Efficient Light Aircraft Design – Options from Gliding

Howard Torode

Member of General Aviation Group

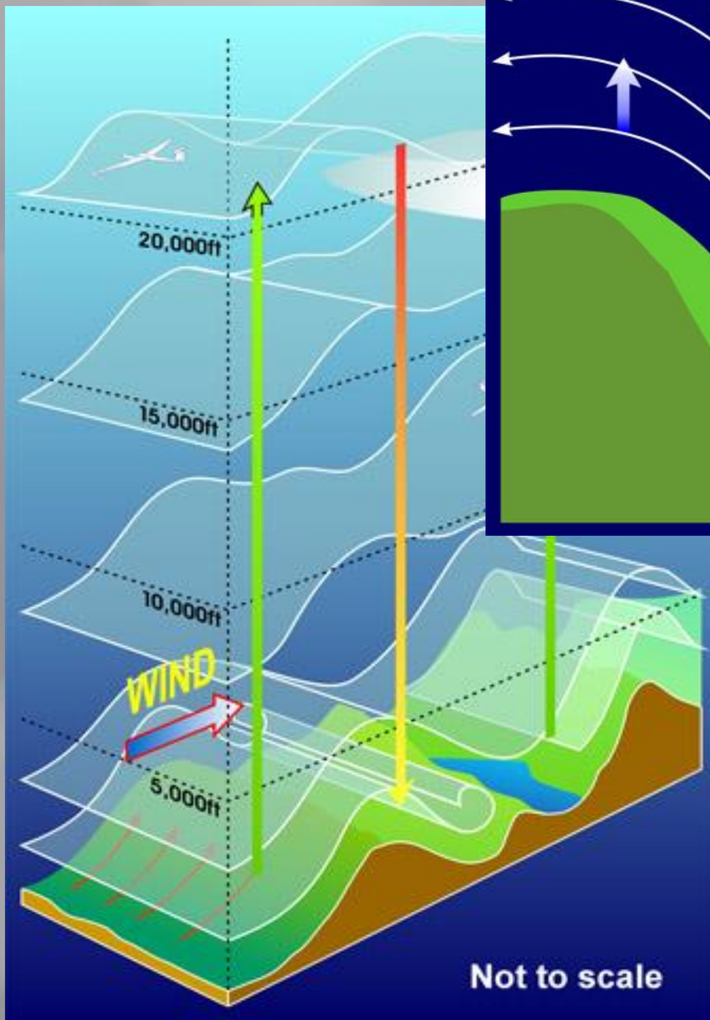
and

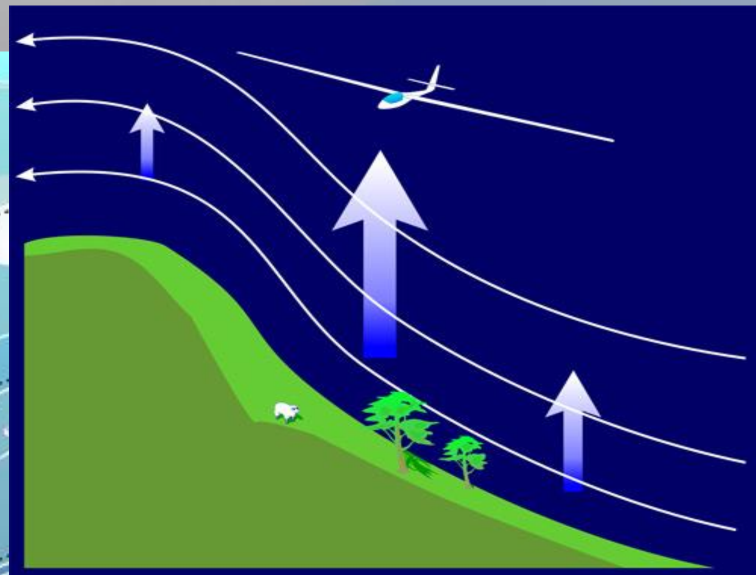
Chairman BGA Technical Committee

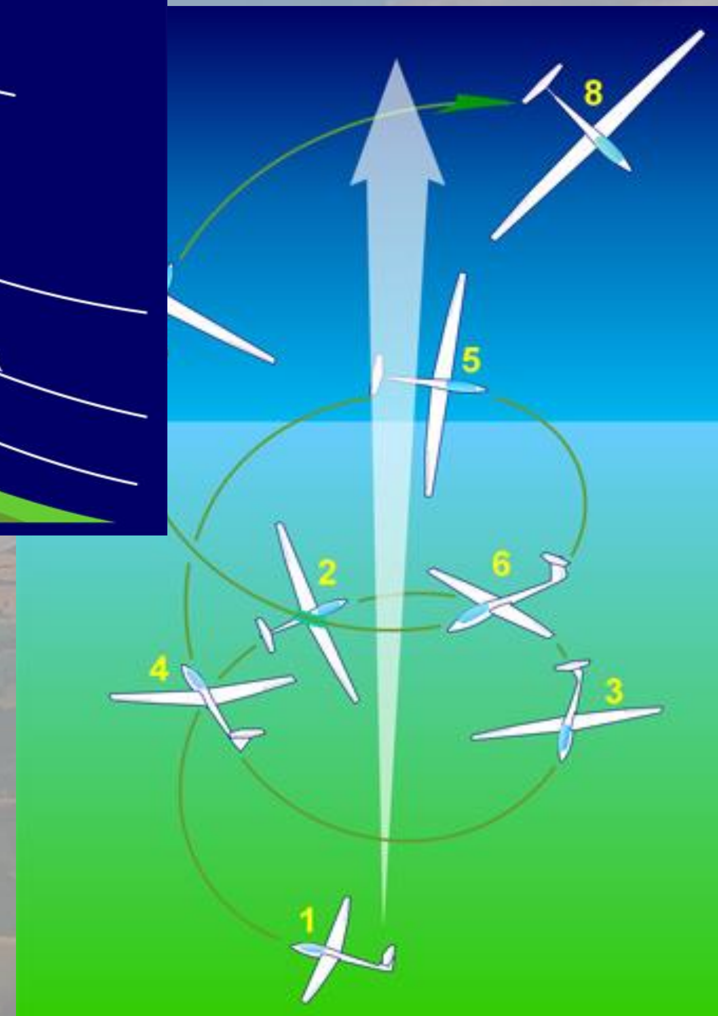
Presentation Aims

- Recognise the convergence of interest between ultra-lights and sailplanes
- Draw on experiences of sailplane designers in pursuit of higher aerodynamic performance.
- Review several feature of current sailplanes that might be of wider use.
- Review the future for the recreational aeroplane.

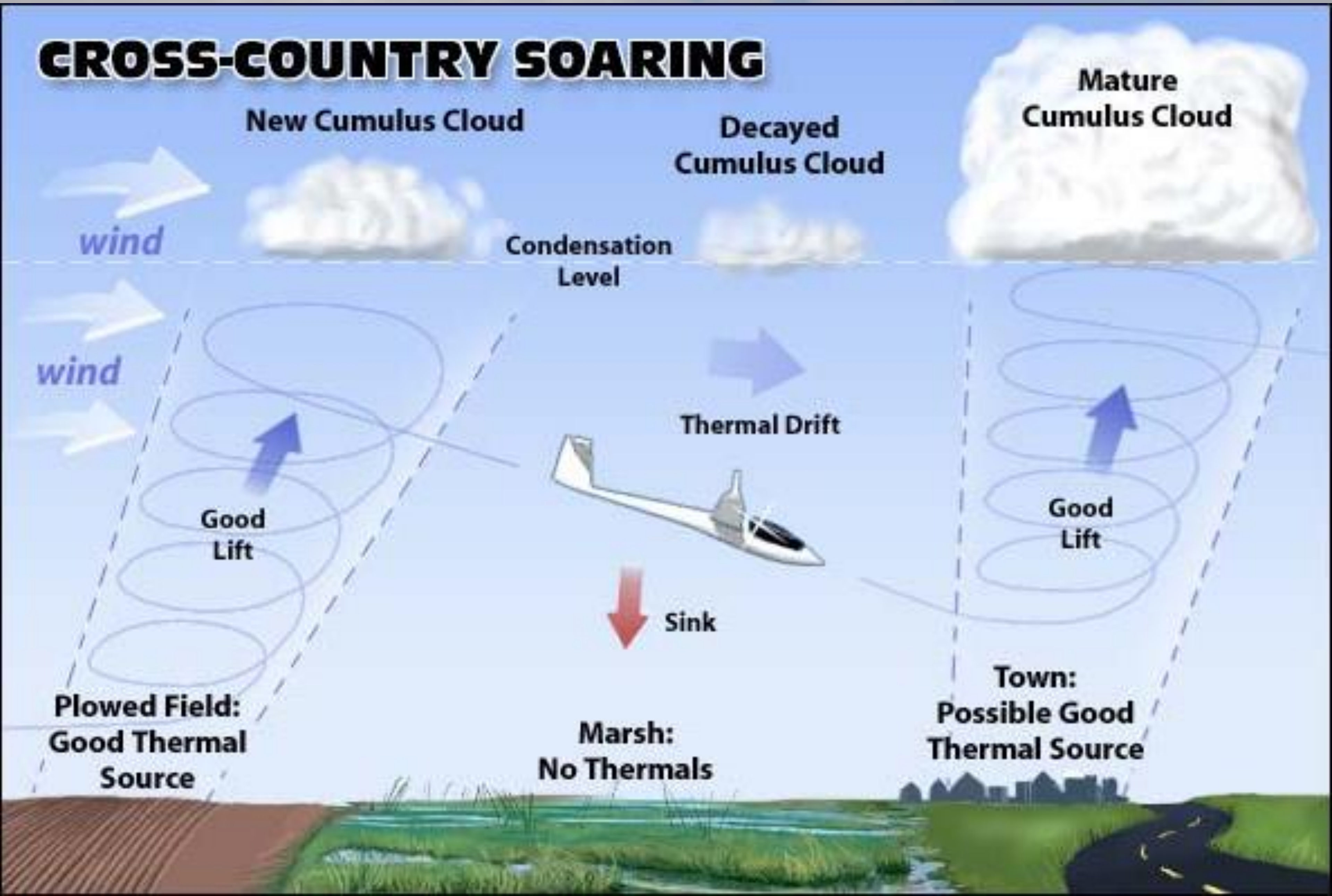
Lift occurs in localised areas





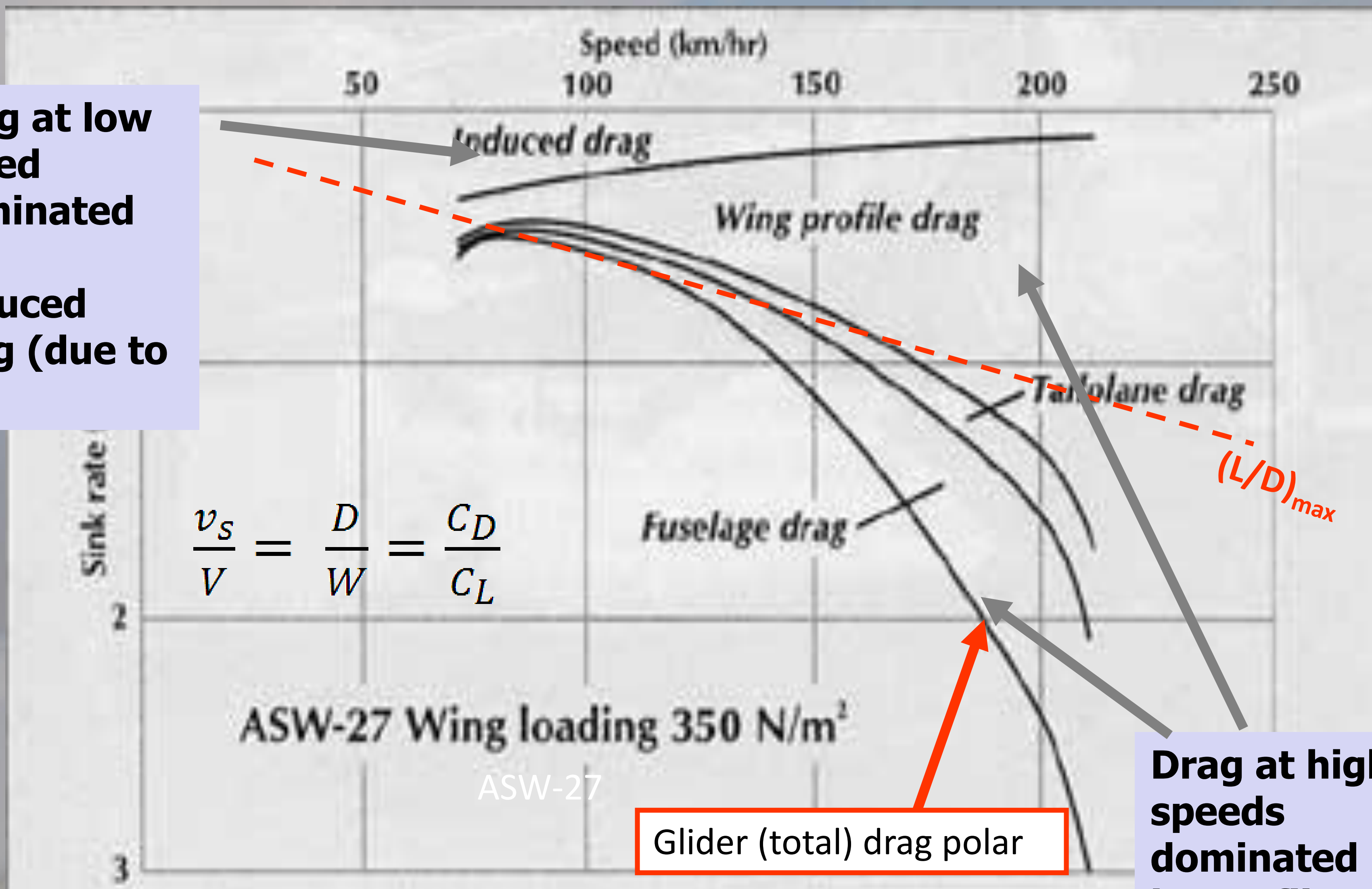


A glider needs efficiency and manoeuvrability


CROSS-COUNTRY SOARING
New Cumulus Cloud
Decayed Cumulus Cloud
Mature Cumulus Cloud
wind
wind
Condensation Level
Thermal Drift
Good Lift
Good Lift
Sink
Plowed Field: Good Thermal Source
Marsh: No Thermals
Town: Possible Good Thermal Source

Drag contributions for a glider

Drag at low speed dominated by Induced drag (due to lift)



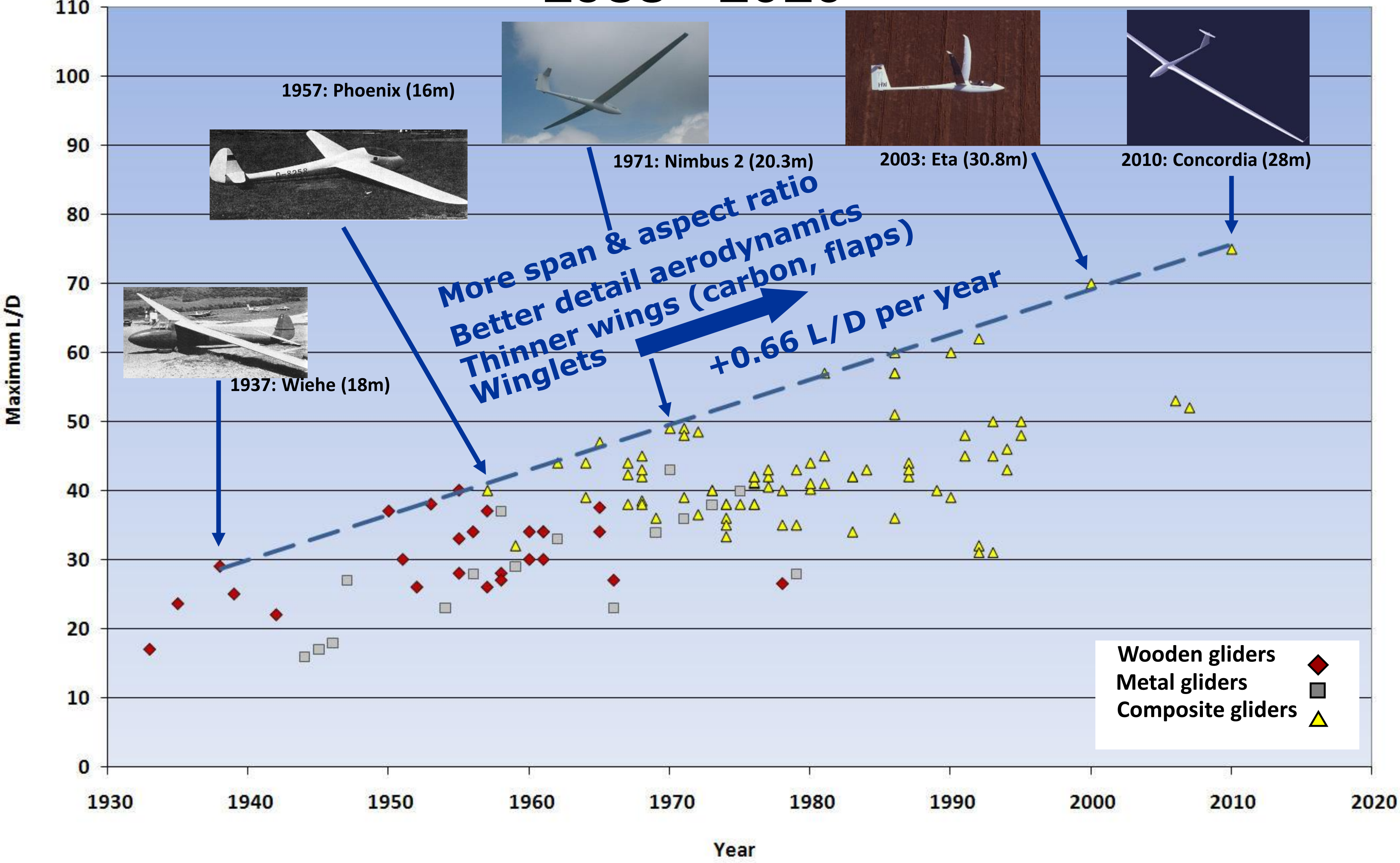
$$\frac{v_S}{V} = \frac{D}{W} = \frac{C_D}{C_L}$$

Drag at high speeds dominated by profile drag & skin friction

So what are the configuration parameters?

- Low profile drag: Wing section design is key
- Low skin friction: maximise laminar areas
- Low induced drag – higher efficiencies demand greater spans, span efficiency and Aspect Ratio
- Low parasitic drag – reduce excrescences such as: undercarriage, discontinuities of line and no leaks/gaps.
- Low trim drag – small tails with efficient surface coupled with low stability for frequent speed changing.
- Wide load carrying capacity in terms of pilot weight and water ballast

Progress in aerodynamic efficiency 1933 - 2010



In praise of Aspect Ratio

- Basic drag equation in in non-dimensional, coefficient terms:

$$C_D = \mathrm{C_{D0}} \mathrm{f}(R_e, \delta) + \frac{k}{\pi A} \mathrm{C_L^2}$$

- For an aircraft of a given scale, aspect ratio is the single overall configuration parameter that has direct leverage on performance. Induced drag - the primary contribution to drag at low speed, is inversely proportional to aspect ratio
- An efficient wing is a key driver in optimising favourable design trades in other aspects of performance such as wing loading and cruise performance.
- Aspect ratio also raises vehicle overall lift curve slope providing a responsive, controllable aircraft.

Refinement of sailplane wing planforms 1922-1934

Images courtesy of Vince Cockett - scale soaring UK

Efficiency of load distribution for wings of AR=15

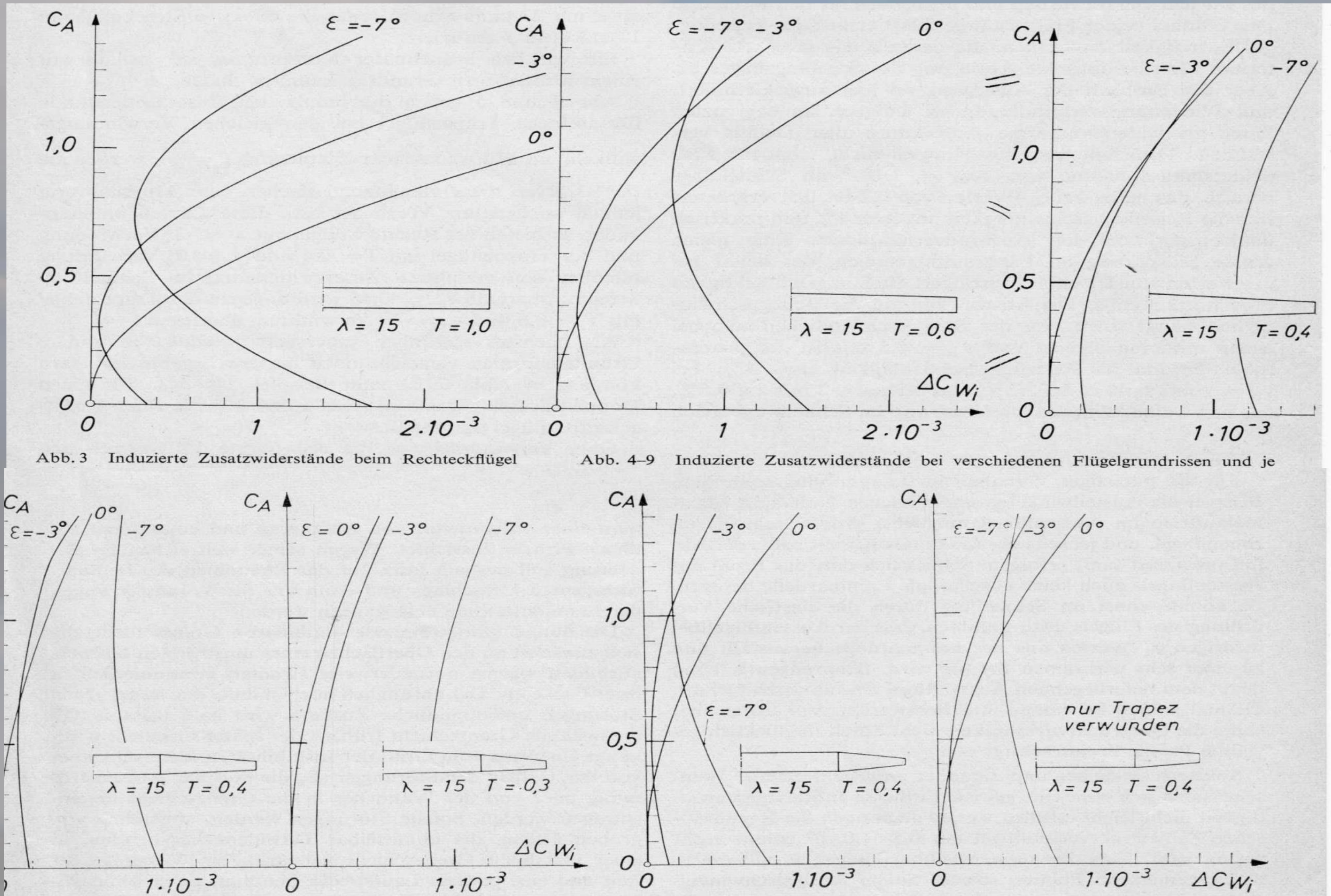


Abb. 3 Induzierte Zusatzwiderstände beim Rechteckflügel

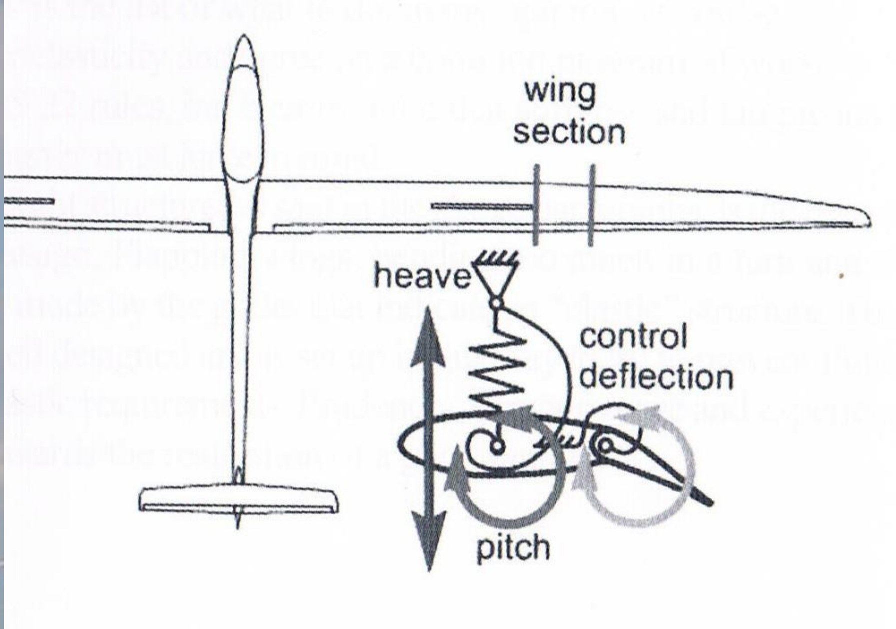
Abb. 4–9 Induzierte Zusatzwiderstände bei verschiedenen Flügelgrundrissen und je drei Verwindungswinkel. Verwindungsverlauf für gerade Vorder- und Hinterkante

Induced drag additional to the ‘elliptic perfection’ of k =1

Aspect ratio – additional complexity?

- Higher stresses (eg. Root BM)
  - Leads to greater weight.
  - Limited volume for Undercarriage & fuel.
- Aero-elasticity issues (requiring analysis).
  - Torsional stiffness and control mass balance
- Control issues
  - Higher roll inertia
  - Roll control power and longer control runs
- Lower Reynolds numbers (at tip)
- Practical issues of space
  - In workshop and hanger
  - Need for transport joints?

Aero-elasticity and Flutter



- Vibrations can take many forms but most modes are 'soft' (but usually graphically reported!)
- Aero-elastic analysis is a key task in design. The only organisations fully capable are GE universities.
- The key parameter is adequate wing torsion rigidity, which, when coupled with control mass balancing can usually avoid interactions with bending or control surface modes

In flight demonstration of aileron induced flutter on a sailplane

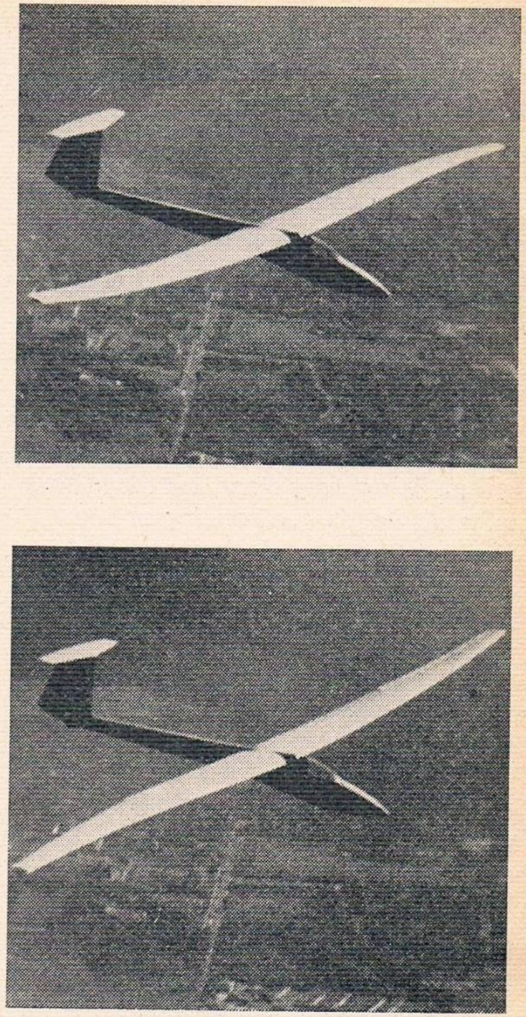


Figure 1 and 2: Anti-symmetric wing bending oscillation f=3.3 Hz at V=90 km/h.

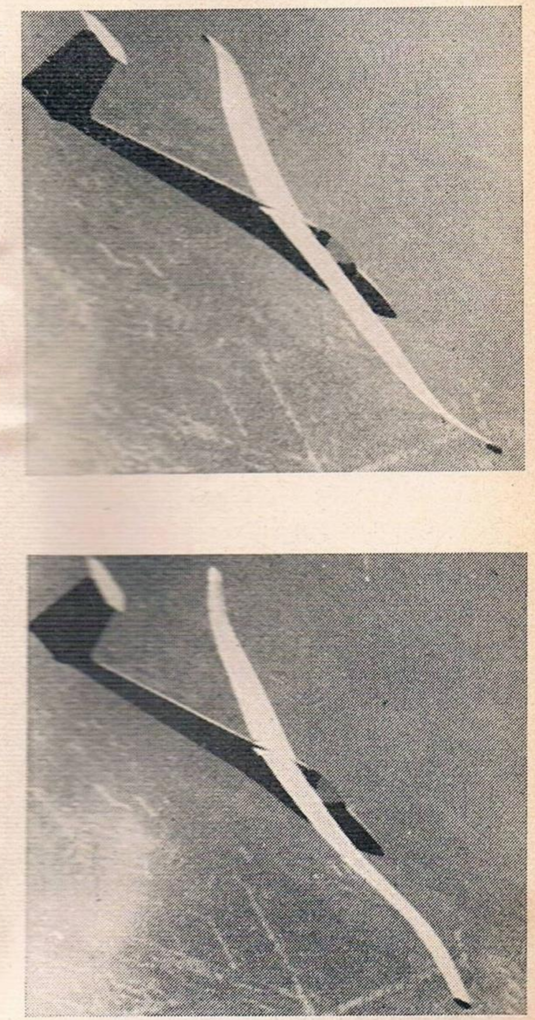
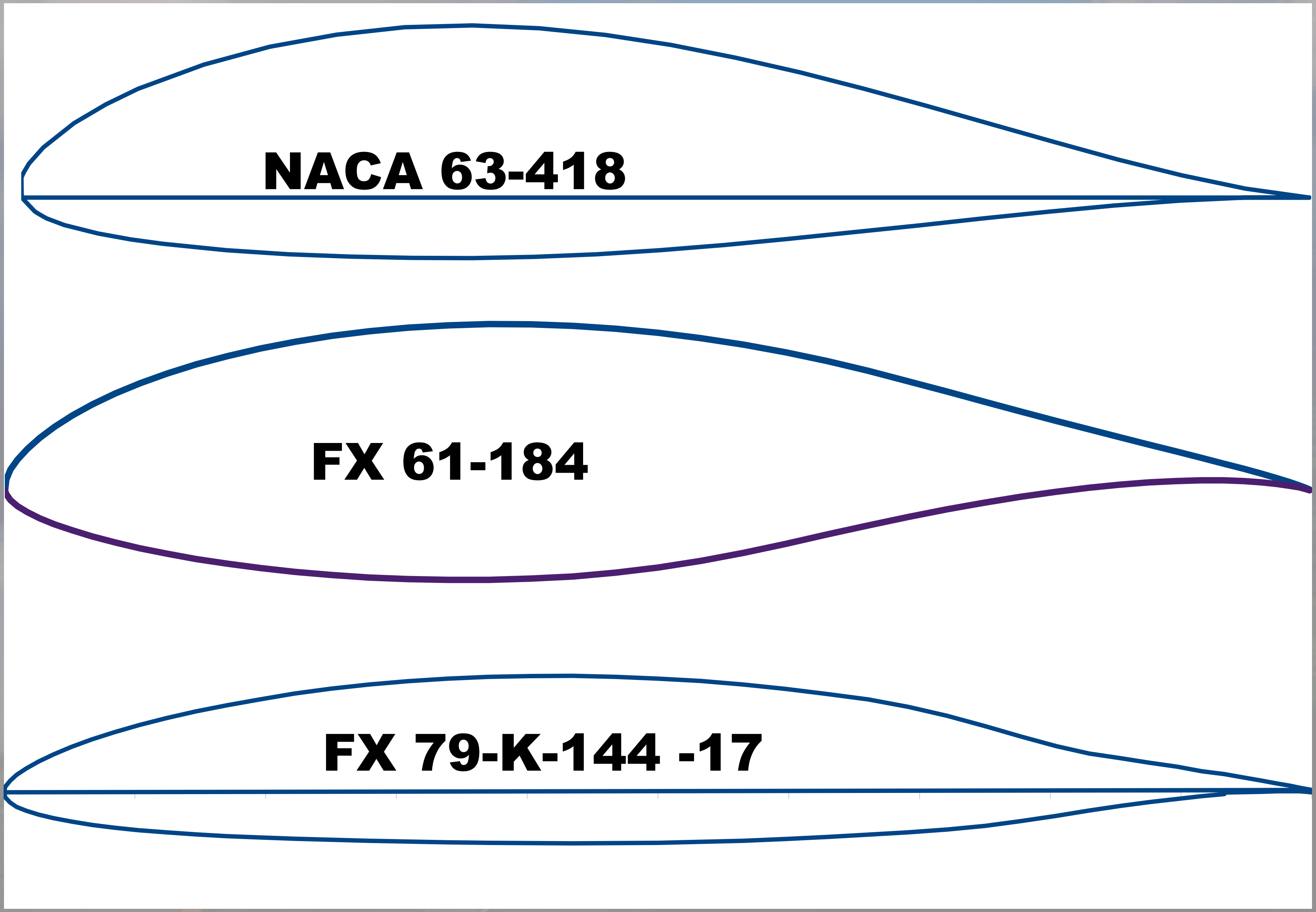


Figure 3 and 4: Anti-symmetric wing bending oscillations f=5.8 Hz at V=140 km/h.

Laminar aerofoils
The key to modern sailplane performance



Glider Performance Flaps

- These a simple, centre-hinged flaps, for performance optimisation in fast and slow flight. They move DOWN AND UP and are often mixed in functions with aileron control.
- They are NOT normally designed for high lift. Split, Fowler, ventilated and high lift flaps are TOO DRAGGY for sailplanes
- Flap configuration can influence or limit lateral control in high lift configuration particularly if mixed with aileron function.

Relevance of thickness to sailplane wing sections

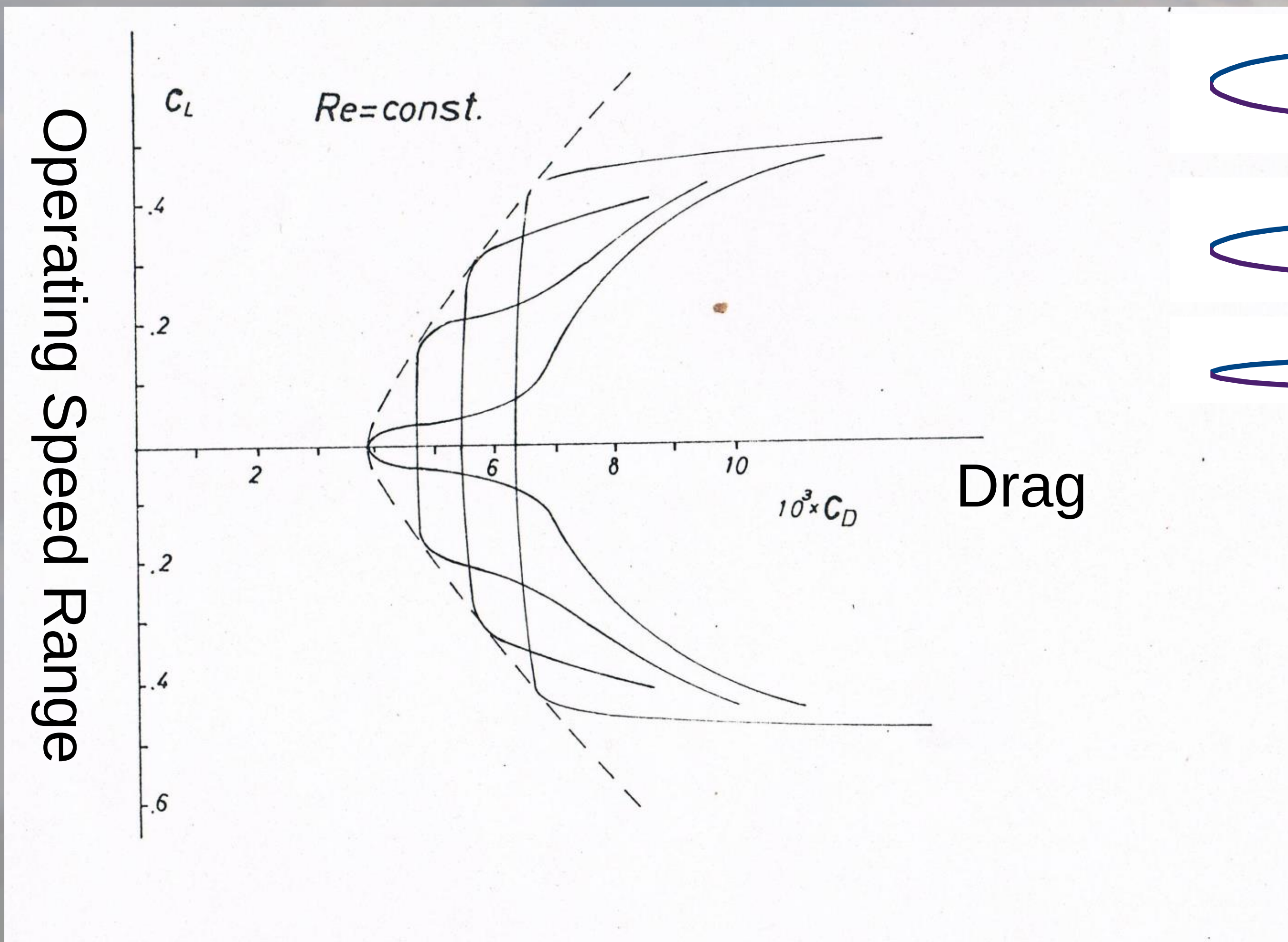


Fig.5 Typical lift-drag polars for different low drag ranges

Reynolds Number sensitivity of a laminar section

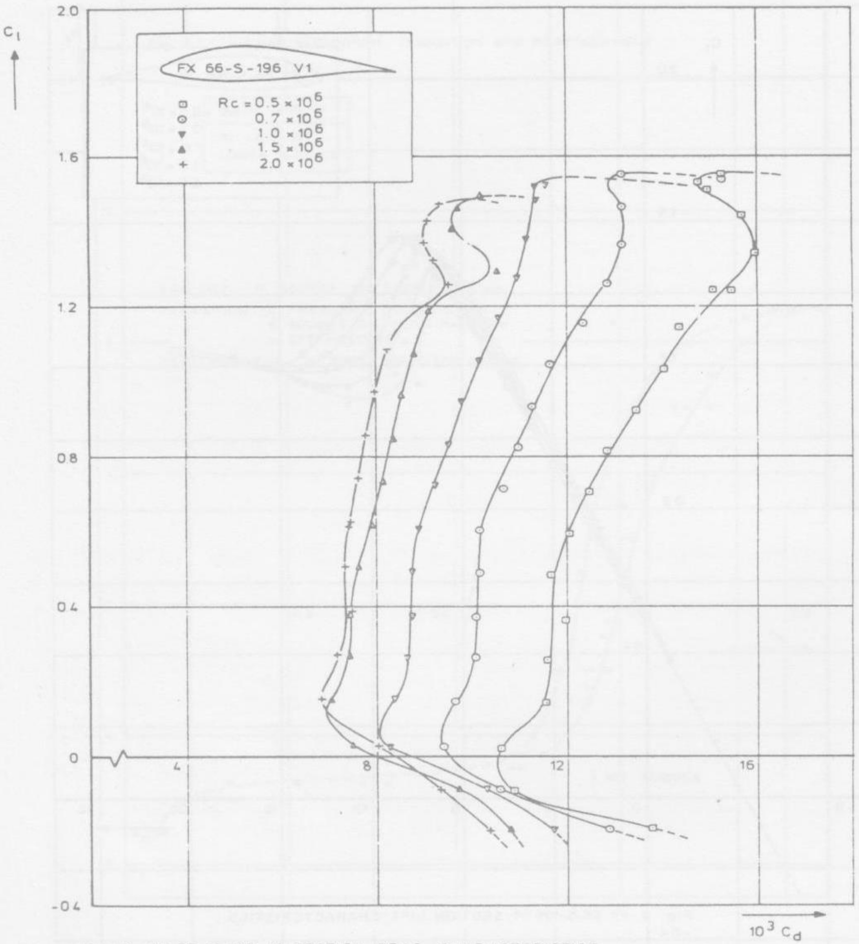


Fig 10 FX 66-S-196 V1 SECTION DRAG CHARACTERISTICS

Reynolds Number sensitivity of a laminar section

- A cross plot against ‘flight Re’ demonstrates a reduction of aerodynamic performance as airspeed and Re reduces.
- This can be accounted as an additional term in ‘lift dependent drag’
- This effect become more significant as chord reduces

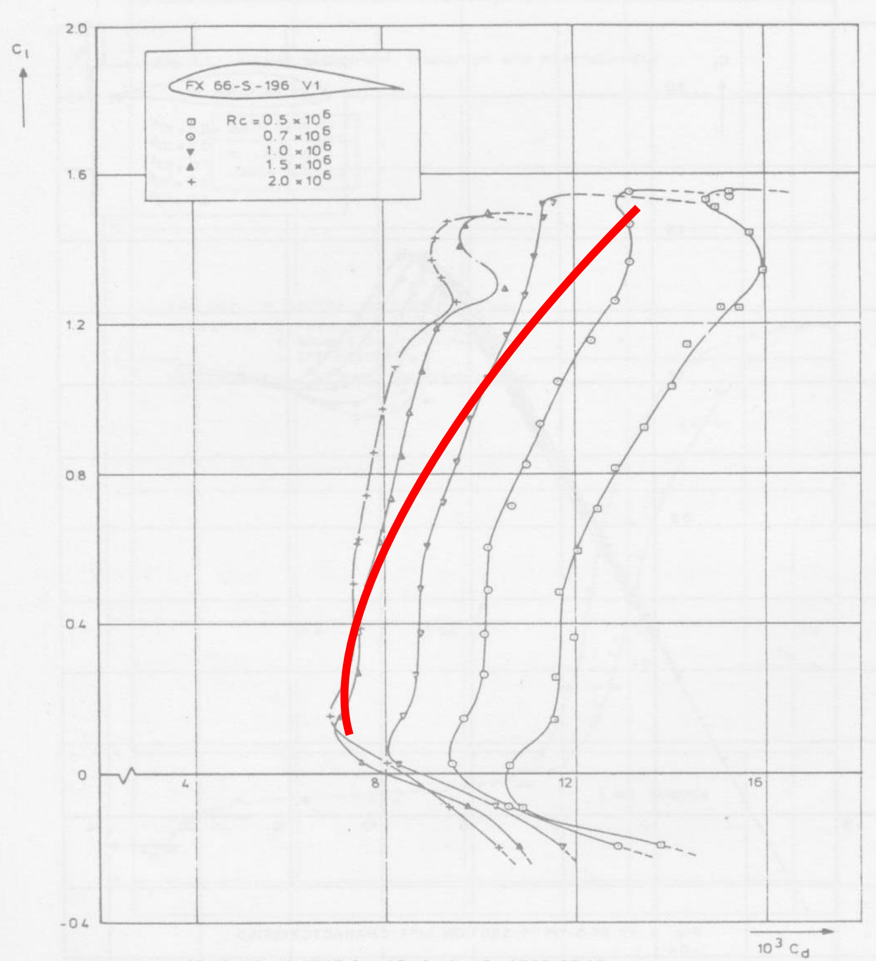
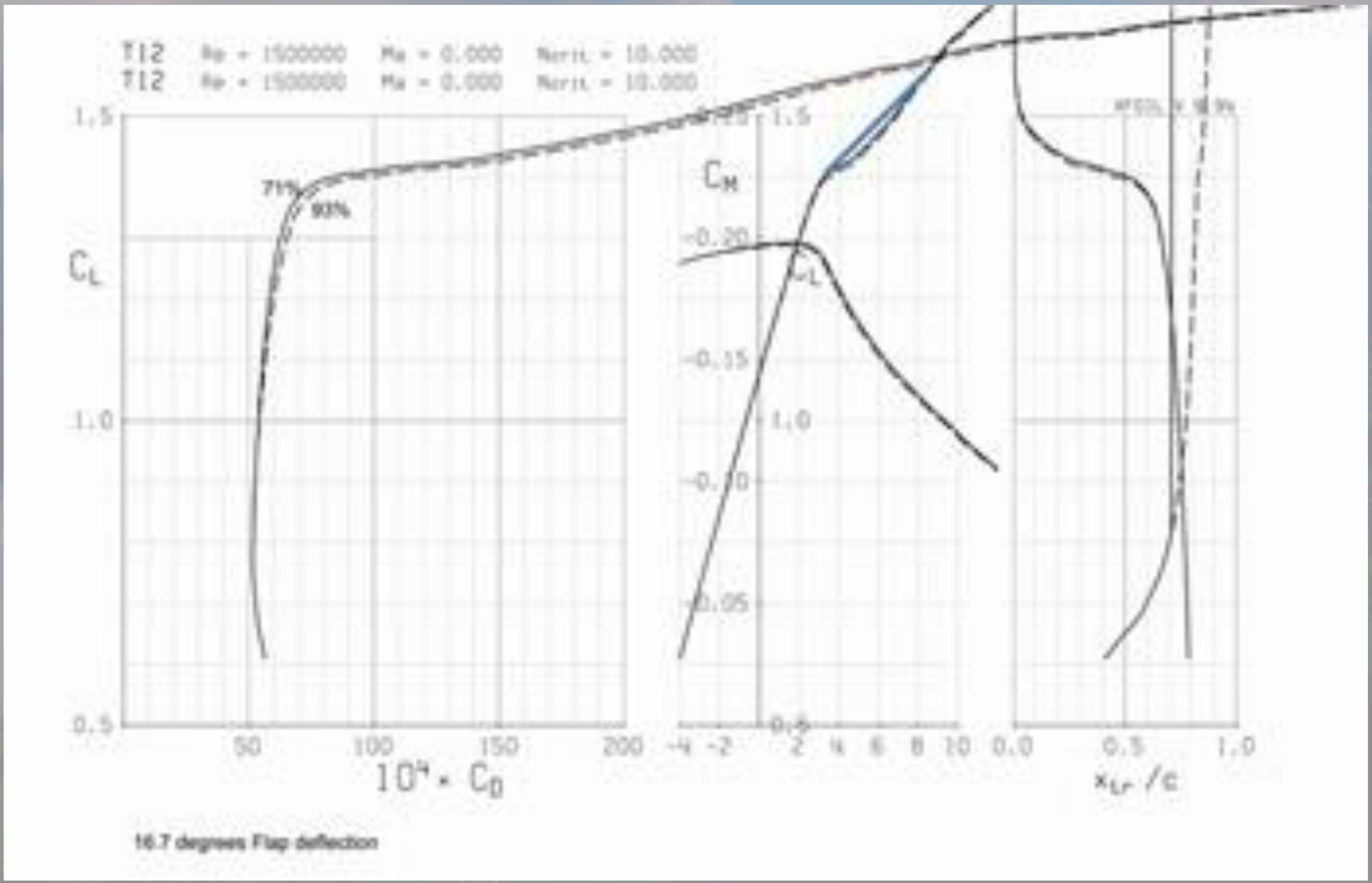


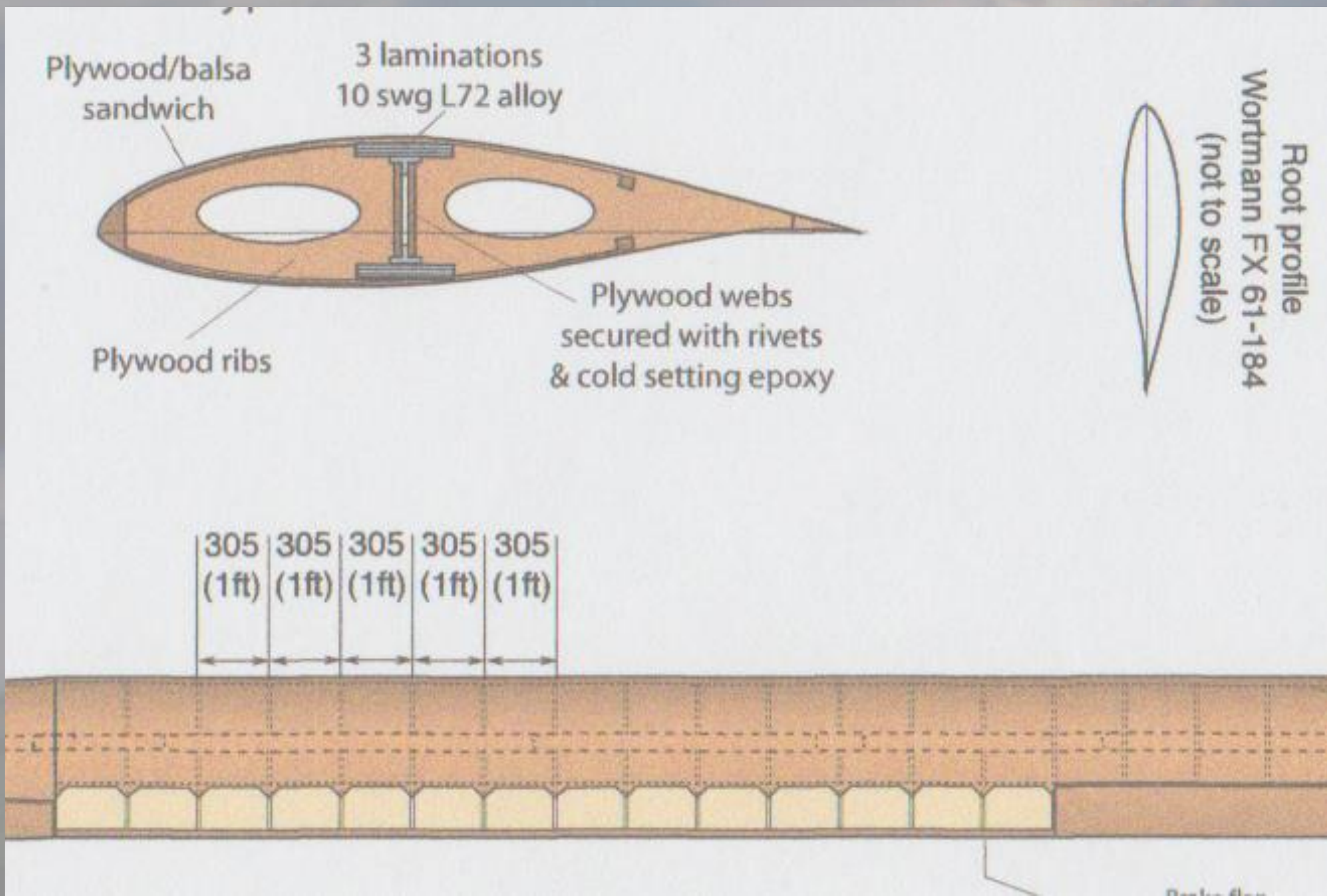
Fig 10 FX 66-S-196 V1 SECTION DRAG CHARACTERISTICS

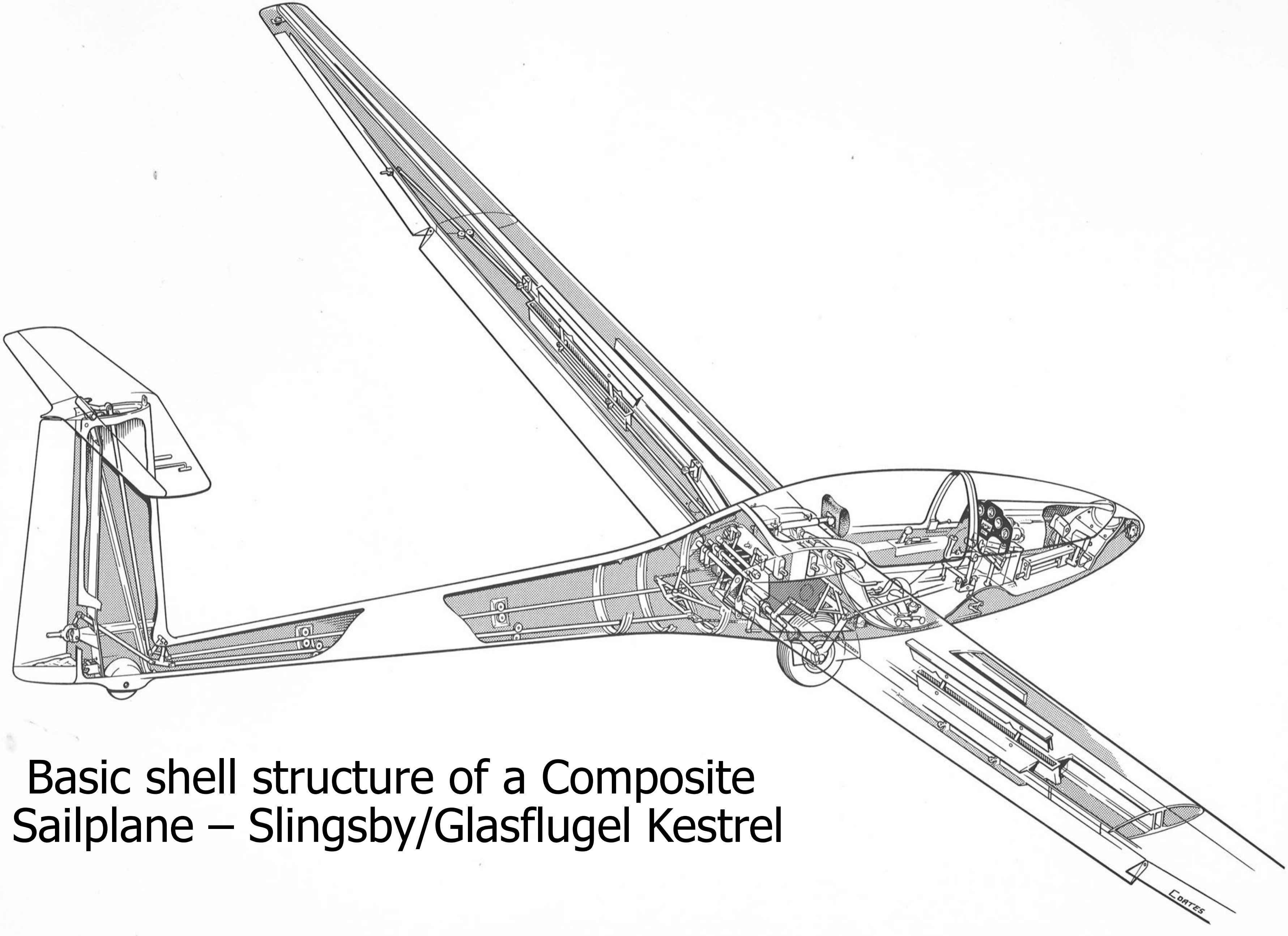
Boermans T12 aerofoil characteristics



Construction of a higher aspect ratio wing in wood – finish standard required

A successful ‘mixed materials’ approach to constructing a high aspect ratio, laminar wing using small-scale, simple moulds

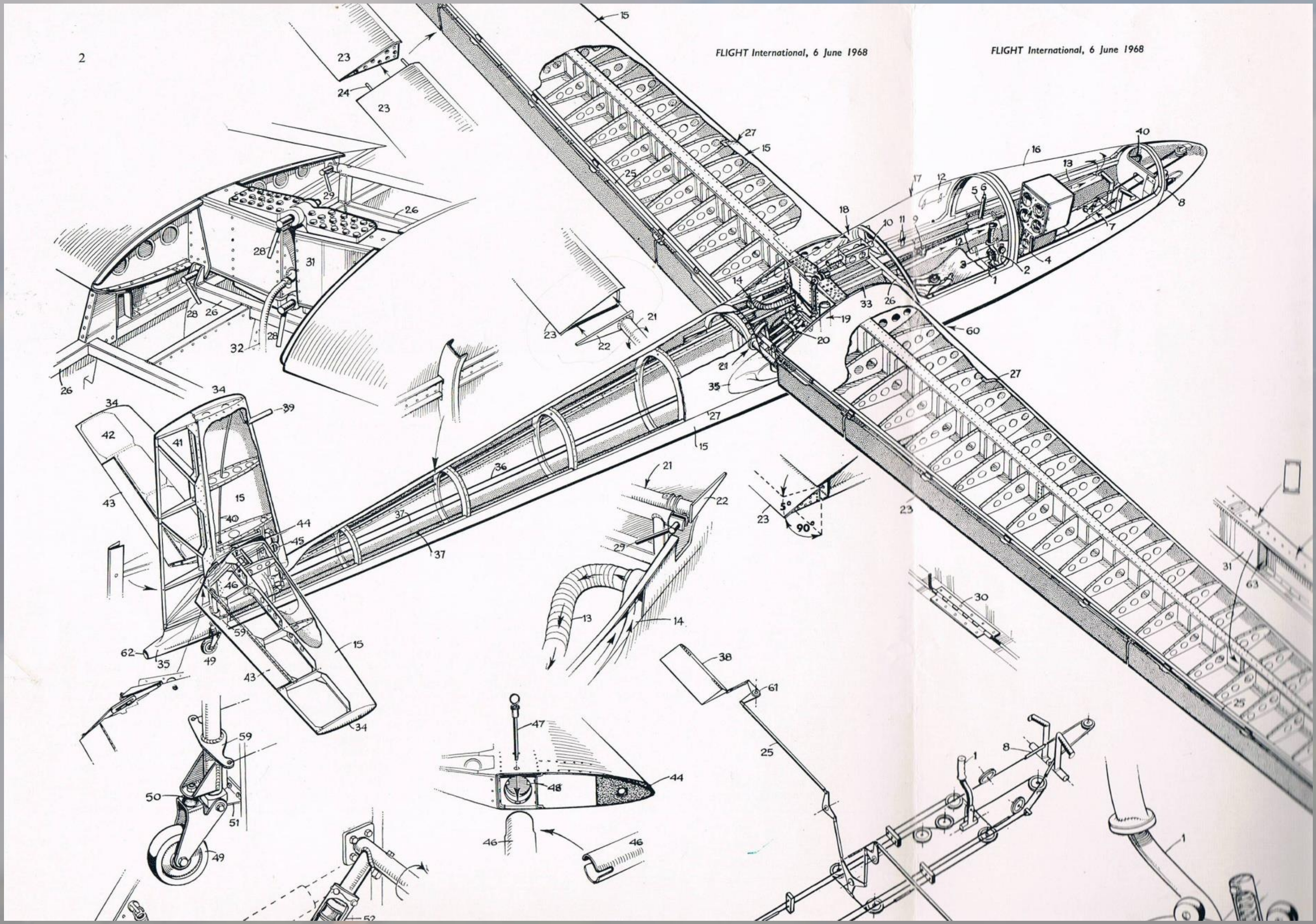




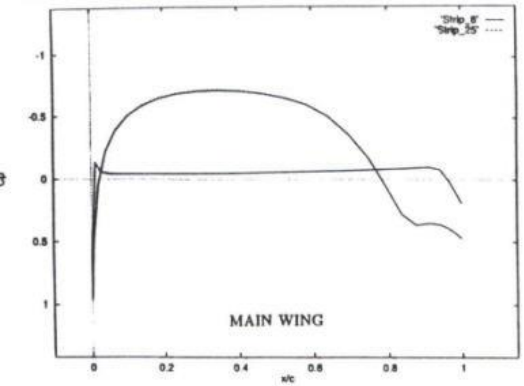
Basic shell structure of a Composite Sailplane – Slingsby/Glasflugel Kestrel

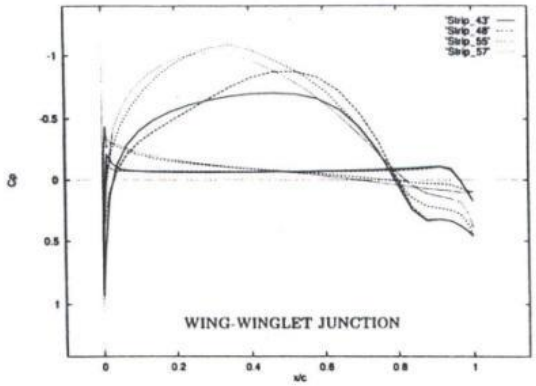
Homebuilding in GRP?

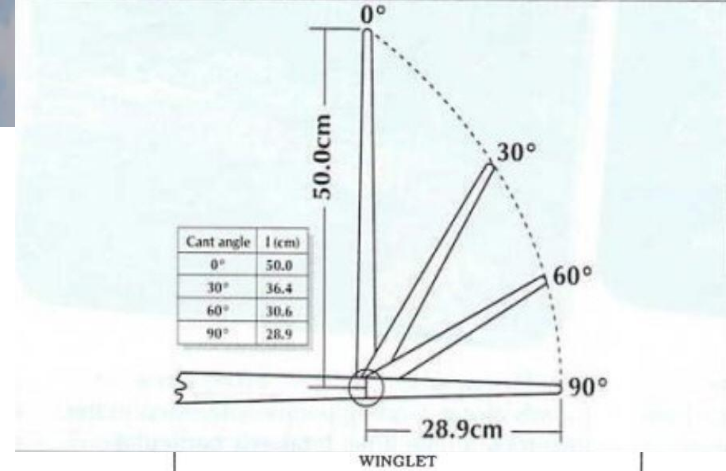
Metal structure solution –HP14



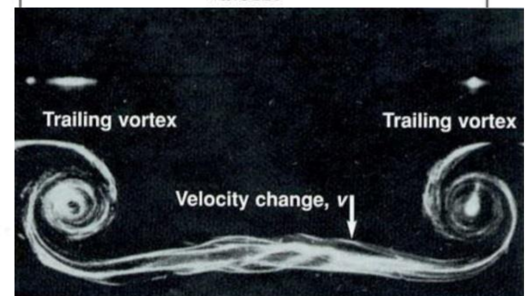
Winglet Design

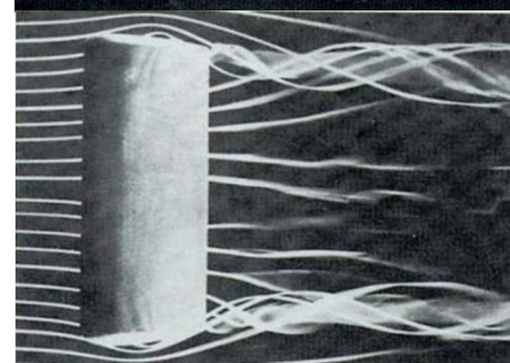


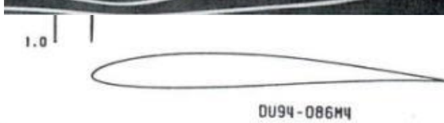




Cant angle	l (cm)
0°	50.0
30°	36.4
60°	30.6
90°	28.9







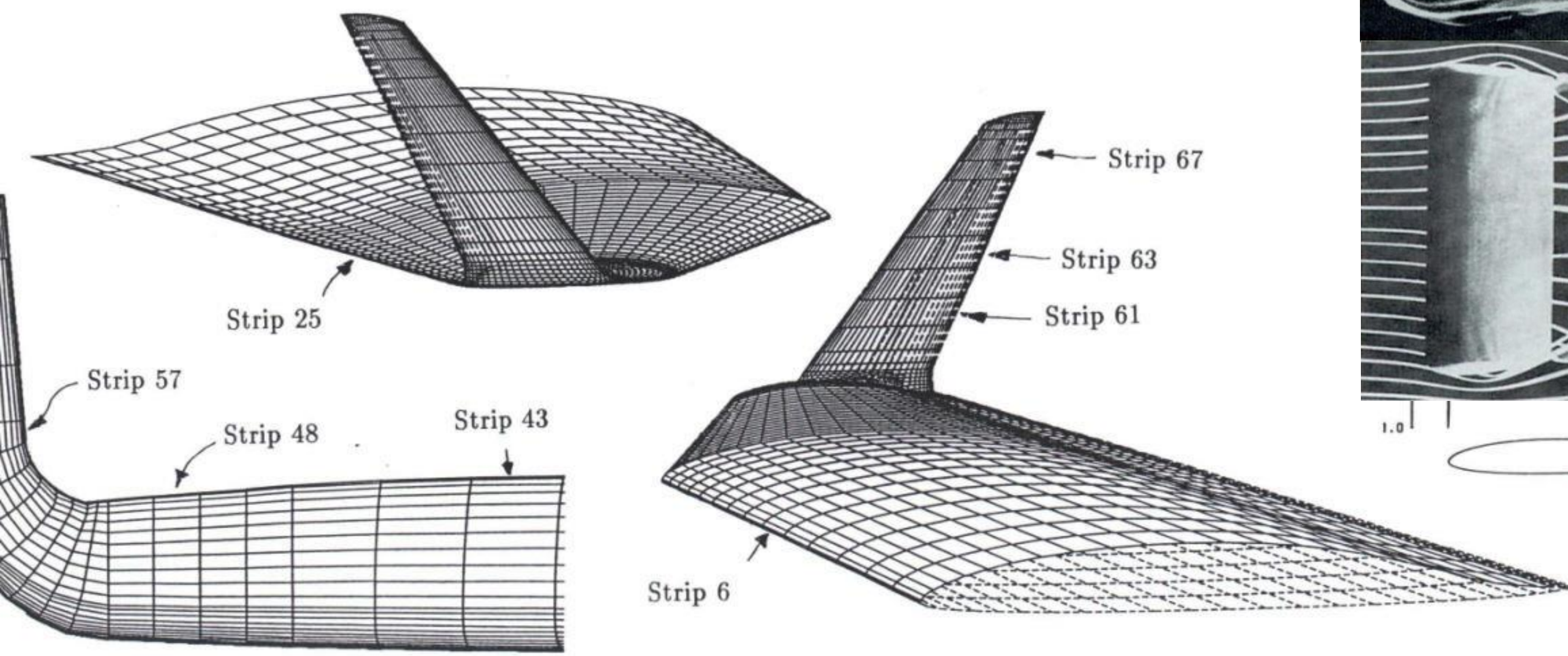
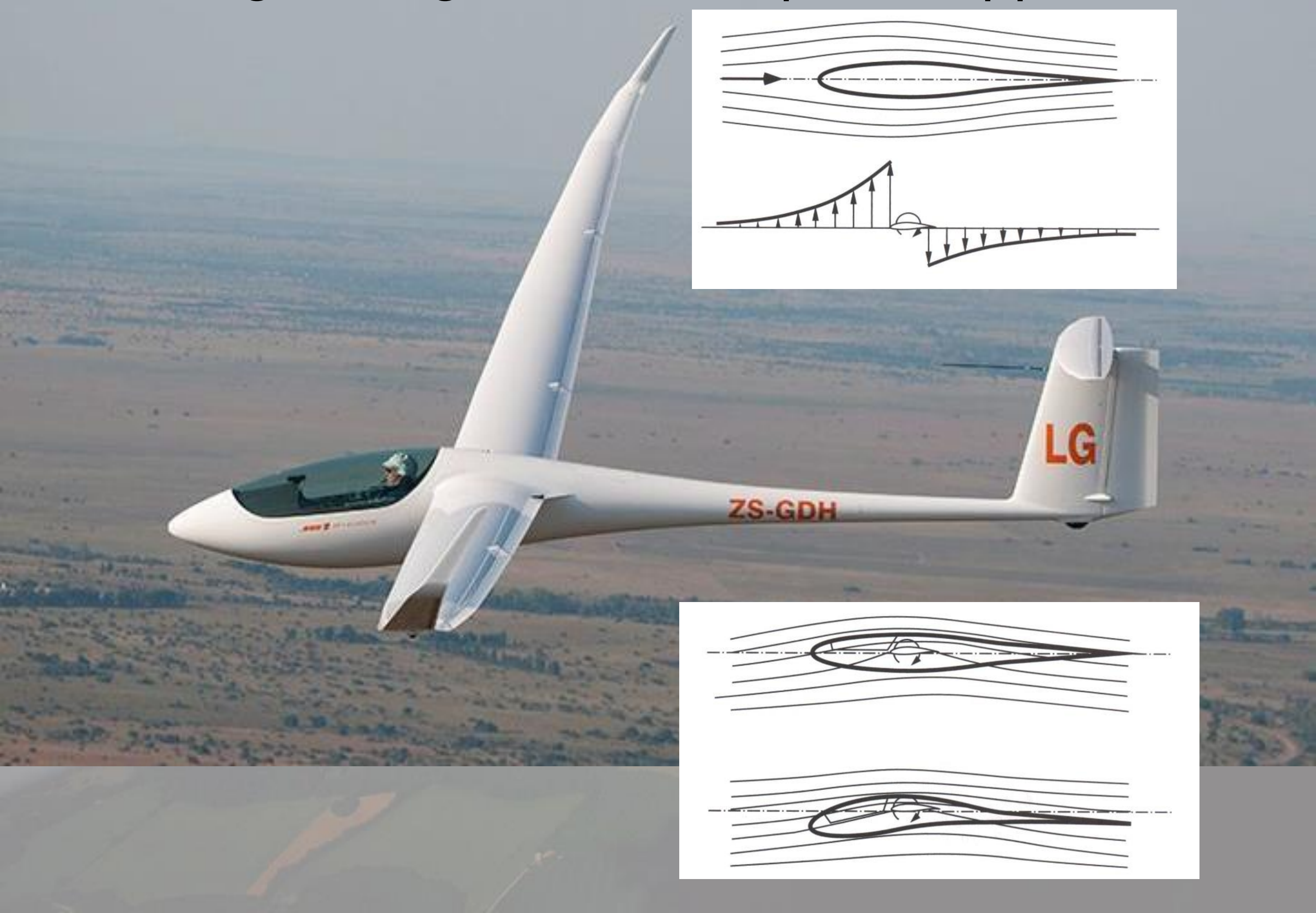


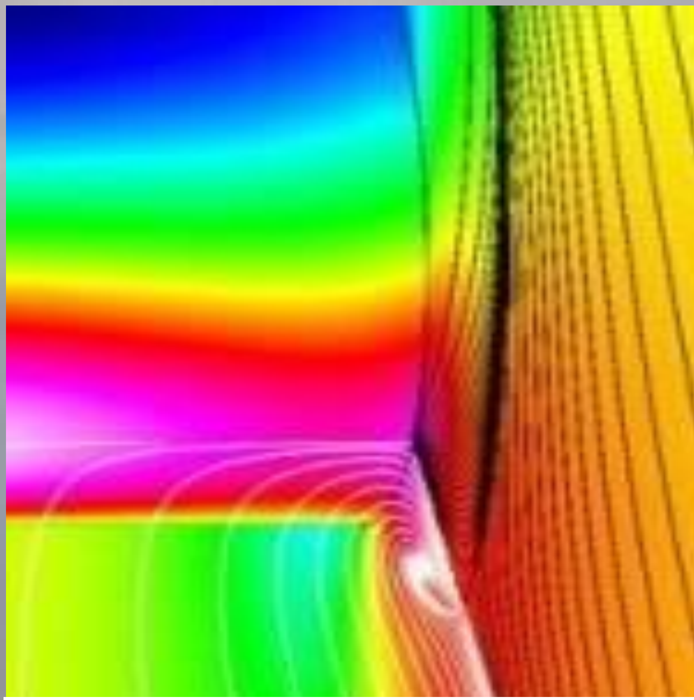
Figure A.19: Calculated inviscid FASD pressure distributions - final winglet design at C_l=0.3

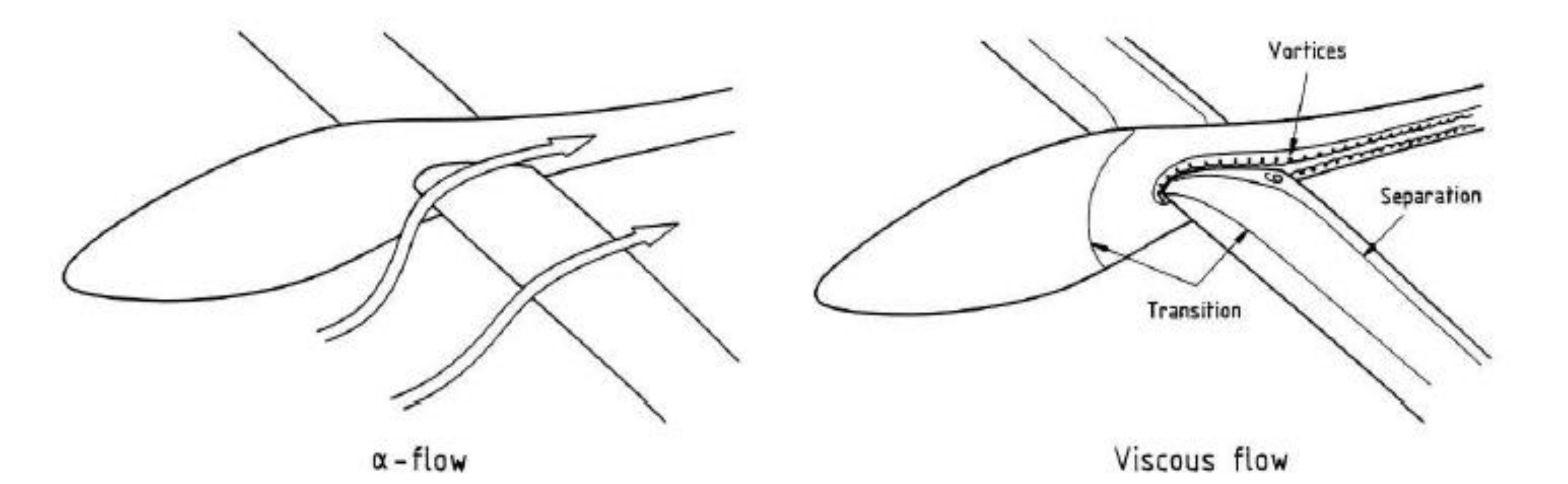
Current winglet designs

Fuselage design – semi empirical approach

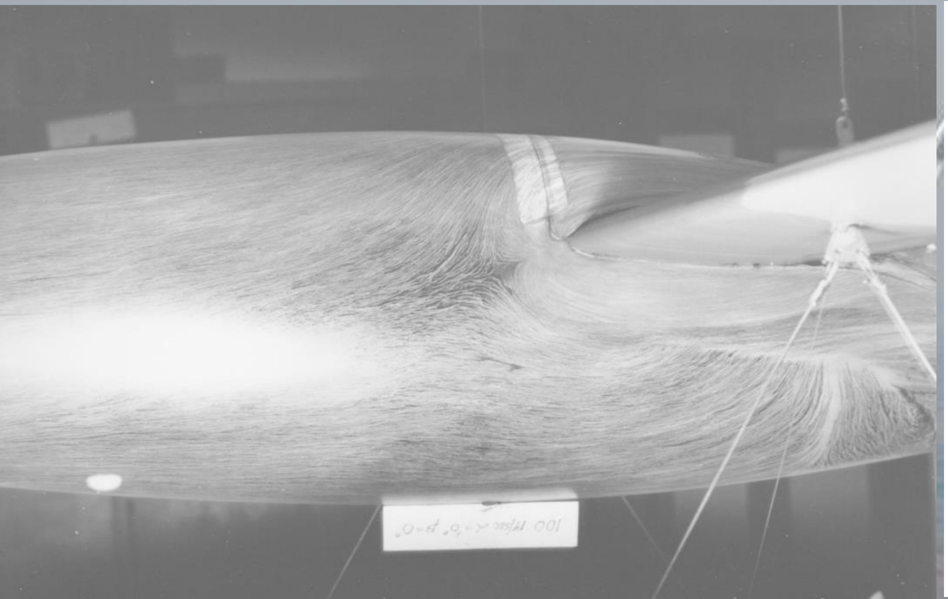


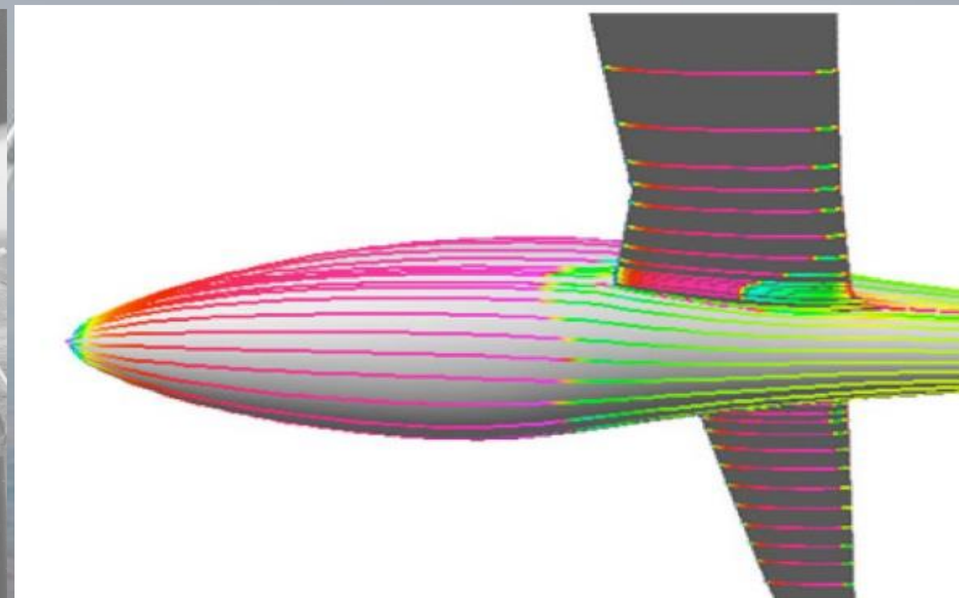
Corner vortex and effect on wing and fuselage flows

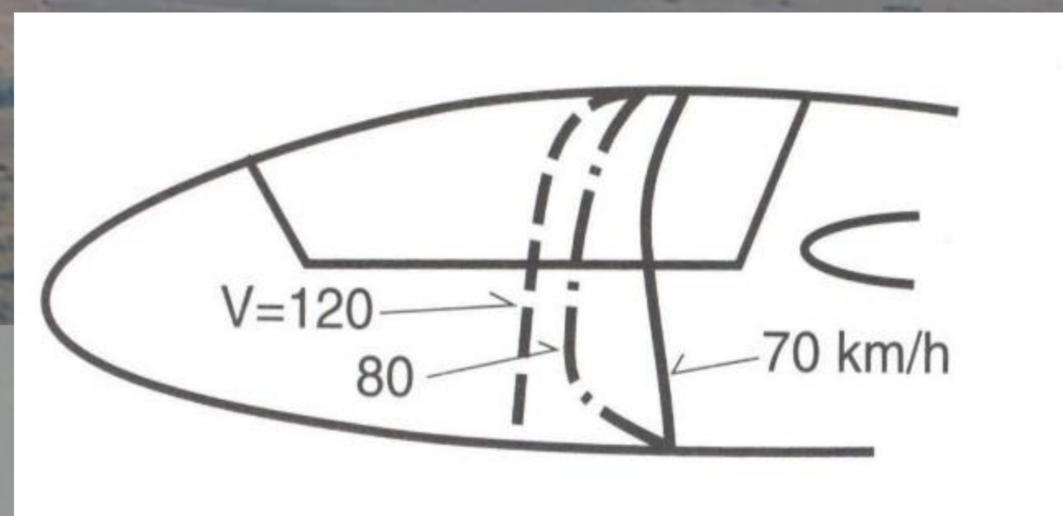




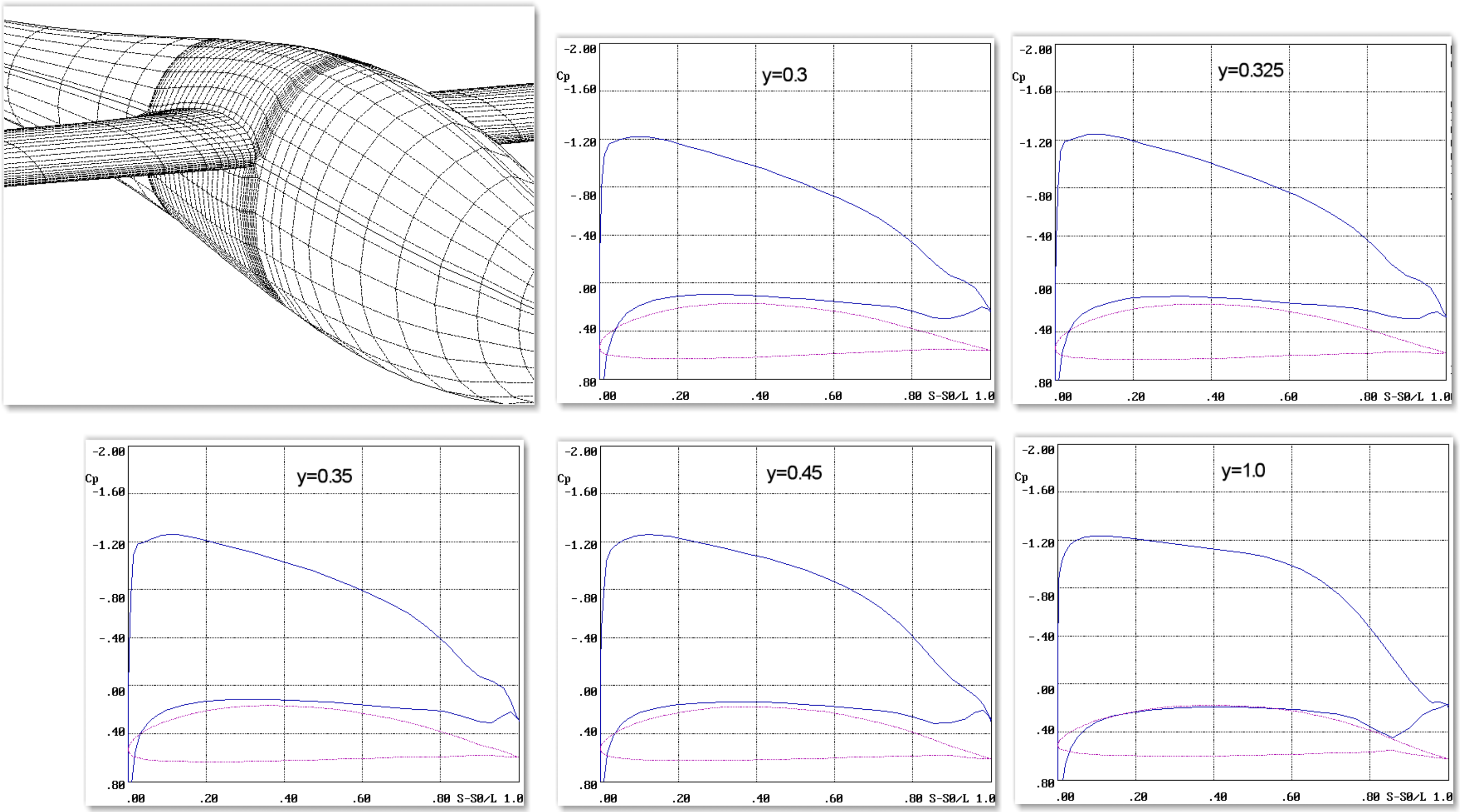
Fuselage design – extent of laminar flow







Wing to fuselage junction design



For the first half metre of the wing the wing section is tailored to a 'turbulent ' style section to accommodate better the stream-wise gradients and span-wise cross-flows that precipitate transition.

Jonker Sailplanes South Africa

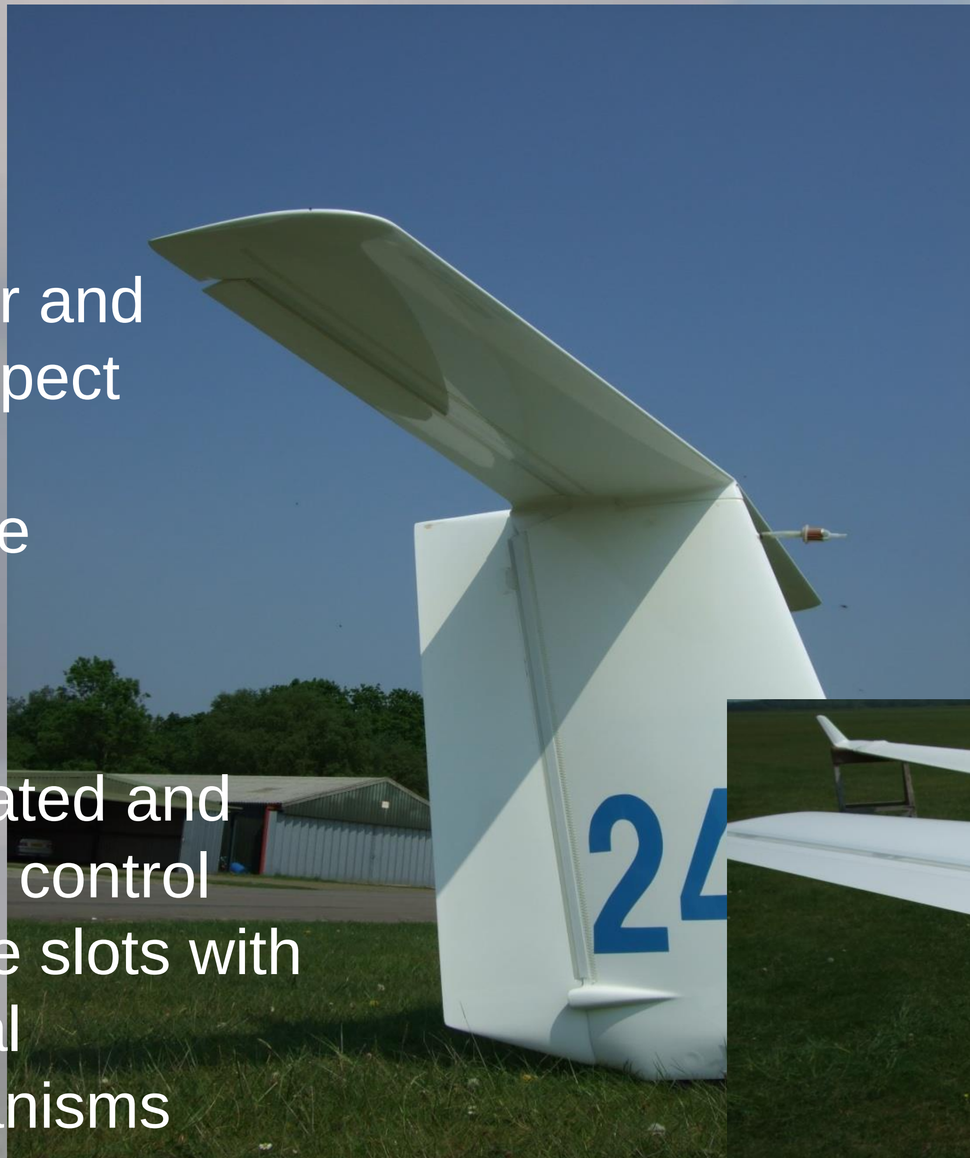
Wing to fuselage design – practical details

- Tailored wing section at root
- Contraction behind & above leading edge
- All junctions and hatches sealed
- Very limited contour filleting

Tailplane to fin junction design (1)

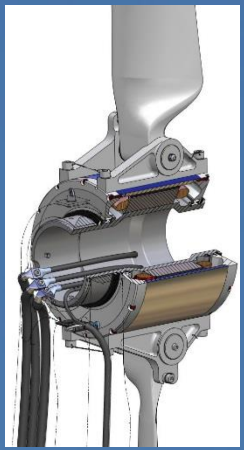
Narrow chord elevator and high aspect ratio tailplane

Tailplane max thickness well ahead of that of the fin



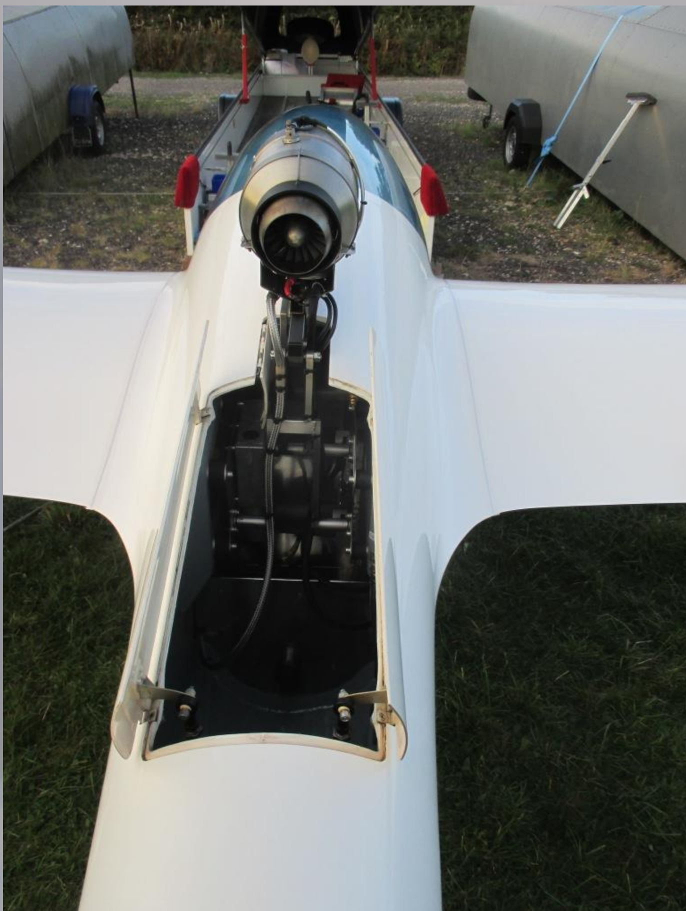
Separated and sealed control surface slots with internal mechanisms

Electric propulsion – Antares 20E



- 42kW (56hp) brushless DC motor
- 72 Li-ion batteries, 41Ah capacity, 76kg
- 52hp for 13 minutes

Typical Jet installation



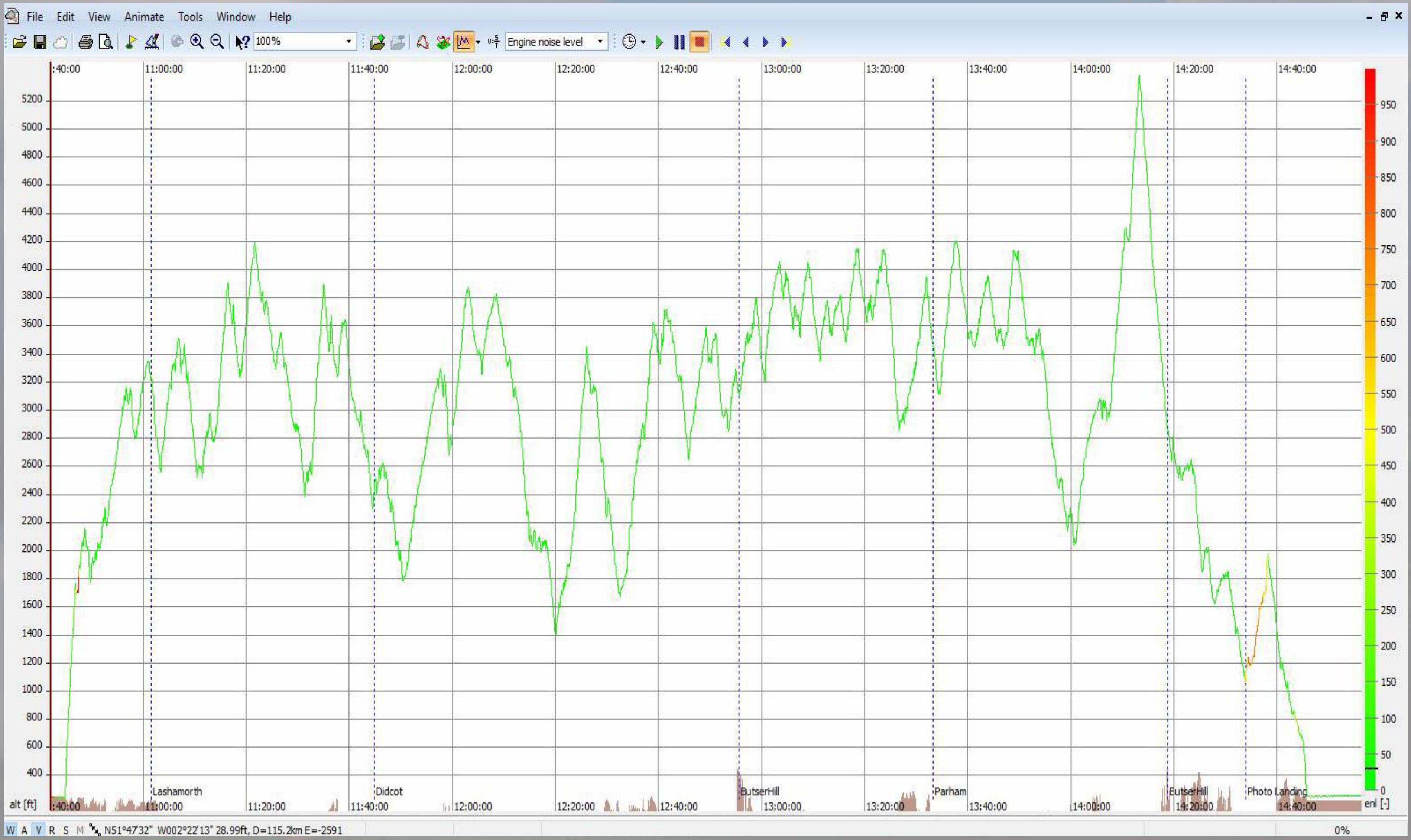
Front Electric Sustainer

Convergence of interest between powered sailplane and microlight?

- Smaller number of high cost, very high performance gliders
- Emergence of cheaper self-launching (probably electrically powered) motor gliders offers
- autonomous operation
- low operating cost and group ownership

Recreational Cross Country out of Lasham by an electric sustainer sailplane

Typical height profile



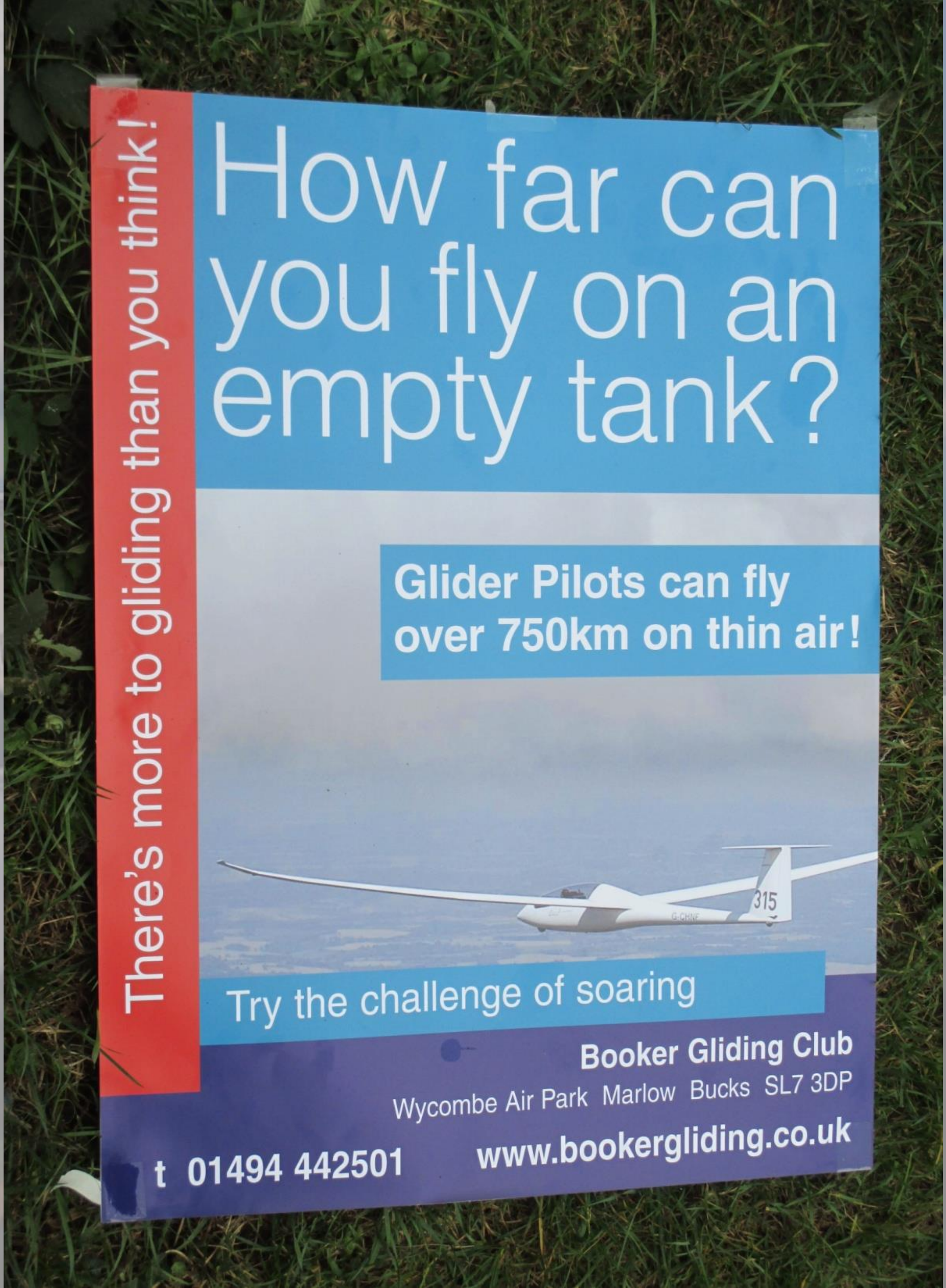

Lines of energy in the atmosphere

What the future holds?

- Micro-light and lighter GA aircraft are converging on the same design space.
- Limited endurance remains an issue at least for electric power in the short term.
- High efficiency design enables greater use of available energy in the atmosphere

GUIDE TO LOW LOSS RECREATIONAL AVIATION

- To harvest and store atmospheric energy one does not have to stop for thermals, BUT a flightpath strategy involving exchange of speed and height is required.
- The more efficient your airframe the easier this process becomes.
- Critically, a track must be chosen to maximise transit through areas of ‘good air’.
- While this process is weather dependent this should not constrain your recreational enjoyment. Indeed the satisfaction level should be enhanced.
- Piloting and airmanship, including lookout, must be sufficiently good to accommodate the necessary changes in heading and altitude, while complying with rules of the air in uncontrolled airspace.
- There is an emerging need to adapt response, handling and instrumentation to maximise pilot awareness


How far can you fly on an empty tank?
There's more to gliding than you think!
Glider Pilots can fly over 750km on thin air!
315
Try the challenge of soaring
Booker Gliding Club
Wycombe Air Park Marlow Bucks SL7 3DP
t 01494 442501
www.bookergliding.co.uk

Questions ? – Discuss ?