Aircraft design
1. Wing
2. Fuselage

5A: Fixed wing aircraft design

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In this lecture you will learn:

- How aircraft are designed
- What considerations impact the design of an aircraft?

What determines the wing shape and composition?

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- We have already discussed some of the factors that make a wing work well – can you recall these?
- The best wing design is not necessarily the best wing to manufacture and use – there are many competing factors that influence what a wing will look like:
  - Weight
  - Shape
  - Manufacturability
  - Cost
  - Durability

What determines the drone's shape and composition?

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Weight	Shape	Manufacture	Cost	Durability
Heavier materials are more common and easier to work with	*More aerodynamic shapes are difficult to manufacture*	*Methods are dependent on production volume and quality*	*Higher costs are associated with more efficient designs*	*An aircraft designed to be durable may have added weight and/or cost more*

- These are **competing** factors that force us to compromise for the end product design
- All aircraft can be summarized as "compromise designs" that function in the best way possible by emphasizing the positive aspects while minimizing the negative aspects

Wing design

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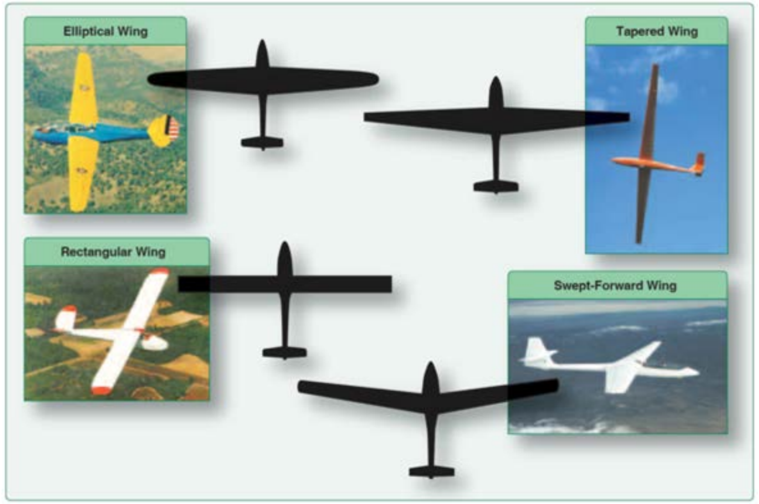
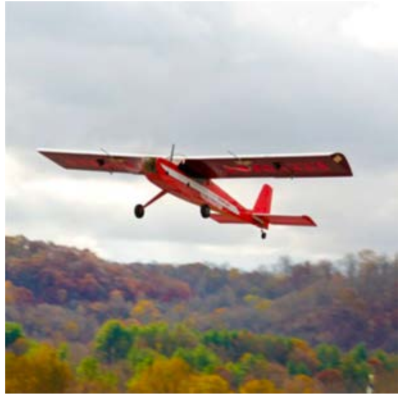
- Aerodynamically, we can show that an elliptical wing planform is the most efficient design because of the spanwise lift distribution
  - *But an elliptical wing is difficult to manufacture, and so the lift and drag penalties of using a simpler design are usually worth pursuing*
- A straight (rectangular) wing is the simplest design and is frequently used when the simplicity of manufacturing is weighted very high
  - However, these wings have more drag than other designs, and can also weigh more because of the constant chord design

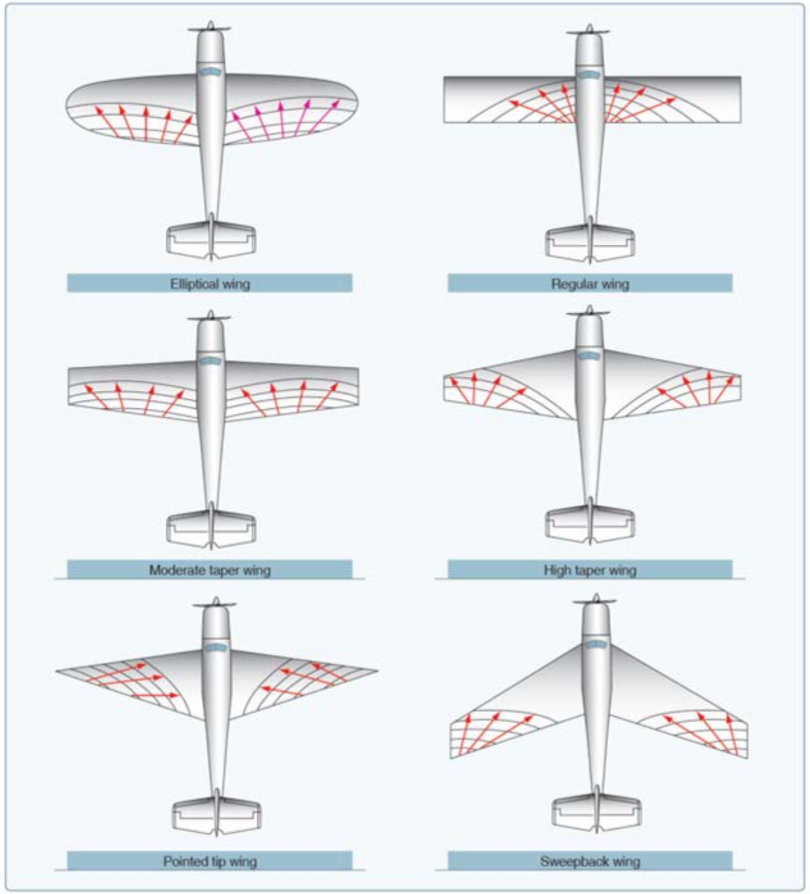




Wing design

- Tapered wings are very common
  - If the wing has a straight taper (straight leading and trailing edges), then its manufacturing is reasonably easy
  - The tapered wing has good aerodynamic performance while saving weight on the outboard portion of the wing
  - One drawback to the tapered wing design is that they are more susceptible to tip stall, which happens when they outboard section of the wing stalls before the inboard portion

The progression of flow separation when a wing approaches the stall speed



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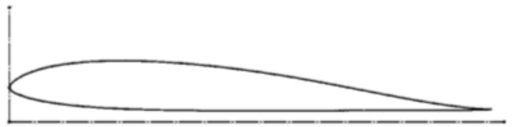
Wing design

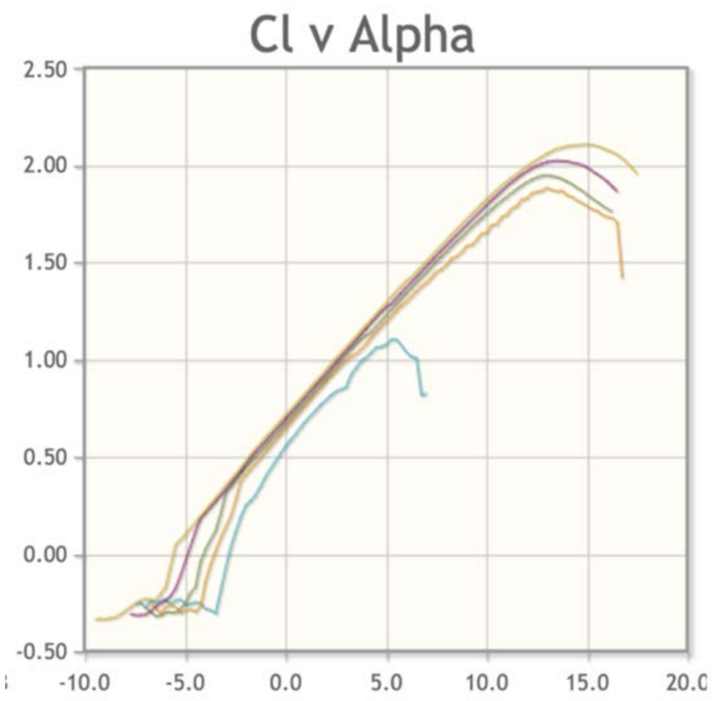
- The airfoil selection (airfoil shape) for the wing is critical to achieve desired performance of the aircraft
- We have not discussed pitching moment effects caused by the airfoil, but briefly we will mention that the airfoil shape can impact the pitch stability of the aircraft
  - Stability will be discussed in more detail later
- The airfoil shape is selected to optimize certain aerodynamic characteristics, such as:
  - Stability
  - Resistance to stall and gentle stall characteristics
  - Low drag
  - Operating speed range
- When an aircraft does not have a tail, it must have an airfoil that contributes to stability which the tail would normally provide

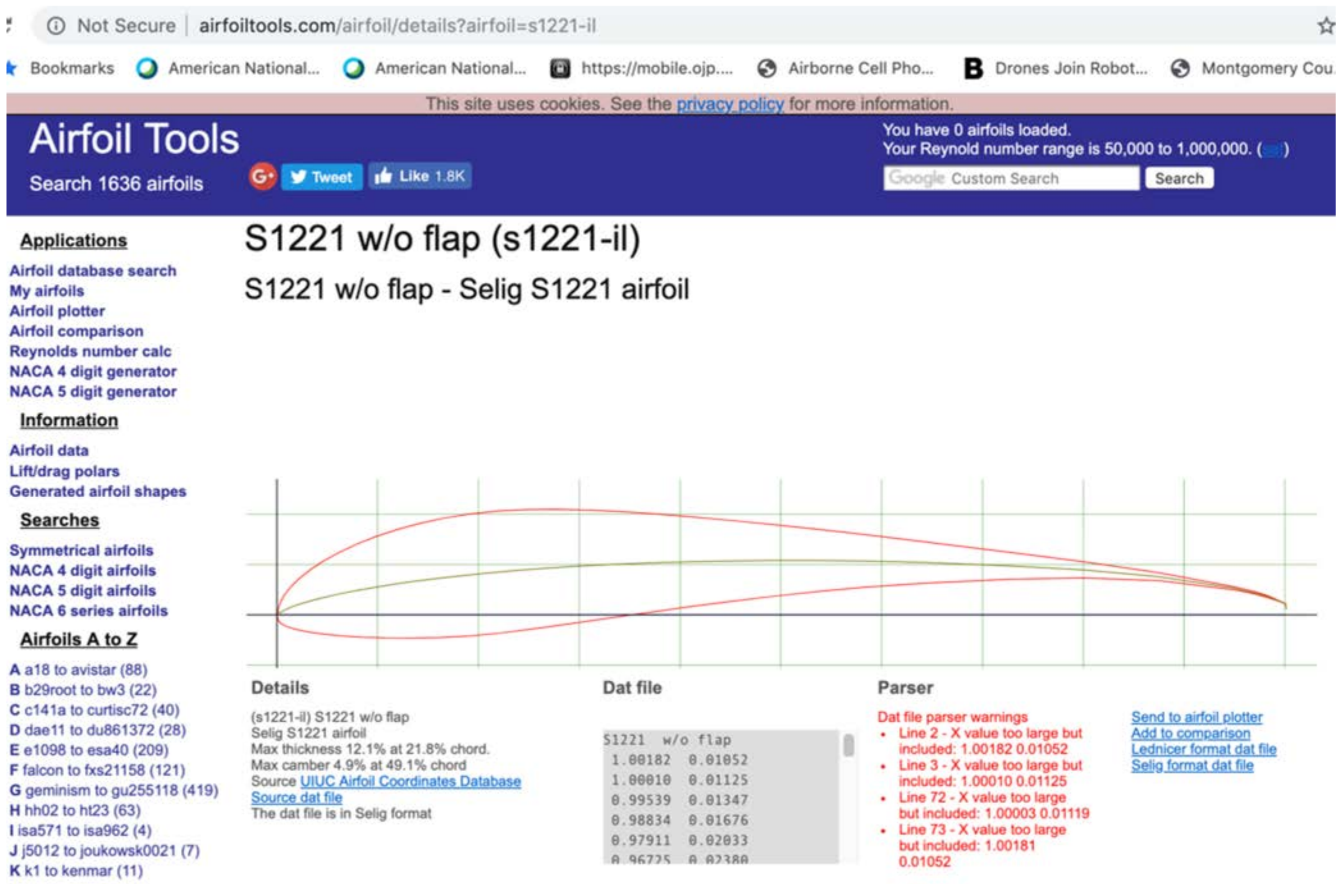


The MH60 airfoil used on EcoSoar. It is specifically designed for flying wings (tailless aircraft)

Wing design - airfoil shapes

- There are software tools to evaluate candidate airfoils for your aircraft
  - The Selig S1221 airfoil is a high lift airfoil for drone-scale aircraft





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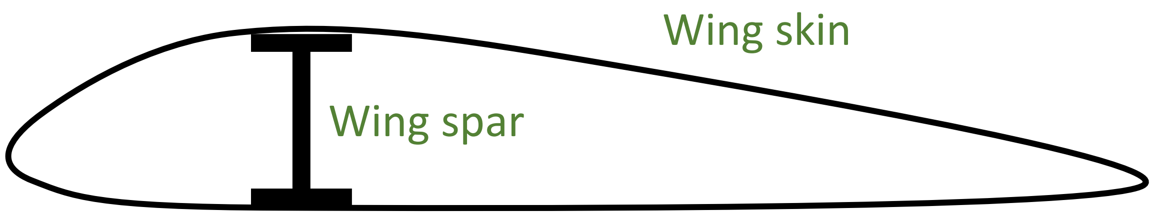
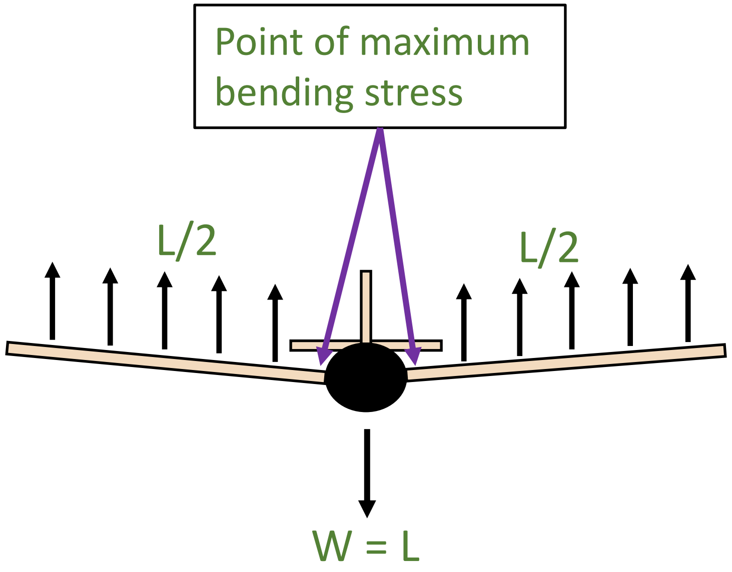
- Material selection in wing design is driven by a need to carry the bending loads that are generated by the wing
  - Bending stresses are high at the wing root
  - The wing *spar* is the structure that carries the loads in the wing
    - It is designed to efficiently carry bending loads





The material selected for the wing spar should be strong and lightweight. Carbon epoxy is frequently used.

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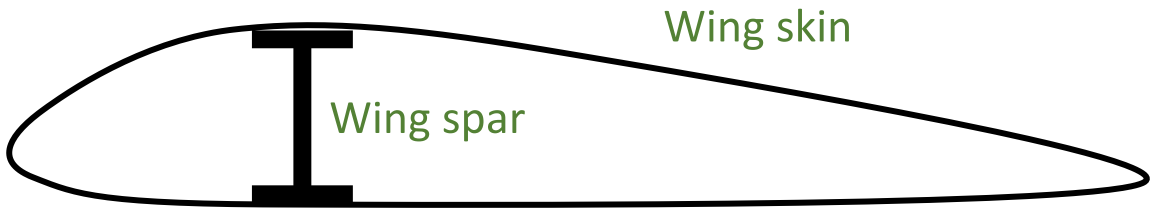
- The wing skin and fairings are critical from an aerodynamics standpoint – they should be smoothly shaped components that minimize separated flow which causes drag
  - Carbon epoxy can be used for wing skins but the manufacturing costs are high because a mold is needed
  - Foam, plastics and plastic films are also good wing surface materials



The material selected for the skin should be strong and lightweight, but it also has to be easy to shape. Carbon epoxy is frequently used but so are plastics and films

The EcoSoar aircraft skin is comprised of a foam core material and paper/plastic skin

The Aerosonde wings are fabricated using a mold

Wing sizing

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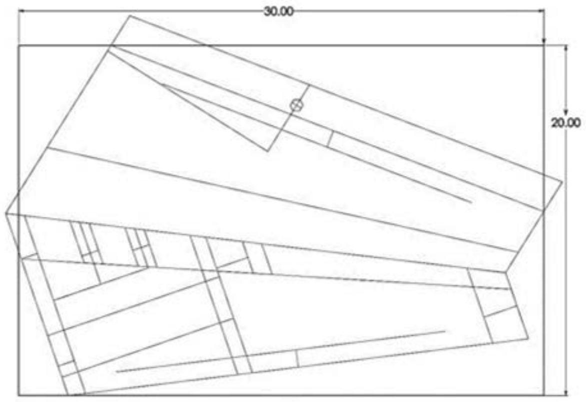
- Preliminary aircraft design is a step-by-step process guided by some early performance assumptions to generate aircraft dimensions
- Early constraints might be a maximum wingspan limitation (for transportability)
  - EcoSoar sizing began with a limitation on the wing size based on available sizes of the foam core material used to build the wing – 30” x 20”
- Next, the cruise speed of the aircraft is selected
  - In the case of EcoSoar, a speed of 14m/s was selected so that images captured by an on-board camera would have enough overlap to create a mosaic



The wing skins for EcoSoar were constrained to a 30” dimension

Wing sizing

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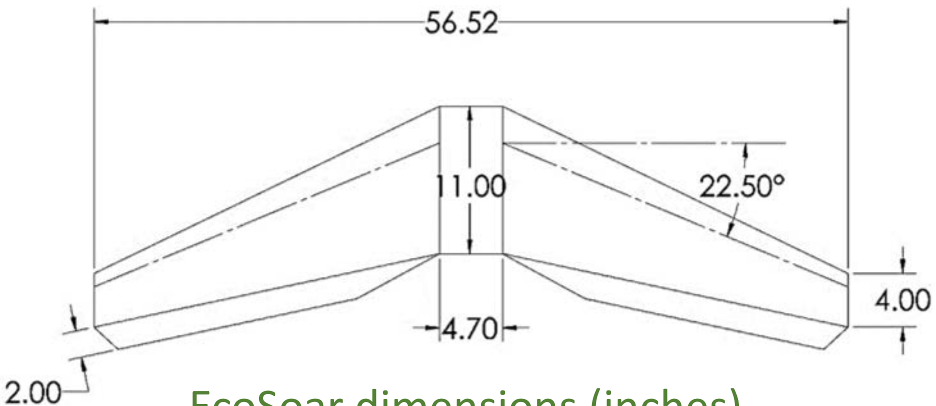
- Next, a cruise lift coefficient can be selected (a C_L = 0.6 is a good place to start)
- With this information, we can now calculate the lifting capacity and how much weight the aircraft will carry:

$$W = L = \frac{1}{2}\rho V^2 S C_L$$

$$W = \frac{1}{2}(1.225\ {}^{kg}/_{m^3})(14\ {}^{m}/_{s})^2(0.145m^2)0.6 = 10.4N$$



EcoSoar dimensions (inches)

- It is easier to think of this in terms of kilograms, which is 1.1 kg
- So this becomes the target weight to design the aircraft around. If the resulting aircraft is heavier, it will either fly faster, or at a higher angle of attack to produce a higher lift coefficient

Fuselage design considerations

- For fixed wing aircraft, aerodynamics is an important factor
  - This is because of the higher operational speed of fixed wing aircraft – the drag is a much bigger consideration
  - If the aircraft has an internal combustion engine, the drag due to cooling can be high
- Launching constraints may determine if the motor/propeller are on the front or rear of the aircraft

The Textron Aerosonde has a gimbaled camera that must be exposed to work properly, but it adds significant drag when flying a cruise speed