Aerodynamics and Autonomous Soaring

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2005 Math & Science Odyssey
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About NASA

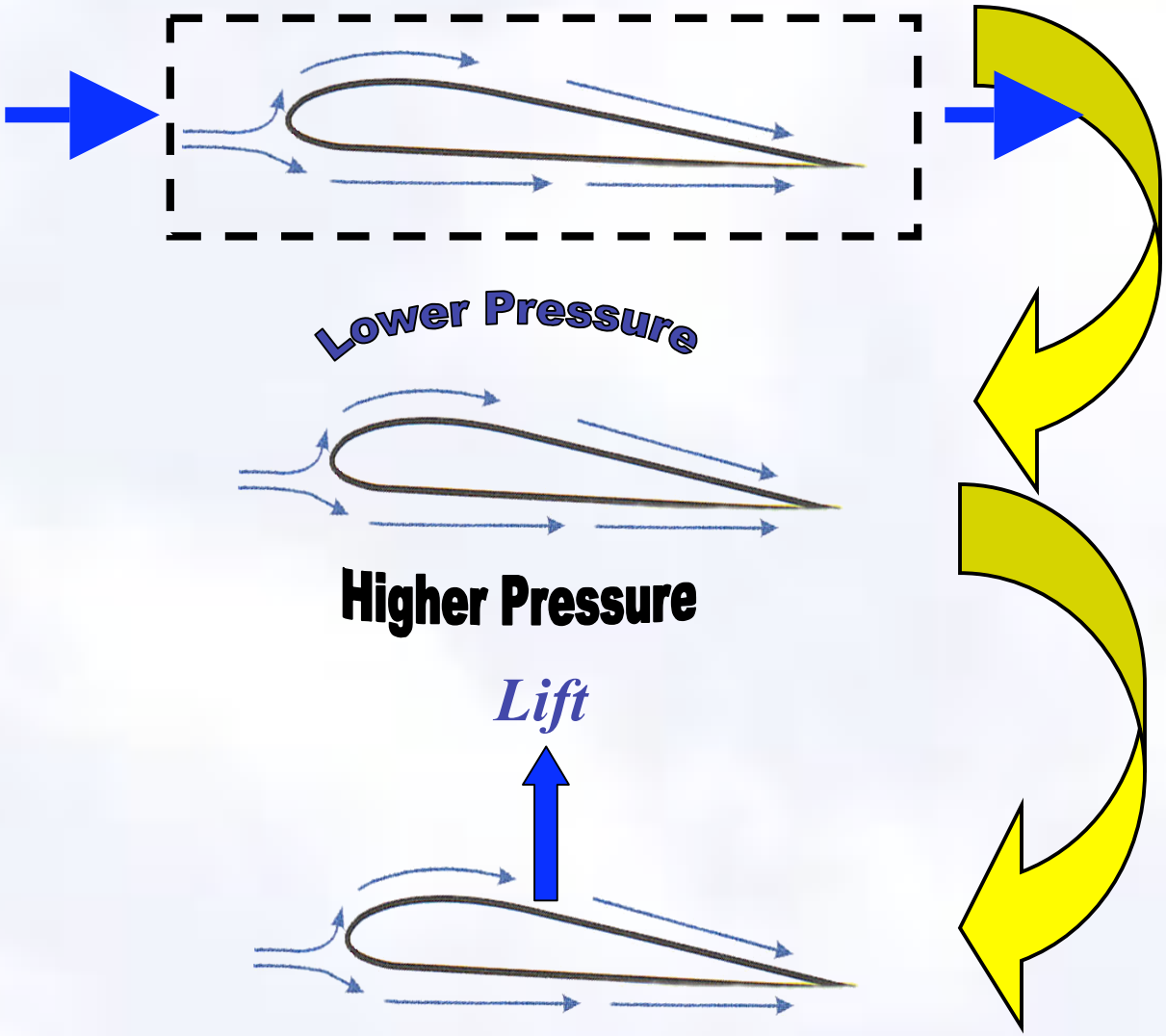
- National Aeronautics and Space Administration
- Aeronautics
  - Jet airplanes
  - Helicopters
  - Autonomous airplanes
- Space
  - Space shuttle
  - Space station
  - Mars rovers

Aerodynamics: The Mysteries of Flight

Outline

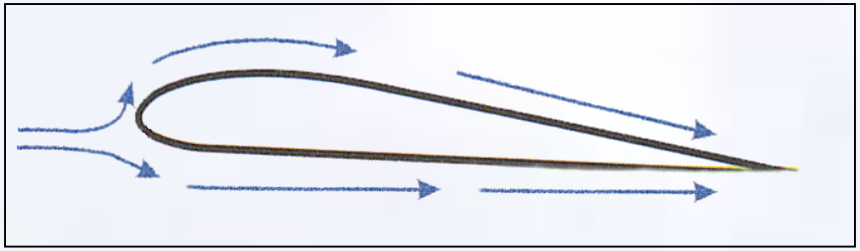
- Basics of Flight…How Flight Works
- Flight Systems
- Controlling Flight

Bernoulli's Principle



Airfoil: The Blueprint for Lift

The shape of the wing is called the airfoil.

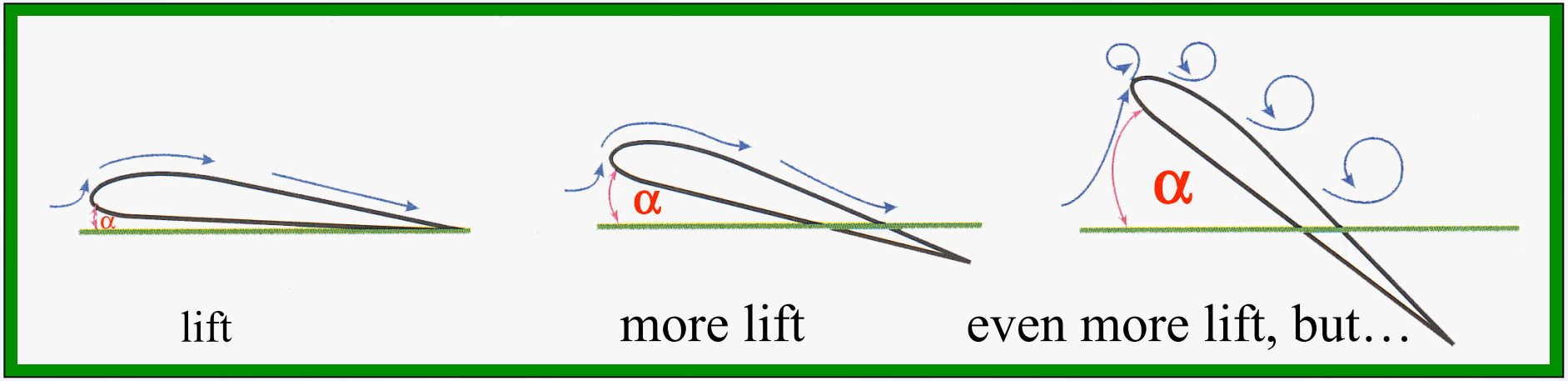


A wing can produce more lift by

- increasing velocity (by speeding up)
- increasing angle-of-attack (by ‘pitching up’)
- changing the shape of the wing (with control surfaces)

Angle-Of-Attack: Quick Lift

Lift can also be increased by increasing the airplane's ***angle-of-attack*** *(α)* ...

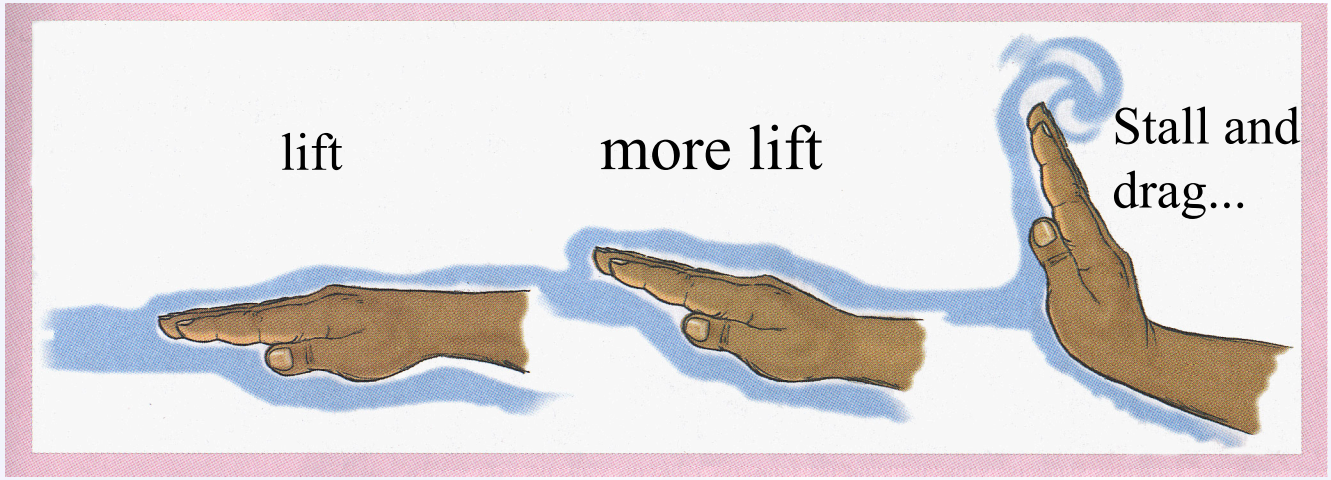


Too much α results in ***stall***, or loss of lift…

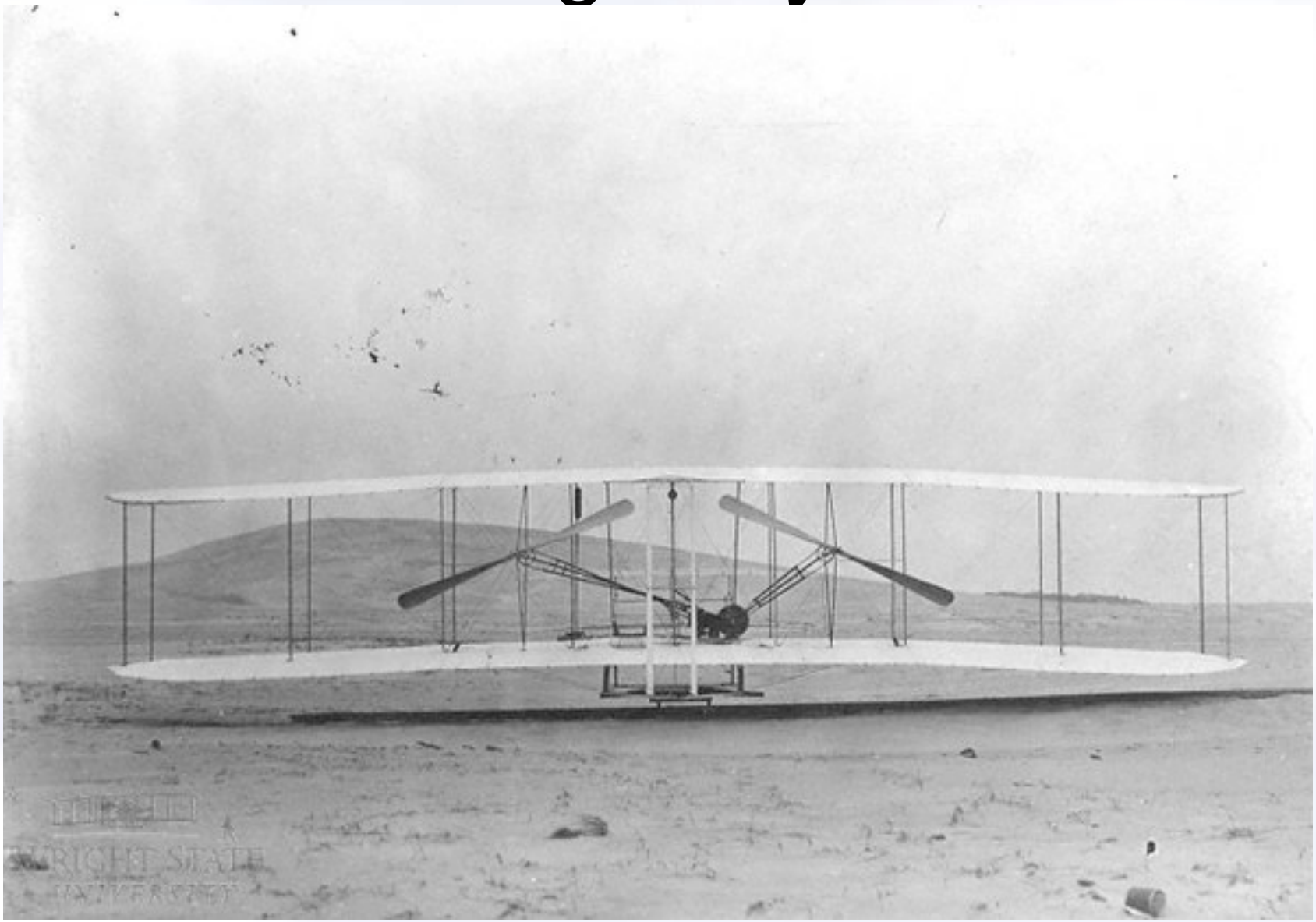
Stall also results in a LOT of drag...

Angle-Of-Attack: Do-It-Yourself

Next time you're in the car, stick your hand outside the window...



Wright Flyer



Wright Flyer

Wright Flyer

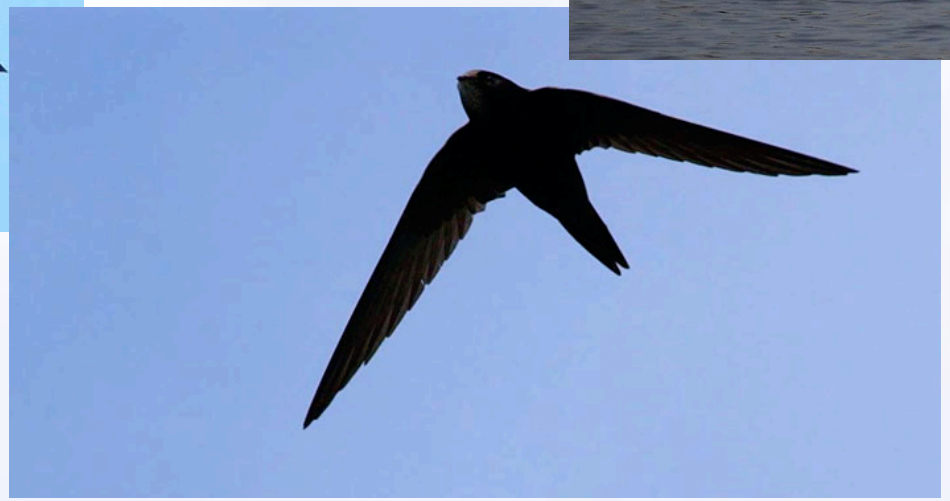
Discovery Channel's Recreation of the First Flight

http://exn.ca/flight/wright_brothers/flights/default.asp

F/A-18

F/A-18

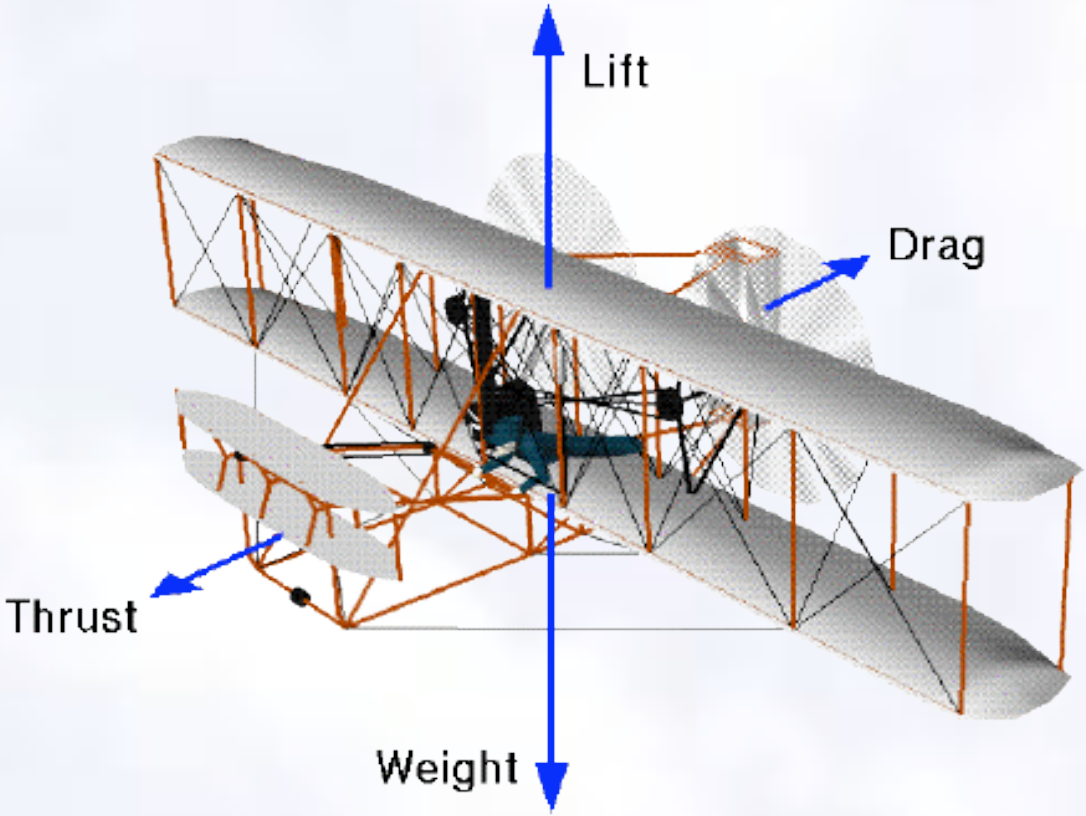
Biological Flight Systems… Birds!



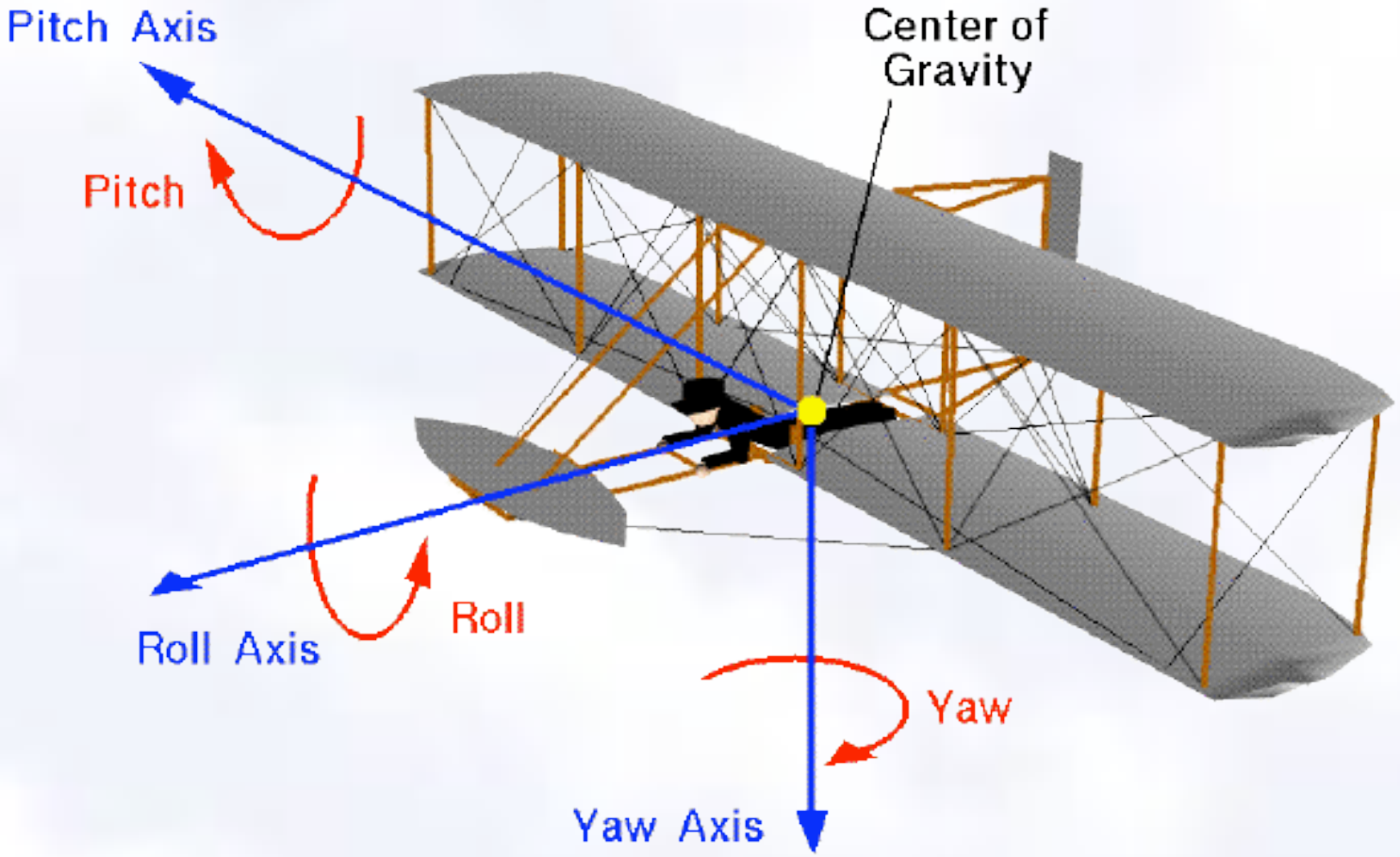
Control

- Need to balance forces
- Want to get where you're going!

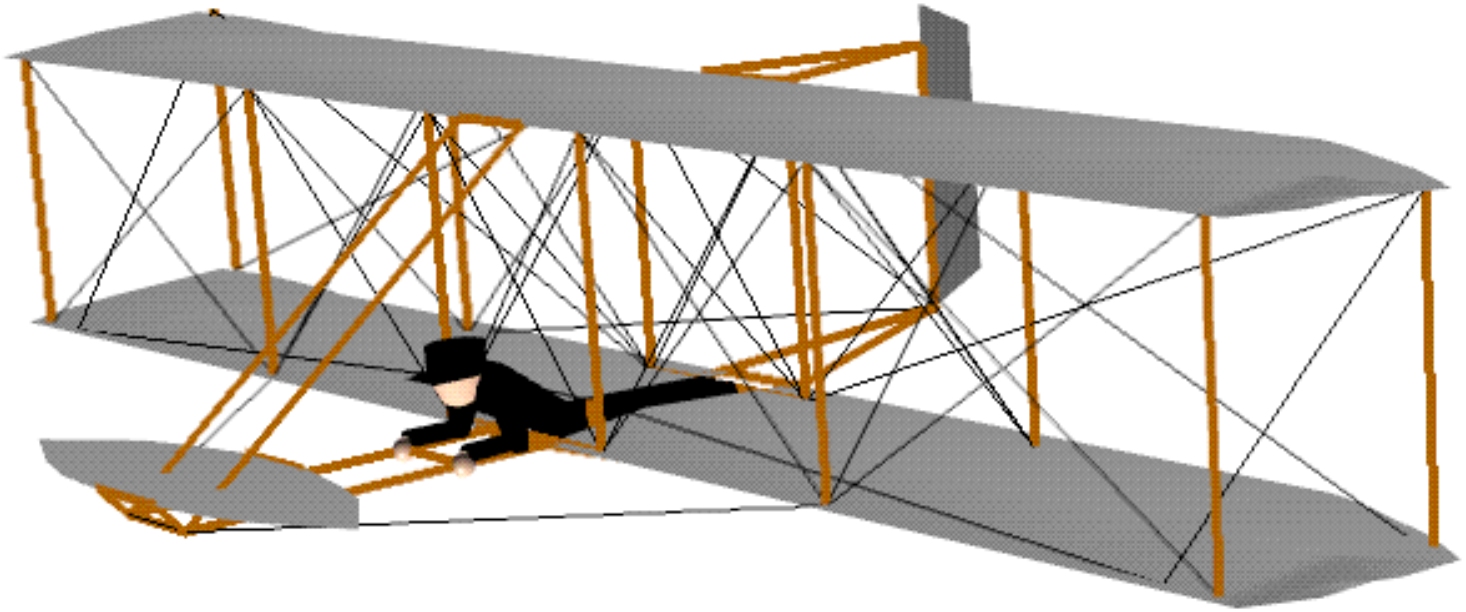
Aircraft Forces



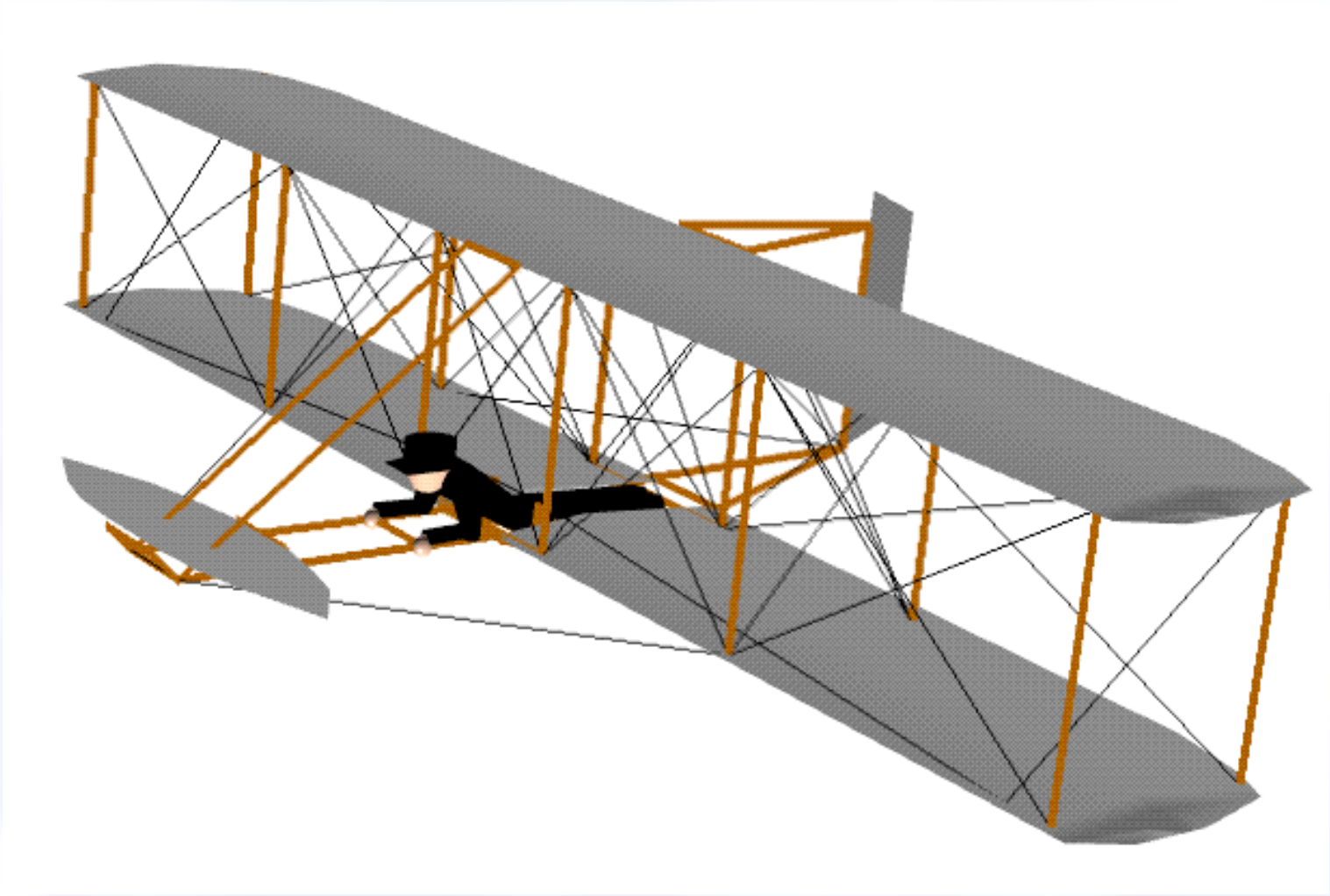
Aircraft Axes



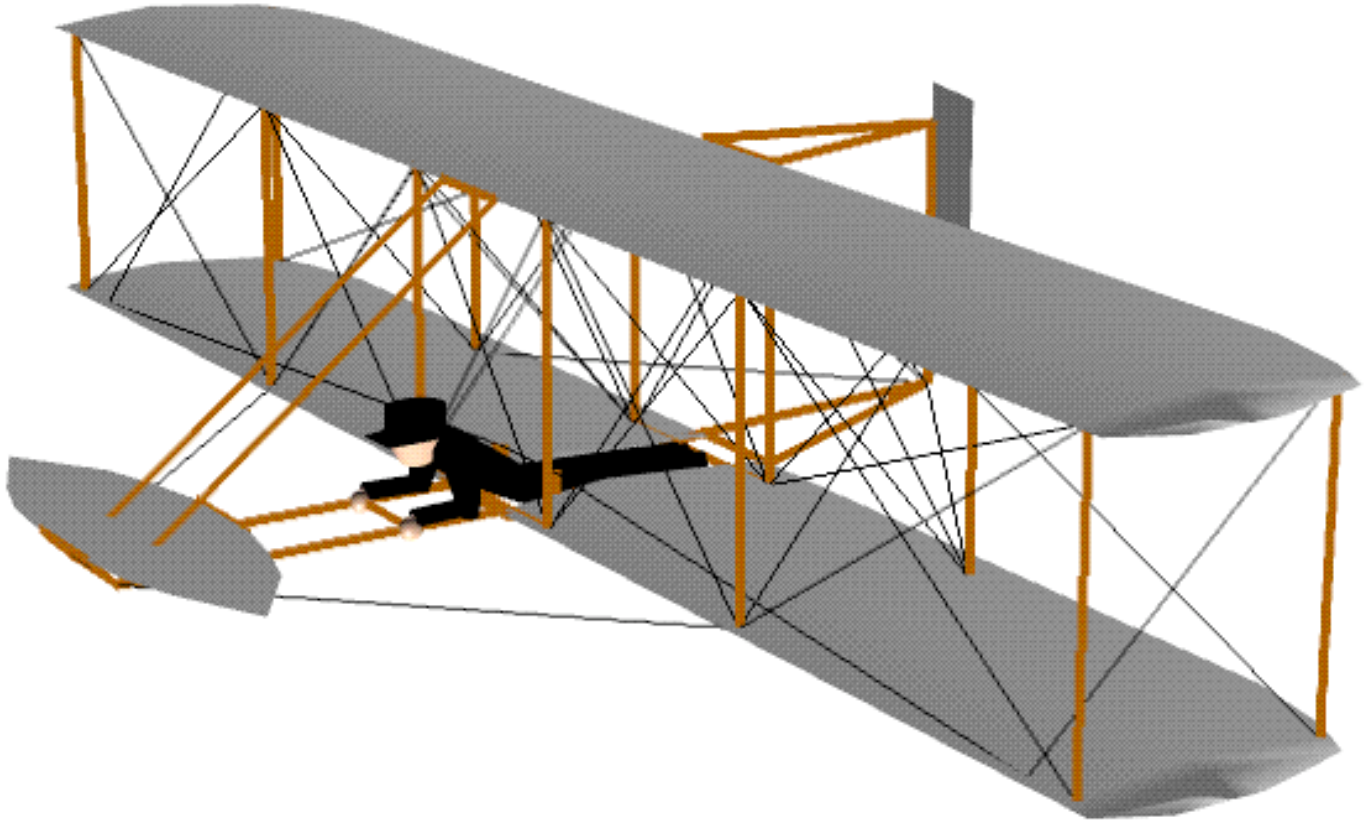
Roll



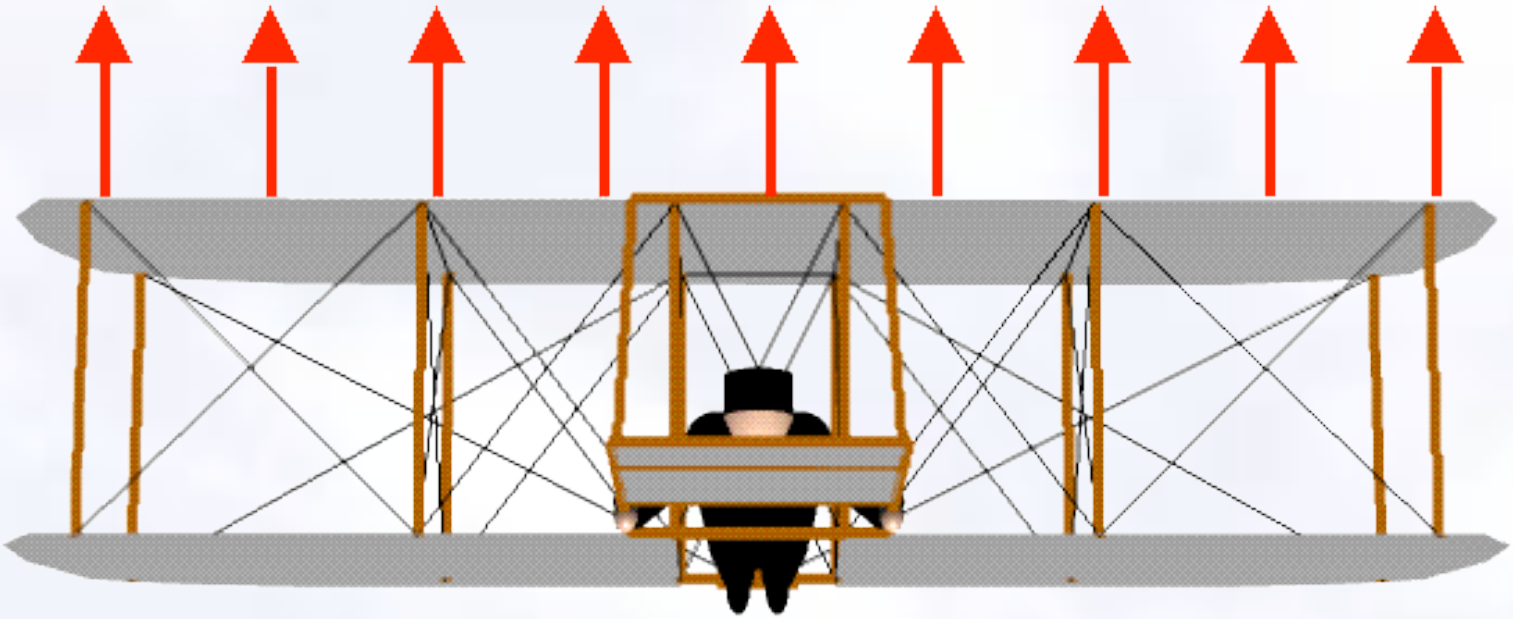
Pitch



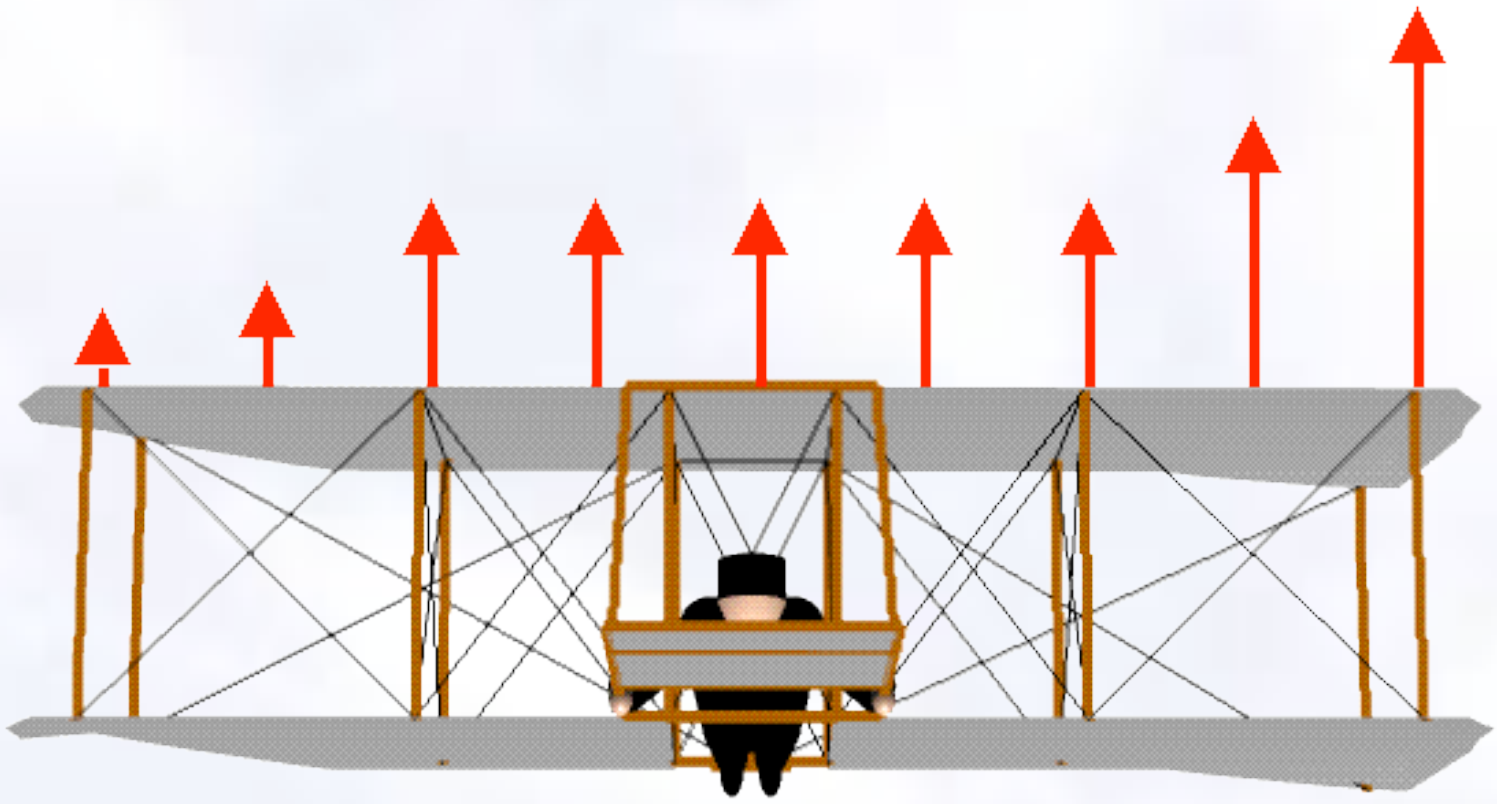
Yaw



Wing Warping



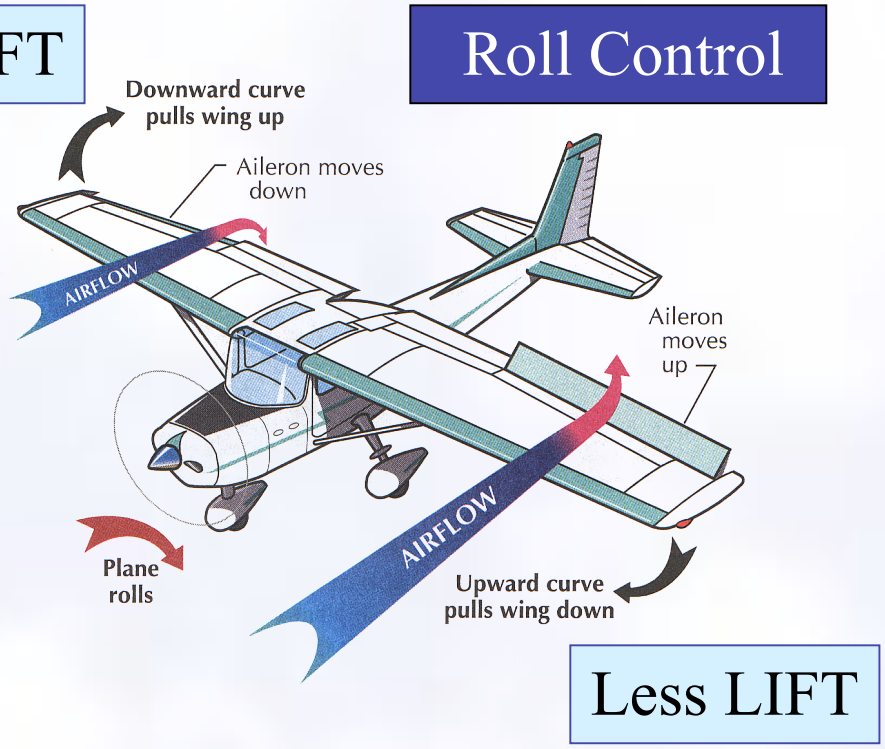
Wing Warping



Controlling the Airplane – ROLL

To make the airplane **ROLL** to one side, you **INCREASE** the **LIFT** on one side of the wing using **ailerons**...

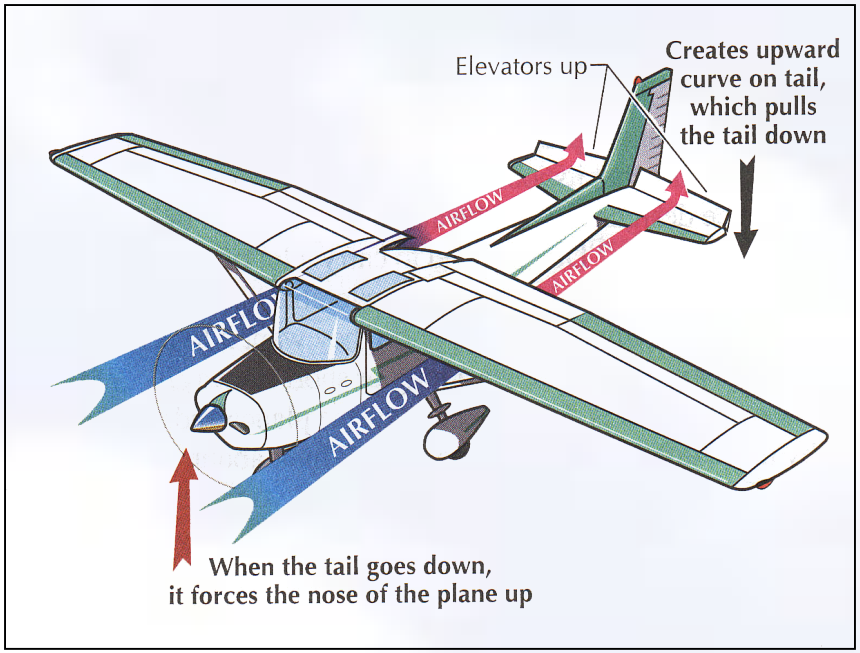
With more lift on one wing, and less on the other, the aircraft **ROLLS** towards the weaker side...



Controlling the Airplane

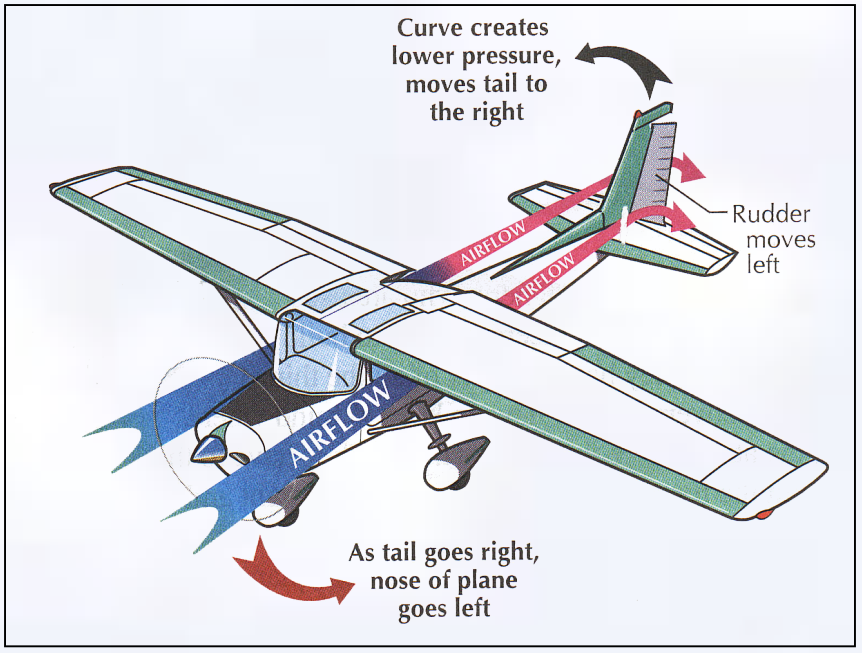
Pitch Control

The **elevators** control the **lift** on the **horizontal tail**, and make the nose go **up and down**...



Yaw Control

The **rudders** control the **lift** on the **vertical tail**, and make the nose go **left and right**...



Active Aeroelastic Wing

- F/A-18 with more flexible wings
- Control surface deflection creates wing twist
- This is similar to wing warping!

Avian Flight Controls

Tilly the Eagle

Discovery Channel's Animal Planet

http://animal.discovery.com/convergence/spyonthewild/birdtech/birdtech.html

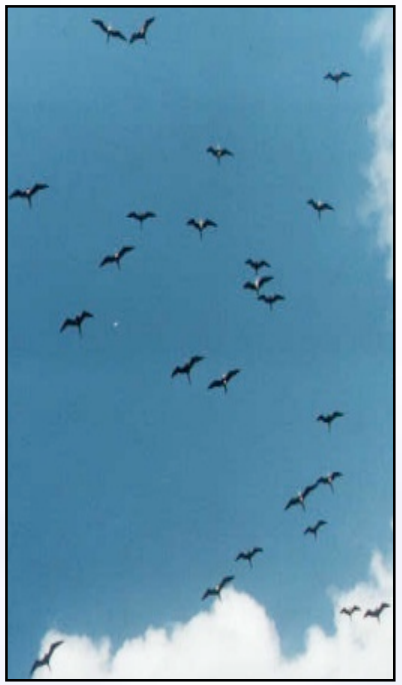
More Info…

- “Wild Blue Wonders: Exploring the Magic of Flight,” by Lane Wallace. EAA, 2001.
- “A History of Aerodynamics,” by John D. Anderson, Jr. Cambridge University Press, 1997.
- “Illustrated Guide to Aerodynamics,” by H.C. Smith. The McGraw-Hill Companies, 1991.
- http://www.first-to-fly.com/
- http://www.nasa.gov/
- http://wright.nasa.gov/

Autonomous Soaring

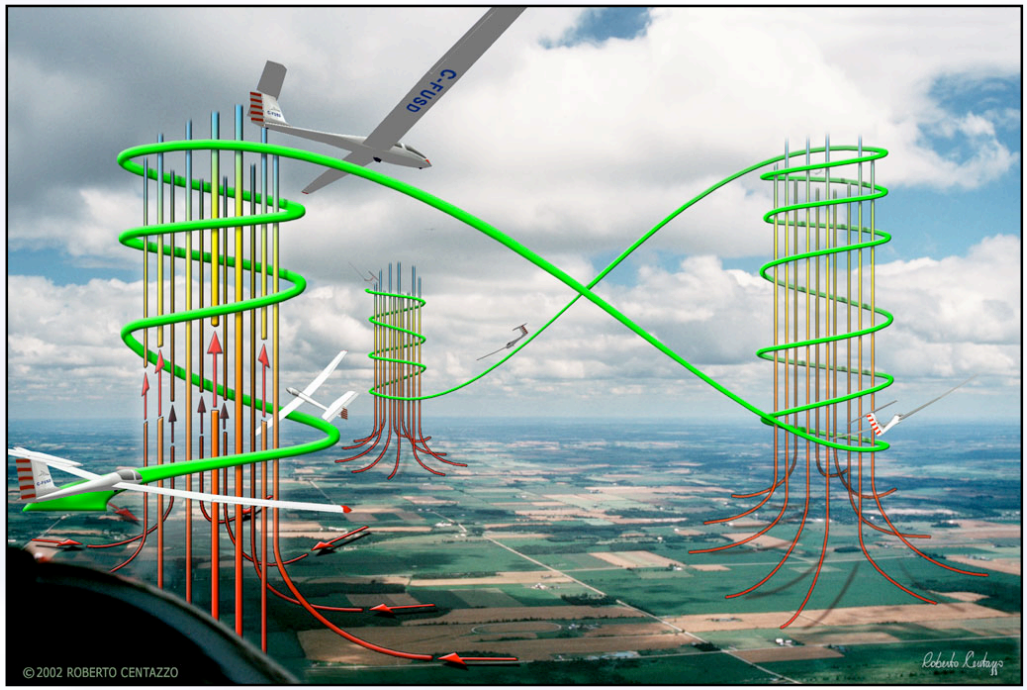
How to Make an Airplane Soar

- Soaring is when a bird or glider uses wind currents to stay up.
- Birds like to soar because they don't have to flap their wings all the time.
- At NASA we decided to see if a computerized airplane could also soar.



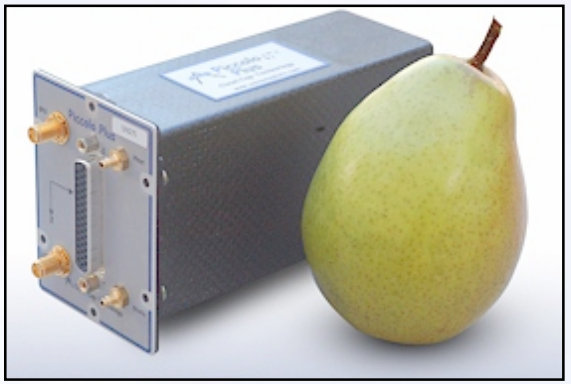
Updrafts

- Updrafts form when the sun heats the ground
- The warm ground makes the air near the ground hotter than the air above it.
- Hot air rises.
- If an airplane or bird stays in the rising air, it will rise



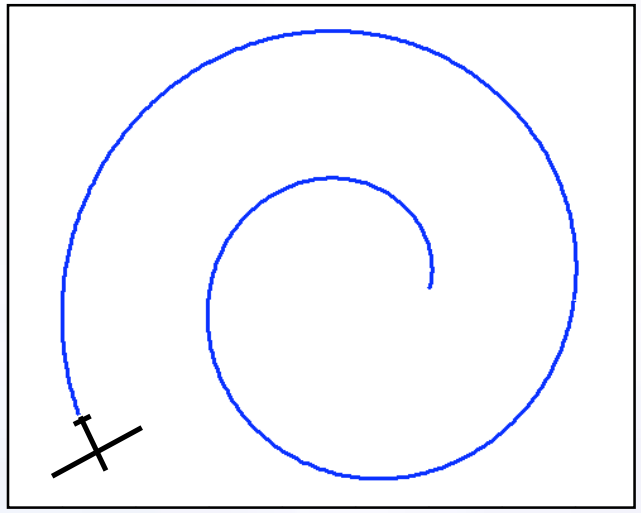
Research Airplane

- CloudSwift Aircraft
  - Span: 4.26m (14ft)
  - Weight: 6.58kg (14.5lb)
  - Stall speed: 18kt
  - Mission speed: 25kt
- Piccolo Autopilot
  - Weight: 212g (7.5 oz)
  - Sensors:
    - Rate gyros
    - Accelerations
    - Static & total pressure
    - GPS position & velocity
  - Custom software developed for this project



Search Path

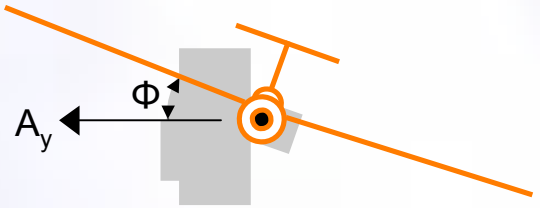
- The airplane did not know where the updrafts were.
- Archimedes spiral pattern was chosen for the airplane to fly while searching for updrafts.



$$r = a * \psi + b$$

Soaring UAV Simulation Study, Climb Performance

- A flight simulator was used to predict if the airplane would soar or not.
- Equations were used to calculate the forces and moments on the airplane.

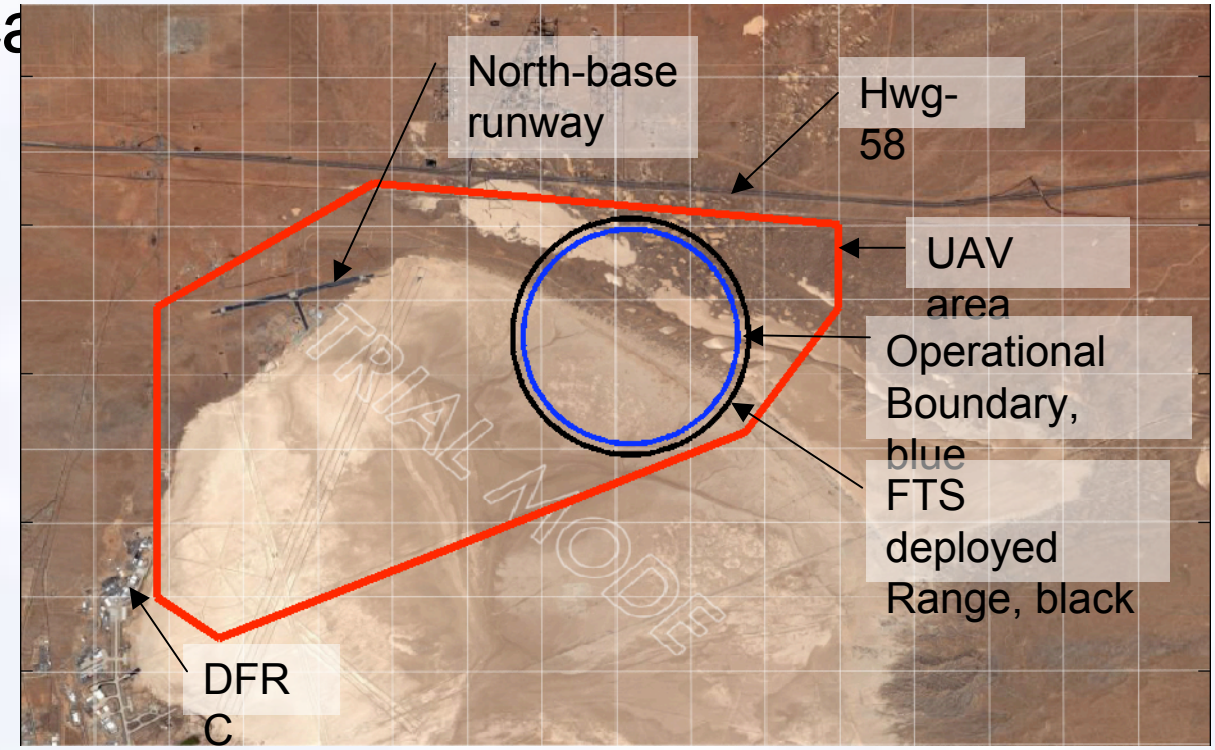


$$N_z = \frac{1}{\cos(\phi)}$$

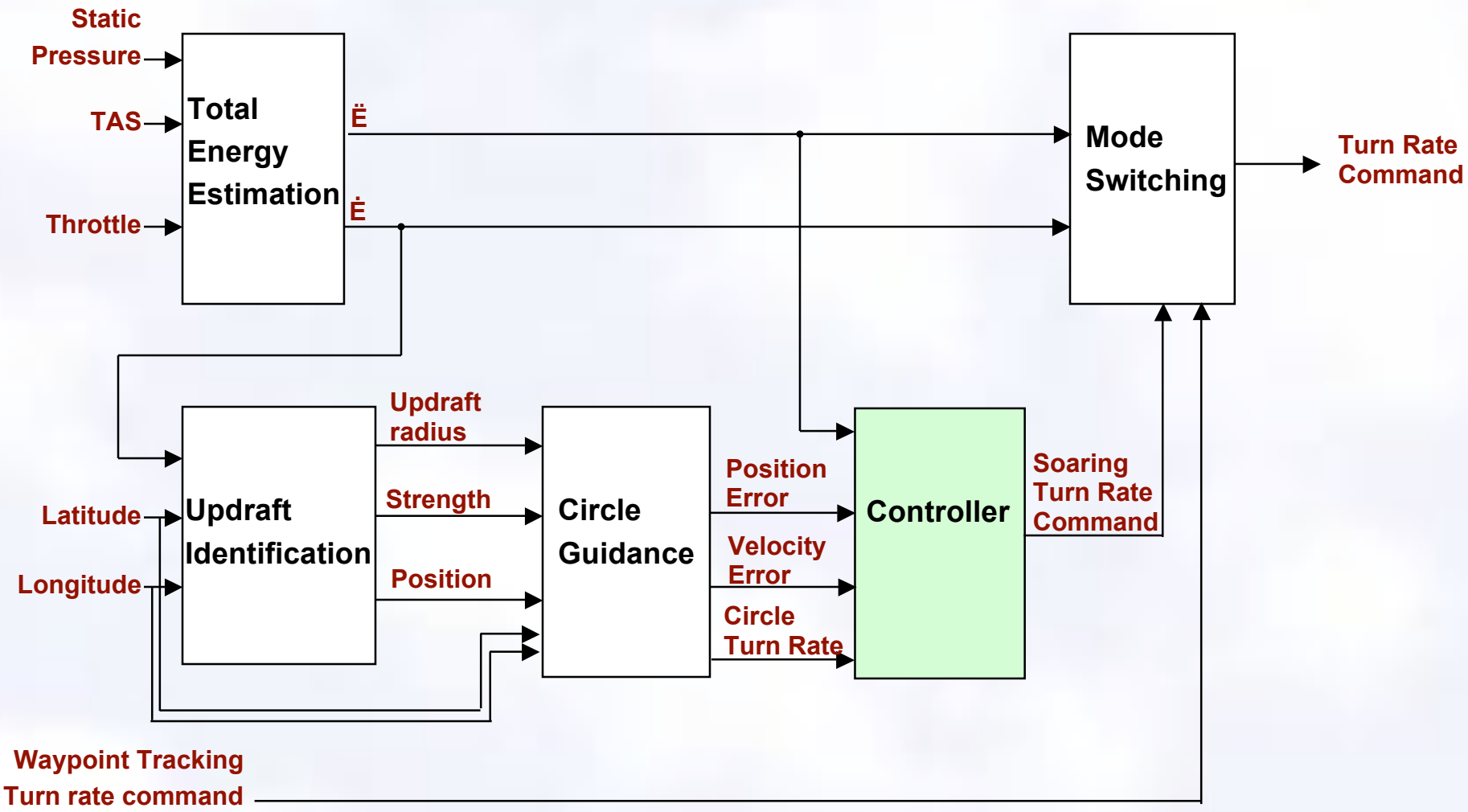
$$S_i = \frac{V * \left(1 + N_z^2\right)}{2 * \frac{L}{D}}$$

Flight Test Plan

- Safety bounds were used to make sure that the airplane didn't fly over to highway 58 and hit a ca



Algorithms for Soaring

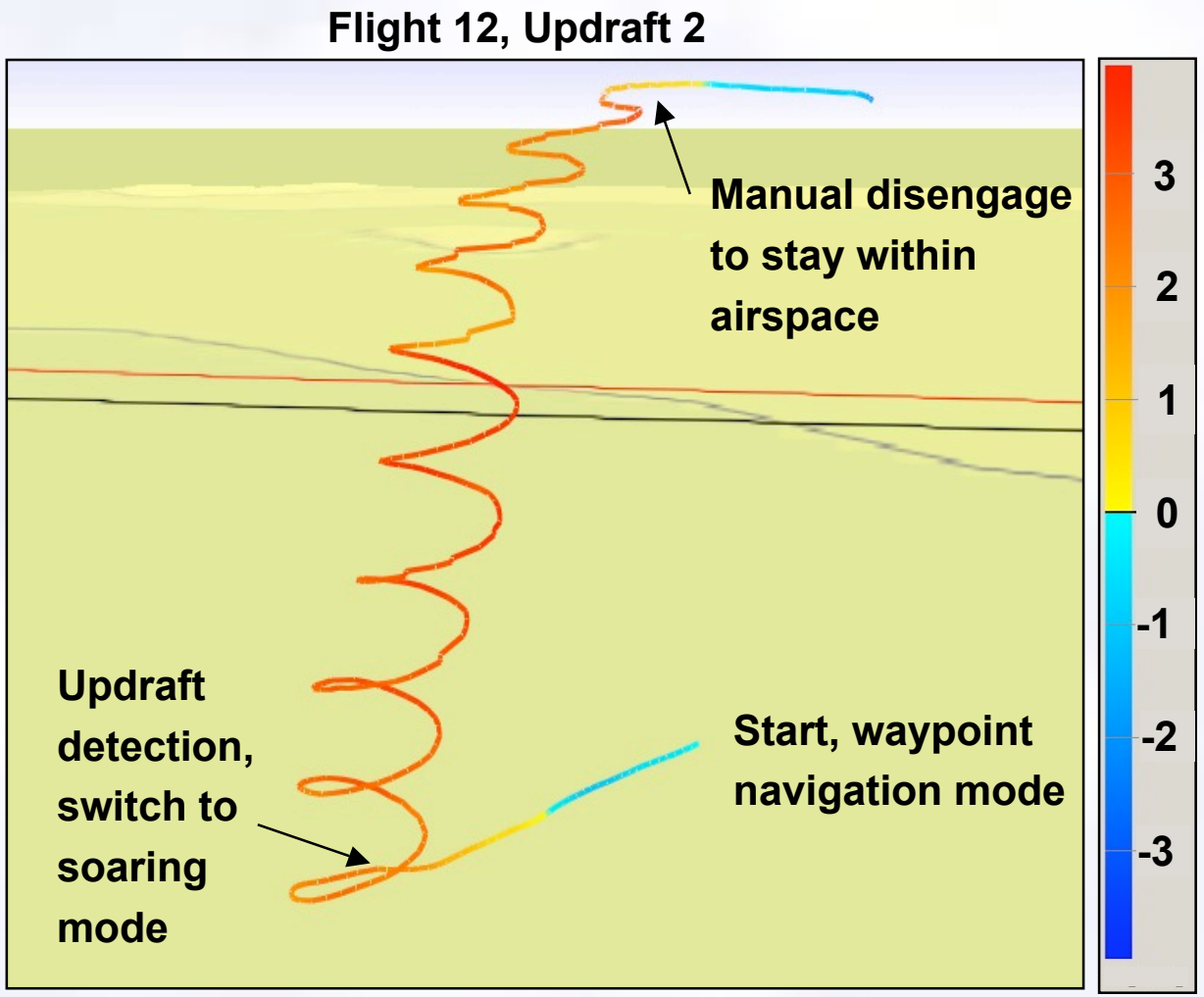


Flight Test Results

- 17 flights were conducted
  - perform aircraft checkout
  - autopilot gain tuning
  - FTS range tests
  - research flights
- 23 updrafts were found.
- Average climb for all updrafts = 172m (567ft)

Flight Test Results

- Highest climb in a single updraft
- Sept 9, 2005.
- 844m (2770ft) altitude gain.



- Play: cloudSwift_flt12_up2.gc

Questions?