An introduction to Tailless RC Sailplanes

Bill Kuhlman

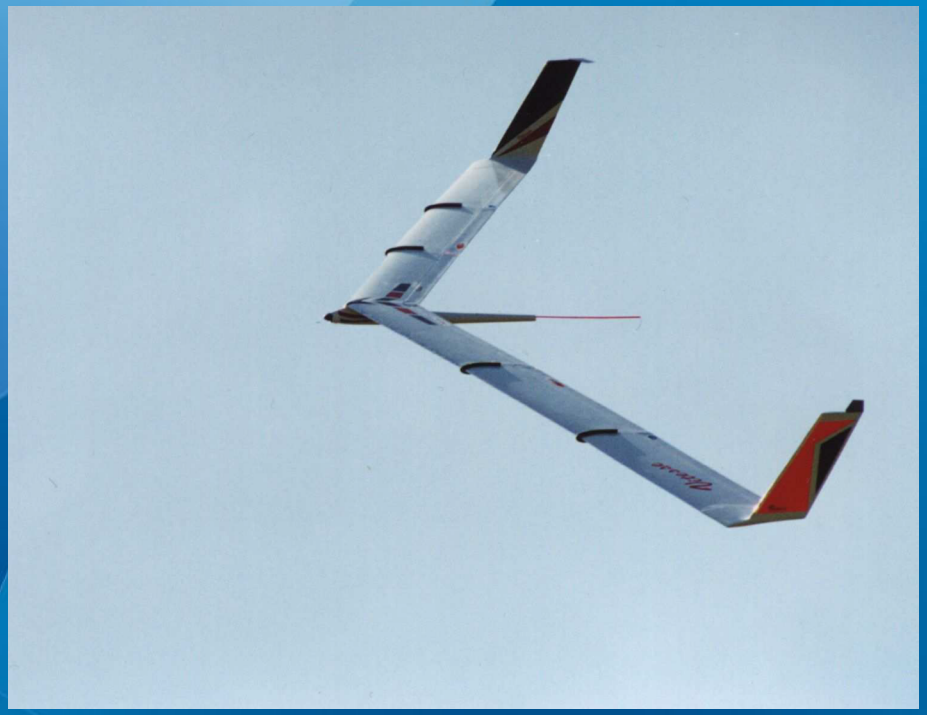
An introduction to Tailless RC Sailplanes

Part 1: Planks

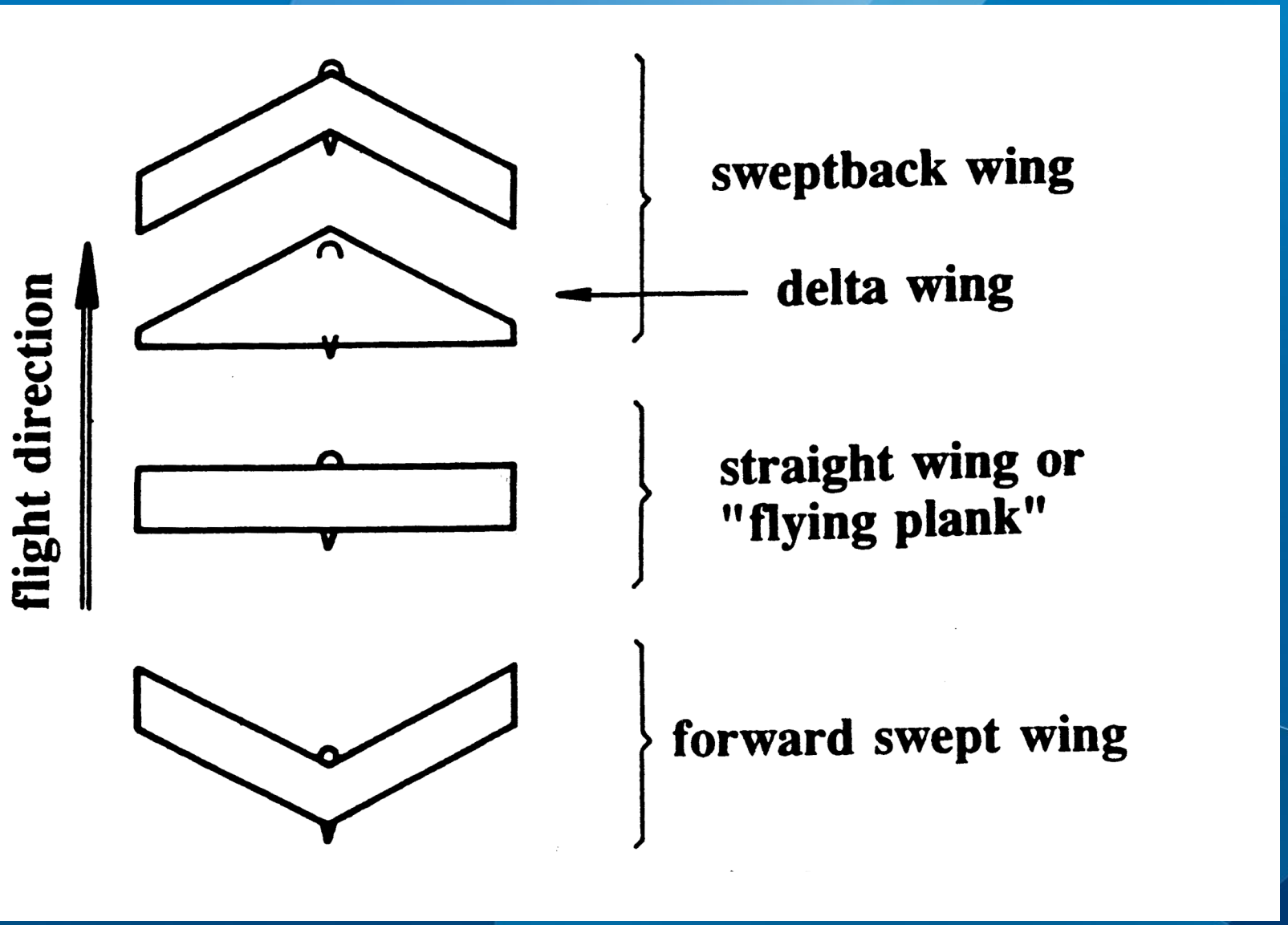
Part 2: Swept wings

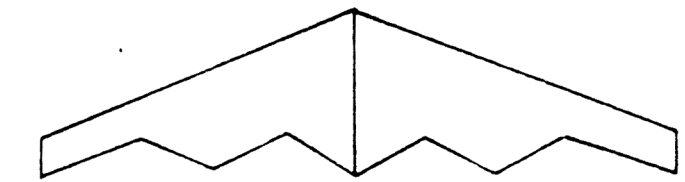


Bill with (L) an R-2 and (R) a highly modified Raven MB. The R-2 spans 100”, the Raven 110”. Both of these are considered to be plank planforms.

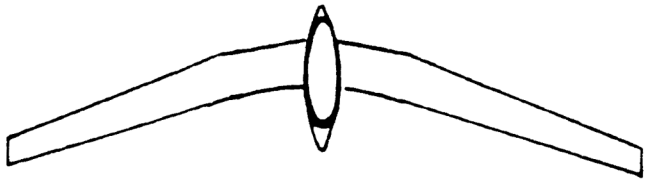


The Vitesse, a sophisticated swept wing designed and built by Dave Camp and Glyn Fonteneau. Span is 134”, and features compound winglets.

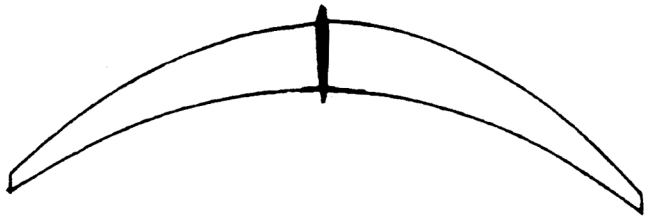

flight direction
sweptback wing
delta wing
straight wing or
"flying plank"
forward swept wing



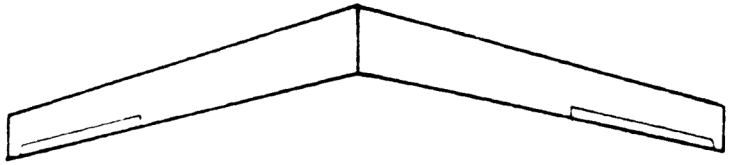
B-2



SB-13



Crescent wing



Flying Rainbow

Part 2: Swept Wings

- Section 1: Notes on Swept Wings
- Section 2: Obtaining Pitch Stability
- Section 3: Yaw-Roll Interaction & Effective Dihedral
- Section 4: Example Models
- Section 5: Appendix

Part 2: Swept Wings

- Section 1: Notes on Swept Wings

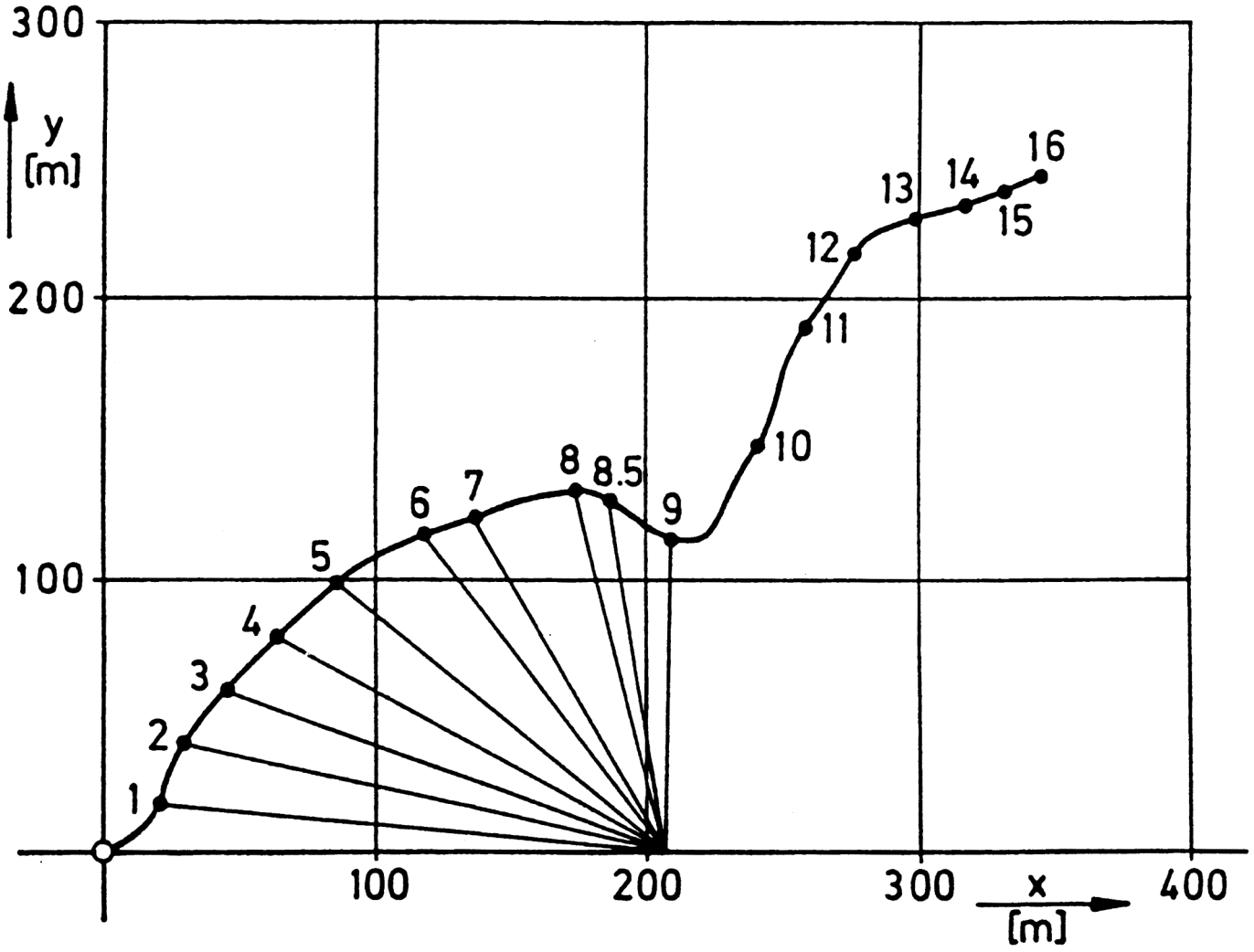
Disadvantages

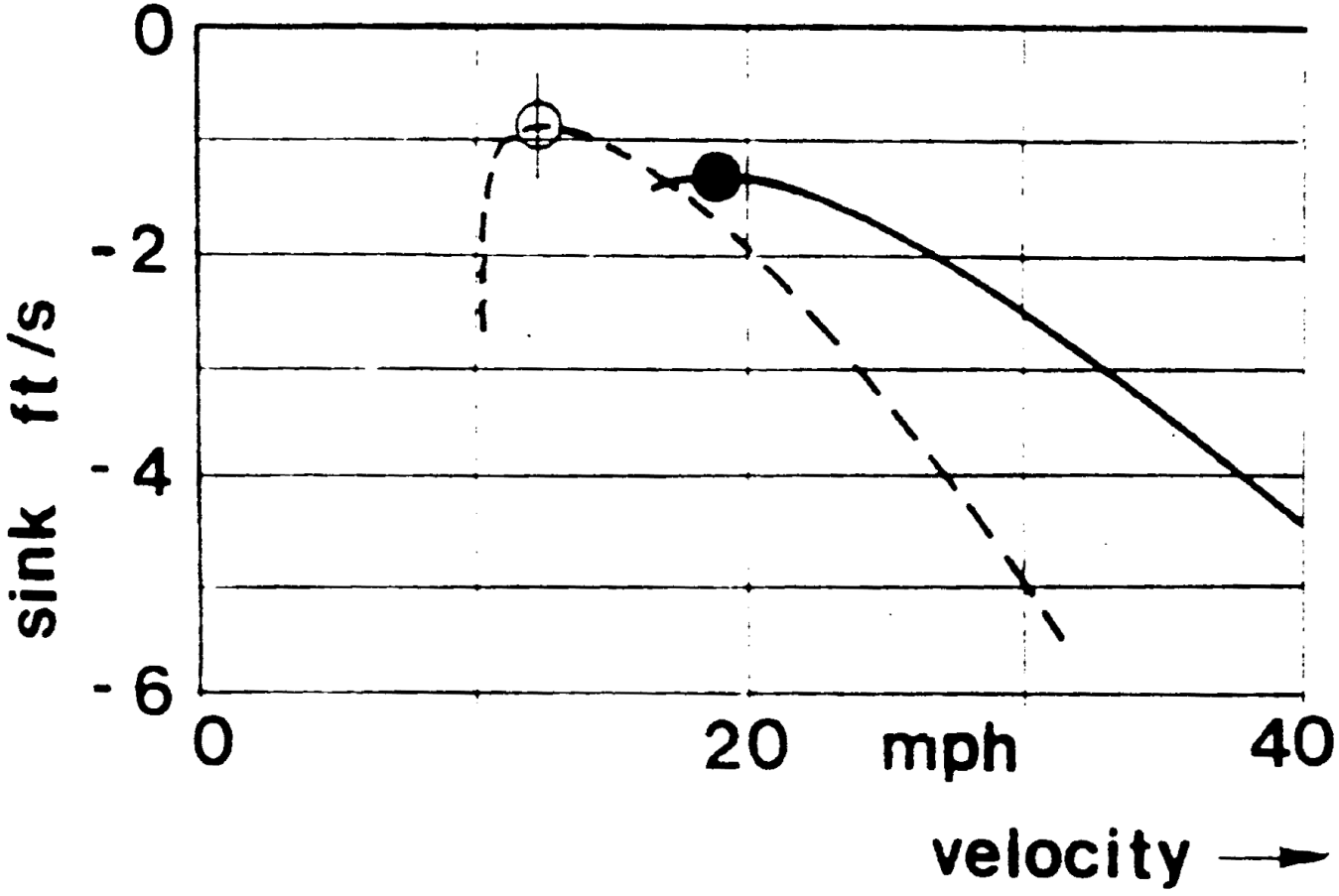
- Low C_{Lmax} (Small maximum lift)

  Lower launch launch height

  and

  Lower flight duration


300
y
[m]
200
100
100
200
300
x
[m]
400
1
2
3
4
5
6
7
8
8.5
9
10
11
12
13
14
15
16

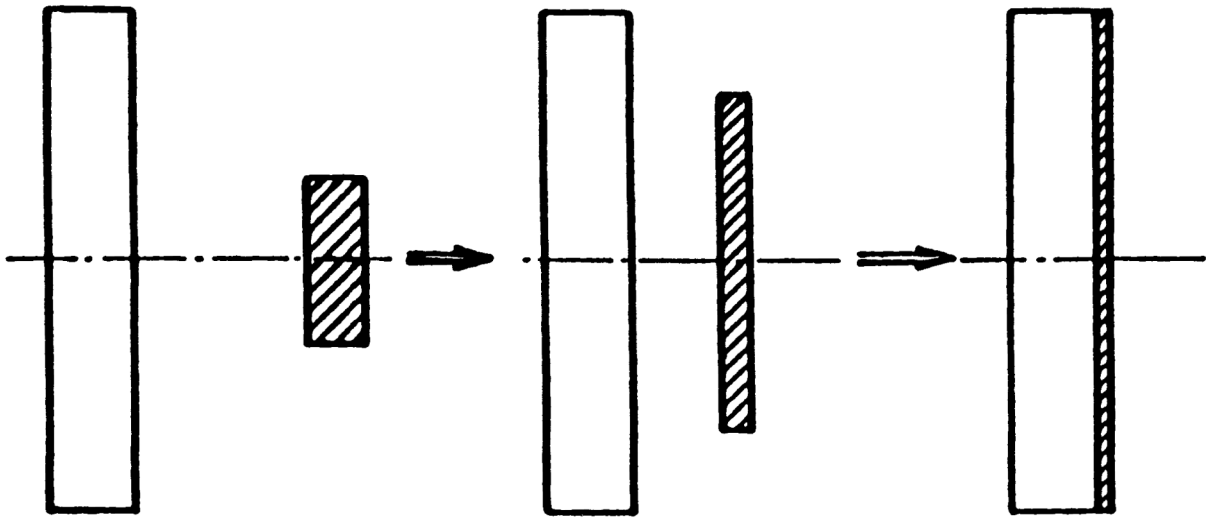

0
-2
-4
-6
sink ft/s
0
20
mph
40
velocity

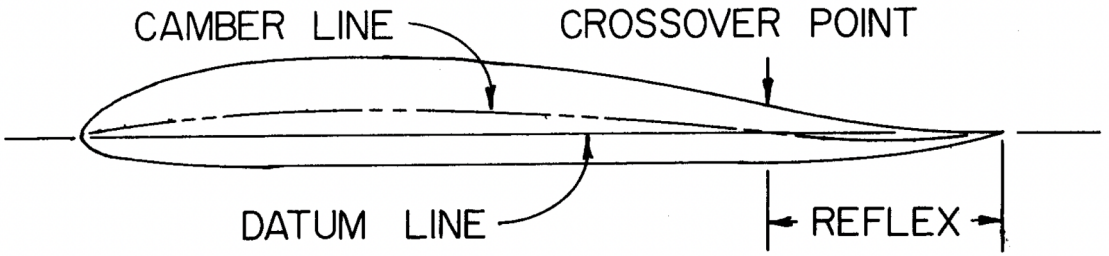
Advantages

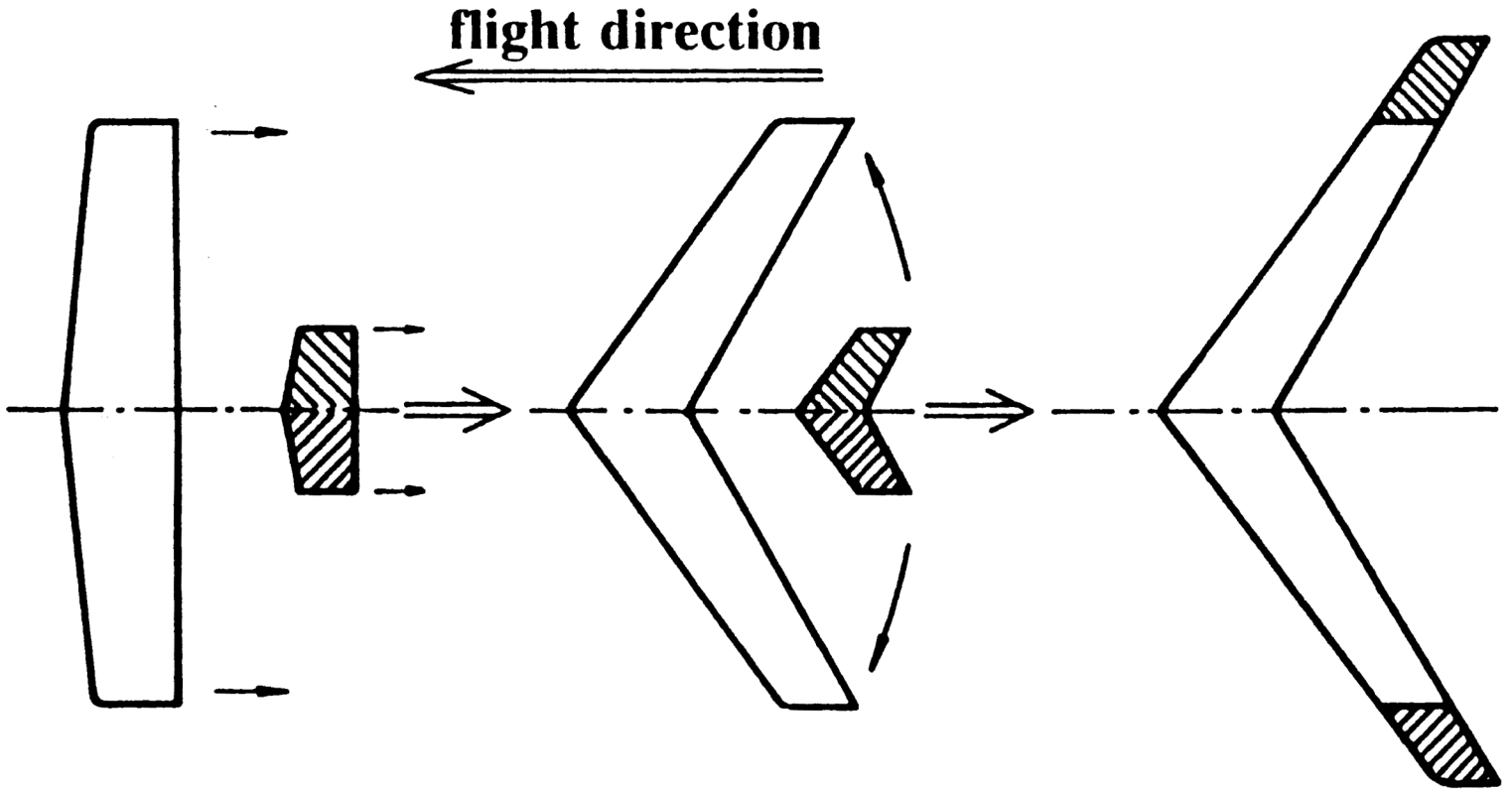
- Lower weight
- Better thermalling ability
- Consistent handling regardless of C_L

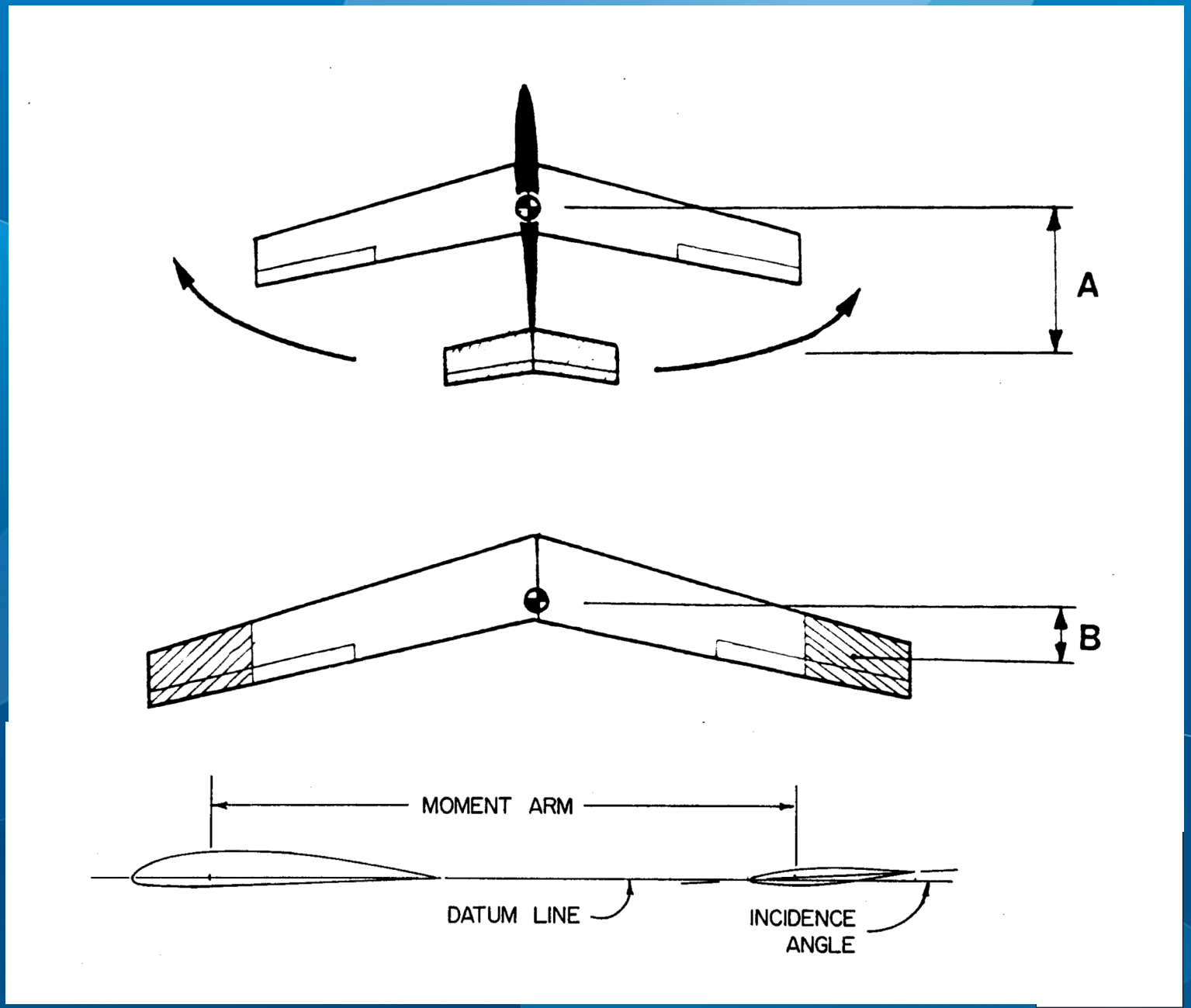
Part 2: Swept Wings

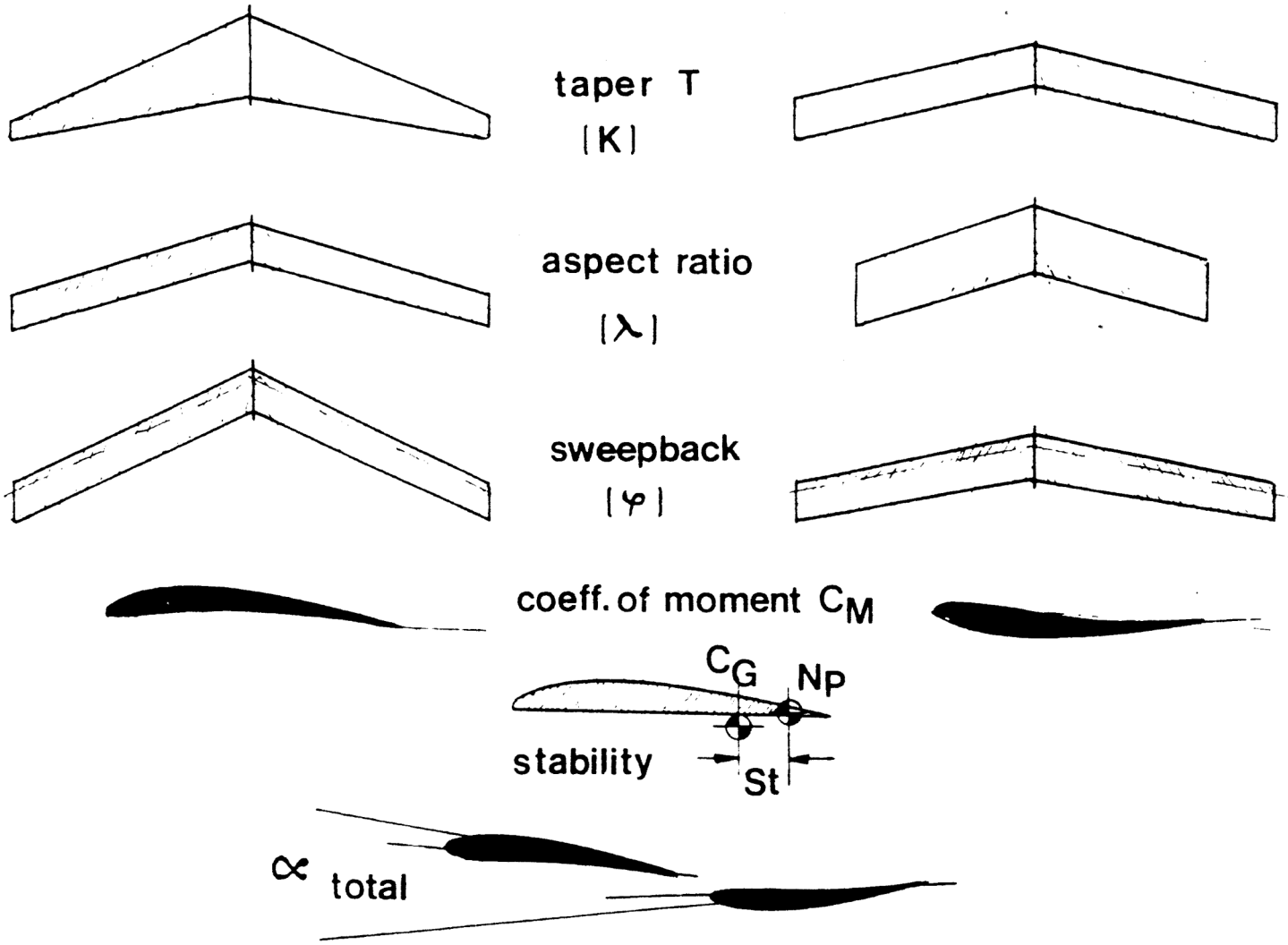
- Section 2: Obtaining Pitch Stability




CAMBER LINE
CROSSOVER POINT
DATUM LINE
REFLEX


flight direction


A
B
MOMENT ARM
DATUM LINE
INCIDENCE
ANGLE


taper T
[K]
aspect ratio
[λ]
sweepback
[φ]
coeff. of moment C_M
C_G
Np
stability
St
∝ total

$$\alpha_{total} = \frac{\left(K_1 \cdot C_{M_i} + K_2 \cdot C_{M_a}\right) - \tilde{C}_L \cdot St}{1.4 \cdot 10^{-5} \cdot \lambda^{1.43} \cdot \varphi}$$

$$\alpha_{geo} = \alpha_{total} - \left(\alpha_{o_{root}} - \alpha_{o_{tip}}\right)$$

Helmut Schenk's MAGIC FORMULA

b = wingspan
t_i = root chord
t_a = tip chord
λ = aspect ratio b/t_m
φ = angle of sweepback
(measured at 25 % - line)
C_{M_i} = coefficient of moment (root)
C_{M_a} = coefficient of moment (tip)
$\tilde{C}_L$ = coefficient of lift (overall value)
St = stability value

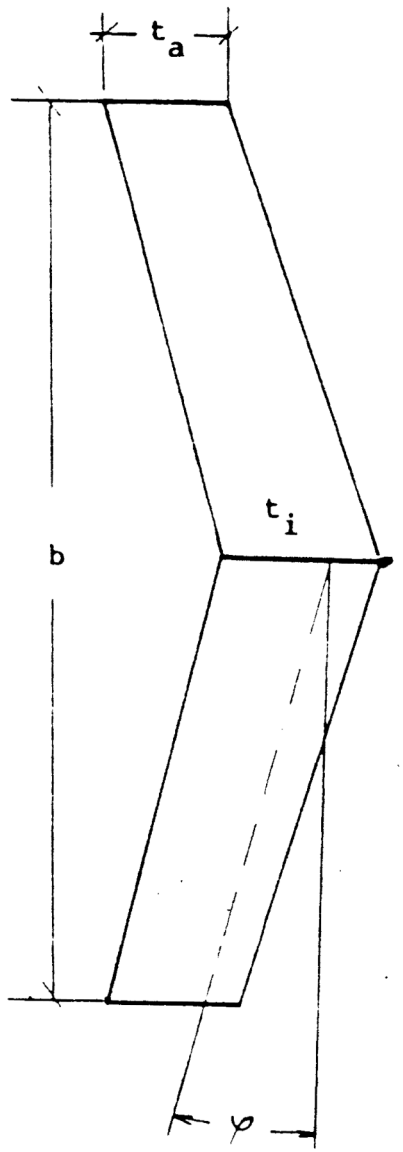
$\tau = t_a/t_i$ (taper ratio)

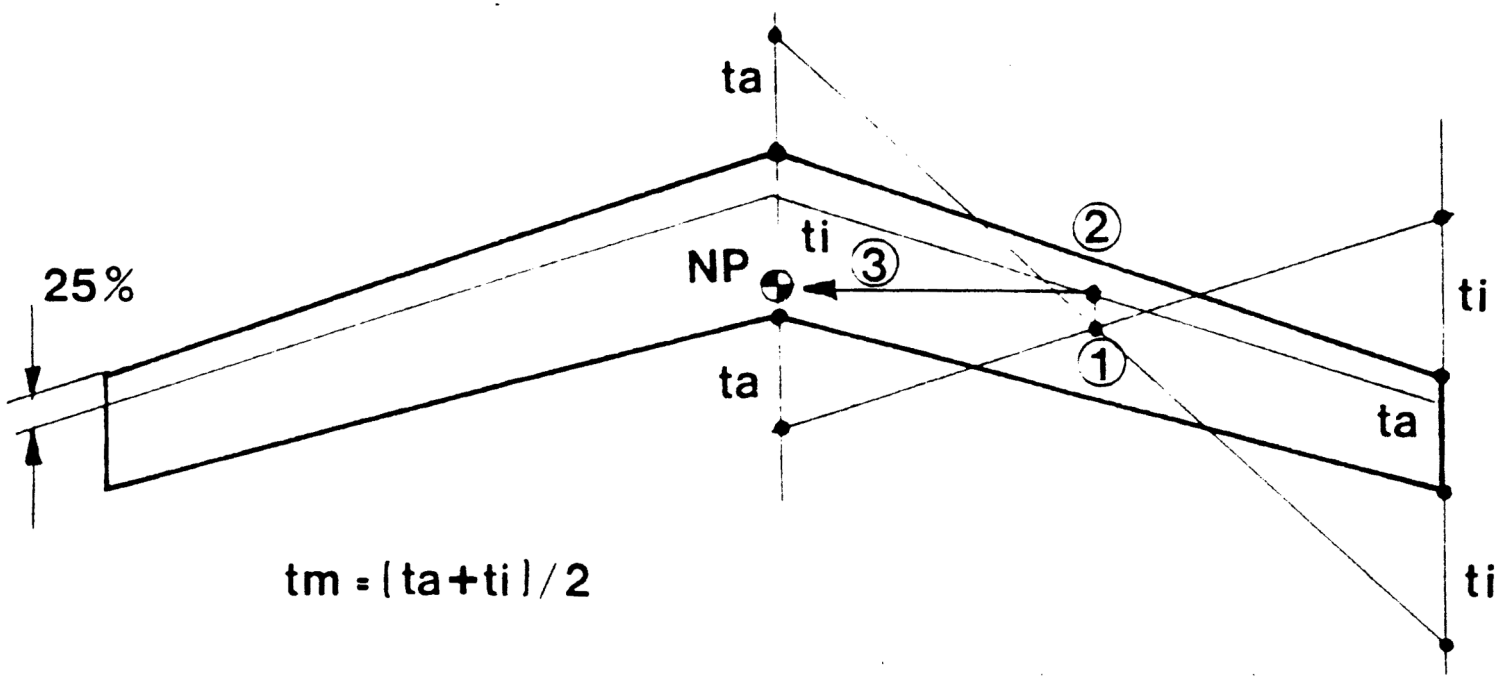
$t_m = (t_a + t_i)/2$ (average chord)

$K_1 = 1/4 * (3 + 2\tau + \tau^2)/(1 + \tau + \tau^2)$

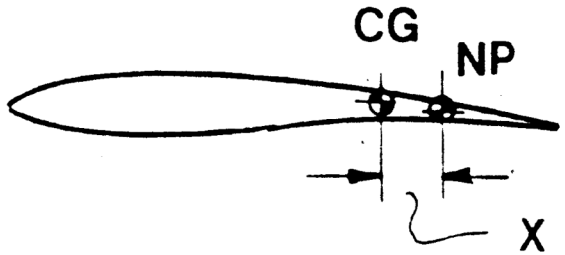
$K_2 = 1 - K_1$

K_1; K_2 are factors derived by Schenk and depend on taper ratio



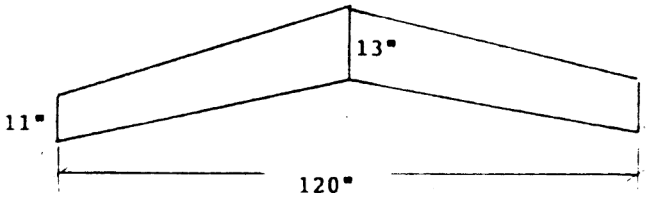


$tm = [ta + ti] / 2$



$X = 0.05 \cdot tm$

$X = ST \cdot tm$



chosen values

$b = 120$

$t_i = 13$

$t_a = 11$

$\varphi = 17$ deg

airfoils:

root: E 222

$\alpha_o = -3.65$ $\quad C_{M_i} = -0.097$

tip : E 230

$\alpha_o = +1.73$ $\quad C_{M_a} = +0.053$

assumed values

$\tilde{C}_L = 0.6$ (C of lift)

St = 0.05 (Stability)

calculated values

$\bar{\tau} = 11/13 = 0.85$

$t_m = (13+11)/2 = 12$

$\lambda = 120/12 = 10$

Total and geometric twist:

$$K_1 = \frac{1 * (3 + 2*0.85 + 0.85^2)}{4 * (1 + 0.85 + 0.85^2)}$$

$K_1 = 0.52$

$K_2 = 0.48$

$$\alpha_{total} = \frac{(0.52*(-0.097)+0.48*(0.053)) - 0.6*0.05}{1.4 * 10^{-5} * 10^{1.43} * 17}$$

$$= \frac{-0.050 + 0.025 - 0.03}{1.4 * 10^{-5} * 27 * 17}$$

$$= \frac{-0.055 * 10^5}{643}$$

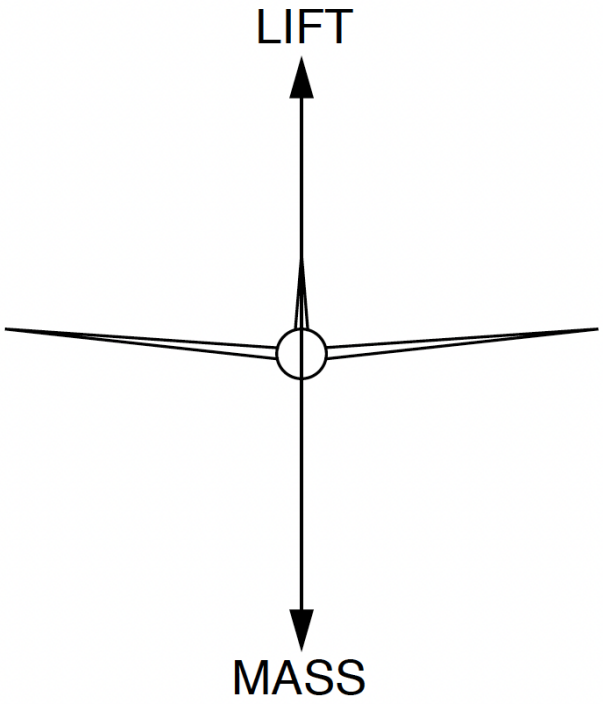
$\alpha_{total} = -8.6$ deg

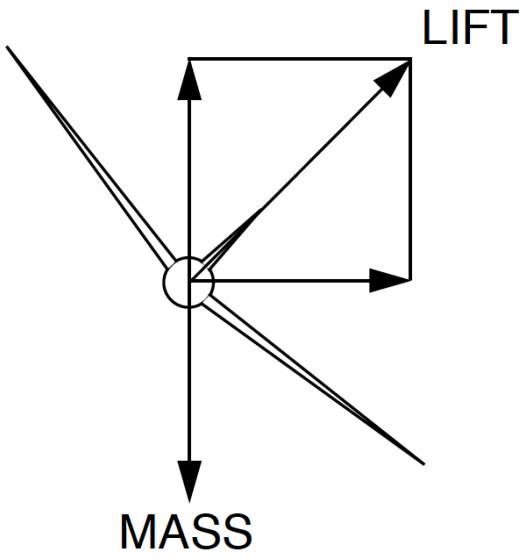
$\alpha_{geo} = -8.6 - (-3.65 - 1.73)$

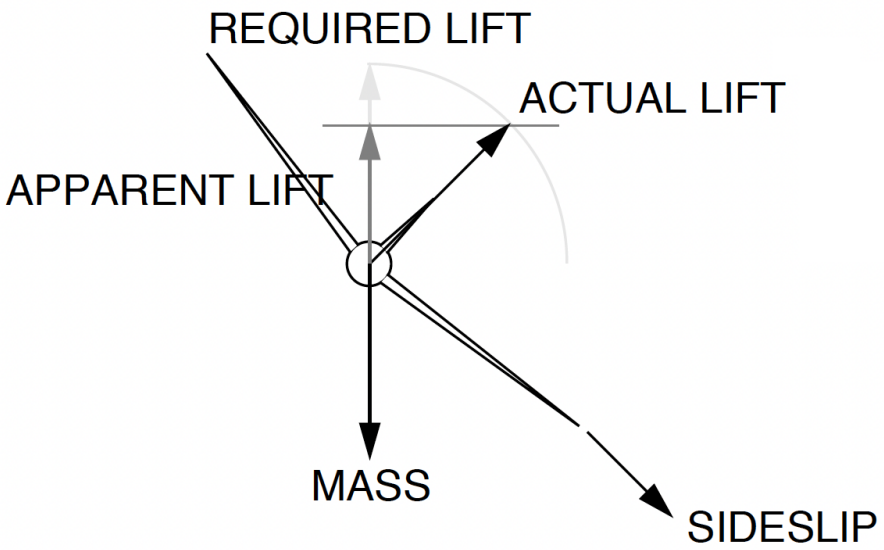
$\alpha_{geo} = -3$ deg

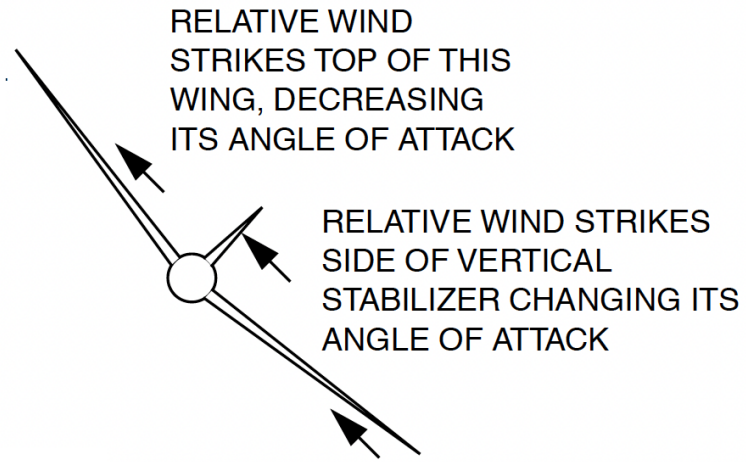
Part 2: Swept Wings

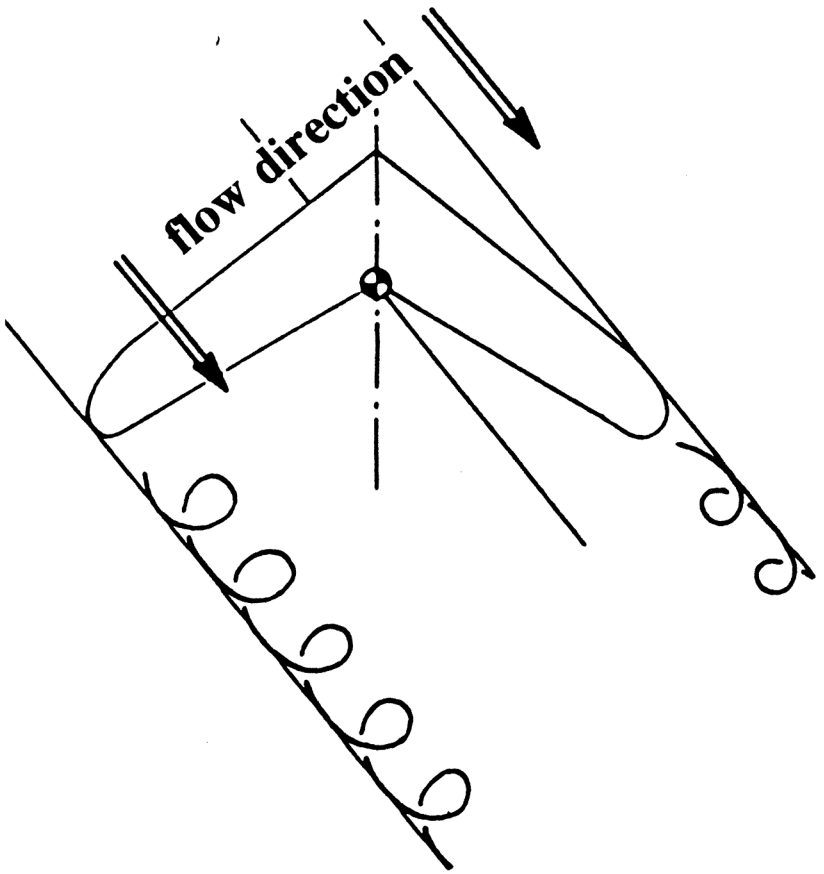
- Section 3: Effective Dihedral

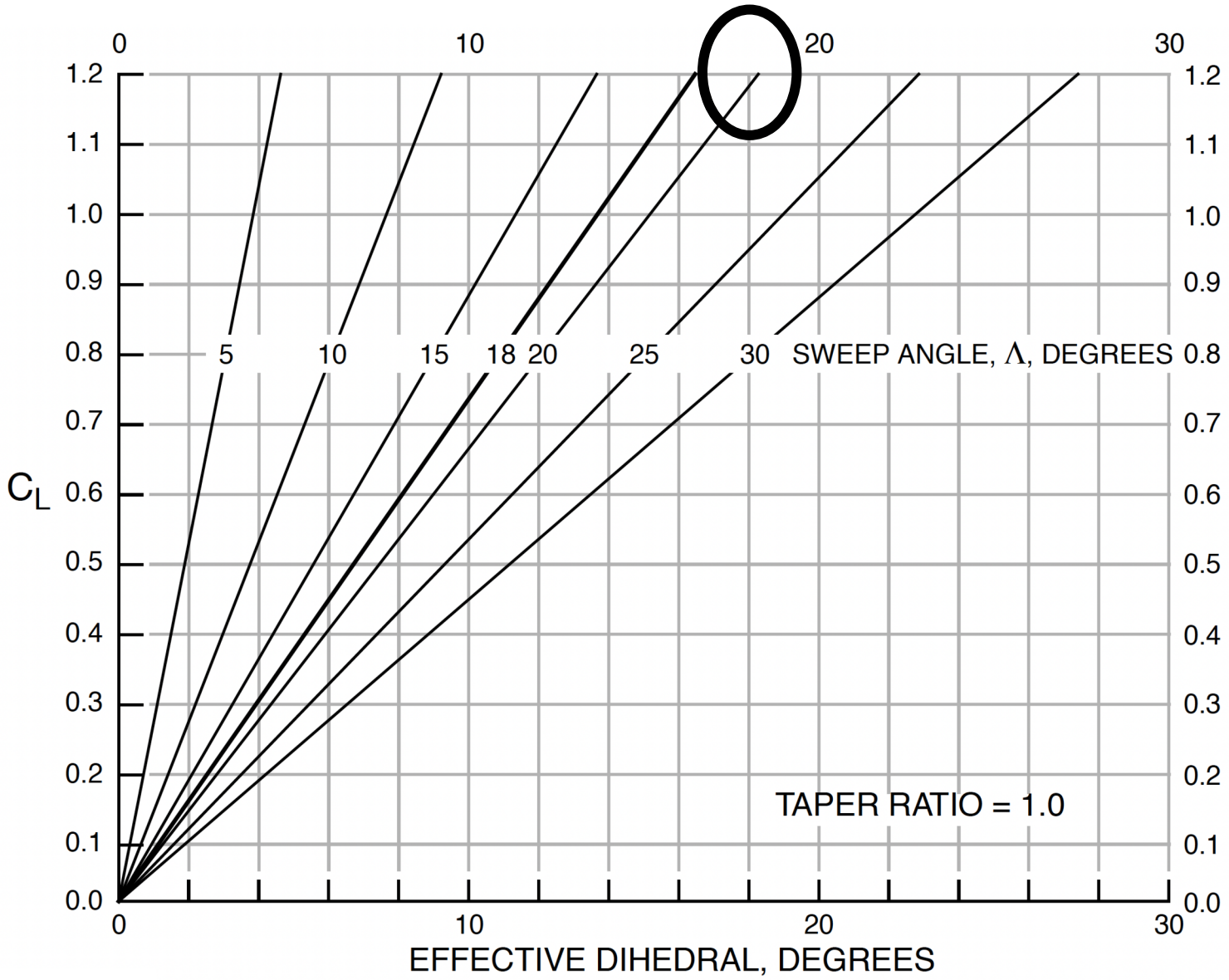

LIFT
MASS

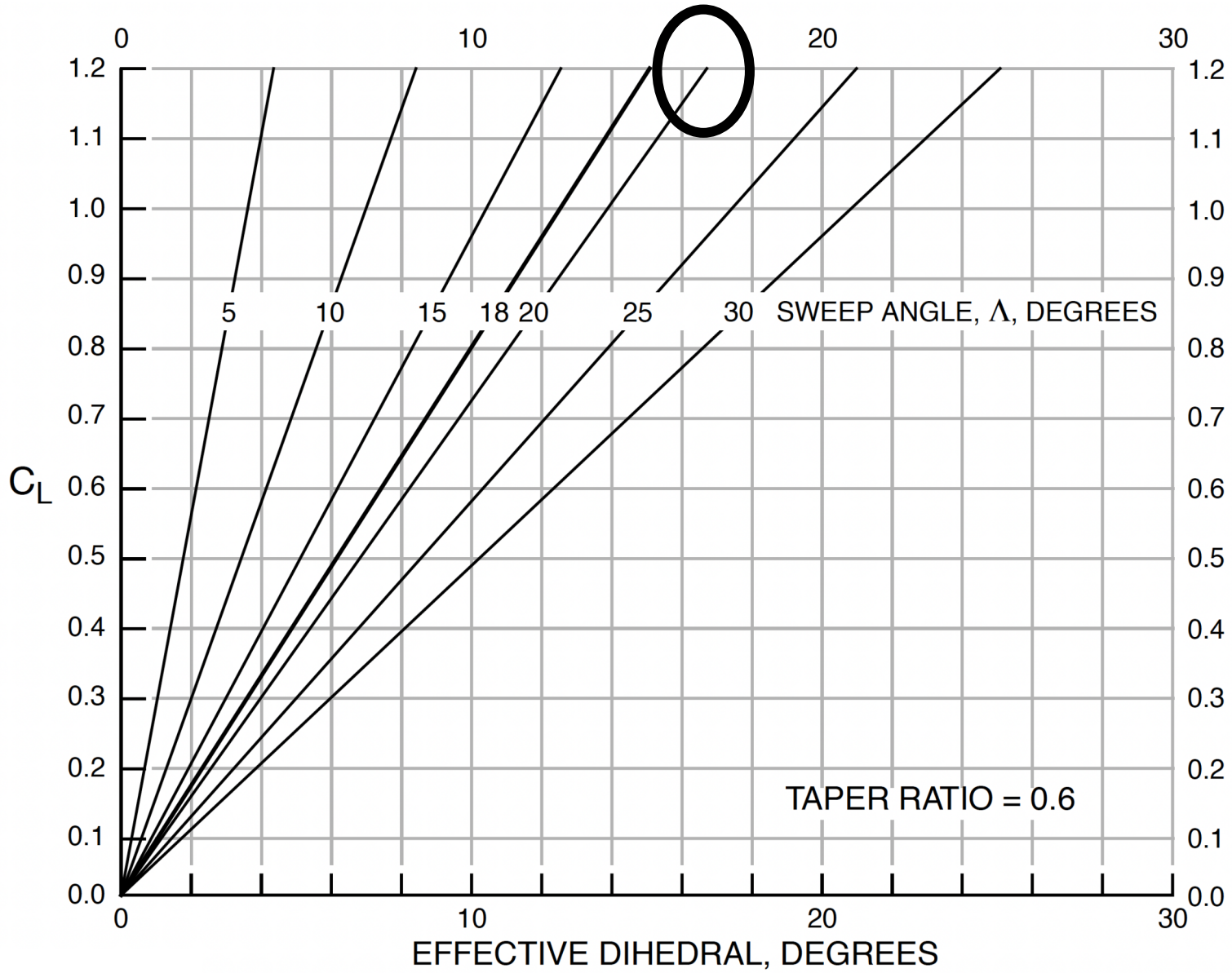

LIFT
MASS

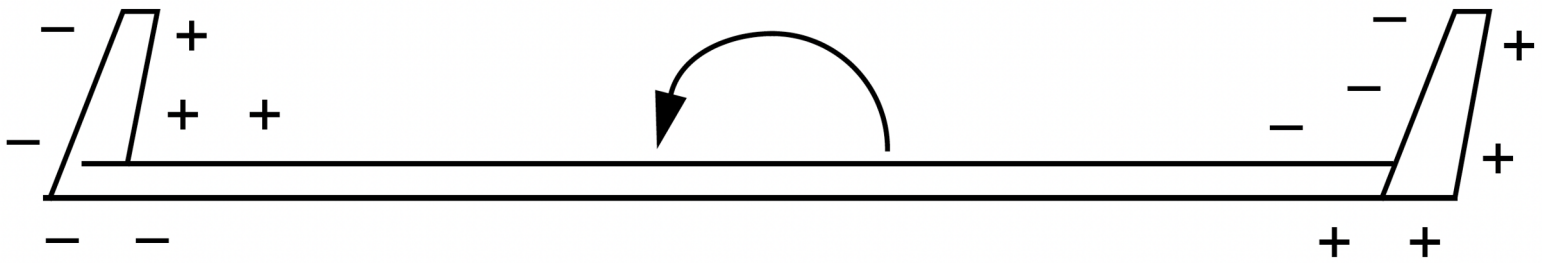

REQUIRED LIFT
ACTUAL LIFT
APPARENT LIFT
MASS
SIDESLIP


RELATIVE WIND
STRIKES TOP OF THIS
WING, DECREASING
ITS ANGLE OF ATTACK
RELATIVE WIND STRIKES
SIDE OF VERTICAL
STABILIZER CHANGING ITS
ANGLE OF ATTACK
RELATIVE WIND STRIKES BOTTOM
OF THIS WING, INCREASING ITS
ANGLE OF ATTACK


flow direction

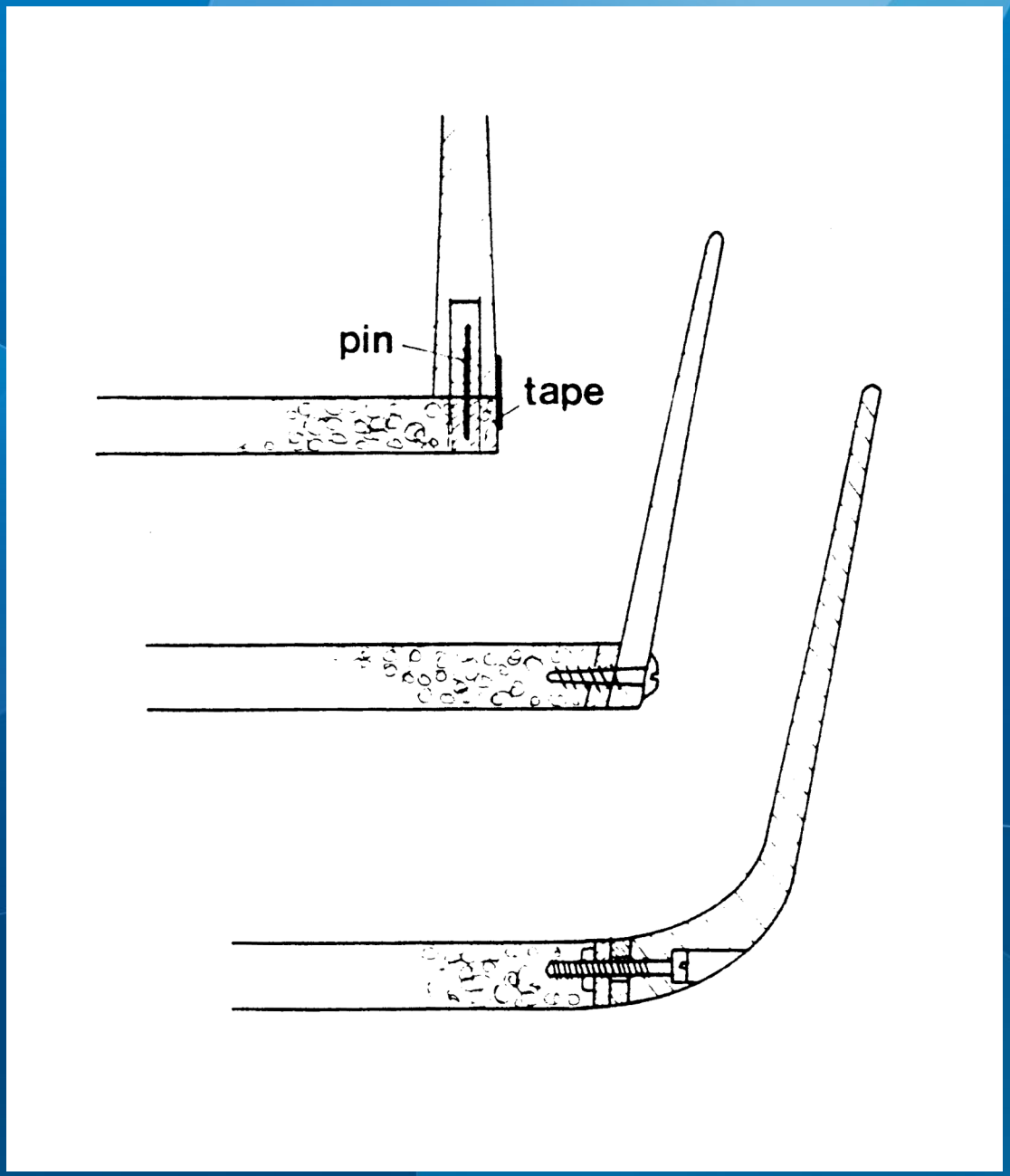

0
10
20
30
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
5
10
15
18
20
25
30
SWEEP ANGLE, Λ, DEGREES
C_L
TAPER RATIO = 1.0
EFFECTIVE DIHEDRAL, DEGREES

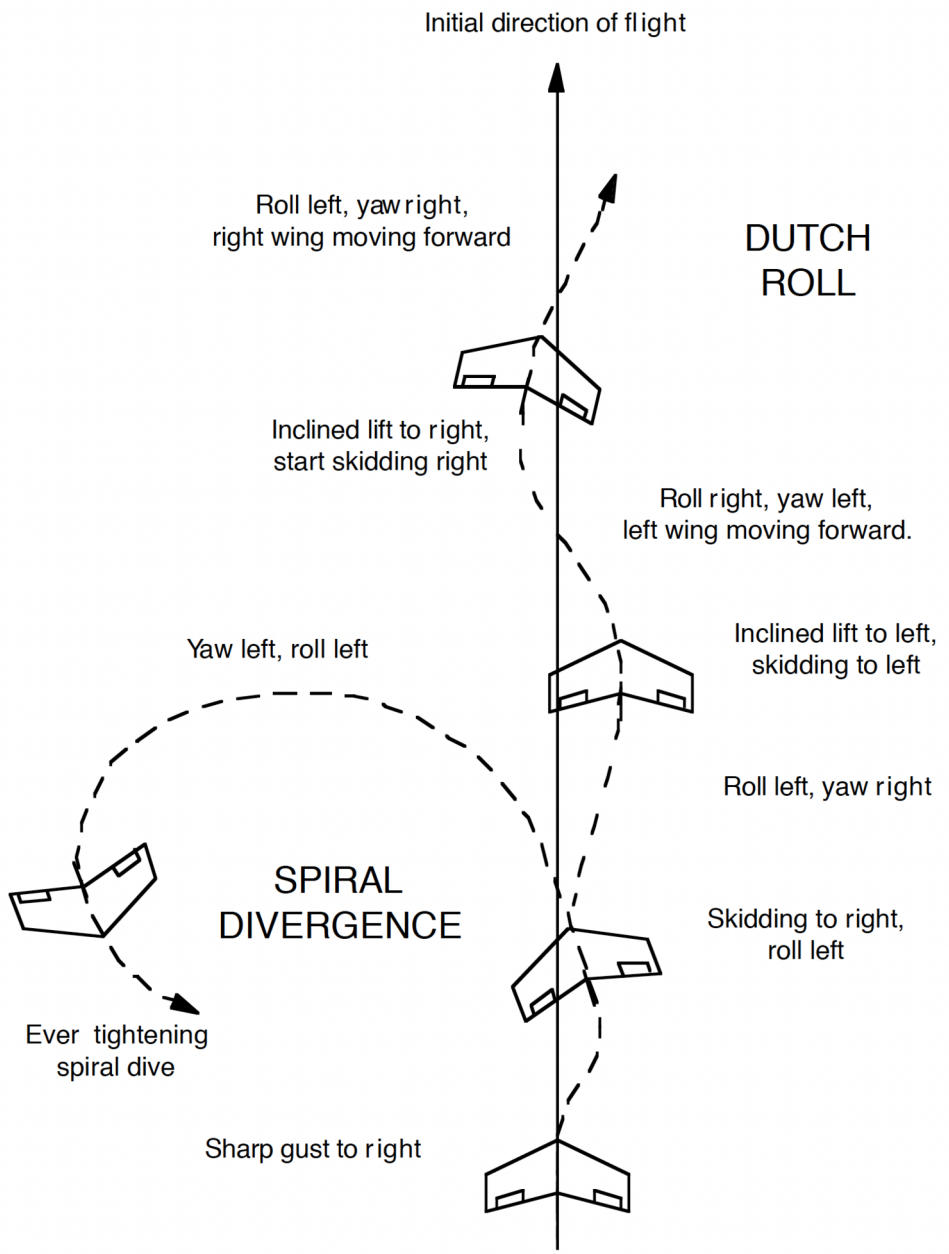

0
10
20
30
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
C_L
5
10
15
18
20
25
30
SWEEP ANGLE, Λ, DEGREES
TAPER RATIO = 0.6
EFFECTIVE DIHEDRAL, DEGREES

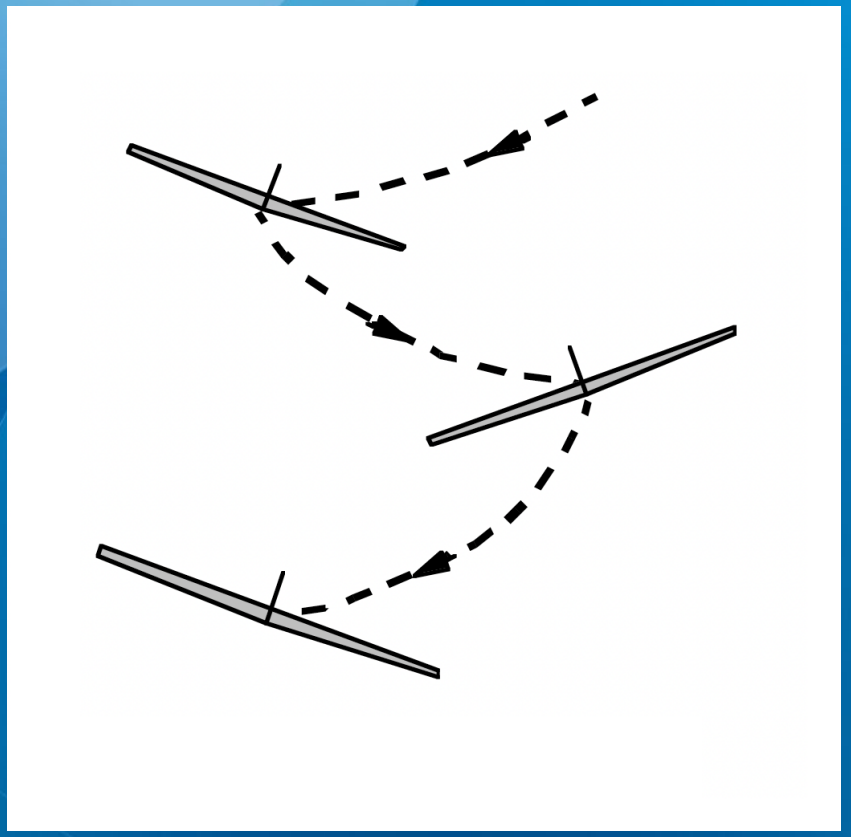


$$EDA_w = \frac{20h_w}{s}$$

The Equivalent Dihedral Angle contributed by the winglet is equal to twenty times the height of the winglet divided by the semi-span (s = b/2).

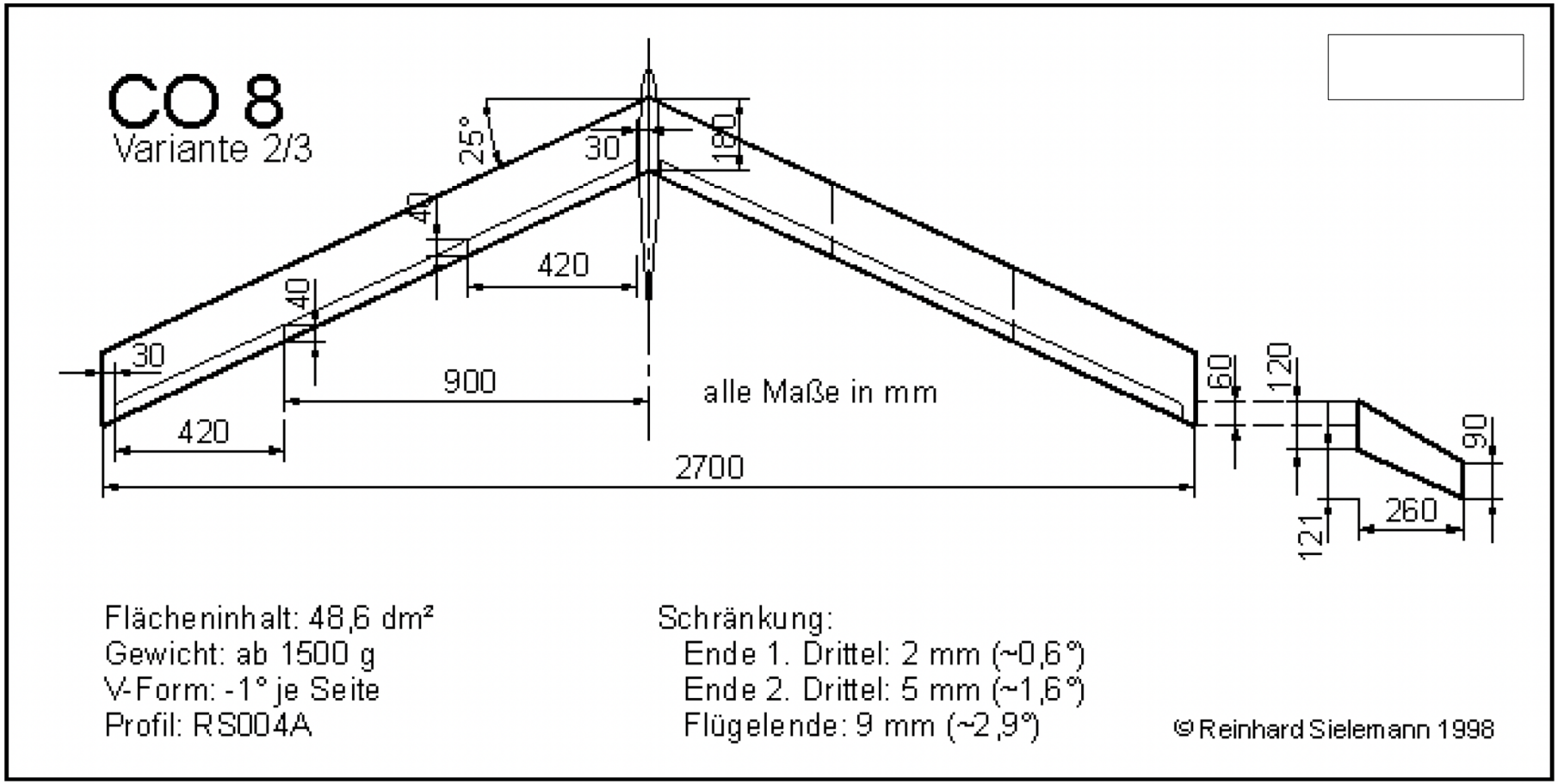

pin
tape





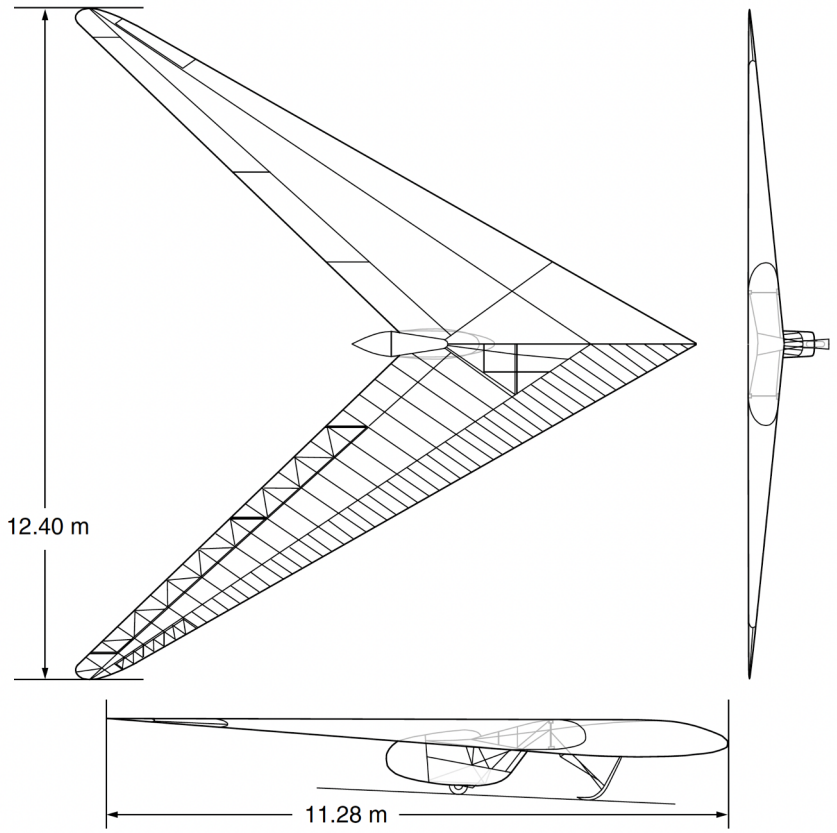
Dutch Roll caused by excessive dihedral

Spiral Divergence caused by vertical surface being too large



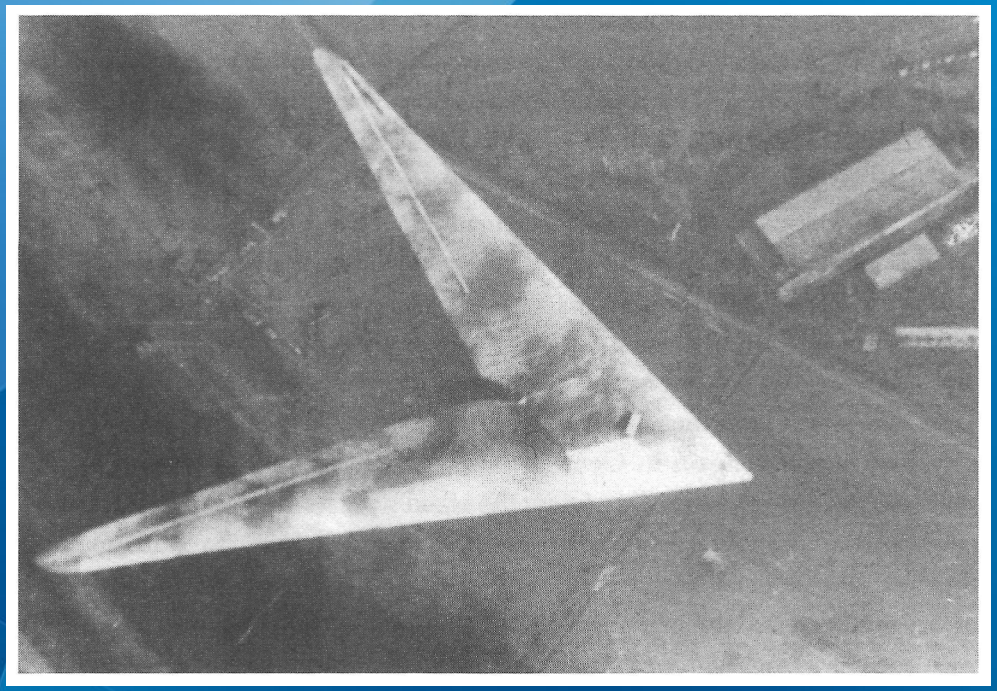
At C_L 0.1: EDA winglets is 3.85°, sweep 1.5°, geometric -1.0° = 4.35°

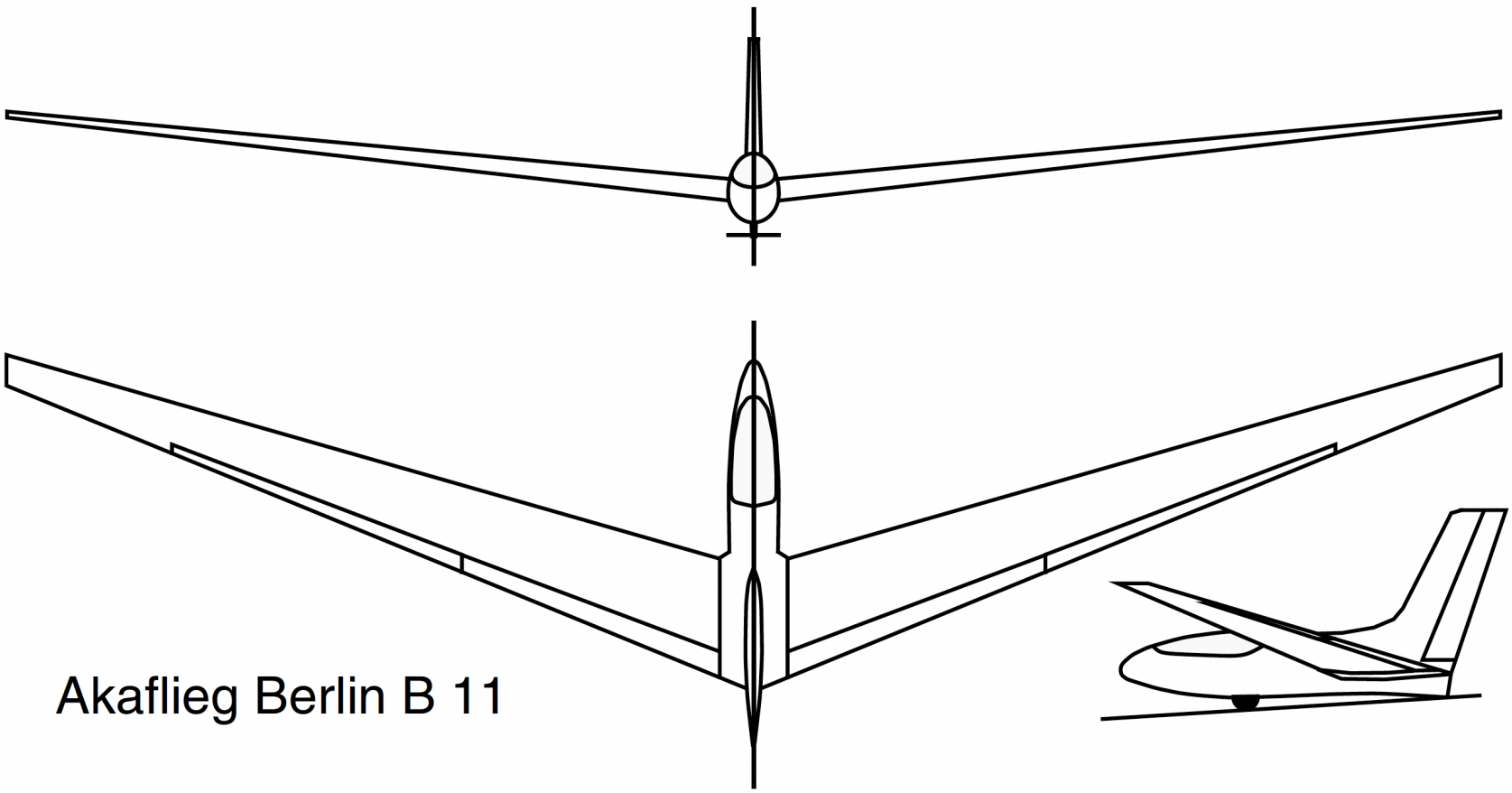
At C_L 0.6: EDA winglets is 3.85°, sweep 11.2°, geometric -1.0° = 14.05°



HORTEN H XIII
Hersfield, 1943

Drawing based on a 3-view in *Nurflügel, Die Geschichte der Horten-Flugzeuge 1933-1960*
by Reimar Horten and Peter F. Selinger

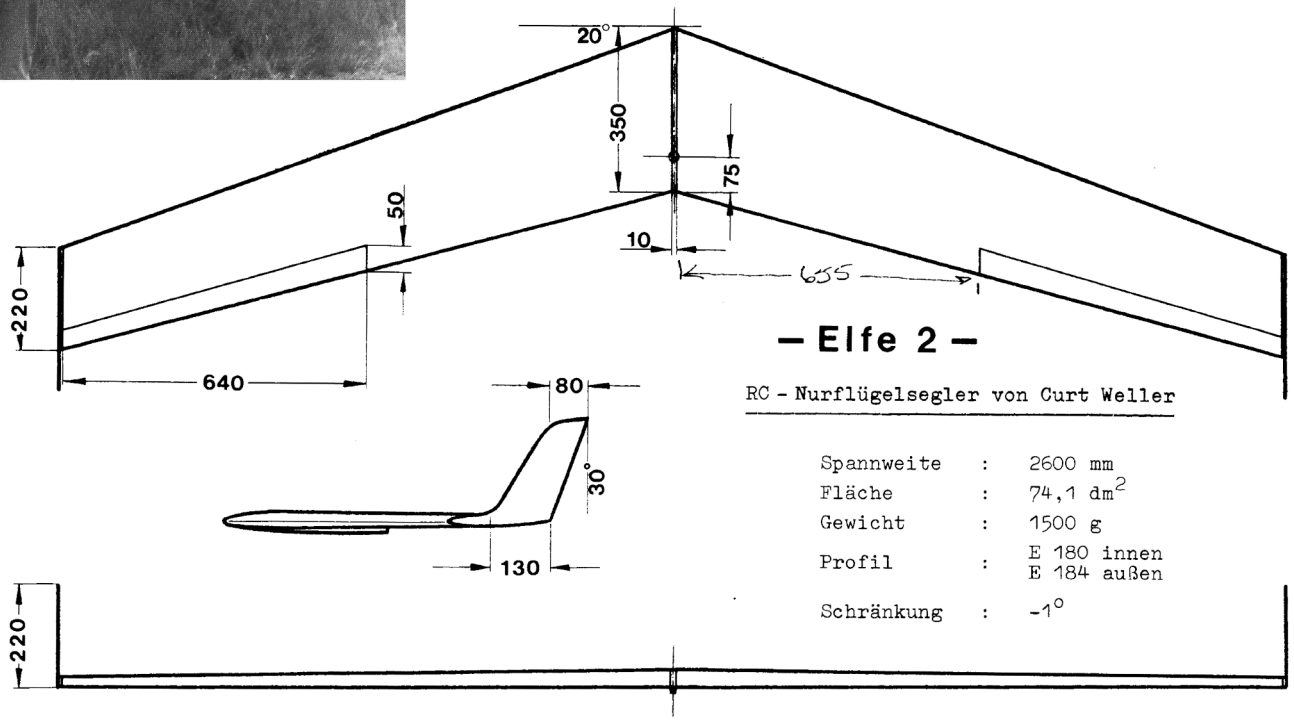



Akaflieg Berlin B 11

Part 2: Swept Wings

- Section 4: Example Models



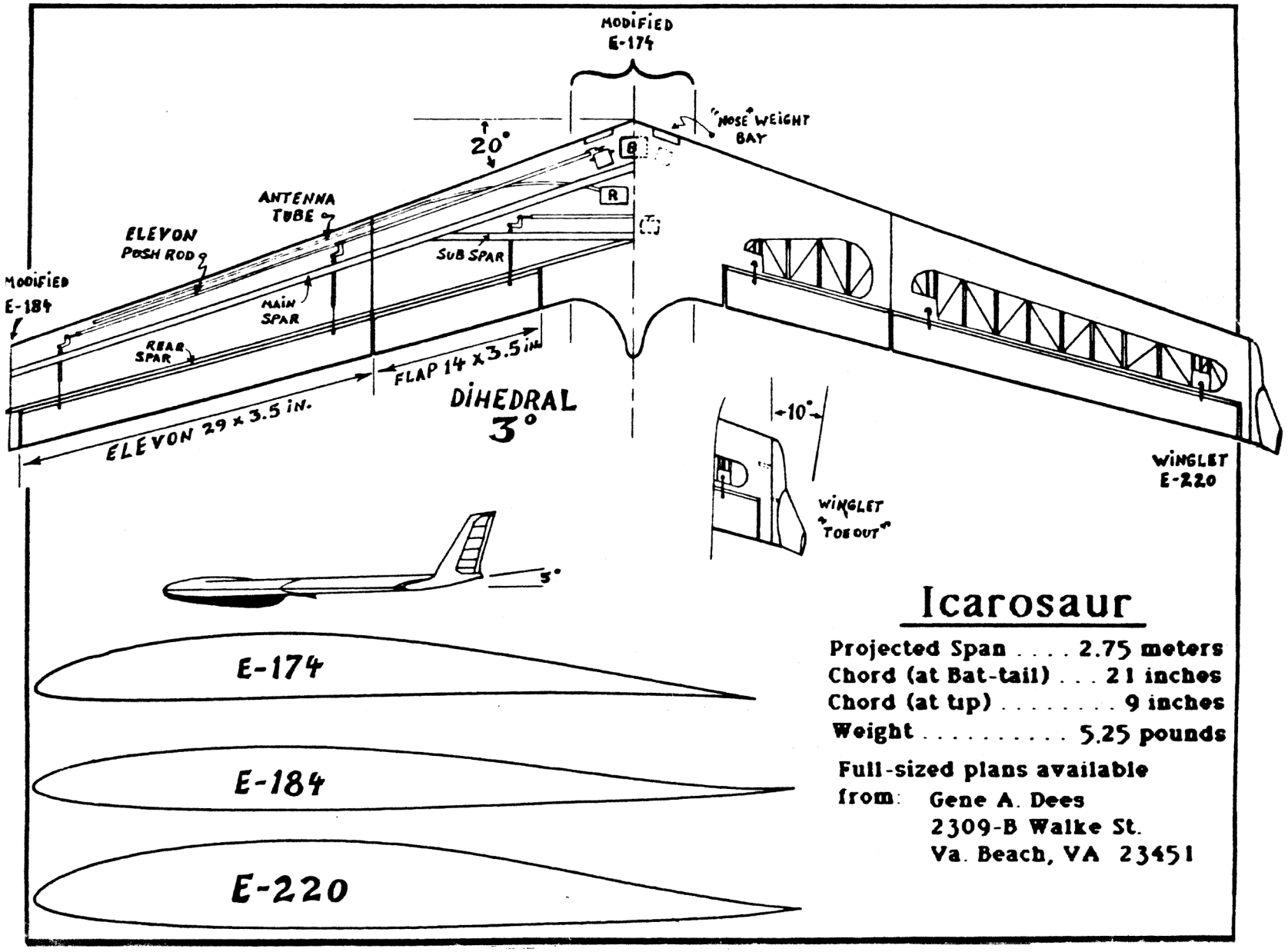


– Elfe 2 –

RC - Nurflügelsegler von Curt Weller

Spannweite	:	2600 mm
Fläche	:	74,1 dm^2
Gewicht	:	1500 g
Profil	:	E 180 innen E 184 außen
Schränkung	:	-1°





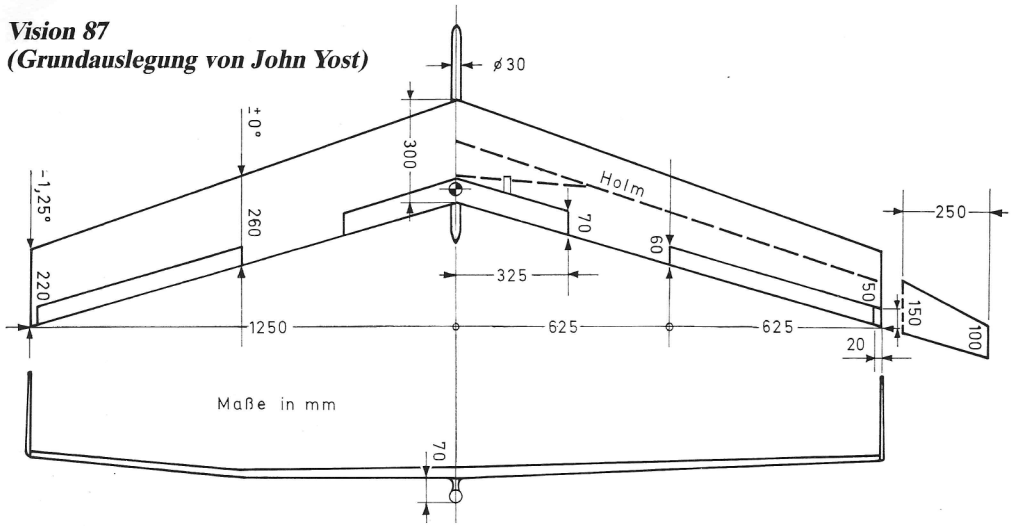
Icarosaur

Projected Span	2.75 meters
Chord (at Bat-tail)	21 inches
Chord (at tip)	9 inches
Weight	5.25 pounds

Full-sized plans available from:

Gene A. Dees
2309-B Walke St.
Va. Beach, VA 23451

Vision 87
(Grundauslegung von John Yost)

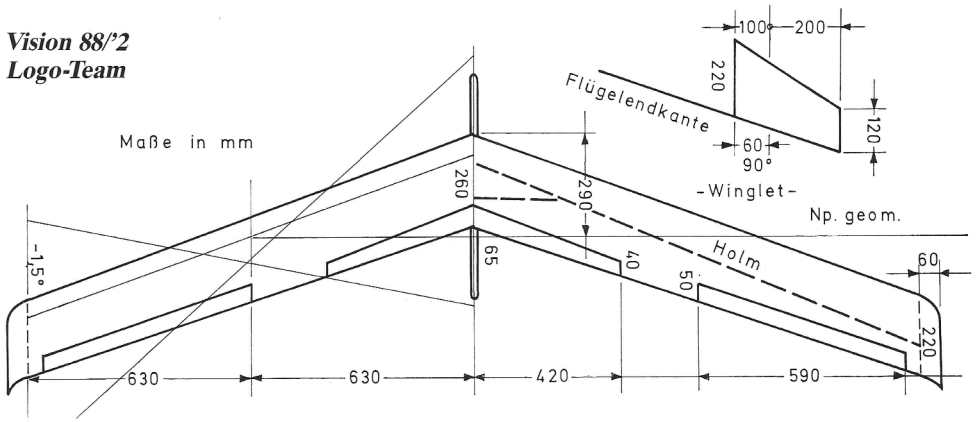


Spannweite:	2500 mm	Verwindung ab Halbspannweite:	−1,25° (= 4 mm)	Stabilitätsmaß:	5 %
Fläche:	65 dm²	Pfeilwinkel Nase:	20°	V-Form:	2,5° je Seite (= 55 mm)
Streckung:	9,6	Pfeilwinkel (t/4):	19,2°	Gewicht:	1950 g – 2925 g
Zuspitzung t_a/t_i:	0,73	Schwerpunkt:	255 mm ab Nase	G/F:	30-45 g/dm²
Profil:	E 228 Tropfen				





Swiss Logo Team
Vision 87
John Yost

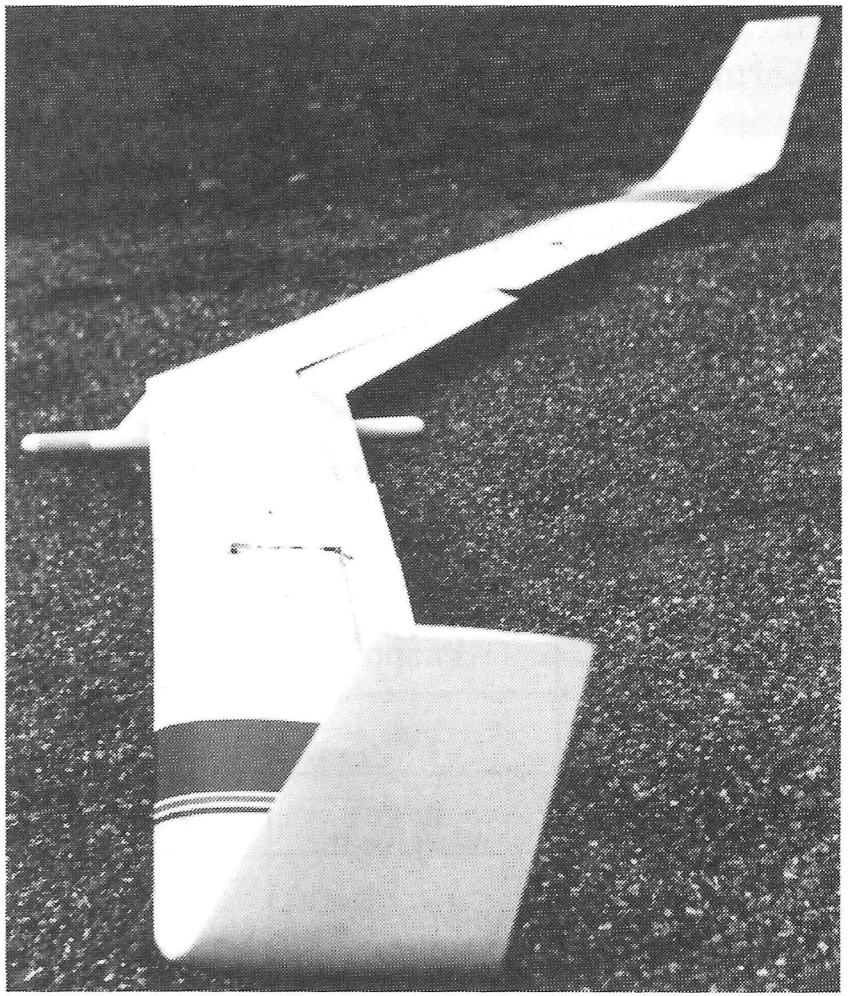


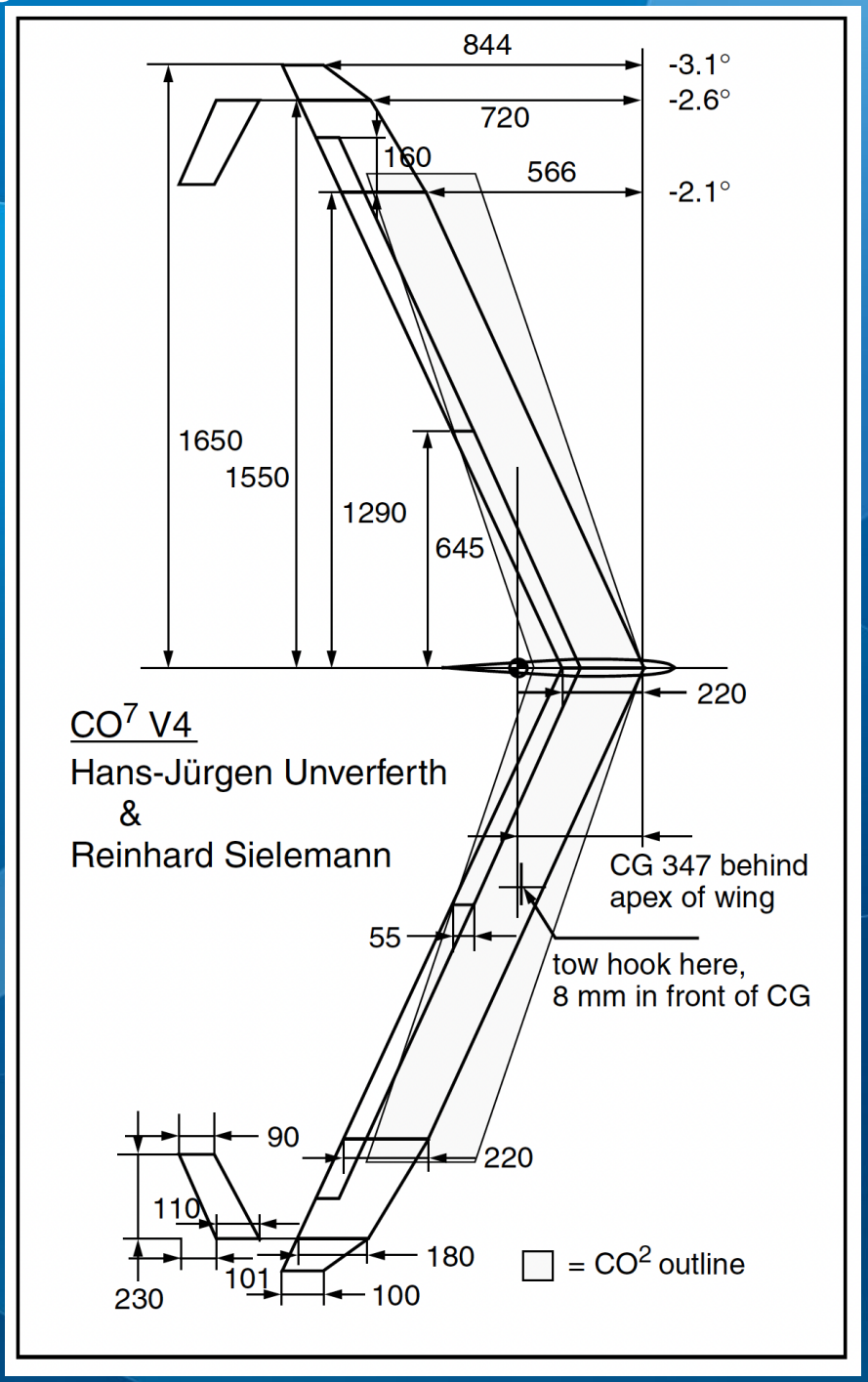
Wegen des abgerundeten Tragflächenanschlusses der Winglets ergeben sich folgende drei Tabellen:

	Basis	Projektion	Oberfläche
Spannweite:	2520 mm	2640 mm	3120 mm
Fläche:	66,5 dm^2	62,9 dm^2	73,1 dm^2
Streckung:	10,5	11,08	13,3

Pfeilung:	20°
Verwindung:	−1,5°
V-Form:	keine
Schwerpunkt:	265 mm ab Nase
Stabilitätsmaß:	7 %
Profil:	EH 1.0/9.0 (smoothed)

Swiss Logo Team
Vision 88/'2
John Yost



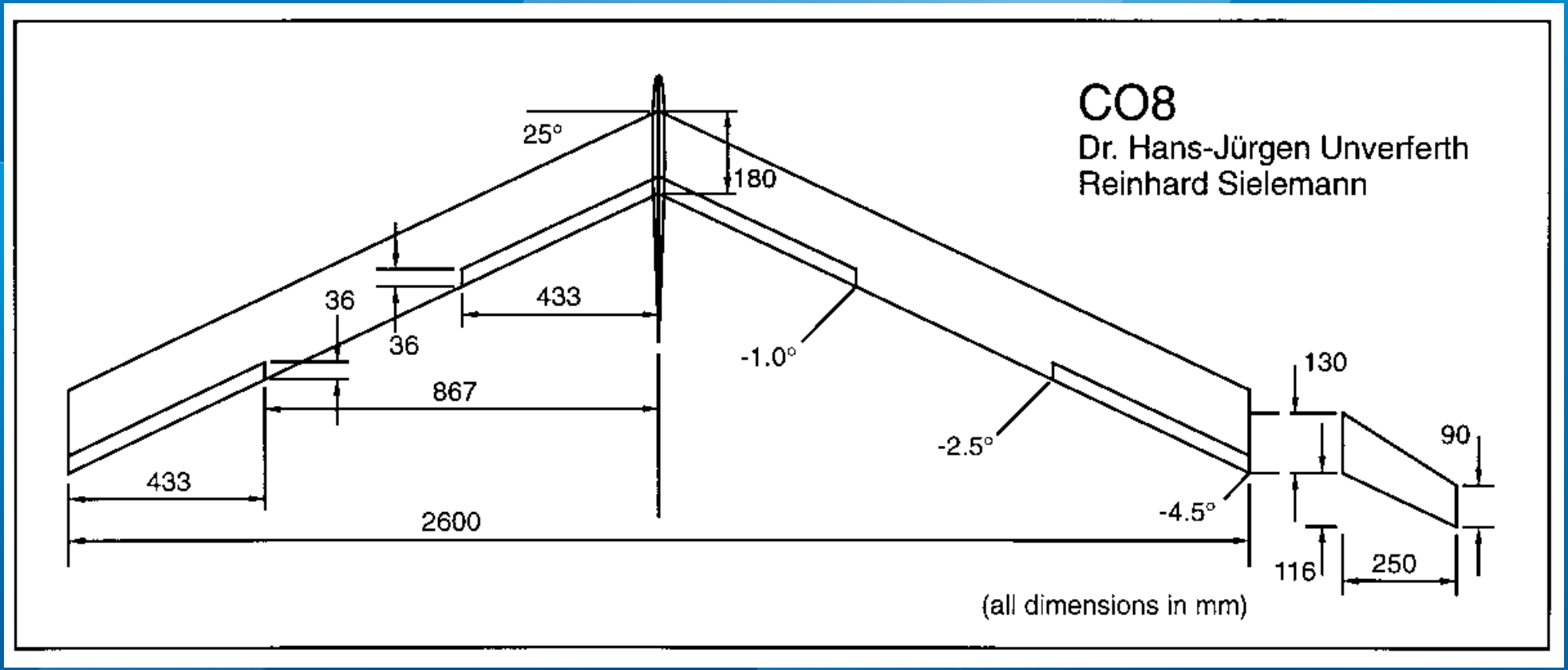


CO^7 V4

Hans-Jurgen Unverferth and Reinhard Sielemann

Span	3.3m
Constant chord	220mm
Sweep angle	25°degrees
Constant chord	220mm
Twist	-2.1°, -2.6°, -3.1°
Control surfaces	Elevons, Flaps

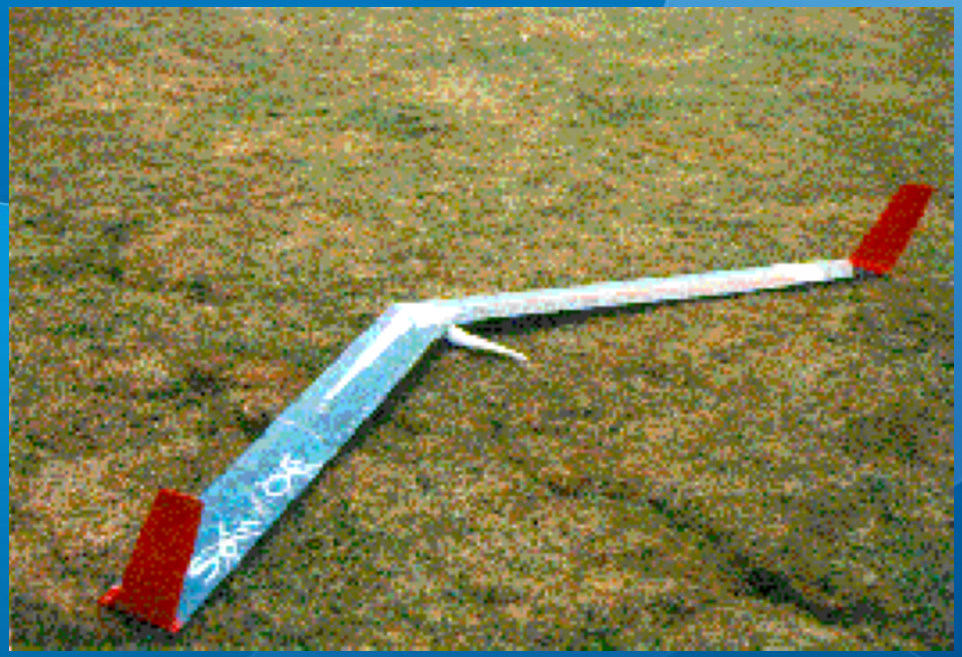




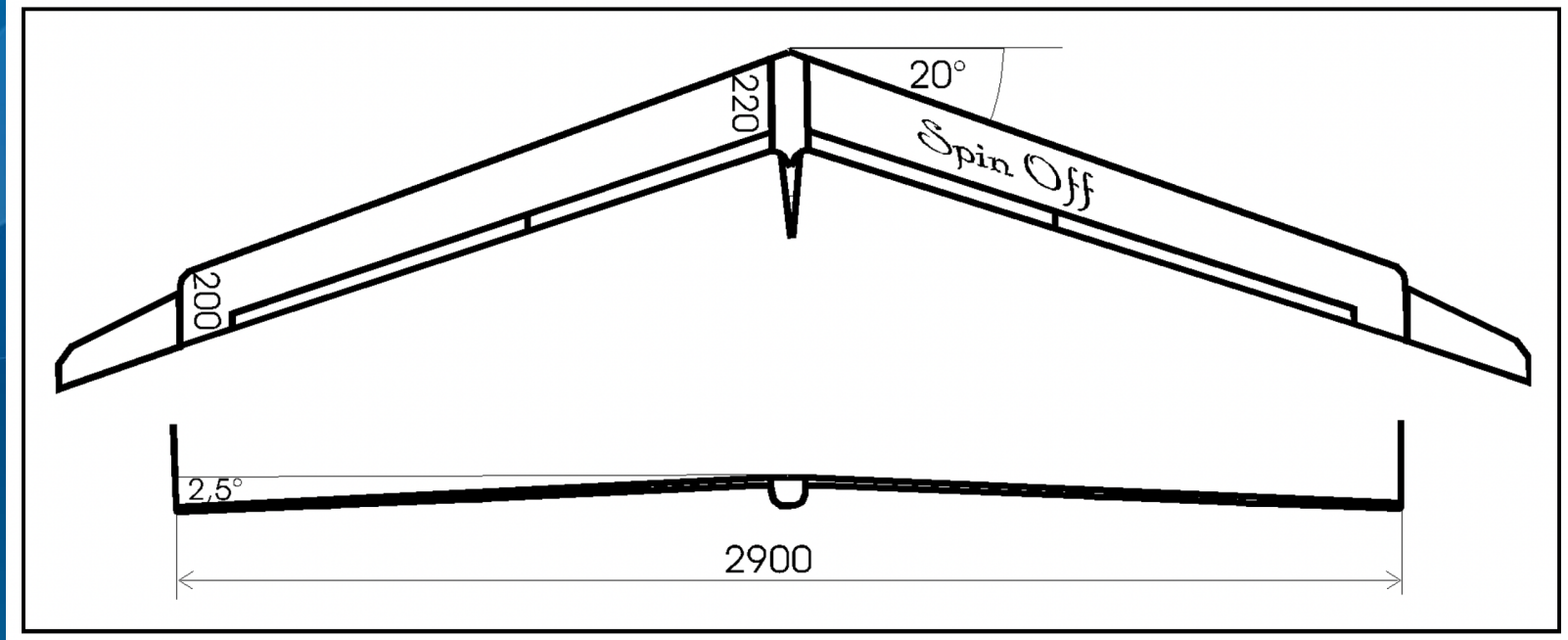
CO8

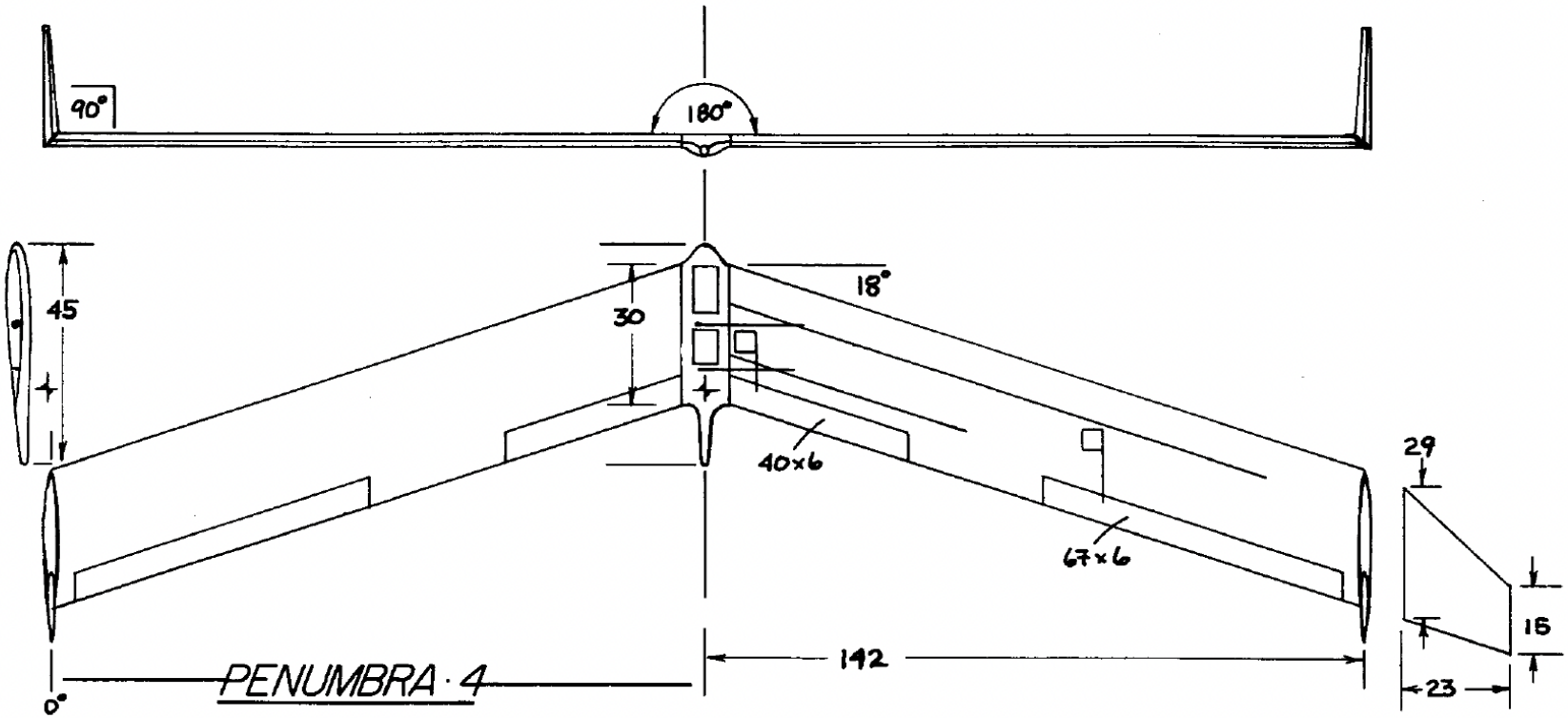
Hans-Jurgen Unverferth and Reinhard Sielemann

Span	2.6m
Constant chord	189mm
Sweep angle	25 degrees
Twist	-0.6°, -1.6°, -2.9° (1/3 span increments)
Control surfaces	Elevons, Flaps






220
20°
Spin Off
200
2,5°
2900

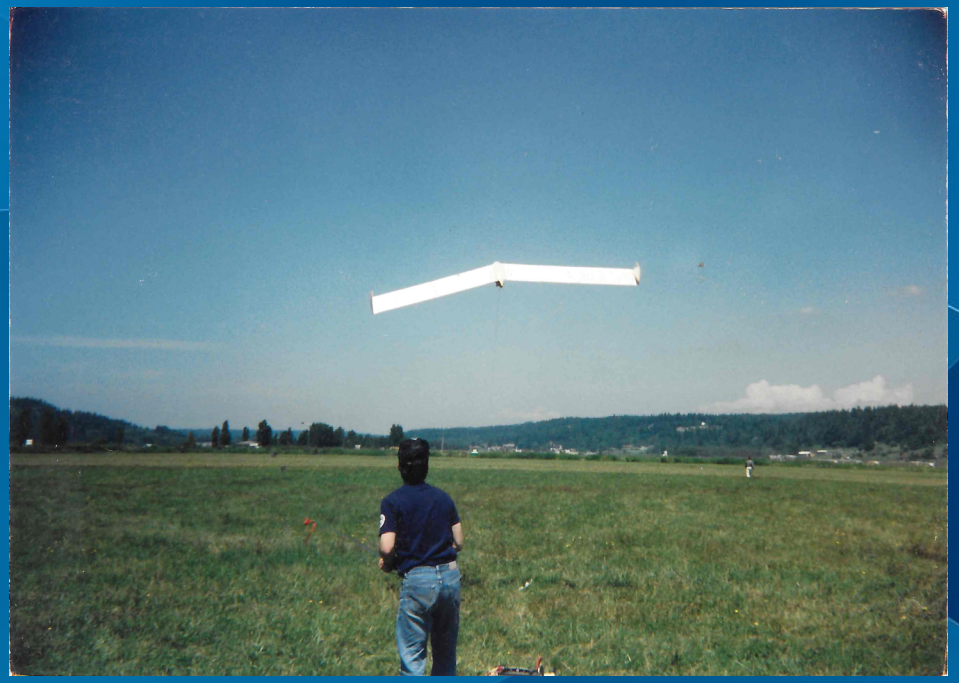


□ = SERVO LOCATION
BATTERY PACK (4x1200 MAH)
AIRFOIL = EH 1.0/9.0
FINS = EH 1.0/9.0
SINGLE TOWHOOK
TOTAL WEIGHT = 100 OZ.

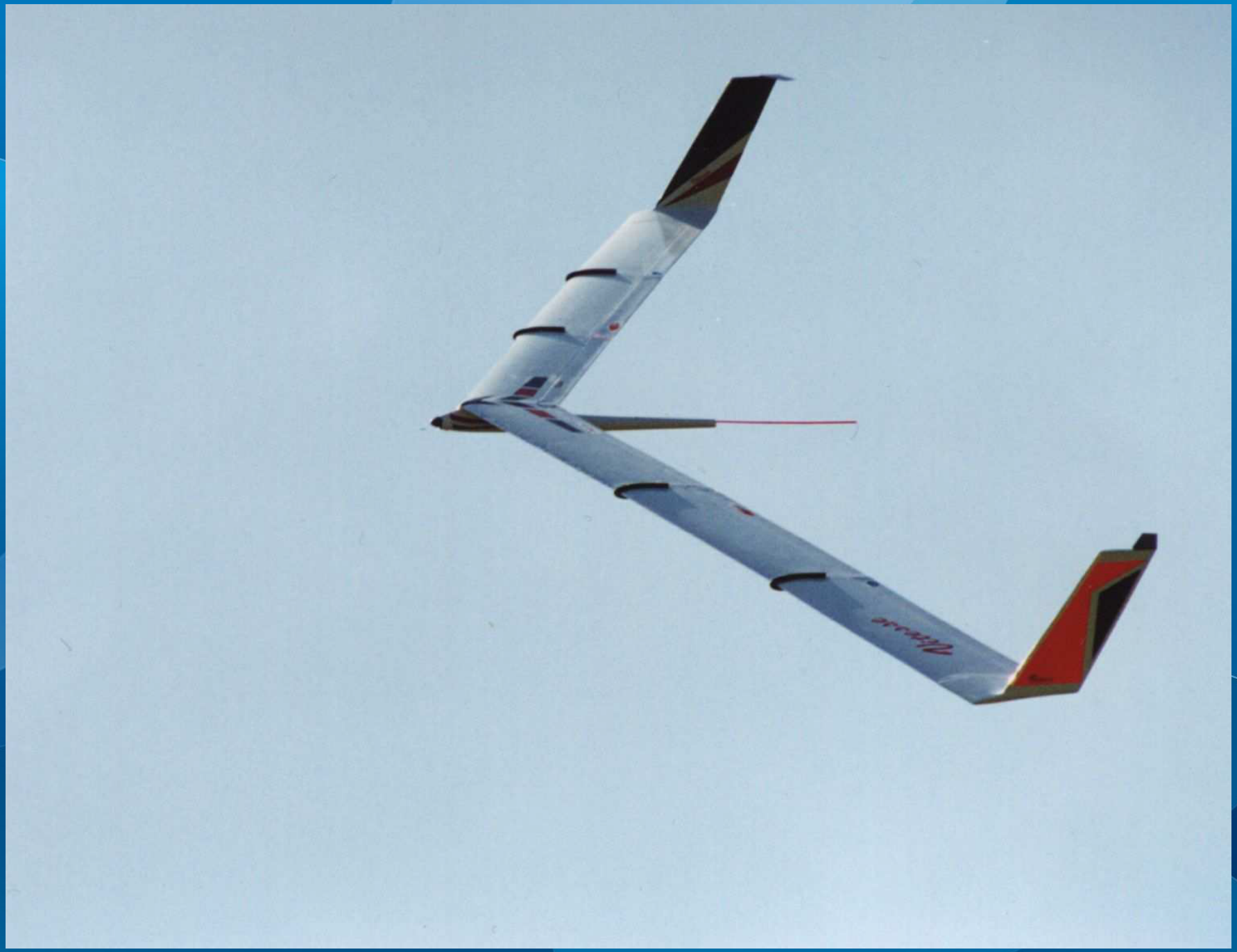
"150" PINK FOAM THROUGHOUT
1 LAYER 3.42 OZ/YD² FIBERGLASS (45°)
1 LAYER 4 OZ/YD² UNI-FIBERGLASS
1 PARTIAL LAYER UNI-GLASS
CARBON REINFORCED SPARS
5/16" & 3/16" WING RODS




DieHard



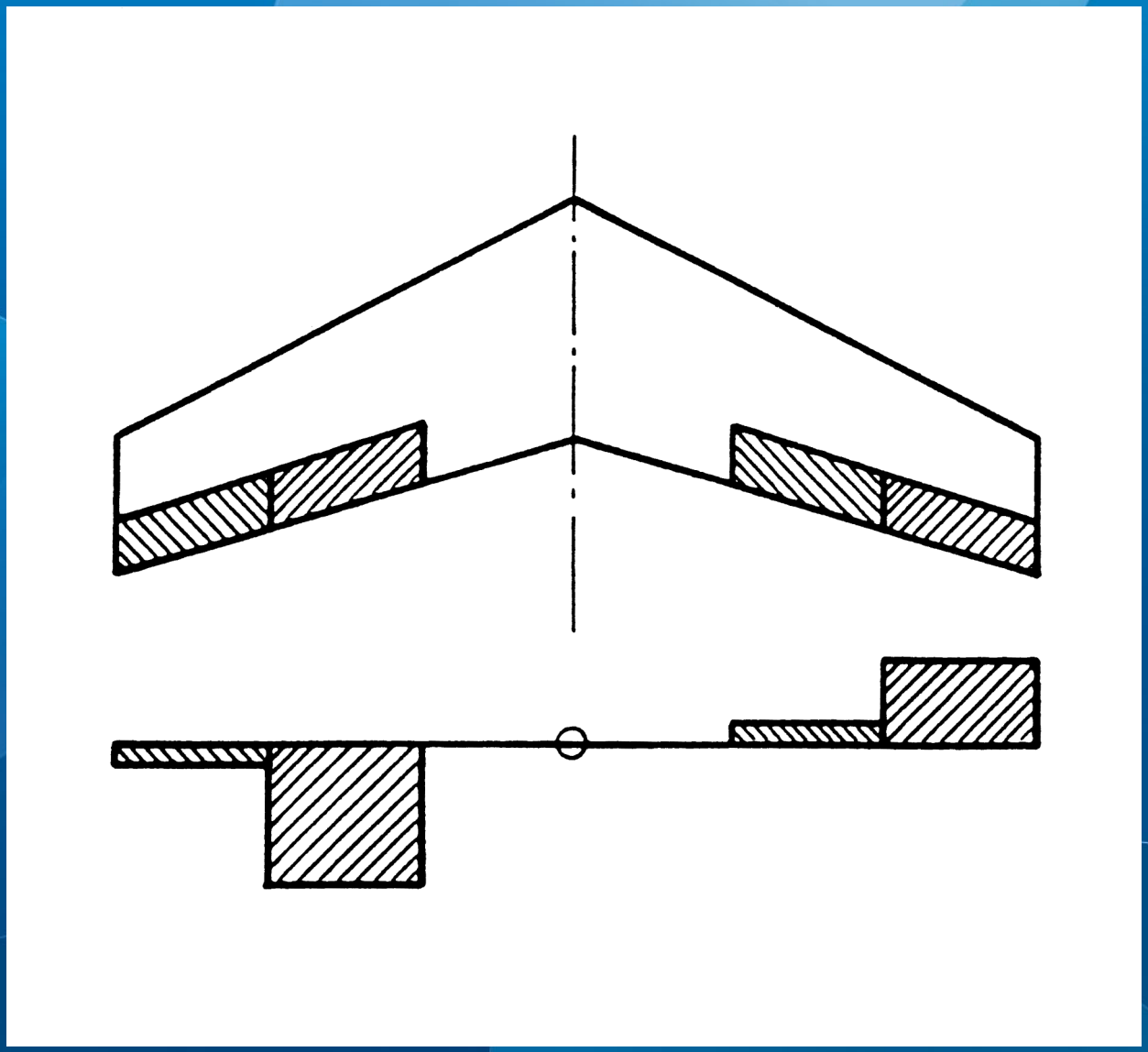




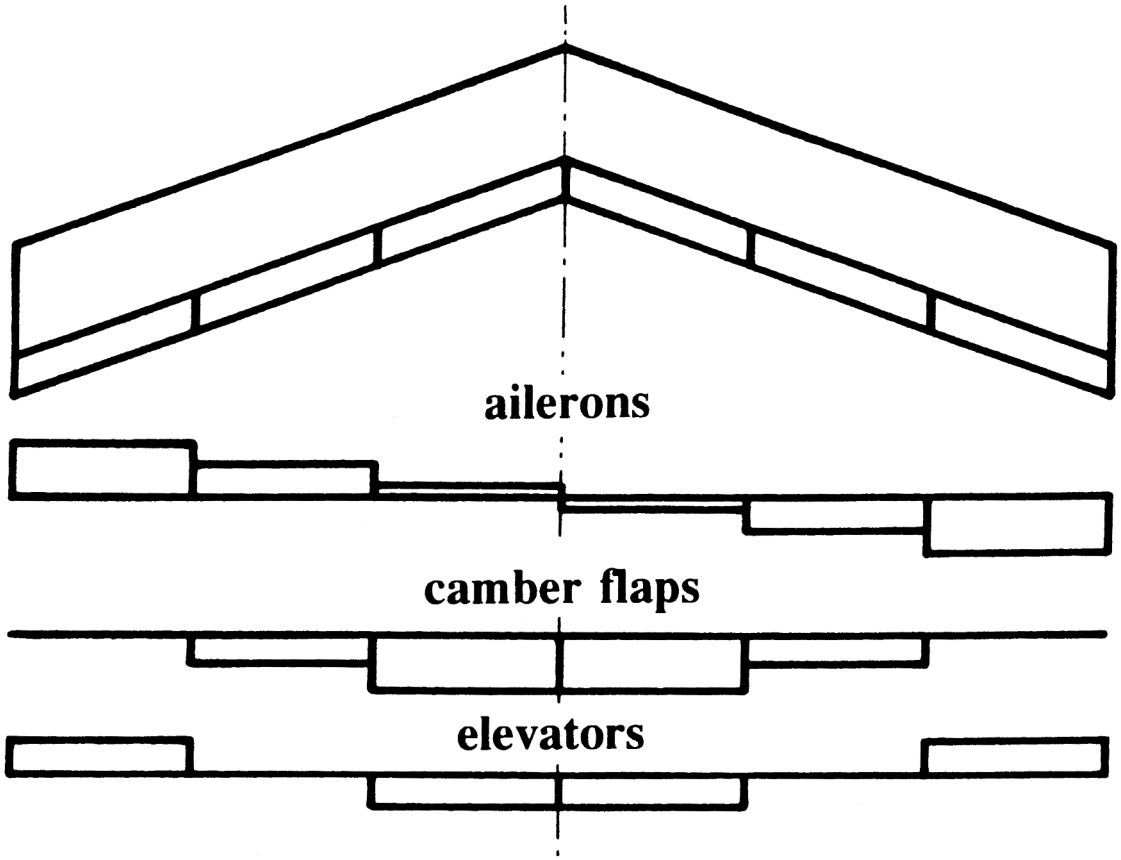
Part 2: Swept Wings

- Section 5: Appendix

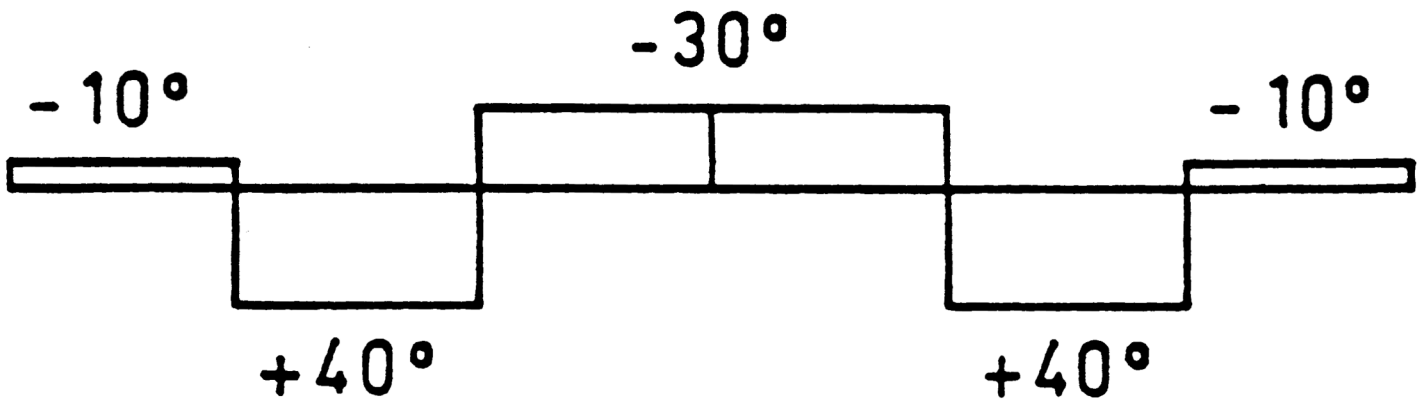
1. 4-flap and 6-flap Control Systems



Reduction of adverse yaw with 4-flap control system

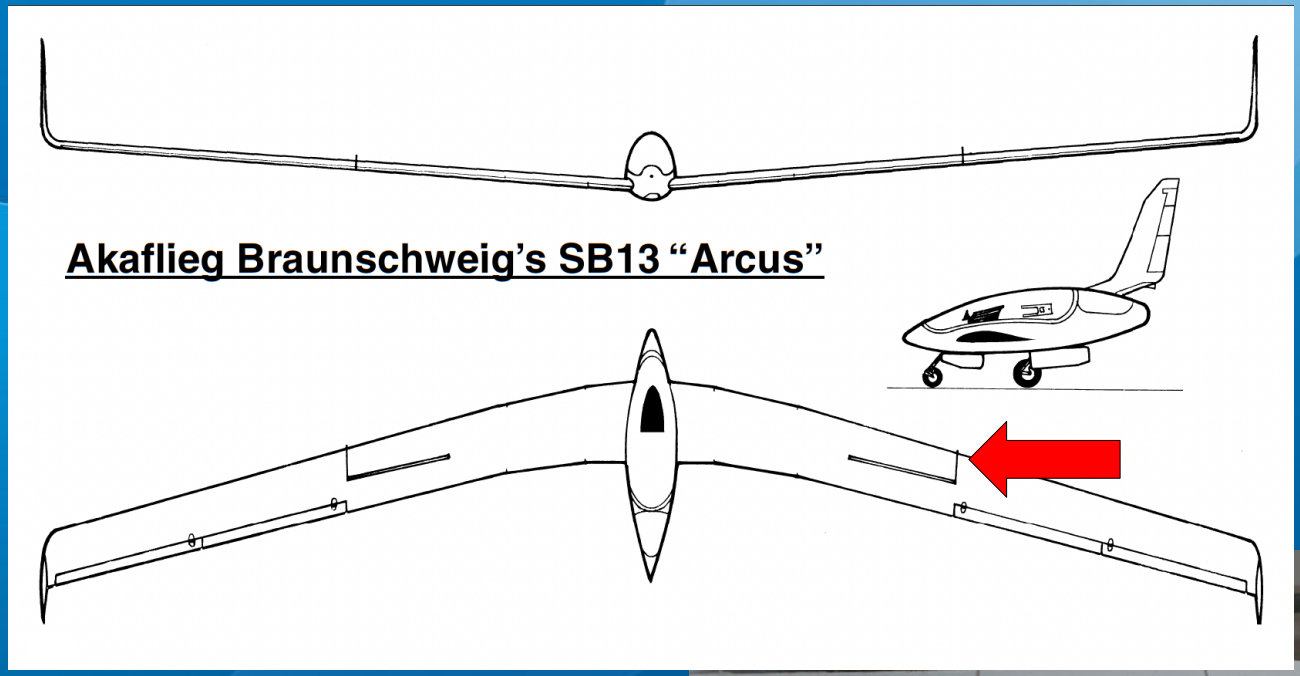


Basic 6-flap control system

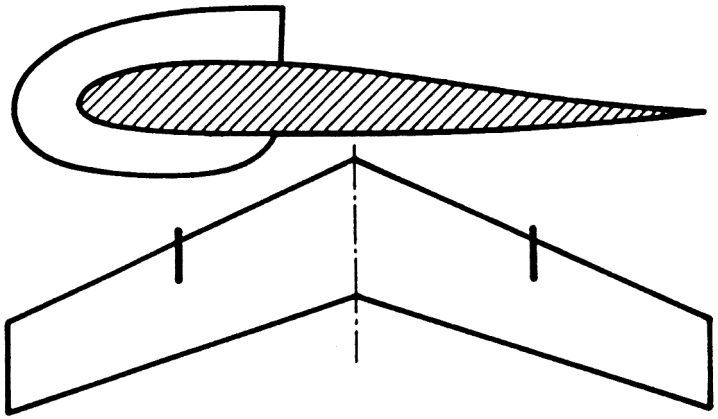


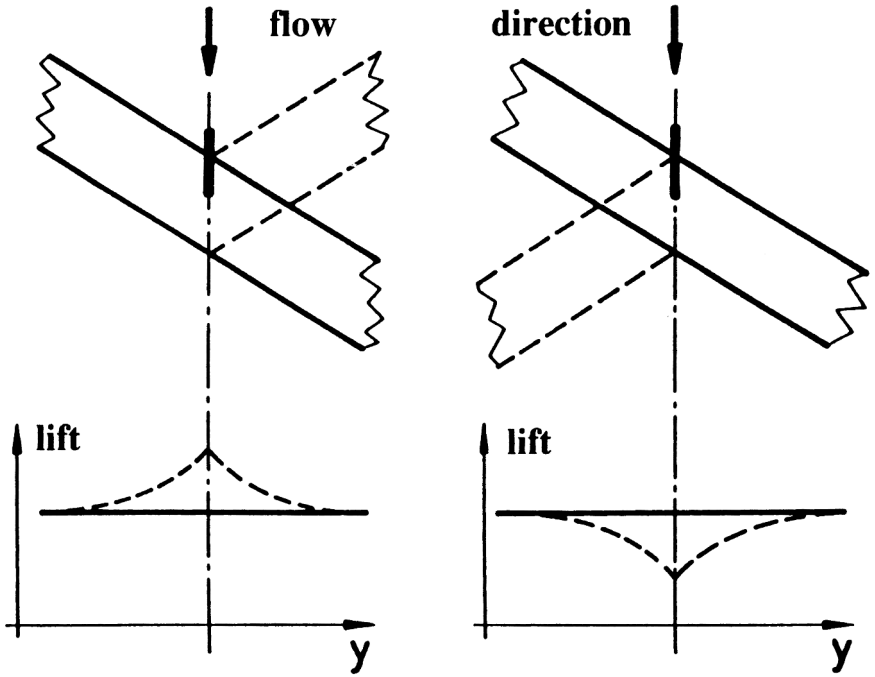
6-flap control system airbrake function

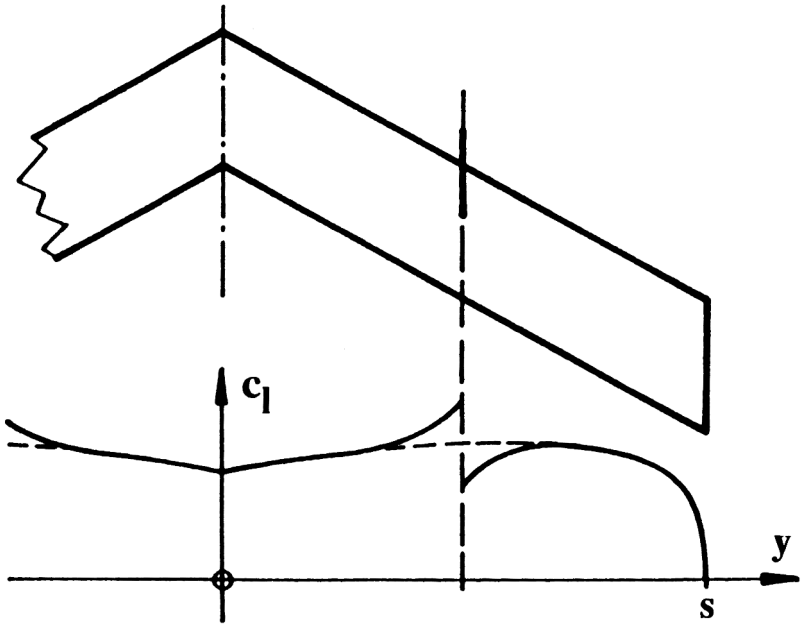
2. Wing Fences


Akaflieg Braunschweig's SB13 "Arcus"

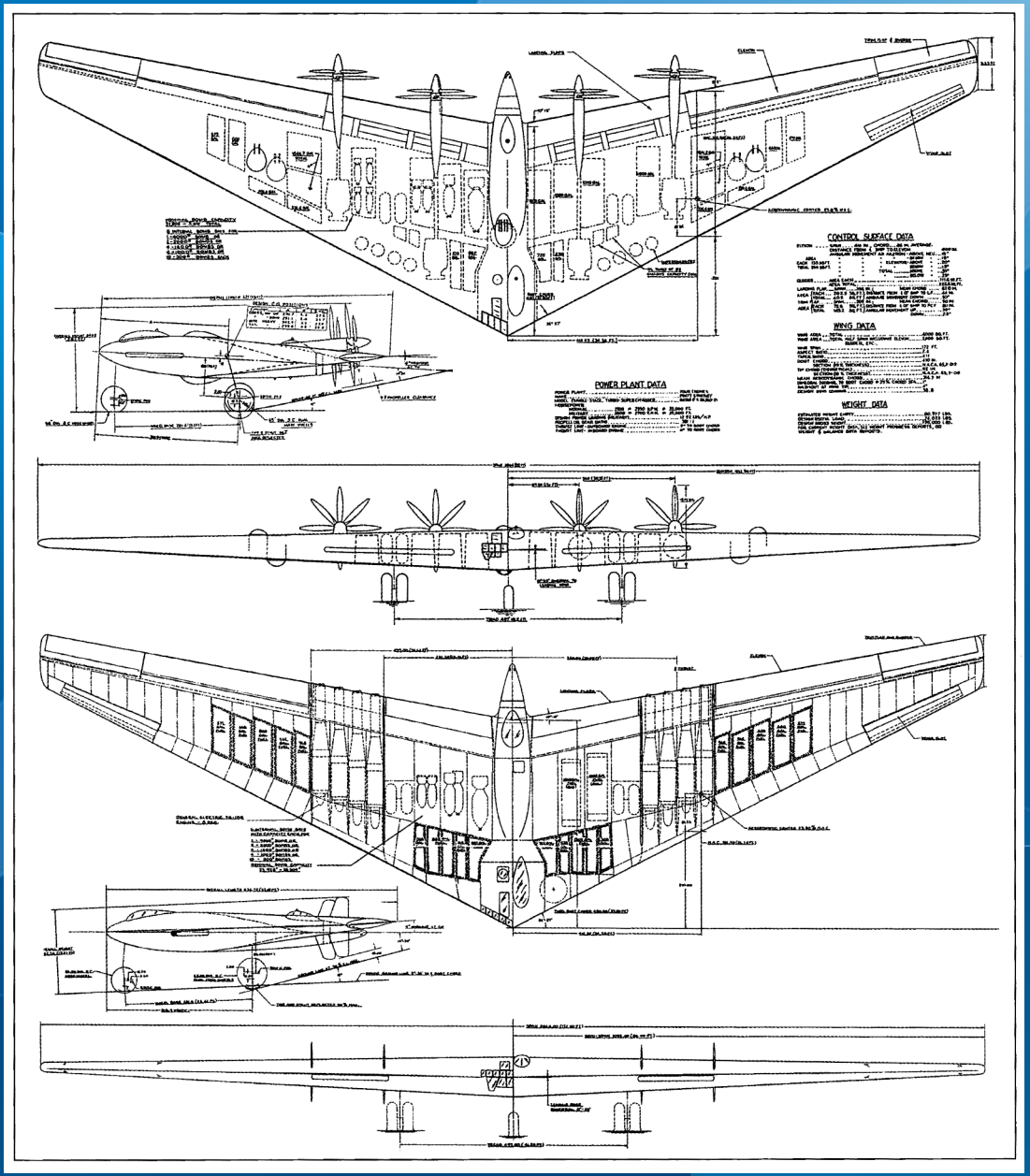

SONY



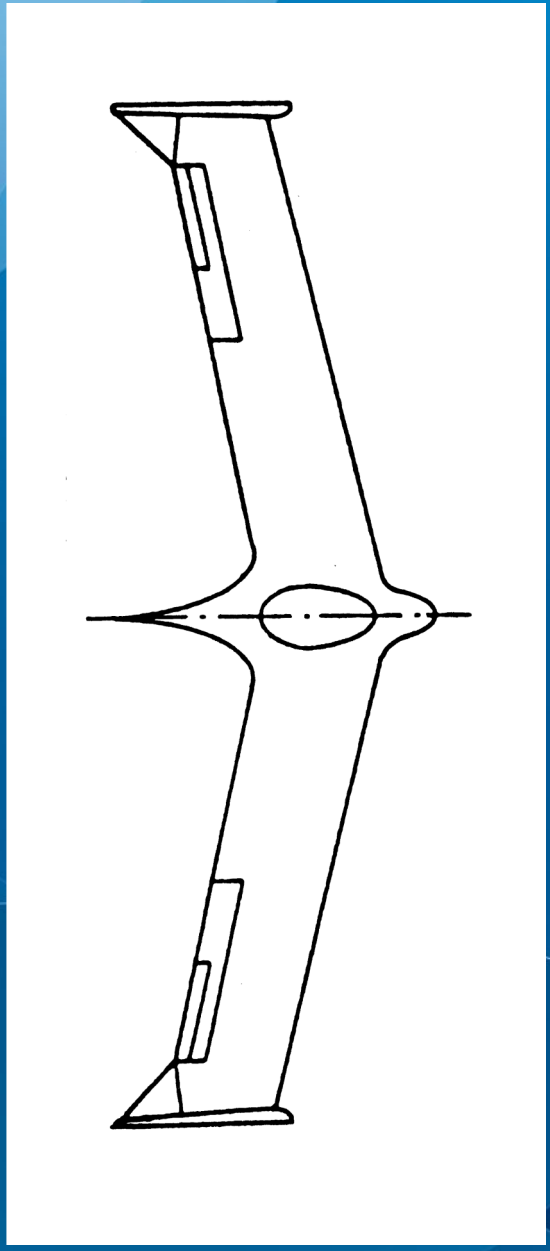

flow
direction
lift
lift
y
y


c_l
y
s

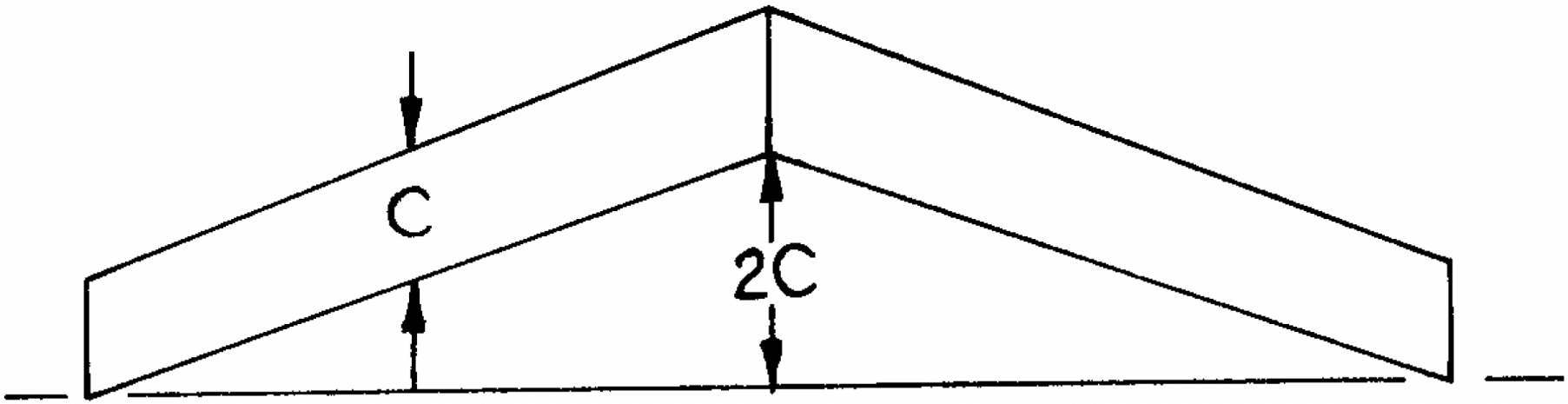
3. Tumbling



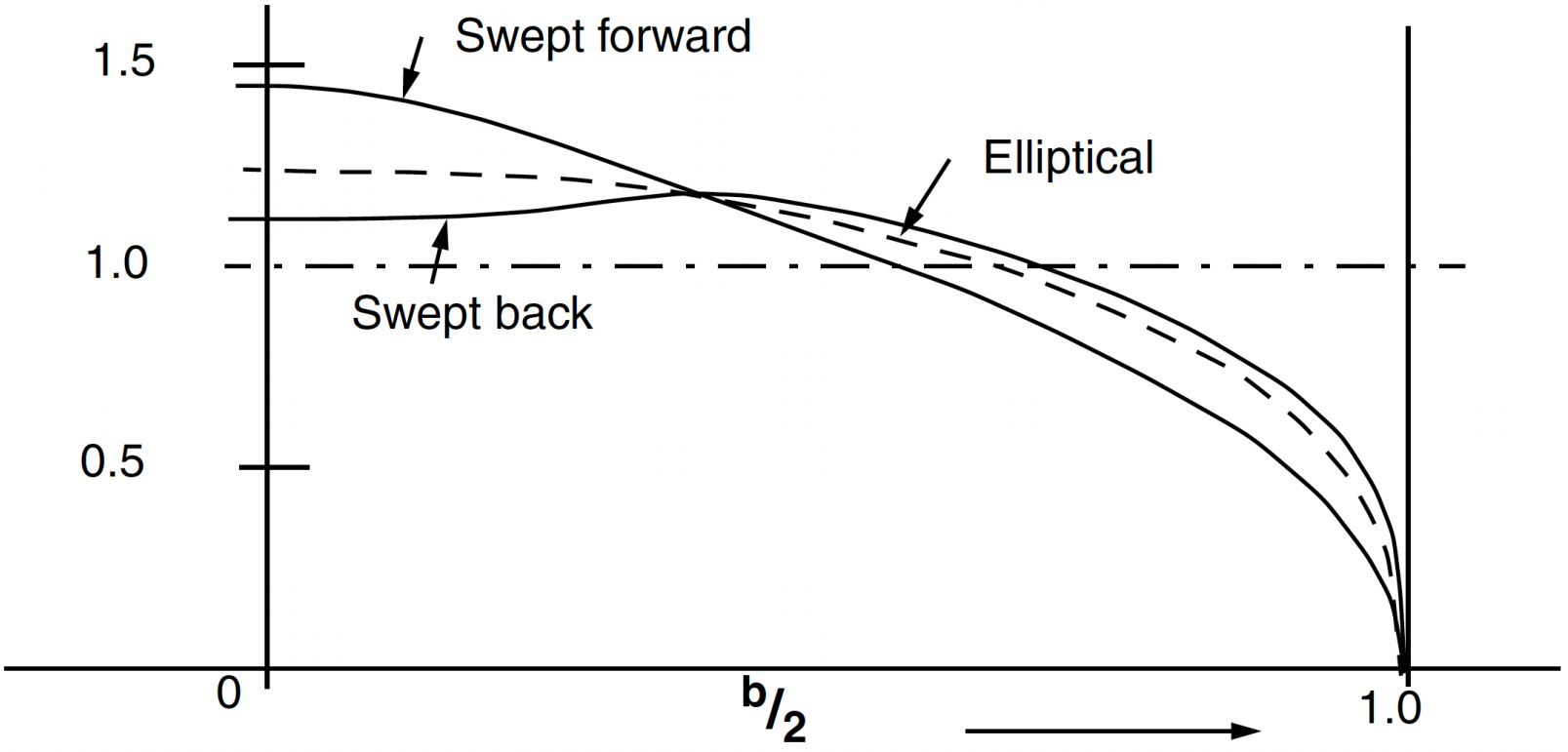
Northrop YB-35 (upper) and YB-49 (lower)

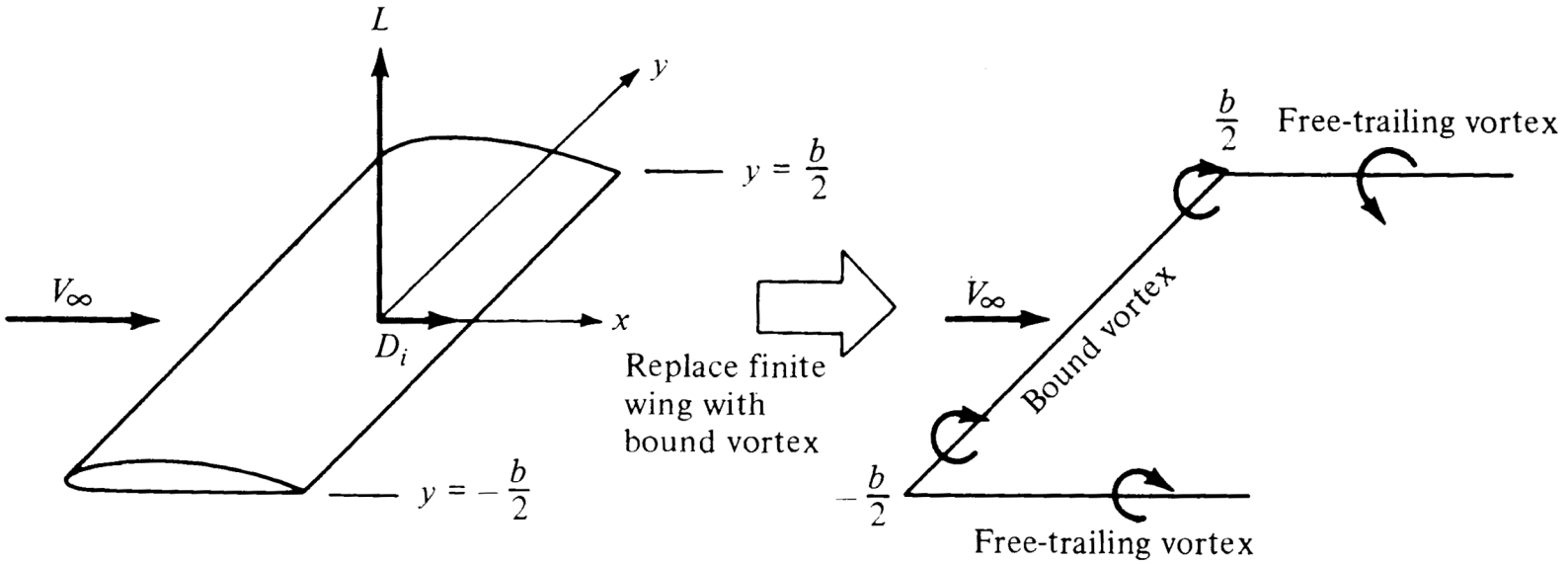


Witold Kasper Wing


C
2C

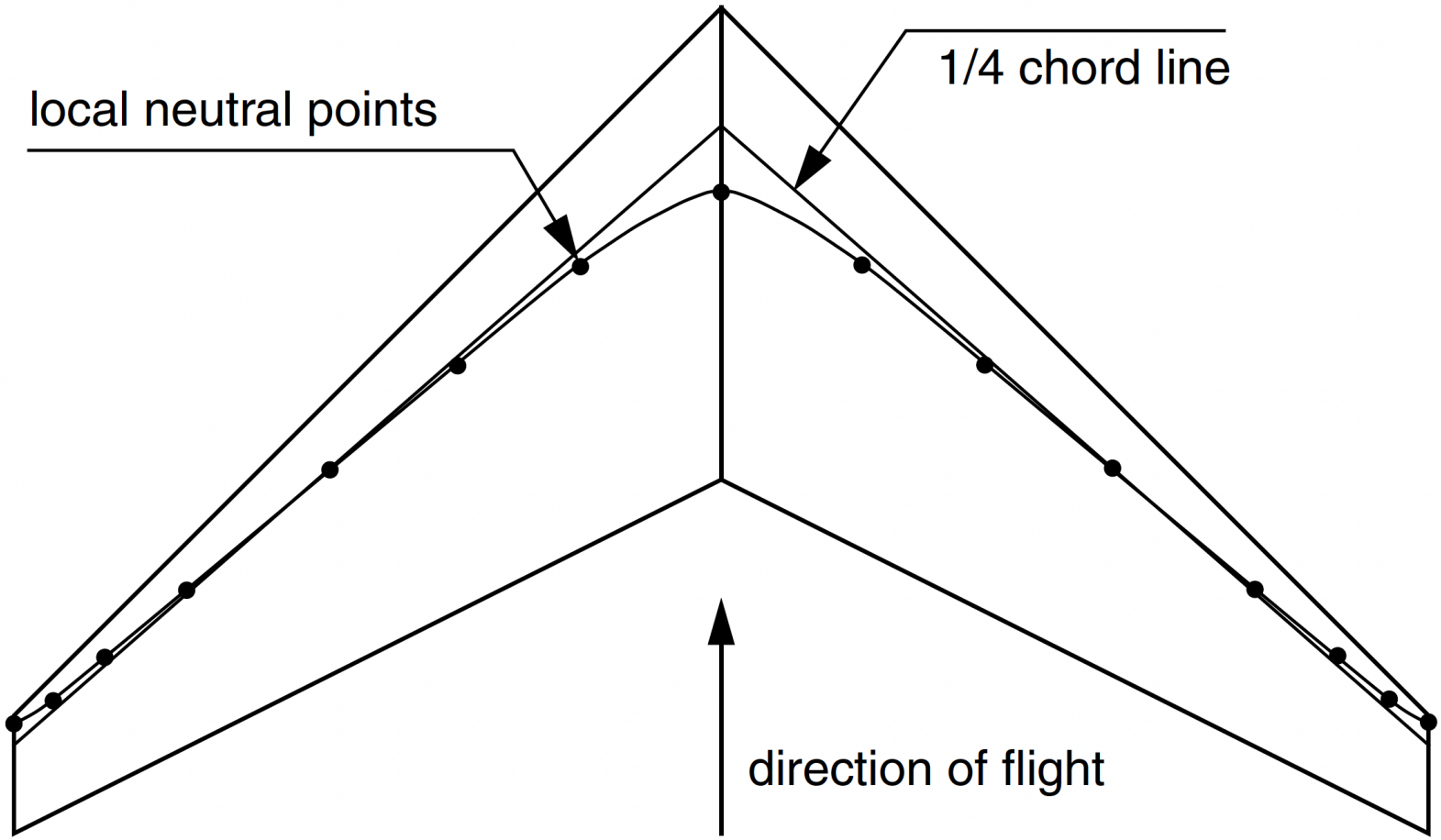
4. The Middle Effect

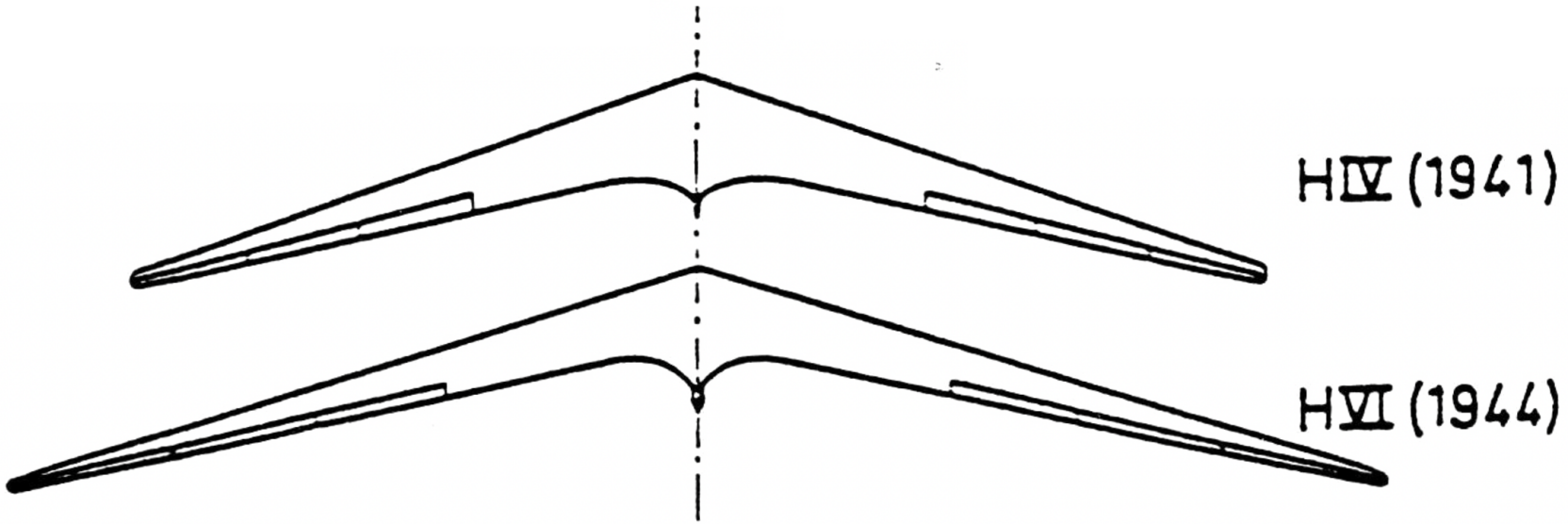

1.5
1.0
0.5
0
Swept forward
Elliptical
Swept back
b/2
1.0



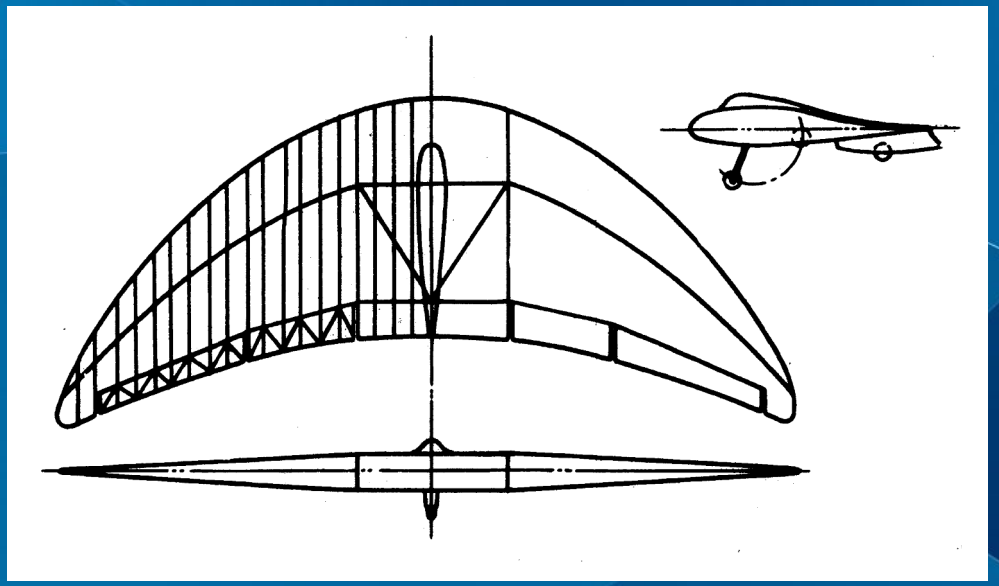
Finite wing

Horseshoe vortex

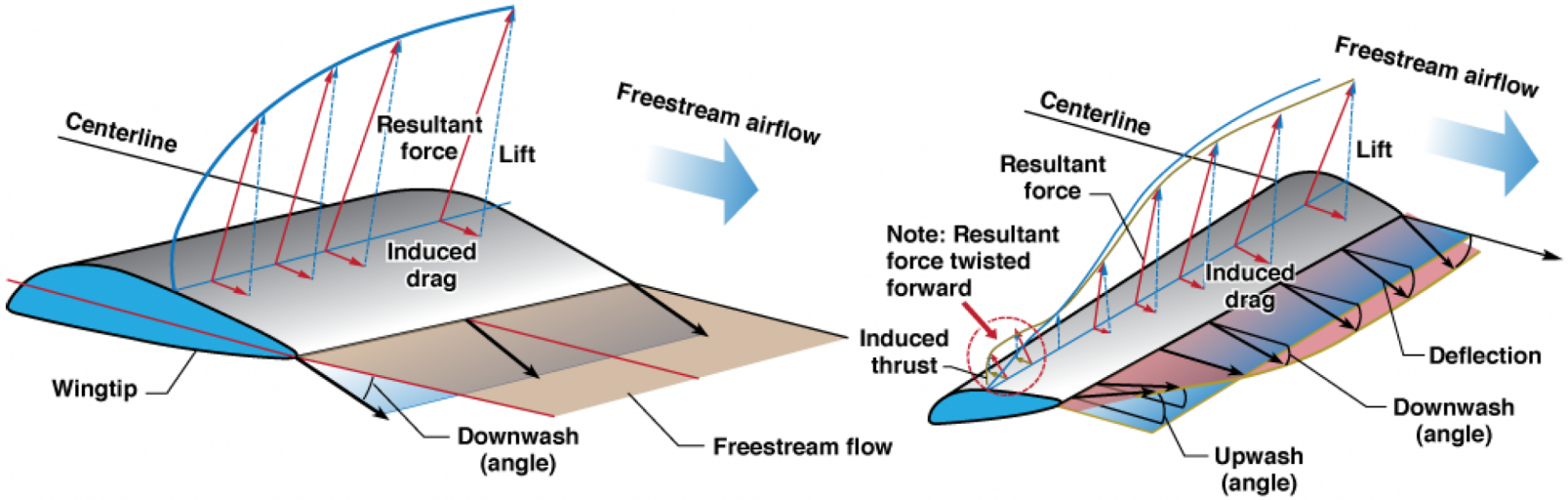

local neutral points
1/4 chord line
direction of flight

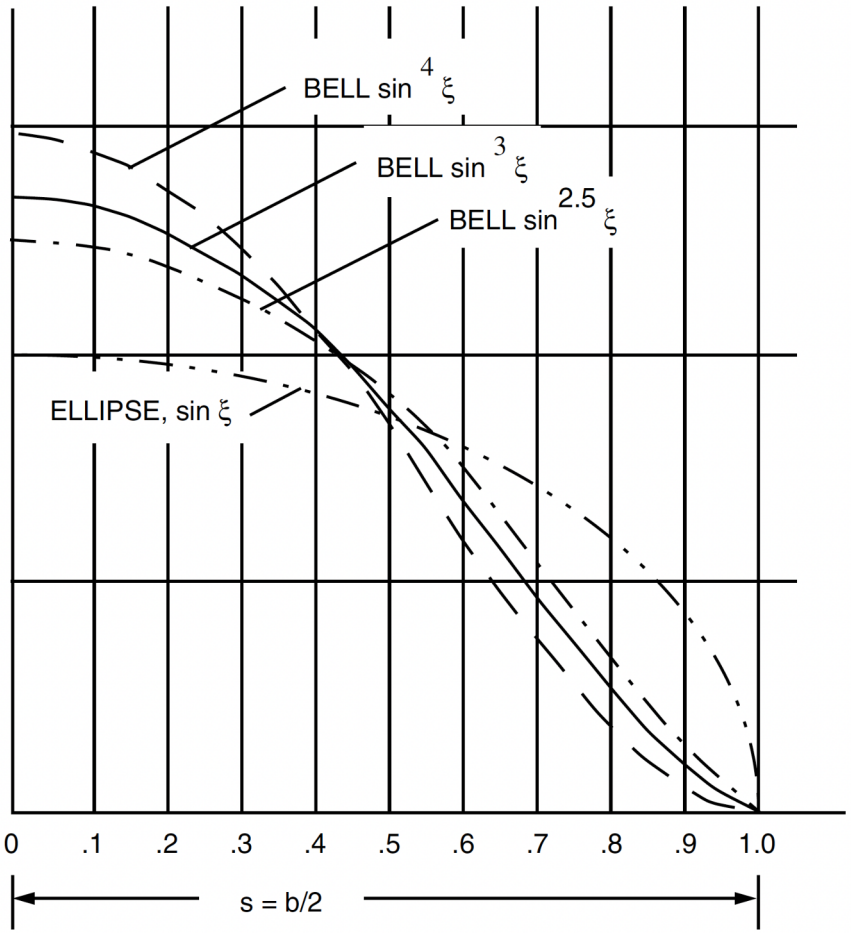


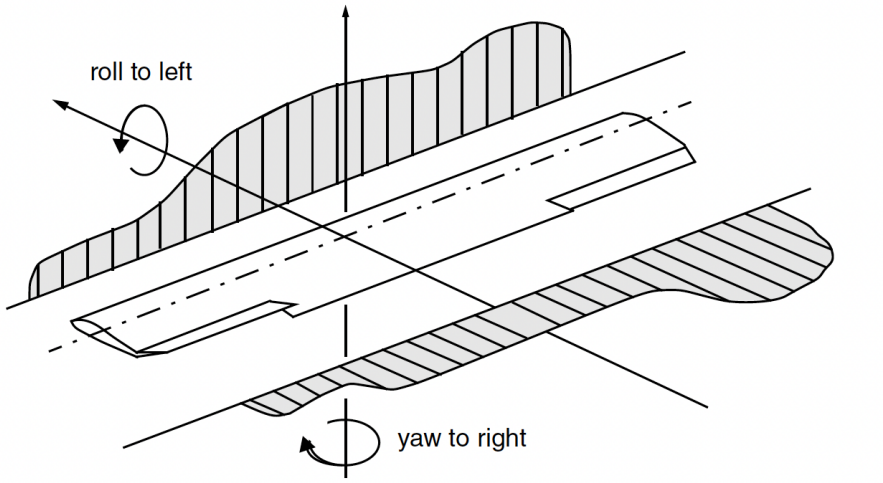
Horten Parabel/Parabola (1937)

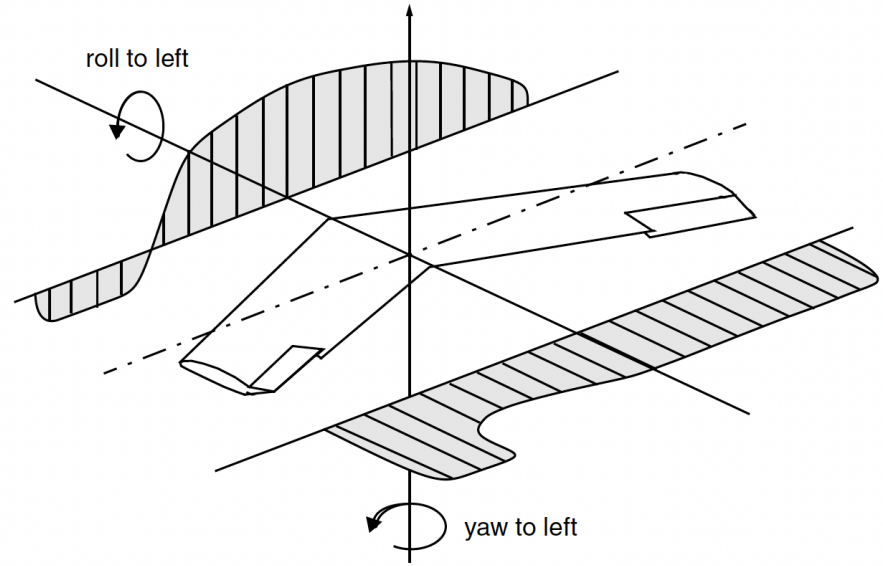


5. Achieving Coordinated Turns Without a Vertical Surface

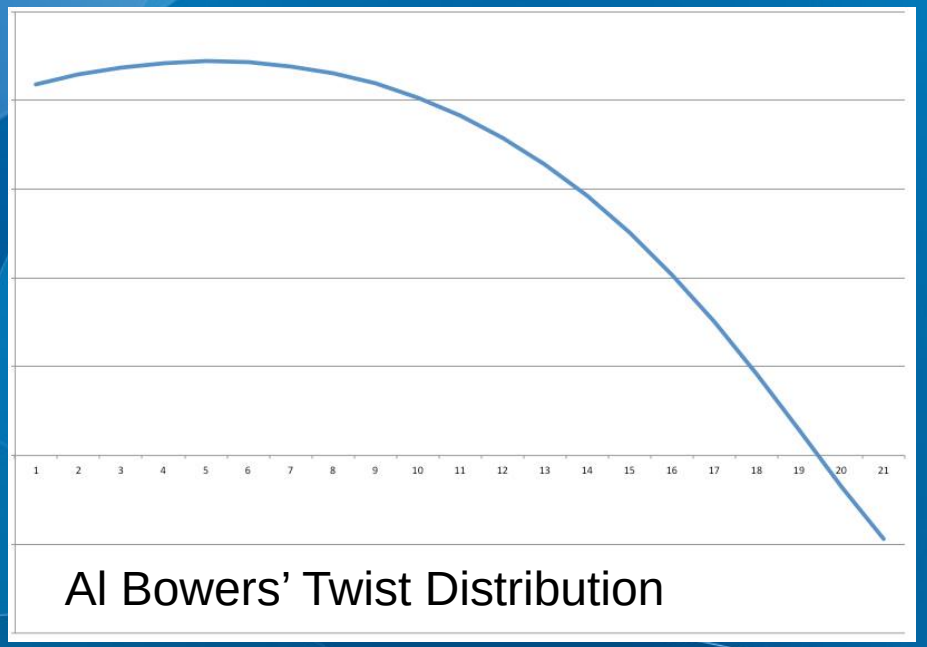

Centerline
Resultant force
Lift
Induced drag
Freestream airflow
Wingtip
Downwash (angle)
Freestream flow
Freestream airflow
Centerline
Resultant force
Lift
Note: Resultant force twisted forward
Induced drag
Induced thrust
Deflection
Downwash (angle)
Upwash (angle)


BELL sin 4 ξ
BELL sin 3 ξ
BELL sin 2.5 ξ
ELLIPSE, sin ξ
0
.1
.2
.3
.4
.5
.6
.7
.8
.9
1.0
s = b/2


roll to left
yaw to right


roll to left
yaw to left

Al Bowers' Twist Methodology for Prandtl/Horten Bell-shaped Lift Distribution



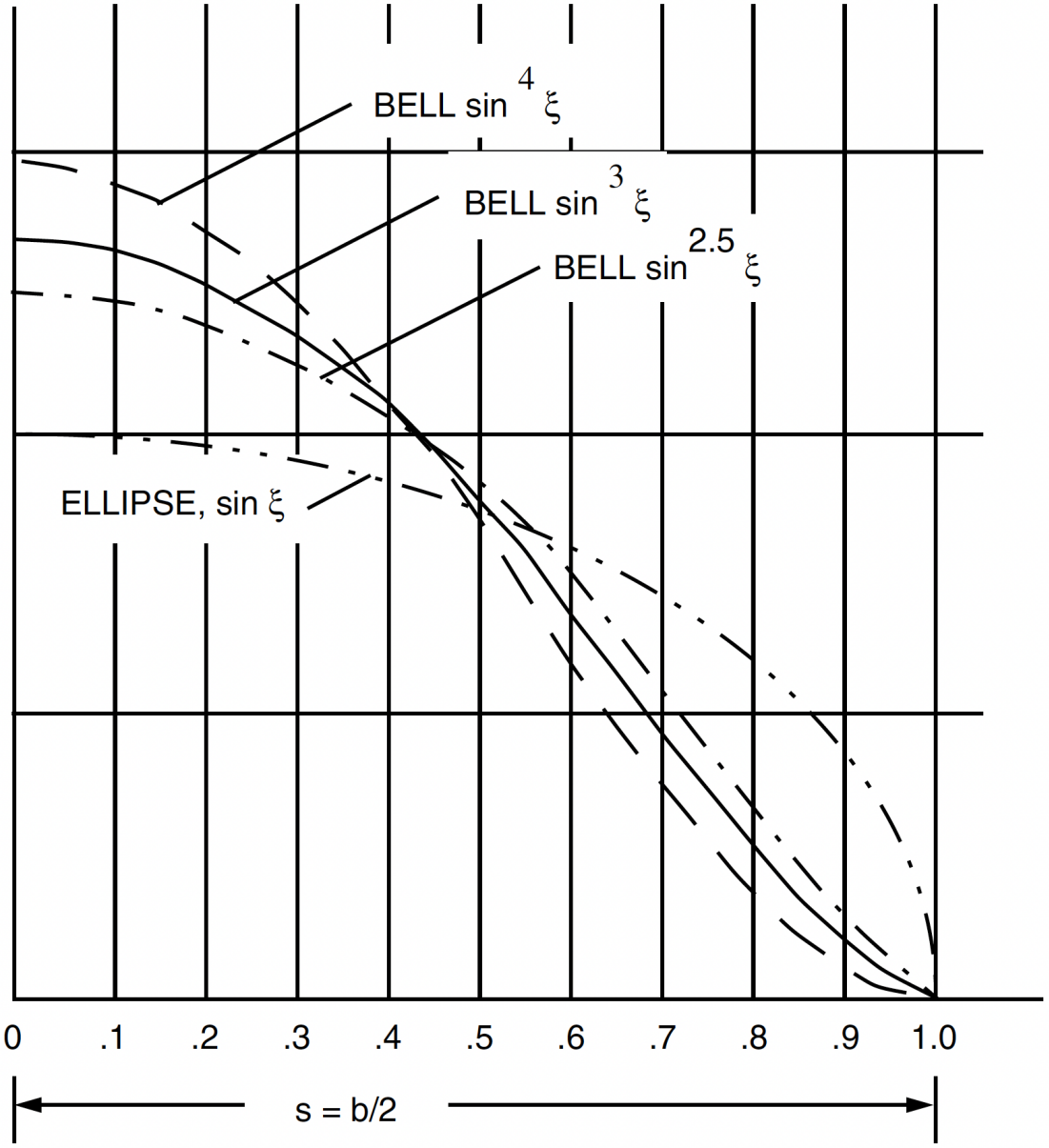
Al Bowers' Twist Distribution

1. High taper
2. Moderate ¼ chord sweep
3. Fairly high aspect ratio
4. Design CL
5. Airfoil choice(s)
6. Check zero lift angle(s)
7. Compute total twist needed
8. Find 0%, 25%, 50% and 100% points on semi-span
9. Compute twist for defined semi-span location

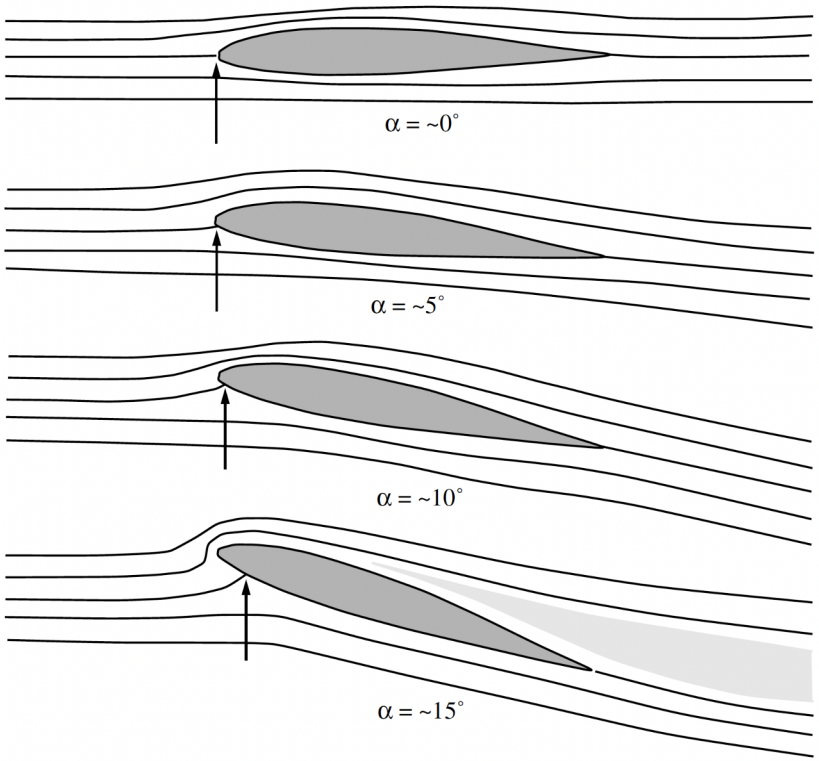
(Now you can build it!)

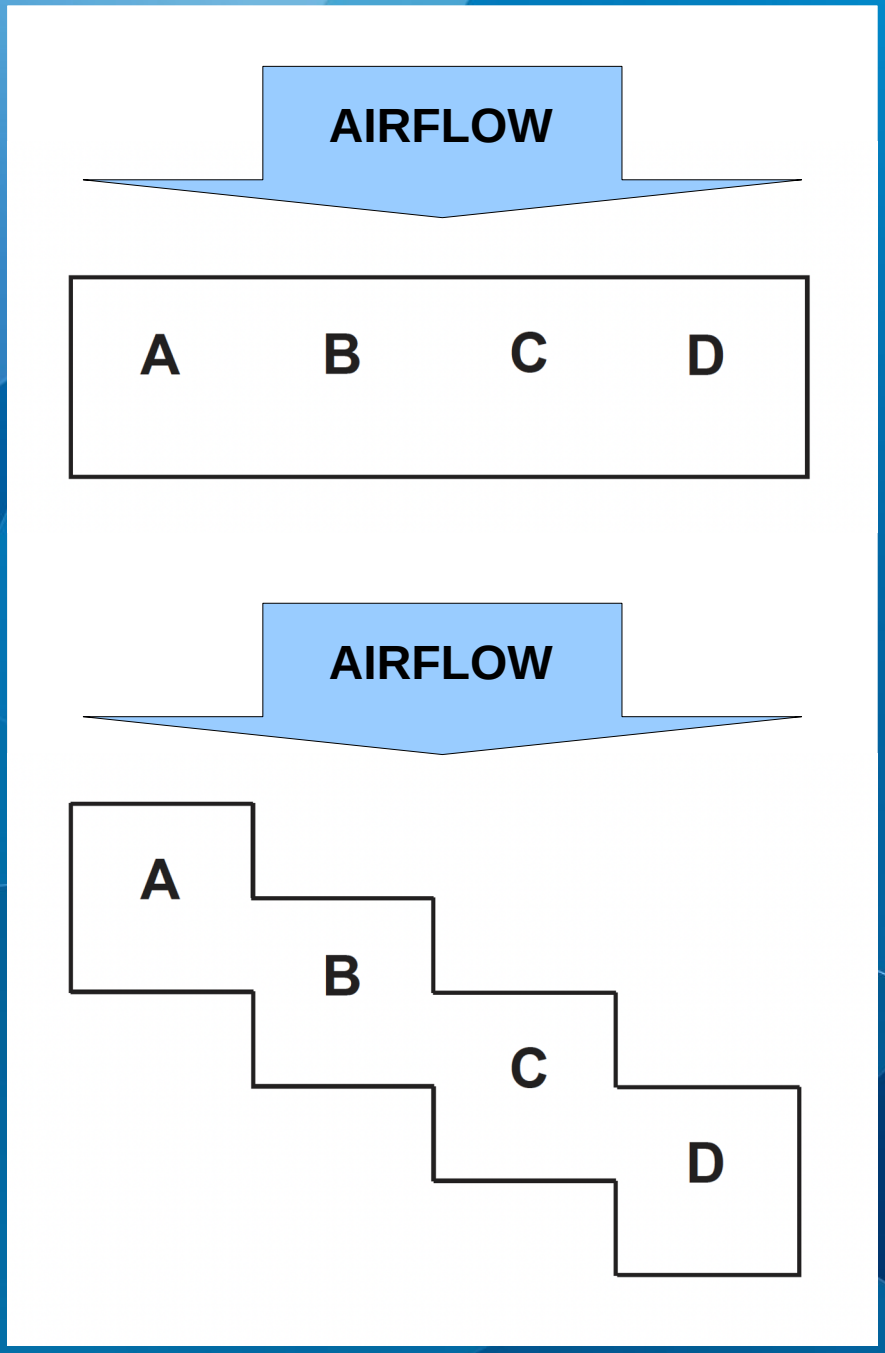


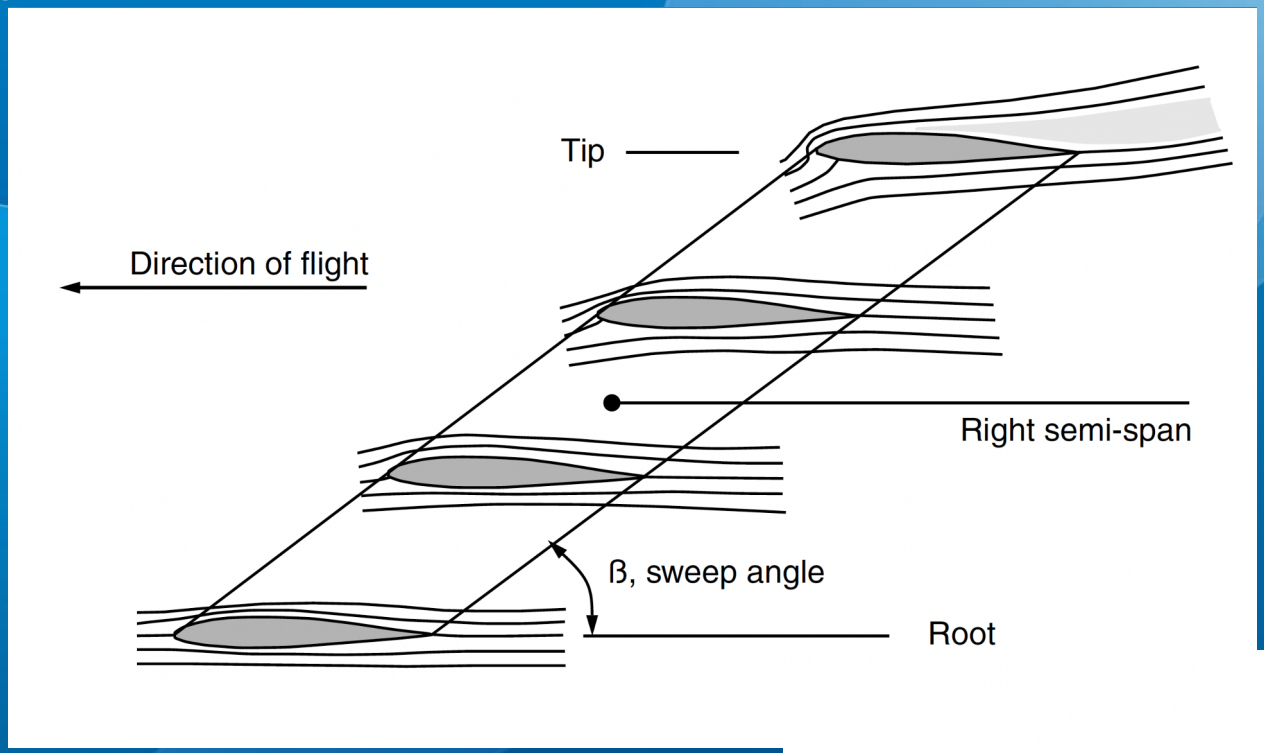
Spanload parameter	Elliptical spanload	Bell spanload
b/2	1.0000	1.2247
Cdi	1.0000	0.8889
e	1.0000	0.8889

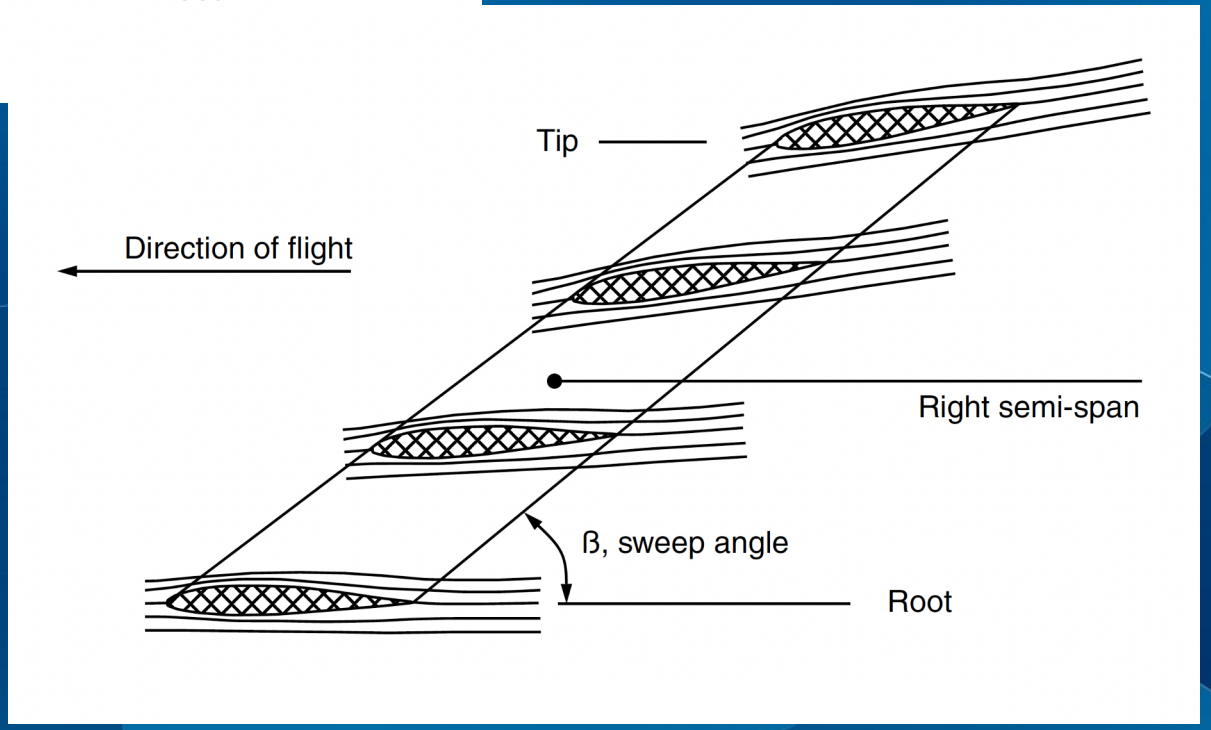

BELL sin 4 ξ
BELL sin 3 ξ
BELL sin 2.5 ξ
ELLIPSE, sin ξ
0
.1
.2
.3
.4
.5
.6
.7
.8
.9
1.0
s = b/2

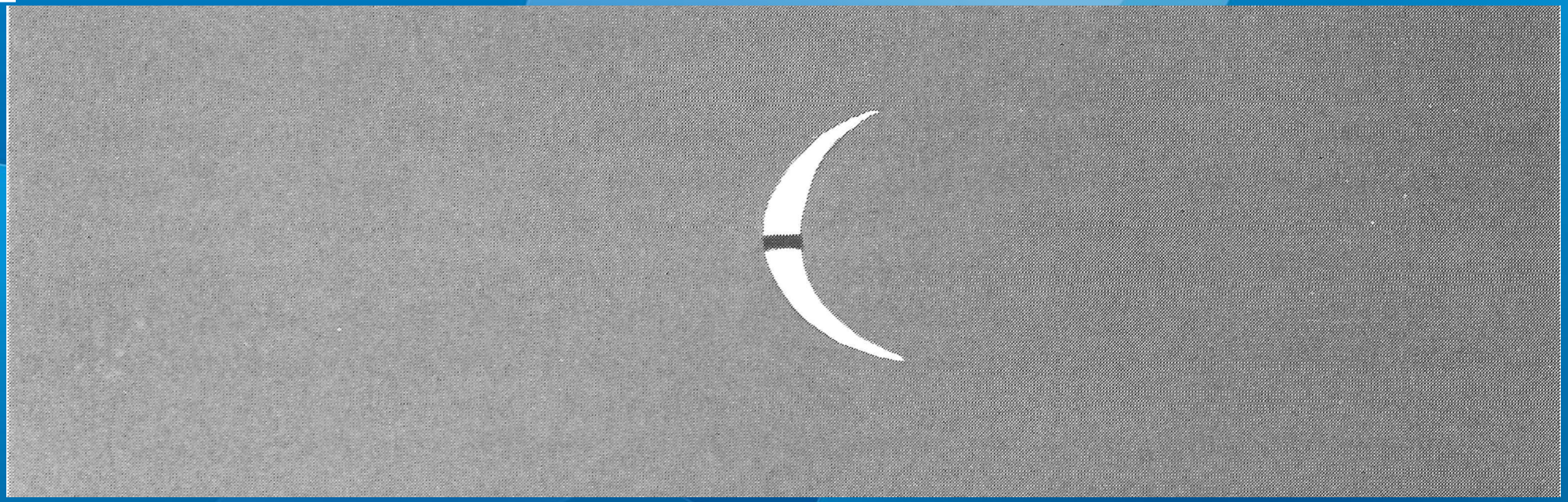
6. And one final complication

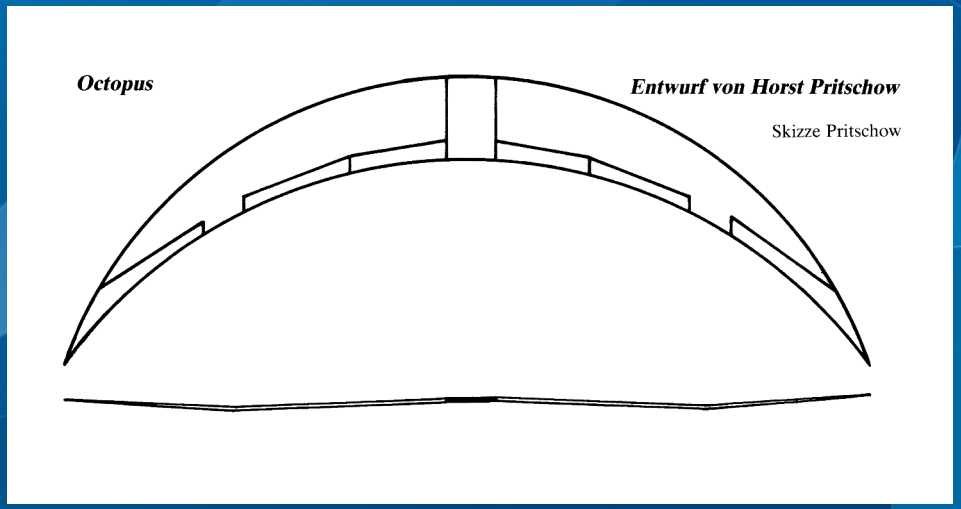

α = ~0°
α = ~5°
α = ~10°
α = ~15°


AIRFLOW
A
B
C
D
AIRFLOW
A
B
C
D

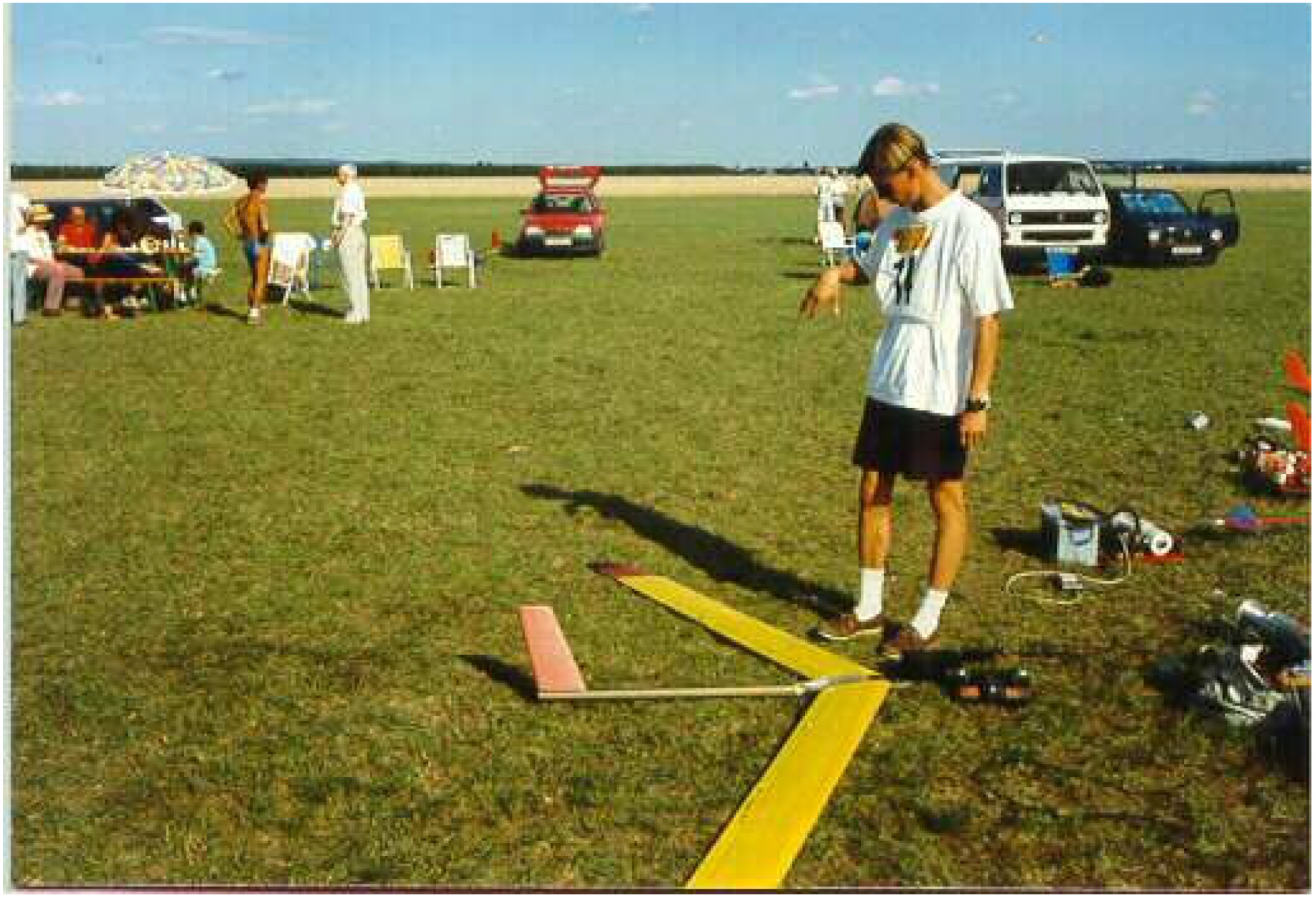

Tip
Direction of flight
Right semi-span
ß, sweep angle
Root


Tip
Direction of flight
Right semi-span
ß, sweep angle
Root

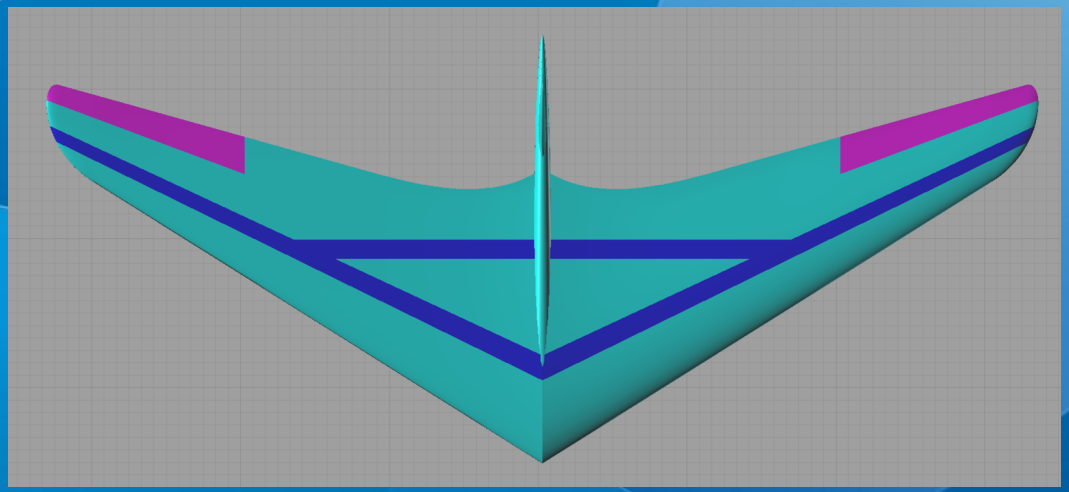


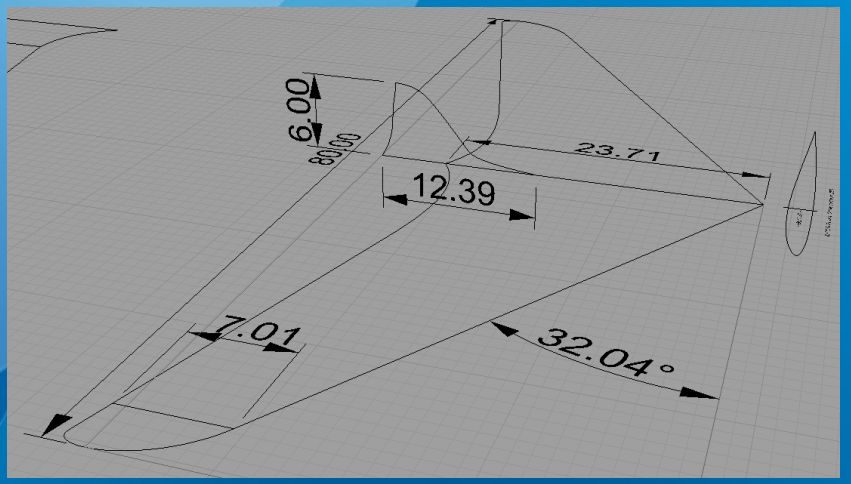

Octopus
Entwurf von Horst Pritschow
Skizze Pritschow

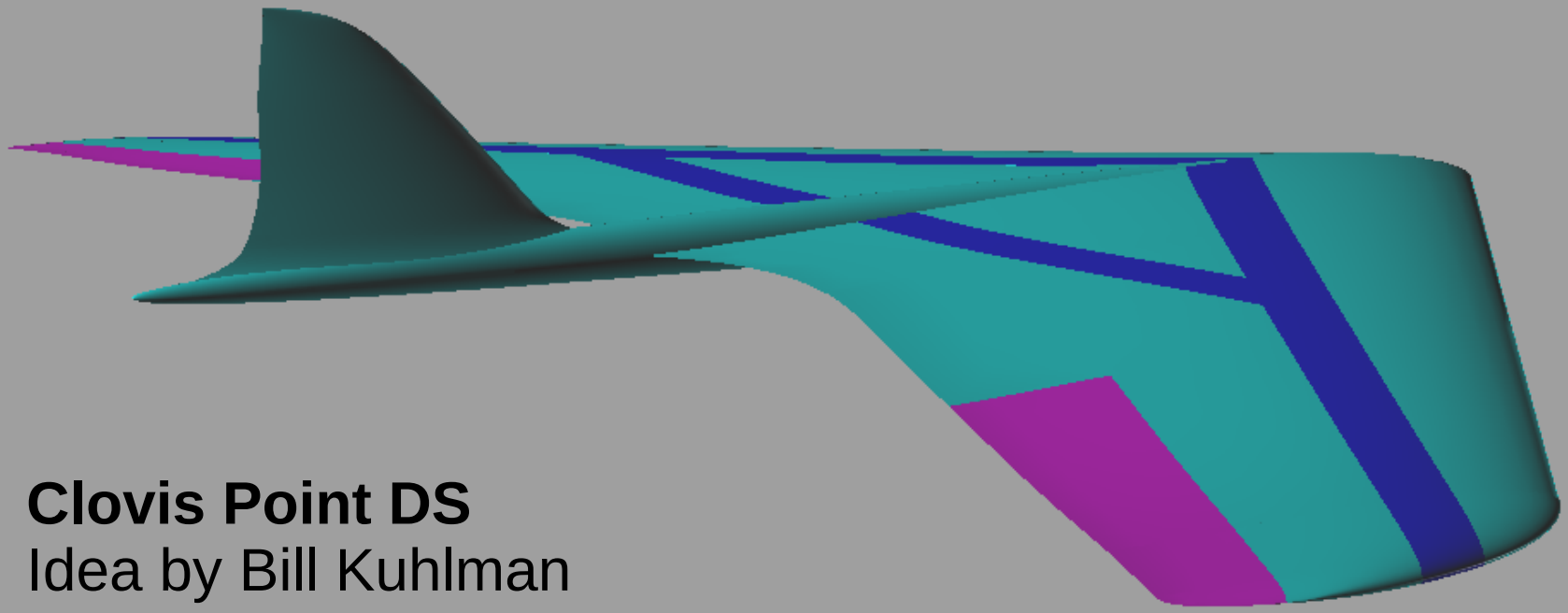




Hans-Jurgen Unverferth’s CO6







Clovis Point DS
Idea by Bill Kuhlman
Design by Steve Seim and Ken Stuhr

Dr. Walter Panknin's Secrets of Success

- Understand what you do
- Build stiff, not just strong
- No play in any linkages
- Precise location of the CG
- Have confidence it will fly

I would add… Although seemingly complex, swept wing RC sailplanes offer experiences you'll not forget.


FINIS