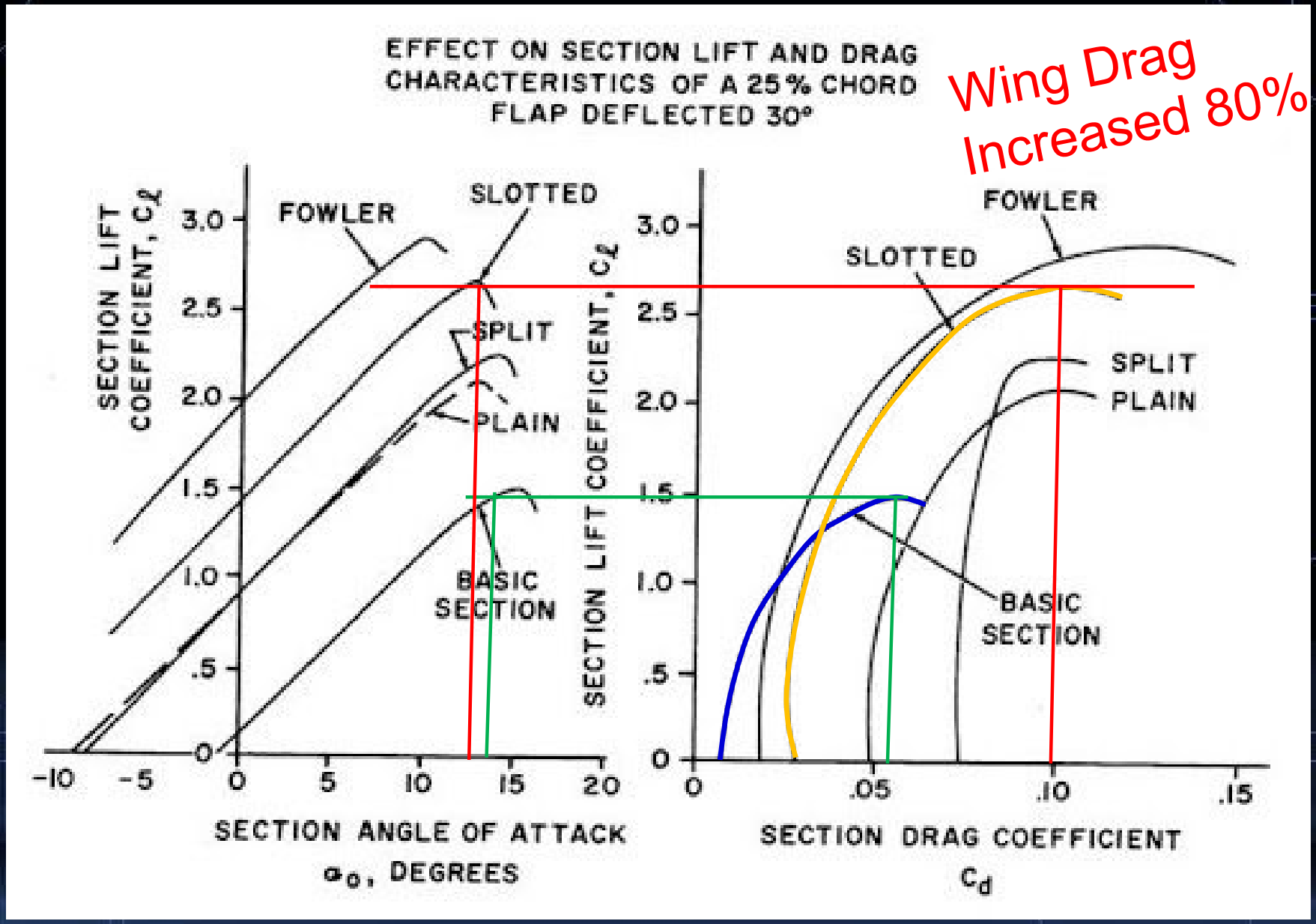
Lift From Flaps



Provides a significant increase in lift …

But also in drag!

Drag from Flaps



	H9 F4U Corsair	FM VOTEC 322	Sr. Telemaster	BT F4U	Actual F4U
Span (in)	86	91	96	82	492
Area (sq in)	1380	1503	1400	1,256	45,216
MAC (in)	16.0	16.5	14.6	15.3	91.9
Length (in)	70	86	69	63	404
Weight (lbs)	31	20	11	20	12,000
Loading (oz/sq ft)	52	31	18	37	611
Cube Load (oz/sq ft^1.5)	17	9	6	12	35
Airfoil	Semi Sym	Symetrical	Flat Bottom	Semi Sym	Semi Sym
Engine (cc)	70	70	70	35	45,884

Votec 332

NACA 0015 Lift in lbs

AoA (deg)	1	2	3	4	4.5	5	6.5	7.5	8	8.5	10	12	14	17
Speed (mph)														
	0.1	**0.2**	**0.3**	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**	**1**	**1.1**	**1.2**	**1.25**	**1.3**
25	1.4	2.9	4.3	5.7	7.2	8.6	10.0	11.5	12.9	14.3	15.8	17.2	17.9	18.7
27	1.7	3.3	5.0	6.7	8.4	10.0	11.7	13.4	15.1	16.7	18.4	20.1	20.9	21.8
30	2.1	4.1	6.2	8.3	10.3	12.4	14.5	16.5	18.6	20.7	22.7	24.8	25.8	26.9
35	2.8	5.6	8.4	11.2	14.1	16.9	19.7	22.5	25.3	28.1	30.9	33.7	35.2	36.6
40	3.7	7.3	11.0	14.7	18.4	22.0	25.7	29.4	33.1	36.7	40.4	44.1	45.9	47.8
45	4.6	9.3	13.9	18.6	23.2	27.9	32.5	37.2	41.8	46.5	51.1	55.8	58.1	60.4
50	5.7	11.5	17.2	23.0	28.7	34.4	40.2	45.9	51.7	57.4	63.1	68.9	71.7	74.6
55	6.9	13.9	20.8	27.8	34.7	41.7	48.6	55.6	62.5	69.4	76.4	83.3	86.8	90.3
60	8.3	16.5	24.8	33.1	41.3	49.6	57.9	66.1	74.4	82.6	90.9	99.2	103.3	107.4
65	9.7	19.4	29.1	38.8	48.5	58.2	67.9	77.6	87.3	97.0	106.7	116.4	121.2	126.1
70	11.2	22.5	33.7	45.0	56.2	67.5	78.7	90.0	101.2	112.5	123.7	135.0	140.6	146.2
75	12.9	25.8	38.7	51.7	64.6	77.5	90.4	103.3	116.2	129.1	142.0	155.0	161.4	167.9
80	14.7	29.4	44.1	58.8	73.5	88.2	102.8	117.5	132.2	146.9	161.6	176.3	183.7	191.0
85	16.6	33.2	49.8	66.3	82.9	99.5	116.1	132.7	149.3	165.9	182.5	199.0	207.3	215.6
90	18.6	37.2	55.8	74.4	93.0	111.6	130.2	148.8	167.4	186.0	204.5	223.1	232.4	241.7

Lift generated in lbs for a given speed and angle of attack

Weight (oz & lbs)	320	20.0					
Wing area (sq in)	1,503		**AoA**	**Total CL**	**Base CL**	**Flap CL**	**Fl Span %**
Takeoff speed (mph)	**38**	Flap 0	5	0.6	0.6	0	0
Cruise speed (mph)	**54**	Flap 0	3	0.3	0.3	0	0
Landing speed (mph)	**26**	Flap 0	17	1.3	1.3	0	0

H9 Corsair

NACA 2415 Lift in lbs

AoA (deg)	-2	-1	0	1	2	3	4	5	6	7	8.5	10	12.5	15
Speed (mph)														
	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1	1.1	1.2	1.3	1.4
25	1.3	2.6	4.0	5.3	6.6	7.9	9.2	10.5	11.9	13.2	14.5	15.8	17.1	18.4
27	1.5	3.1	4.6	6.1	7.7	9.2	10.8	12.3	13.8	15.4	16.9	18.4	20.0	21.5
30	1.9	3.8	5.7	7.6	9.5	11.4	13.3	15.2	17.1	19.0	20.9	22.8	24.7	26.6
35	2.6	5.2	7.7	10.3	12.9	15.5	18.1	20.7	23.2	25.8	28.4	31.0	33.6	36.1
40	3.4	6.7	10.1	13.5	16.9	20.2	23.6	27.0	30.4	33.7	37.1	40.5	43.8	47.2
45	4.3	8.5	12.8	17.1	21.3	25.6	29.9	34.1	38.4	42.7	47.0	51.2	55.5	59.8
50	5.3	10.5	15.8	21.1	26.3	31.6	36.9	42.2	47.4	52.7	58.0	63.2	68.5	73.8
55	6.4	12.8	19.1	25.5	31.9	38.3	44.6	51.0	57.4	63.8	70.1	76.5	82.9	89.3
60	7.6	15.2	22.8	30.4	37.9	45.5	53.1	60.7	68.3	75.9	83.5	91.1	98.6	106.2
65	8.9	17.8	26.7	35.6	44.5	53.4	62.3	71.2	80.2	89.1	98.0	106.9	115.8	124.7
70	10.3	20.7	31.0	41.3	51.6	62.0	72.3	82.6	93.0	103.3	113.6	123.9	134.3	144.6
75	11.9	23.7	35.6	47.4	59.3	71.1	83.0	94.9	106.7	118.6	130.4	142.3	154.1	166.0
80	13.5	27.0	40.5	54.0	67.5	80.9	94.4	107.9	121.4	134.9	148.4	161.9	175.4	188.9
85	15.2	30.5	45.7	60.9	76.1	91.4	106.6	121.8	137.1	152.3	167.5	182.8	198.0	213.2
90	17.1	34.1	51.2	68.3	85.4	102.4	119.5	136.6	153.7	170.7	187.8	204.9	222.0	239.0

Lift generated in lbs for a given speed and angle of attack

Weight (oz & lbs)	496	31.0					
Wing area (sq in)	1,380		**AoA**	**Total CL**	**Base CL**	**Flap CL**	**Fl Span %**
Takeoff speed (mph)	**45**	Flap 0	5	0.8	0.8	0	0
Cruise speed (mph)	**50**	Flap 0	3	0.6	0.6	0	0
Landing speed (mph)	**37**	Flap 0	10	1.2	1.2	0	0
Landing speed (mph)	**31**	Flap 40	10	1.7	1.2	1.0	0.50

Brian Taylor (BT) Corsair

NACA 2415 Lift in lbs

AoA (deg)	-2	-1	0	1	2	3	4	5	6	7	8.5	10	12.5	15
Speed (mph)														
	0.1	**0.2**	**0.3**	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**	**1**	**1.1**	**1.2**	**1.3**	**1.4**
25	1.2	2.4	3.6	4.8	6.0	7.2	8.4	9.6	10.8	12.0	13.2	14.4	15.6	16.8
27	1.4	2.8	4.2	5.6	7.0	8.4	9.8	11.2	12.6	14.0	15.4	16.8	18.2	19.6
30	1.7	3.5	5.2	6.9	8.6	10.4	12.1	13.8	15.5	17.3	19.0	20.7	22.4	24.2
35	2.4	4.7	7.1	9.4	11.8	14.1	16.5	18.8	21.2	23.5	25.9	28.2	30.6	32.9
40	3.1	6.1	9.2	12.3	15.3	18.4	21.5	24.6	27.6	30.7	33.8	36.8	39.9	43.0
45	3.9	7.8	11.7	15.5	19.4	23.3	27.2	31.1	35.0	38.8	42.7	46.6	50.5	54.4
50	4.8	9.6	14.4	19.2	24.0	28.8	33.6	38.4	43.2	48.0	52.8	57.6	62.3	67.1
55	5.8	11.6	17.4	23.2	29.0	34.8	40.6	46.4	52.2	58.0	63.8	69.6	75.4	81.2
60	6.9	13.8	20.7	27.6	34.5	41.4	48.3	55.3	62.2	69.1	76.0	82.9	89.8	96.7
65	8.1	16.2	24.3	32.4	40.5	48.6	56.7	64.8	72.9	81.1	89.2	97.3	105.4	113.5
70	9.4	18.8	28.2	37.6	47.0	56.4	65.8	75.2	84.6	94.0	103.4	112.8	122.2	131.6
75	10.8	21.6	32.4	43.2	54.0	64.7	75.5	86.3	97.1	107.9	118.7	129.5	140.3	151.1
80	12.3	24.6	36.8	49.1	61.4	73.7	85.9	98.2	110.5	122.8	135.1	147.3	159.6	171.9
85	13.9	27.7	41.6	55.4	69.3	83.2	97.0	110.9	124.7	138.6	152.5	166.3	180.2	194.1
90	15.5	31.1	46.6	62.2	77.7	93.2	108.8	124.3	139.9	155.4	170.9	186.5	202.0	217.6

Lift generated in lbs for a given speed and angle of attack

Weight (oz & lbs)	320	20.0					
Wing area (sq in)	1,256		**AoA**	**Total CL**	**Base CL**	**Flap CL**	**Fl Span %**
Takeoff speed (mph)	**38**	Flap 0	5	0.8	0.8	0	0
Cruise speed (mph)	**42**	Flap 0	3	0.6	0.6	0	0
Landing speed (mph)	**31**	Flap 0	10	1.2	1.2	0	0
Landing speed (mph)	**26**	Flap 40	10	1.7	1.2	1.0	0.50

Comparison

Votec 332

Weight (oz & lbs)	320		20.0					
Wing area (sq in)	1,503			**AoA**	**Total CL**	**Base CL**	**Flap CL**	**Fl Span %**
Takeoff speed (mph)	**38**	Flap 0		5	0.6	0.6	0	0
Cruise speed (mph)	**54**	Flap 0		3	0.3	0.3	0	0
Landing speed (mph)	**26**	Flap 0		17	1.3	1.3	0	0

H9 Corsair

Weight (oz & lbs)	496		31.0					
Wing area (sq in)	1,380			**AoA**	**Total CL**	**Base CL**	**Flap CL**	**Fl Span %**
Takeoff speed (mph)	**45**	Flap 0		5	0.8	0.8	0	0
Cruise speed (mph)	**50**	Flap 0		3	0.6	0.6	0	0
Landing speed (mph)	**37**	Flap 0		10	1.2	1.2	0	0
Landing speed (mph)	**31**	Flap 40		10	1.7	1.2	1.0	0.50

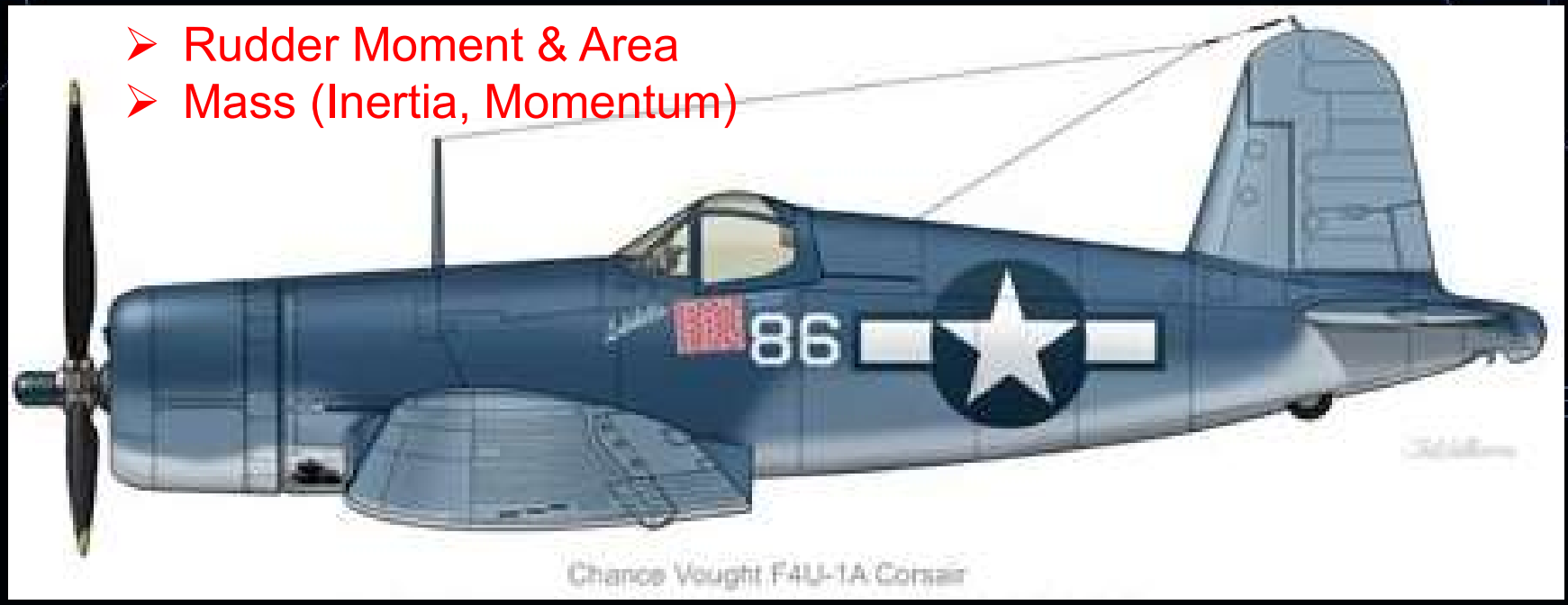
BT Corsair

Weight (oz & lbs)	320		20.0					
Wing area (sq in)	1,256			**AoA**	**Total CL**	**Base CL**	**Flap CL**	**Fl Span %**
Takeoff speed (mph)	**38**	Flap 0		5	0.8	0.8	0	0
Cruise speed (mph)	**42**	Flap 0		3	0.6	0.6	0	0
Landing speed (mph)	**31**	Flap 0		10	1.2	1.2	0	0
Landing speed (mph)	**26**	Flap 40		10	1.7	1.2	1.0	0.50

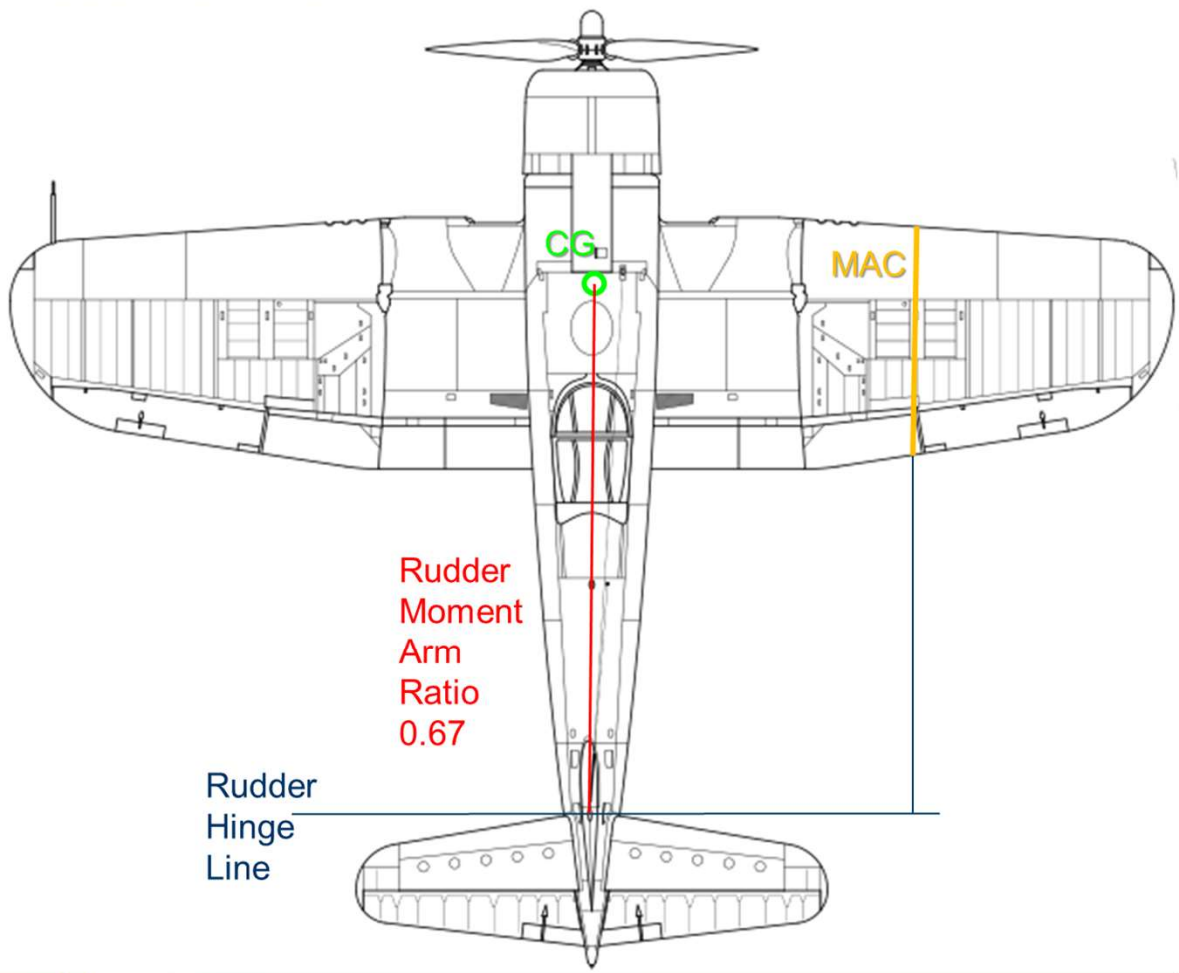
H9 Corsair ~18% Faster Landing

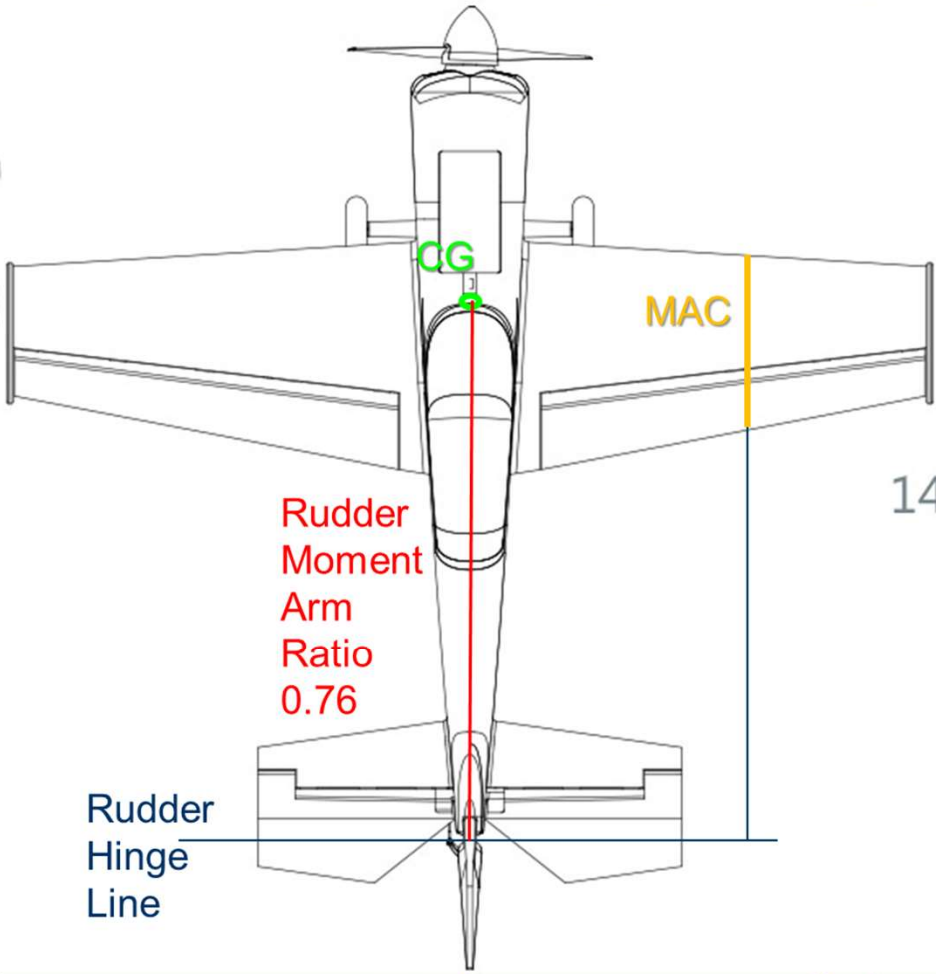
Yaw Control

- Rudder Moment & Area
- Mass (Inertia, Momentum)



Chance Vought F4U-1A Corsair


CG
MAC
Rudder
Moment
Arm
Ratio
0.67
Rudder
Hinge
Line


CG
MAC
Rudder
Moment
Arm
Ratio
0.76
Rudder
Hinge
Line

Turning Tendency On The Runway

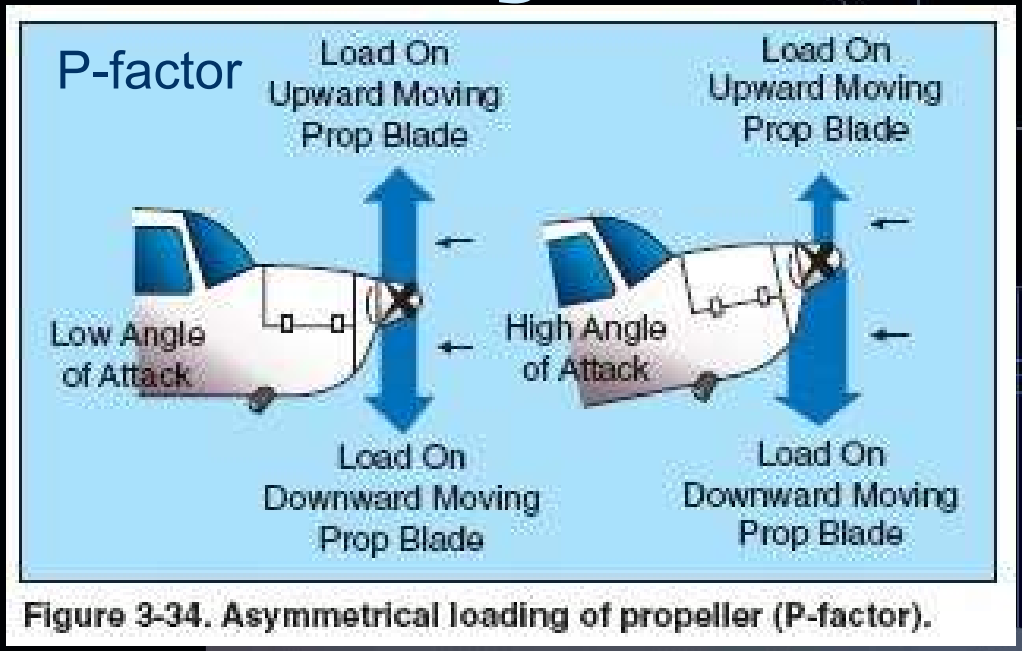
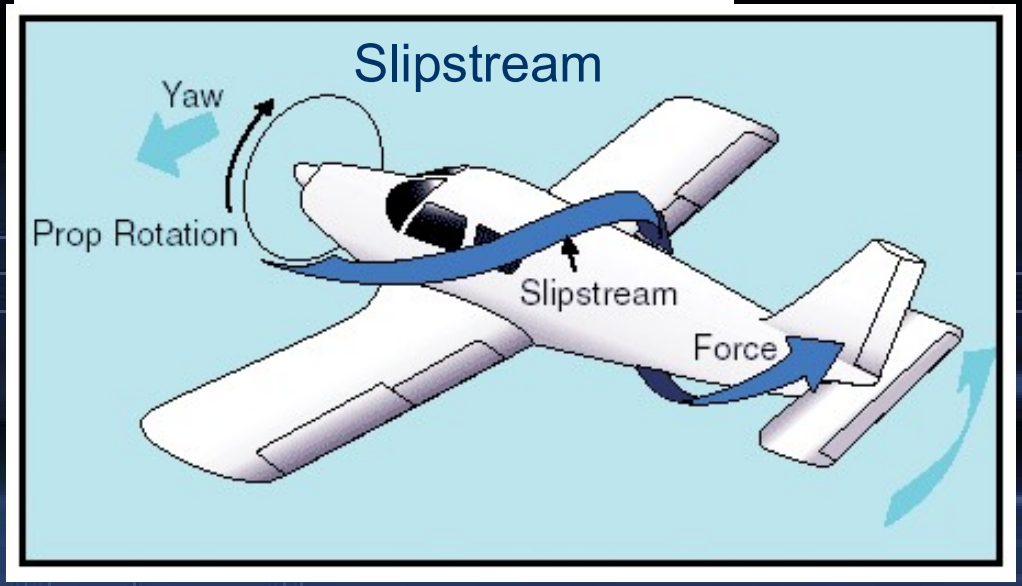
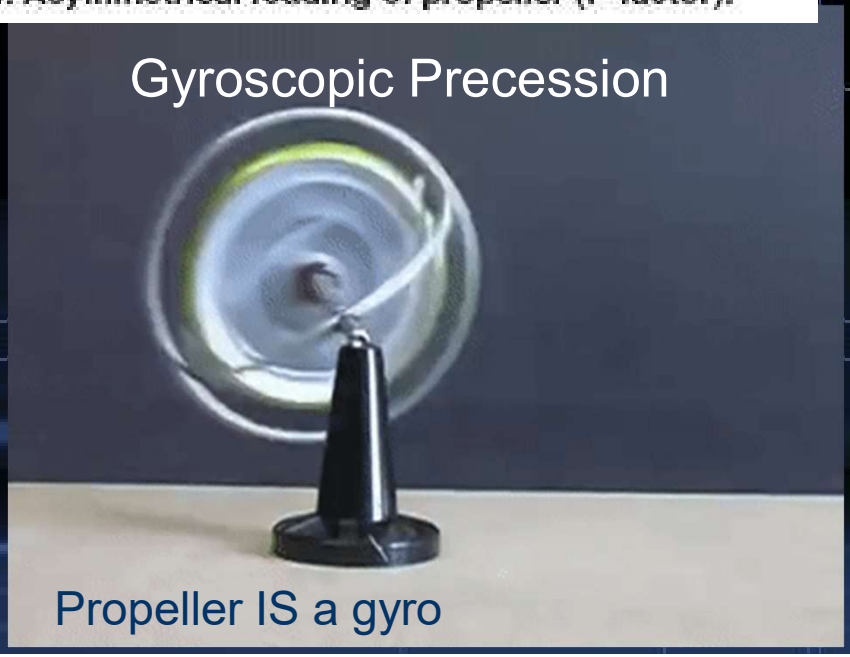


Figure 3-34. Asymmetrical loading of propeller (P-factor).





Warbird Flying Summary

- Wing loading leads to higher takeoff speeds and longer roll
- Lower power to weight means lower acceleration
- Wing loading that leads to higher landing speeds
- High drag flaps require more throttle management
- Steering impacts
  - Higher weights affect inertia and momentum
  - Shorter moment arms and less effective rudder
  - Turning tendencies
- Generally, on acro and sport planes …
  - Takeoff: gun the engine …they'll get airborne.
    Warbirds on the runway longer and at higher speeds demanding more from the pilot.
  - Landing: high AOA is A-OK, and 3' drop = wounded pride
    Warbird don't like high AOA and 3' drop = wing damage.

Tail Sizing

H-stab and V-stab Areas Based On

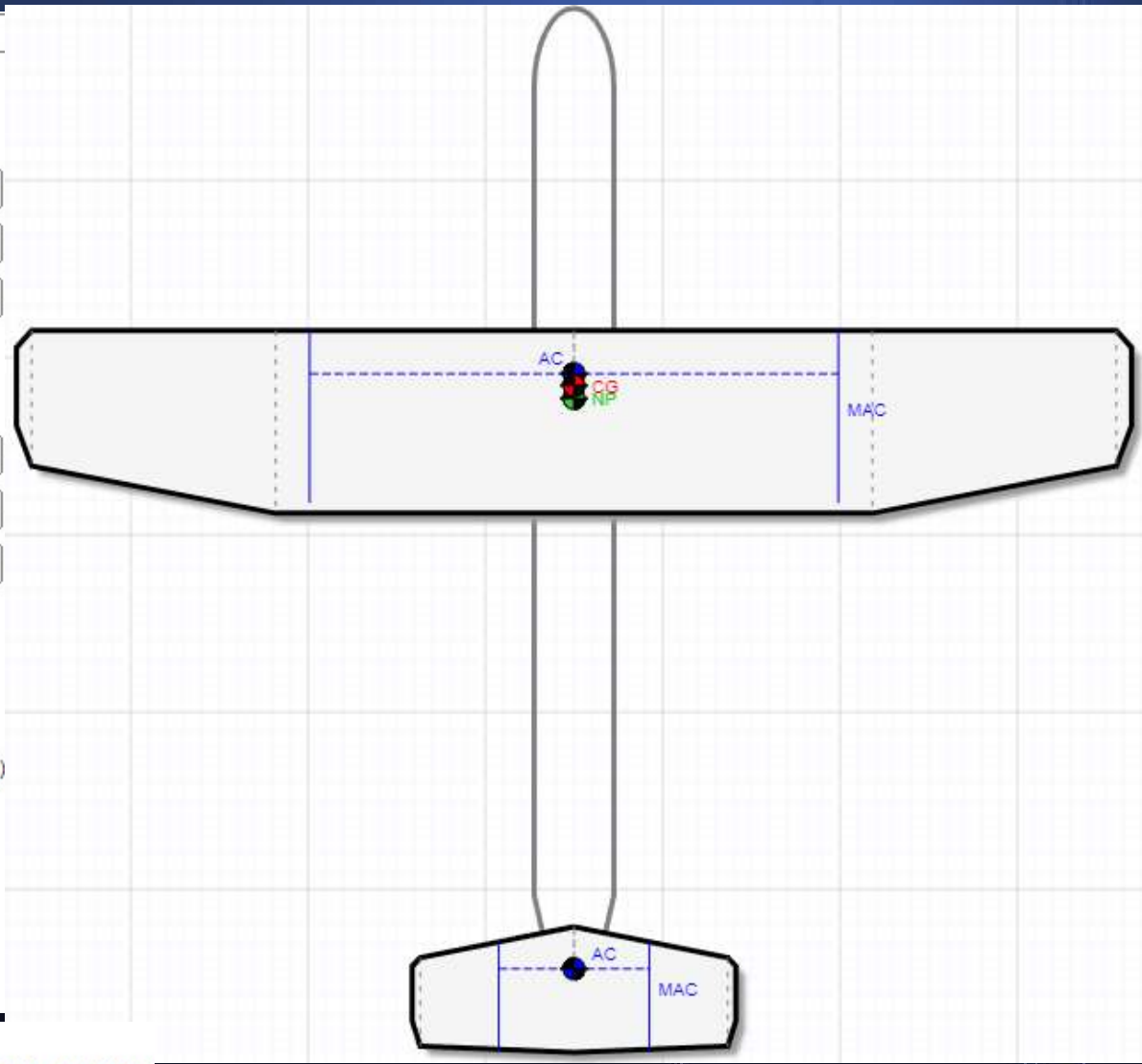
- MAC - Average Wing Chord
- Wing Area (WA)
- Tail Moment Arm (TMA)
- Constant (C) for airfoil section type
  (symmetrical/semi-sym: 0.52, flat bottom: 0.57, under camber: 0.60)

Uh … WHY?

Area = C x MAC x WA / TMA

eCalc

Aircraft or Project Name:	Fenix 042F				
Wing:	Monoplane				
Root Chord [R]:	334.7 mm				
Tip Chord [T1-T5]:	334.7	248.3	142.8	0	
Sweep [S1 - S5]:	0	0	31.4	0	
Panel Span [W1 - W5]:	546.2	446.60	27.80	0	
Tail:	std. Stabilizer (80%) (Tail Effectivness)				
Root Chord [R]:	230 mm				
Tip Chord [T1-T5]:	162	101	0	0	
Sweep [S1 - S5]:	56.6	72	0	0	
Panel Span [W1 - W5]:	281.6	14.5	0	0	
Distance LE Wing to Tail [D]:	1092 mm (use negative value for canard)				
AC Position:	25 % of MAC (default: 25%)				
Static Margin:	12.5 ... 7.5 % of MAC (recommended: **12.5...5%**)				
Fuselage:	Airliner				
Width:	146 mm				
Length:	1881 mm				
Nose Overhang:	590 mm				



Results: Link to recall Fenix 042F

Aircraft CG range [•]: **85.00 ... 100.78** mm (@ 26.85 ... 31.85% of MAC)

Aircraft NP [•]: 124.45 mm (@ 39.35% of MAC)

Wing AC [•]:	79.15 mm (@ 25% of MAC)	Tail AC [•]:	76.86 mm (@ 25% of MAC)
Wing MAC @ Distance	315.62 mm @ 484.03 mm	Tail MAC @ Distance	195.83 mm @ 137.86 mm
Wing Sweep @ MAC:	0.24 mm	Tail Sweep @ MAC:	27.90 mm
Wing Span:	2041.20 mm	Tail Span:	592.20 mm
Wing Area:	**636866.66** mm²	Tail Area:	**114200.70** mm²
Wing Aspect Ratio:	6.54	Tail Aspect Ratio:	3.07
Fuselage influence:	-16.69mm (= -5.29% of MAC)	Stabilizer Volume (V_{bar}):	0.62

End of Part 2

Questions?