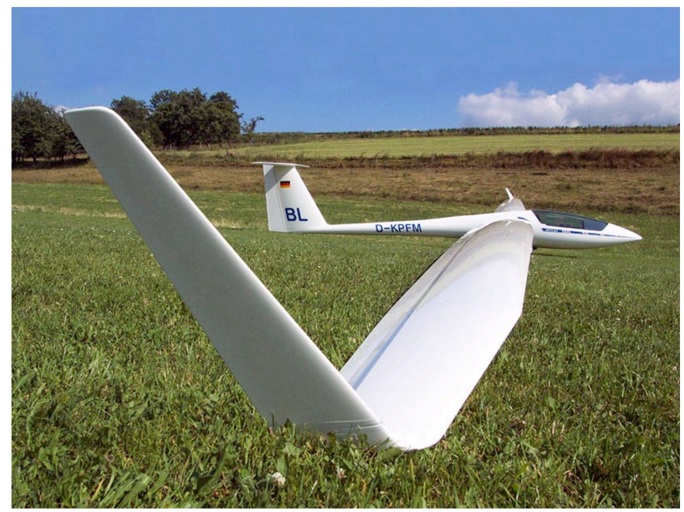
Configuration Aerodynamics of the ASW 22 BL Sailplane

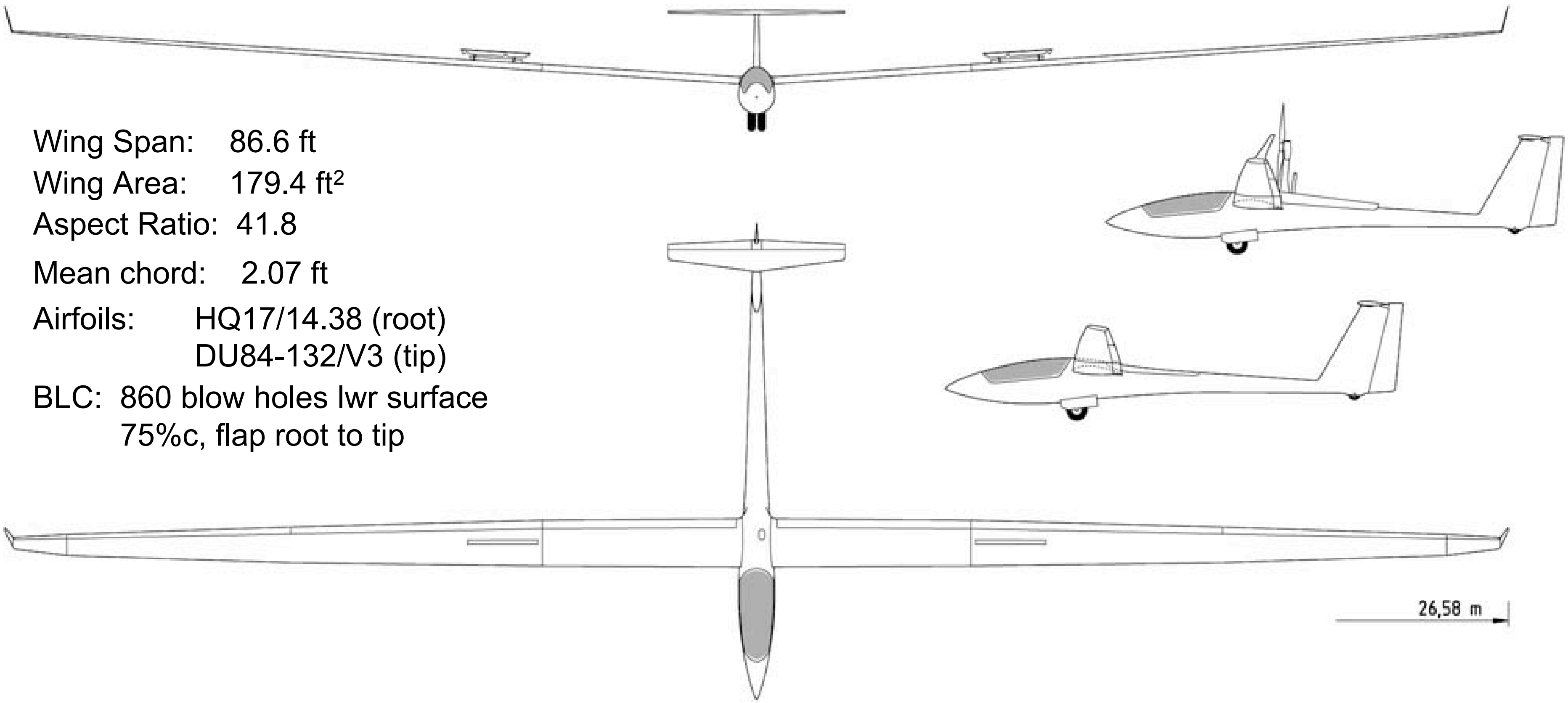


Rodney Bajnath, Beverly Beasley, Mike Cavanaugh

AOE 4124 Configuration Aerodynamics
April 21, 2004

Alexander Schleicher company web site: “www.alexander-schleicher.de”

ASW 22 BL Specifications



Wing Span: 86.6 ft

Wing Area: 179.4 ft^2

Aspect Ratio: 41.8

Mean chord: 2.07 ft

Airfoils: HQ17/14.38 (root)
DU84-132/V3 (tip)

BLC: 860 blow holes lwr surface
75%c, flap root to tip

Max T-O Weight: 1654 lbs.

Payload: 198 lbs.

Water Ballast: 452 lbs.

W/S_{MAX} = 9.22 lbs./ft^2

Conventional controls: ailerons (inner & outer), elevator, rudder

Double panel air brake (upper surface only)

Two wheel retractable main landing gear, fixed tail wheel

Cruise flaps (flap + inner aileron): +9.2° (thermaling), -0.5°, -7.7°, -10.7°

Landing flaps: flap +40°, inner aileron +14°, outer aileron -8°

Alexander Schleicher company web site: www.alexander-schleicher.de
Fred Thomas, *Fundamentals of Sailplane Design*, 1999.
Dick Johnson, “A Flight Test Evaluation of the AS-W22”, Soaring, April 1983.

Three Types of Soaring

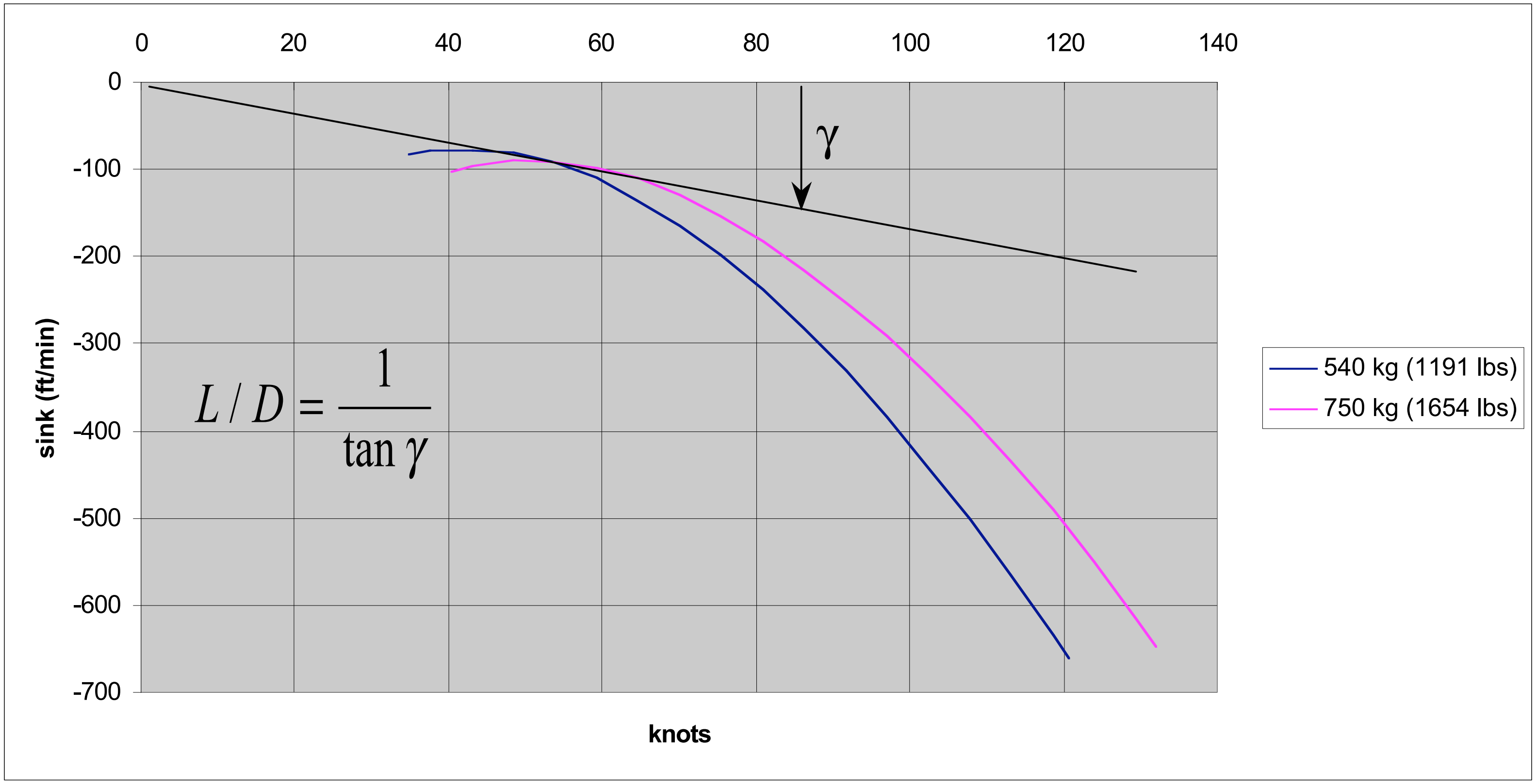
- **Thermal** – circle in rising current of warm air
- **Ridge** – fly in updraft on windward side of ridge
- **Wave** – fly in updraft portion of wave on lee side of mountain

Goal: sink less than the air rises

Result: climb & fly to next thermal!

Soaring Flight Manual, Soaring Society of America, 1992.
Photos, World Championships, Uvalde, Texas, 1991.

ASW 22 BL Factory Speed Polar



Min. sink: 79 fpm @ 43.2 KCAS (1191 lbs. / C_L = 1.05)

Best glide: 64.85 @ 59.4 KCAS (1654 lbs. / C_L = 0.77)

Max Speed: 151 KCAS

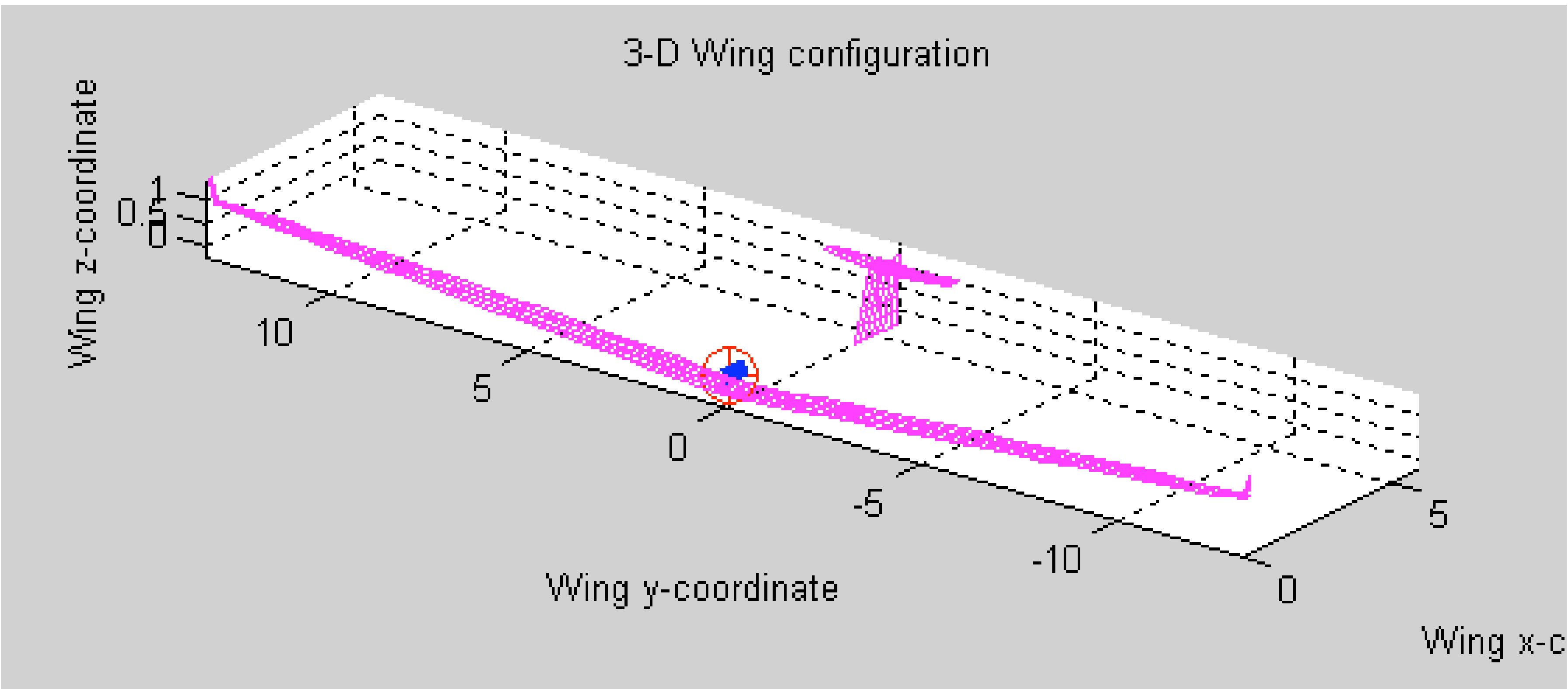
Stall Speed: 35.3 KCAS (light A/C)
41.5 KCAS (heavy A/C)
(Flaps 9° / C_{Lmax} = 1.58)

Alexander Schleicher company web site: www.alexander-schleicher.de
Dick Johnson, "A Flight Test Evaluation of the AS-W22", Soaring, April 1983.

Quest for Low Drag Drives Aerodynamic Configuration of Open Class Sailplanes

- **Large span** – low span loading (minimize induced drag) for a fixed weight
- **Minimum fuselage size** to accommodate pilot - reduce wetted area
- **Laminar flow airfoils** on wing, vertical tail & horizontal tail – low skin friction
- **Laminar flow on fuselage** - low skin friction
- **Smooth composite construction** – reduce drag of surface imperfections
- **Boundary layer control** on wing - fix transition and eliminate laminar bubbles
- **Cruise flaps** – adjust span & chord loading for a range of flight conditions
- **Retractable landing gear** – reduce pressure drag from gear and open doors
- **Winglets** - minimize induced drag in climbs
- **Long tail moment arm** – reduce horizontal tail area, min downwash at tail
- **Aft center of gravity placement** – reduce trim drag
- **Water ballast** – adjust speed for maximum L/D, improve penetration

ASW 22 Planform Analysis



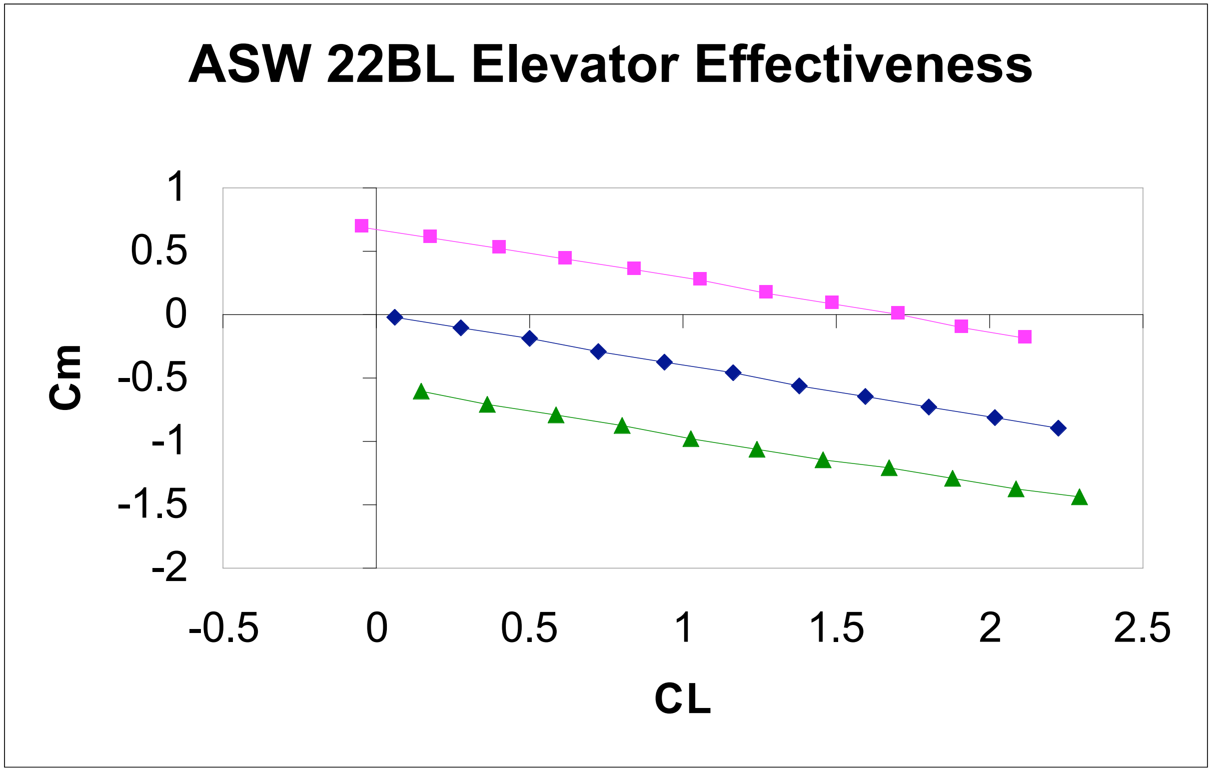
Tornado Model

ASW 22 Planform Analysis

- Without Winglets
  - AR = 38.3
  - b = 25.0 m
  - e = 0.95
  - L/D_{max} = 60
  - W/S_{max} = 9.42 lb/ft^2
- With Winglets
  - AR = 41.8
  - b = 26.58 m
  - e = 0.99
  - L/D_{max} = 62
  - W/S_{max} = 9.21 lb/ft^2
  - Improved stall
  - Better roll rate
  - Lower induced drag

ASW 22BL Trim Analysis

	Tornado	JKay	VLMpc
dC_m/dC_L	-0.410	-0.203	-0.368
C_{mo}	0.0	0.0	0.0



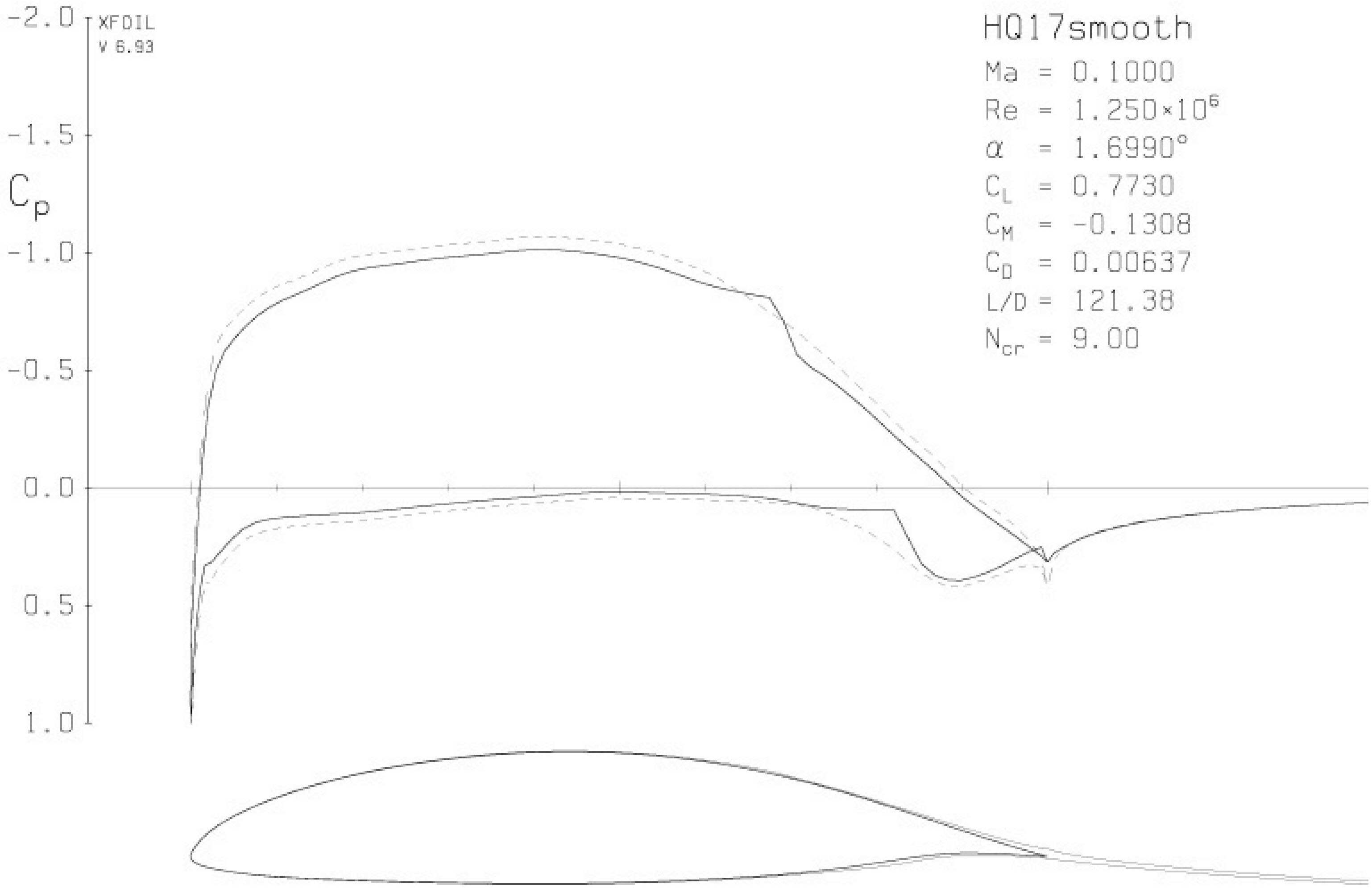
ASW 22BL Stability and Control

Longitudinal					Lateral-Directional			
	Tornado	JKay	VLMpc	DATCOM		Tornado	JKay	DATCOM
$C_{L\_}$	6.30	7.22	4.89	6.34	$C_{n\_}$	0.79	0.011	0.039
$C_{m\_}$	-1.48	-1.47	-1.80	-2.36	$C_{l\_}$	-0.02	-0.004	-0.21
C_{m_e}	-1.70			-1.96				

The ASW 22BL is stable for all major flight conditions.

XFOIL Wing Airfoil Analysis

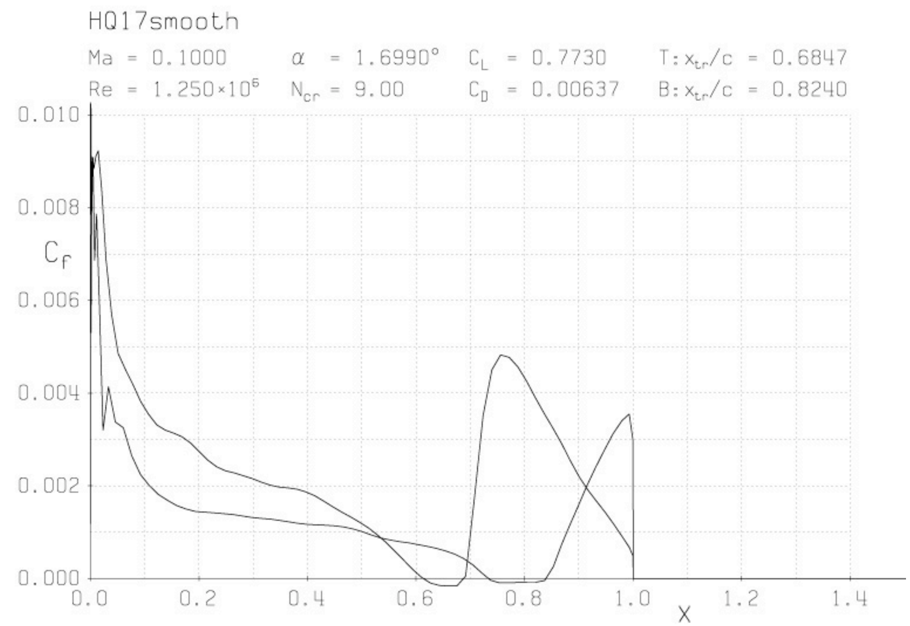
- Favorable pressure gradient to promote laminar flow
- Airfoil analysis at C_L for best L/D (59.4 KCAS @ 1654 lbs.)

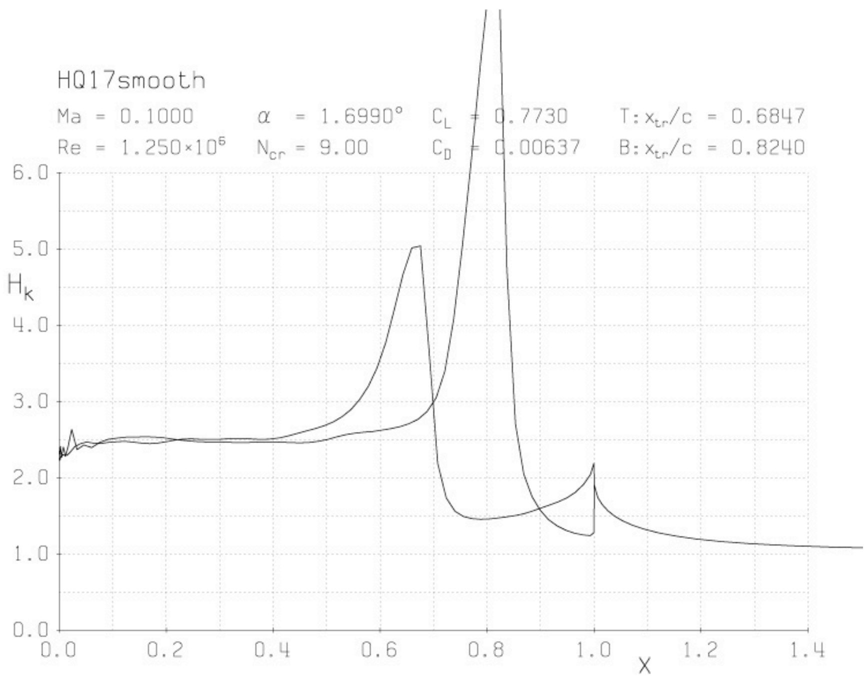


Mark Drela, "XFOIL 6.9 User Guide," 2001.

XFOIL Wing Airfoil Analysis

- Skin friction plot shows presence of laminar separation bubbles on the upper and lower surface where c_f goes to zero

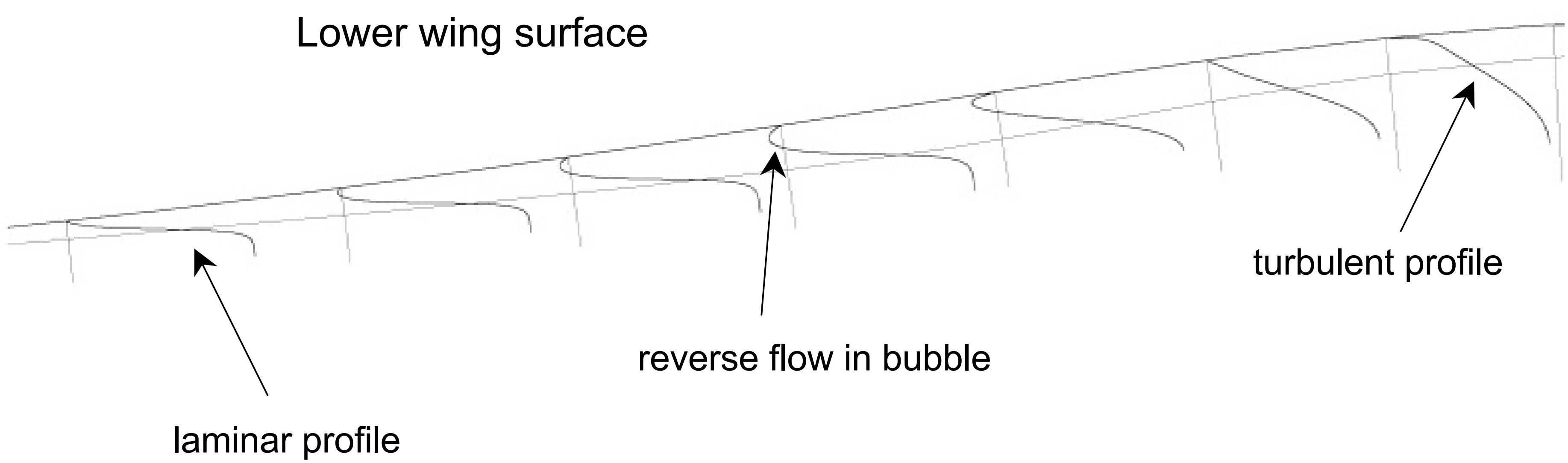




- Shape factor (_*/_) increases dramatically due to transition and the presence of the laminar bubbles

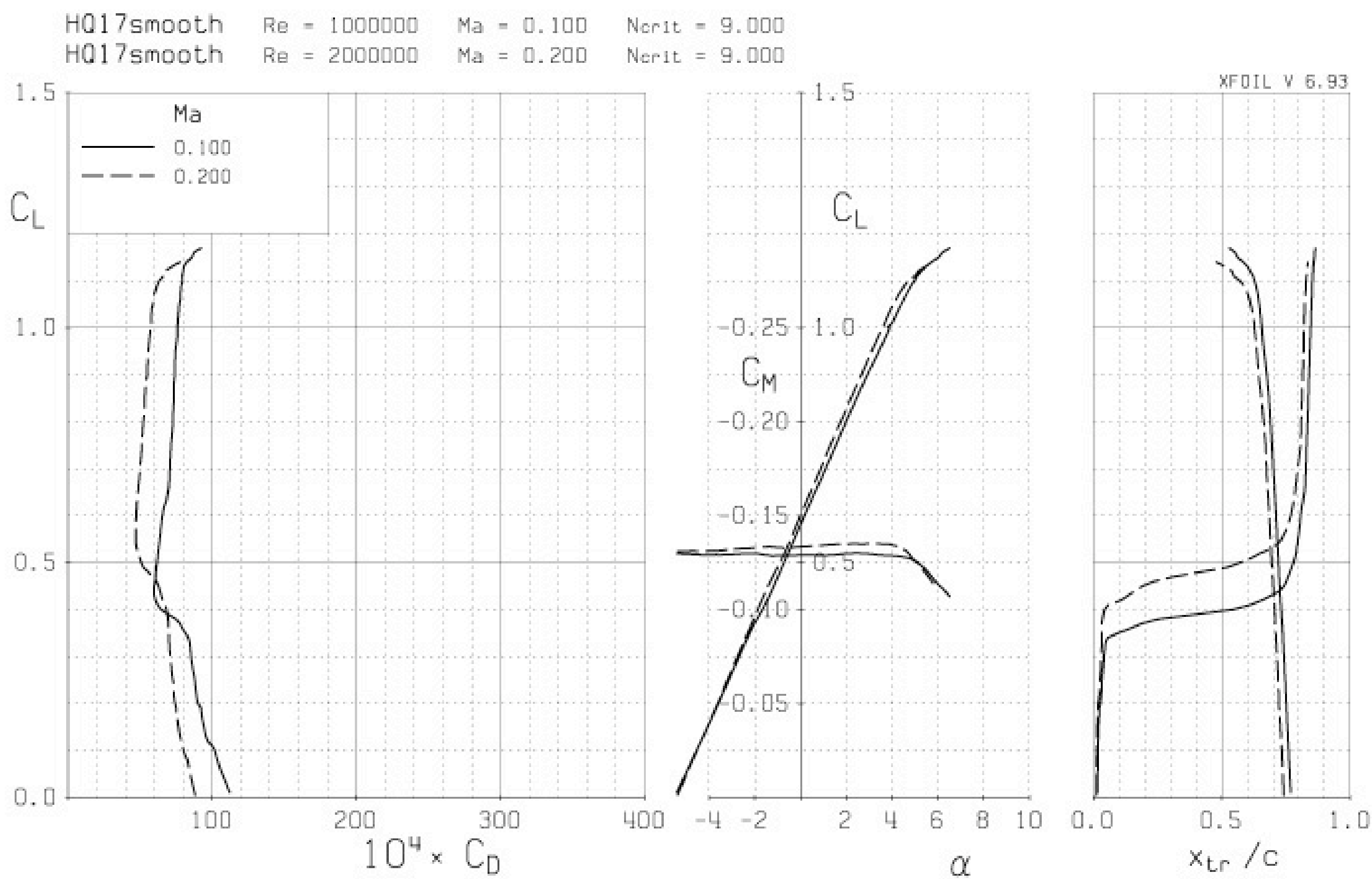
XFOIL Wing Airfoil Analysis

- Boundary layer profiles show reverse flow in the bubble region
- Blowing used to fix transition and eliminate bubble
  - 430 holes (0.0225” diameter) located on bottom of each wing
  - 73%~71% chord just in front of flap and aileron hinge lines
  - 20 mm spacing running from flap root to tip of aileron
  - Four inlet pitot tubes supply pressurized air to blowing holes



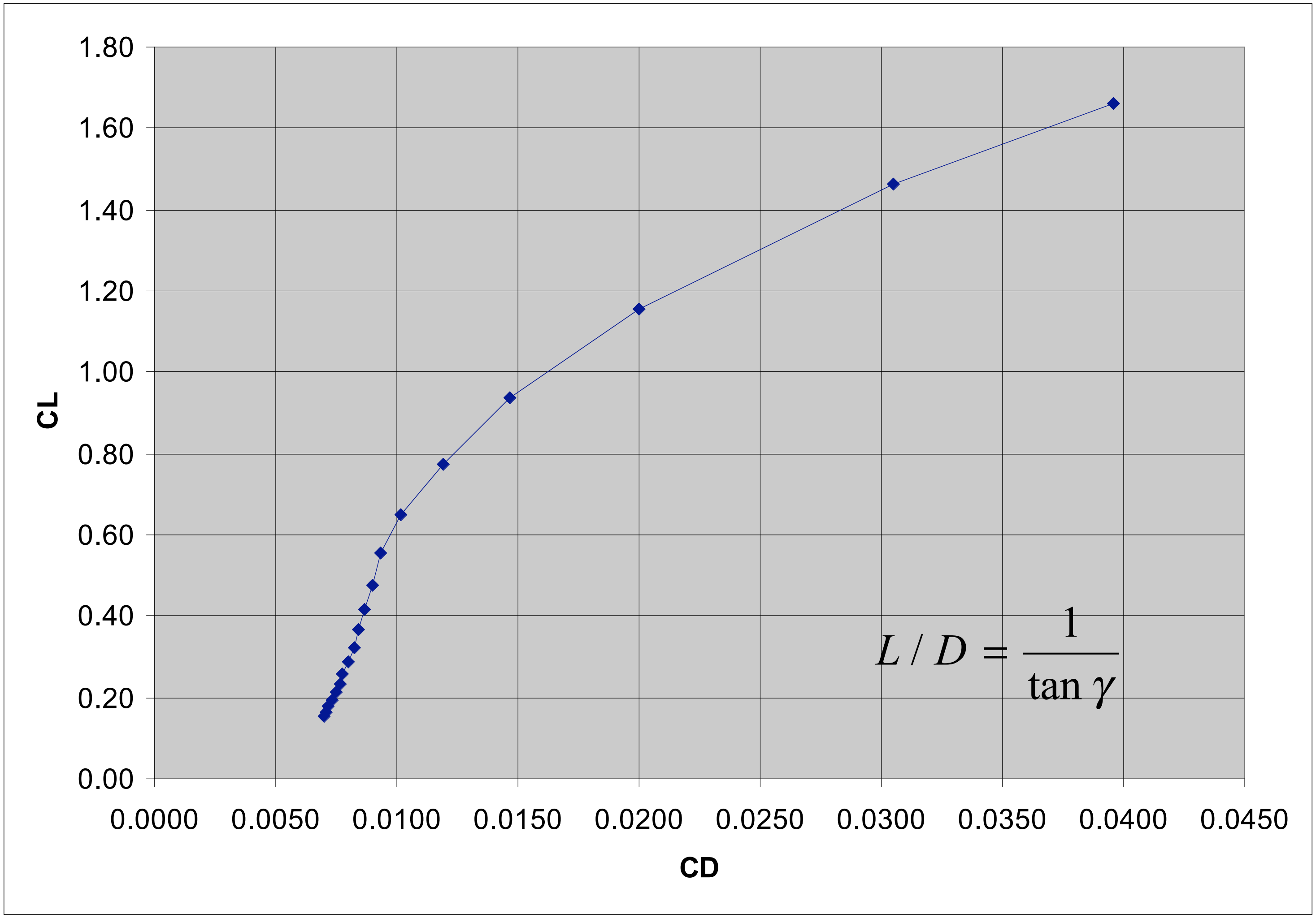
XFOIL Wing Airfoil Analysis

- Polar with upper and lower surface laminar separation bubbles present
- At max L/D speed (C_L=0.773), trips at 0.65c on the upper surface and 0.77c on the lower surface reduce airfoil C_d by 4.9 counts



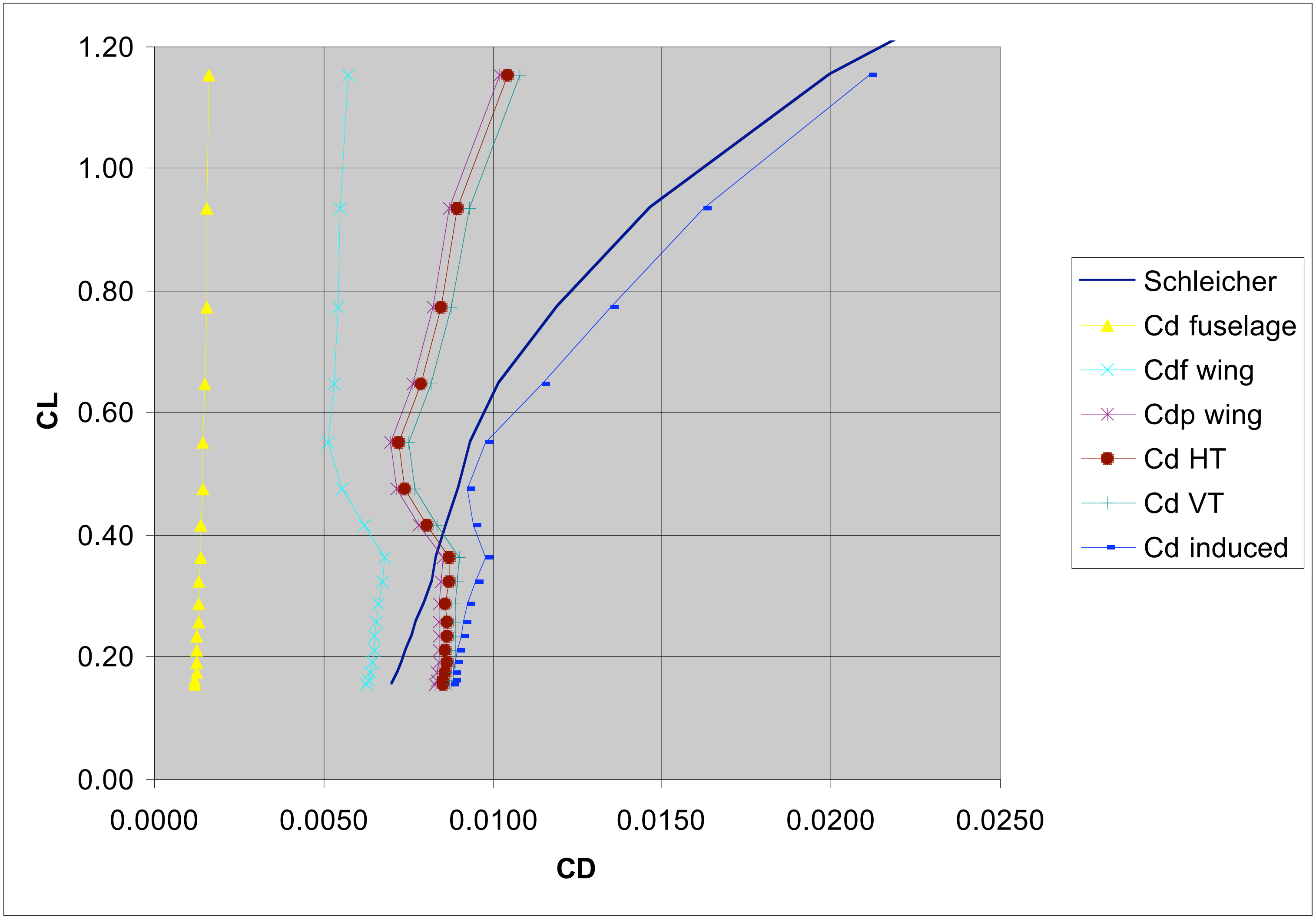
Drag Polar "Extracted" from Company Speed Polar

- C_D extracted from company speed polar using $L/D = 1/\tan\gamma$
- Data for the heavy aircraft (1654 lbs.) at 5,000 ft.



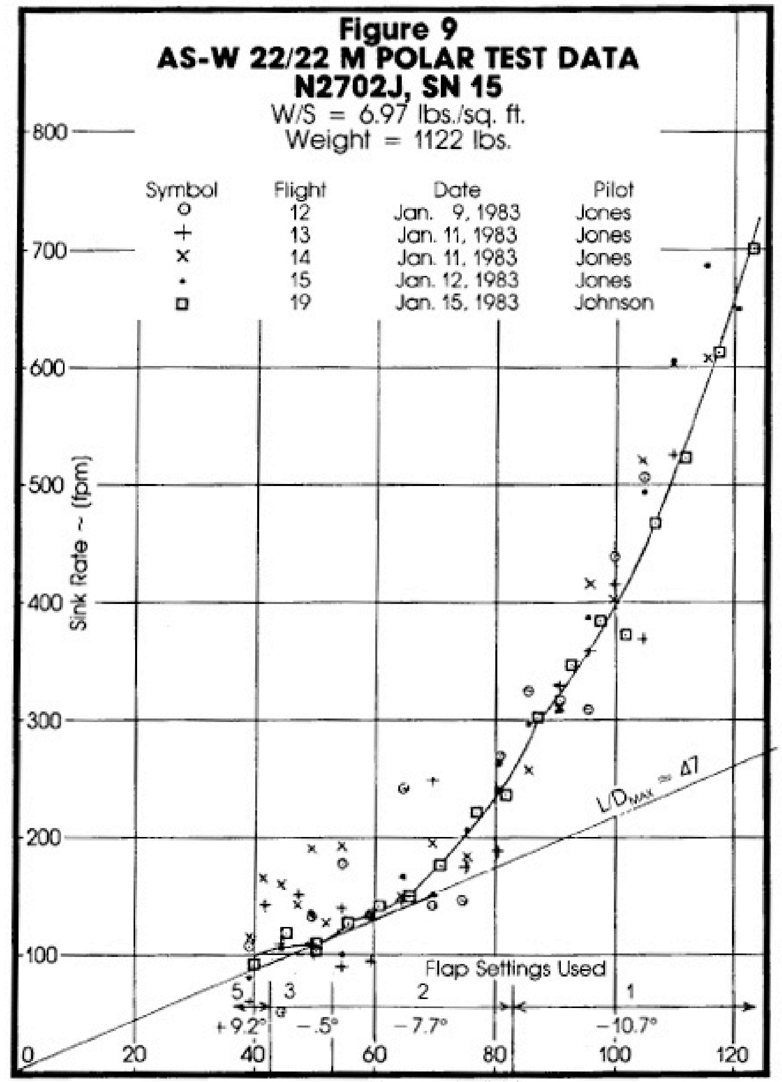
Drag Breakdown

- Attempt to match polar derived from Schleicher company data



Independent Flight Test Verification of Performance

- Flight test of the original ASW 22 by Dick Johnson and David Jones in 1983
- Appeared in the April 1983 issue of Soaring Magazine
- Plot shows amount of scatter in performance flight test data
- Plot shows flap scheduling suggested by Schleicher
- Performance of later 22B and 22BL models improved with increased span and winglets



Dick Johnson, “A Flight Test Evaluation of the AS-W22”, Soaring, April 1983.

ASW 22 BL Stability & Control Analysis

D(#)	Stability Derivatives	DATCOM /rad	DATCOM /deg	Tornado /rad	Tornado /deg
1	CLAlpha	6.3259	0.110400	6.2964	0.109885
2	CDAlpha	0.0979	0.001709	0.0882	0.001539
3	CmAlpha	-1.2551	-0.021903	-1.4740	-0.025724
4	CLAlphadot	0.5129	0.008951	-	-
5	CmAlphadot	-3.9800	-0.069459	-	-
6	CLq	5.7499	0.100347	14.3943	0.251209
7	Cmq	-44.6196	-0.778702	-46.1854	-0.806028
8	CLM	0.0	0.0	-	-
9	CDM	0.0	0.0	-	-
10	CmM	0.0	0.0	-	-
11	CLDeltaM	0.2528	0.004412	0.2412	0.004210
12	CDDeltaM	0.0056	0.000097	0.0093	0.000163
13	CMDeltaM	-1.9618	-0.034237	-1.7300	-0.030192
14	CTV	0.0	0.0	-	-
15	CTDeltaT	0.0	0.0	-	-
16	CyBeta	-0.2824	-0.004928	4.2181	0.073614
17	ClBeta	-0.2064	-0.003602	0.0198	0.000346
18	CnBeta	0.0392	0.000685	0.8100	0.014136
19	Clp	-0.9658	-0.016854	-0.7335	-0.012801
20	Cnp	0.1174	0.002048	-0.1912	-0.003336
21	Cyp	-0.0082	-0.000143	-0.1434	-0.002502
22	Clr	0.1676	0.002926	0.1364	0.002380
23	Cnr	-0.0277	-0.000484	0.3344	0.005836
24	Cyr	0.0840	0.001466	1.7479	0.030504
25	ClDeltaL	0.6251	0.010909	0.2731	0.004766
26	CnDeltaL	-0.0194	-0.000338	0.0102	0.000179
27	ClDeltaN	0.0019	0.000033	-0.0424	-0.000739
28	CnDeltaN	-0.0194	-0.000338	0.4437	0.007743
29	CyDeltaN	0.1099	0.001918	2.4083	0.042030

Phys(#)	Reference		units
1	weight	1653.75	lbs
2	Ixx	10780	slug-ft^2
3	Iyy	626	slug-ft^2
4	Izz	11396	slug-ft^2
5	Ixz	0	slug-ft^2
6	Area	179.37	ft^2
7	Span	86.62	ft
8	Chord	2.067	ft
9	Thrust Angle	0	rad

Ref(#)	Condition		units
1	density	0.002048	slugs/ft^3
2	TAS	107.94	ft/s
3	Mach	0.098	
4	CL	0.773	trim
5	CD	0.01191	trim
6	gamma	-0.01542	radians

c.g. @ 42.5%c

Stability derivatives and reference conditions for analysis

Jan Roskam, “Airplane Design Book VI”, 1990.

ASW 22 BL Stability & Control Summary

- Longitudinal static stability positive
  - Stick-fixed neutral point location: 0.66c Tornado / 0.62c DATCOM
  - C.G. location calculated to be 42.5%c at maximum take-off weight

- Static lateral/directional stability positive
  - $C_N > 0$: Tornado (sign change needed) & DATCOM
  - $C_L < 0$ dihedral effect: Tornado (sign change needed) & DATCOM

- Lateral/directional control
  - Rudder power: _ degree of sideslip per degree of rudder deflection
  - Steady state roll rate 17.02 deg/sec at 45 knots (Johnson flight test value 11.25 deg/sec)
  - Dick Johnson flight test reports “moderately strong adverse yaw”

- Longitudinal Dynamic Stability

Mode	ζ	ω_d (rad/s)	ω_n (rad/s)	f (Hz)	T (sec)
phugoid	-0.00033	0.3127	0.3127	0.0498	20.0933
short period	0.71326	2.8114	4.0111	0.4474	2.2349

- Lateral/Directional Dynamic Stability

Mode	ζ	ω_d (rad/s)	ω_n (rad/s)	f (Hz)	T (sec)	T_2 (sec)	$T_{1/2}$ (sec)
dutch roll	0.16144	0.6143	0.6225	0.0978	10.23		
spiral						84.47	
roll							0.1025

Dick Johnson, “A Flight Test Evaluation of the AS-W22”, Soaring, April 1983.

Conclusions

- Pro
  - Performance, low min sink (79 fpm) and high glide ratio (L/D 64.85)
  - Variable wing loading with jettisonable water ballast. Good penetration on strong days and low minimum sink on weak days
  - Wing extensions and winglet add-ons provide versatility
  - ASW 22BL an improvement over ASW 22 and ASW 22B because of higher L/D and span efficiency (as evidenced by flight testing)
  - Stable configuration
  - Winner of 6 World Championships!

- Con
  - Ground handling difficult due to large span (TEU aileron deflection)
  - Flight test report of moderately strong adverse yaw
  - Complexity (boundary layer control)
  - Technology is 10 years old, current max L/D now in low to mid 70’s
  - Price: $144,339 US / Eastern Sailplanes, Waynesville, OH

References

- Alexander Schleicher company web site, www.alexander-schleicher.de
- Fred Thomas, *Fundamentals of Sailplane Design,* College Park Press, College Park Maryland, 1999.
- Richard H. Johnson, “A Flight Test Evaluation of the AS-W22,” Soaring Magazine, April 1983.
- *Soaring Flight Manual, Private and Commercial,* Soaring Society of America, Jeppesen Sanderson, Inc., 1992.
- Mark Drela, “XFOIL 6.9 User Guide,” MIT Aero & Astro, 2001.
- Jan Roskam, *Airplane Design Part VI: Preliminary Calculation of Aerodynamic, Thrust and Power Characteristics,* Roskam Aviation and Engineering Corporation, Ottawa Kansas, 1990.