Structural design is the methodical investigation of the stability, strength and rigidity of structures. The basic objective in structural analysis and design is to produce a structure capable of resisting all applied loads without failure during its intended life.
“Fundamentally, an aircraft is a structure. Aircraft designers design structures. The structures are shaped to give them desired aerodynamic characteristics, and the materials and structures of their engines are chosen and shaped so they can provide needed thrust.”
The Challenge

- For aircraft, weight must be kept to a minimum.
- Small margins of error/tolerance
- Redundancies are important
- For “real” aircraft, lives are at stake
Aircraft Loads

- Air pressure

Figure 1: Pressure distribution on airfoil
Aircraft Loads

- Inertial forces

*Figure 2. Wing loading distribution*
Aircraft Loads

- Ground loads

Figure 3. Aircraft landing
Aircraft Loads

- Vibrations/flutter

Figure 4. Aircraft tail flutter
Deformation

Figure 5. Deformation types
Deformation

- **Elastic deformation**
  - Temporary shape change
  - Material returns to original shape after load is removed
  - For most materials, linear behavior

- **Plastic deformation**
  - Permanent shape change
  - Occurs after yield strength of material
Failure

Cracking/Fracture  Buckling  Fatigue

Figure 6. Failure modes
Figure 7. Aircraft Structural Layout
Fuselage

- **Stiffeners**
  - Frames/stiffeners run radially
  - Longerons/stringers run longitudinally
  - Sometimes, struts run diagonally to form a truss
  - Together, maintain shape of fuselage and carry mostly compression/tension loads

- **Skins**
  - Wrap around outside of fuselage
  - Helps maintain shape and carry pressure and distributed loads
Wing and Tail

- **Ribs**
  - Run “parallel” to freestream velocity
  - Help maintain airfoil shape

- **Spars**
  - Run “perpendicular” to freestream velocity
  - Carry most of bending and torsional loads
  - Provides attachment points for motors, control surfaces, etc.
Materials

- **Balsa wood**
  - Very high strength-to-weight ratio
  - Easy to work with
  - Grain direction determines properties

- **Plywood**
  - Made from thin layers of wood
  - Cheap, easy to work with
  - Grains are oriented 90° to each other

- **Monokote**
  - Plastic wrap used to create skins
  - Attaches easily to wood
  - Heat shrink allows flexibility and smooth surfaces
Materials

- **Foam**
  - Easily shaped with hot-wire cutter or sandpaper
  - Can be sheeted with balsa or composites
  - Isotropic material (no directional bias)

- **Composites (fiberglass, carbon fiber)**
  - Can either be used in skins or spars
  - Stronger, lasts longer (but heavier) than wood
  - More resistant to the elements
  - Fabric and plies are versatile
  - Messy to work with, potentially hazardous
Next Time

- More detailed description of stress/strain
- Truss structures, weight savings
- Where things can go wrong
- Attachments
- Component sizing
- Landing gear
- Finite element analysis