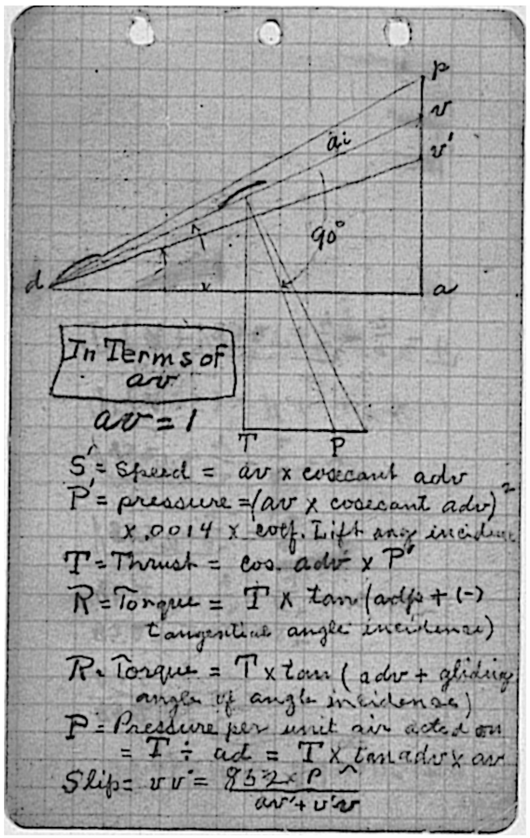
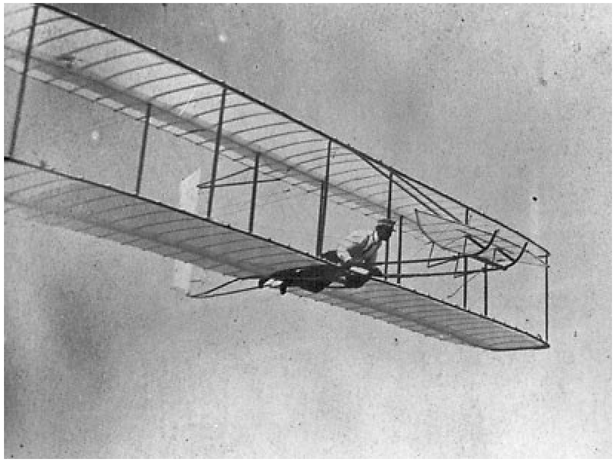
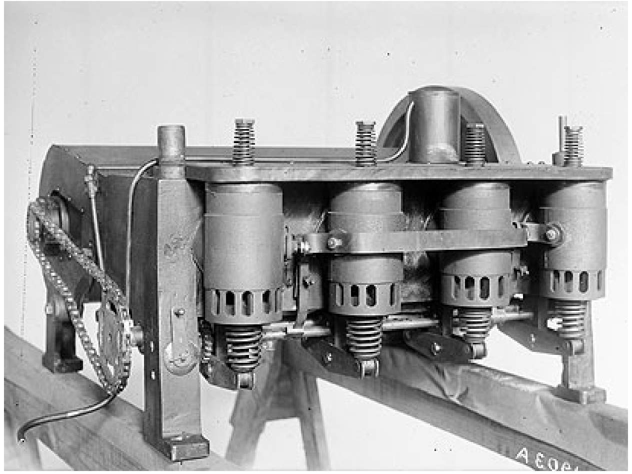
CENTENNIAL OF FLIGHT 1903-2003

From a dream to first powered flight



Kevin Kochersberger, Ph.D.
Rochester Institute of Technology
Mechanical Engineering
Rochester, NY 14623





Aeronautical Experimentalists

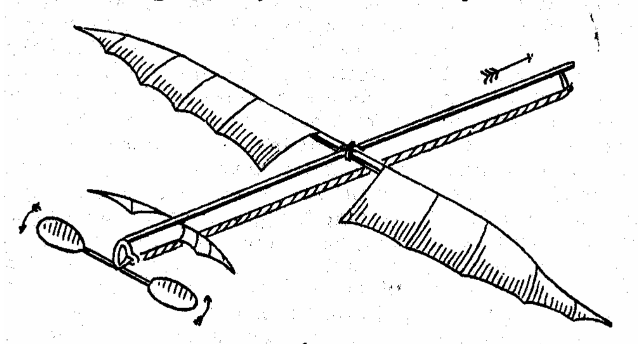
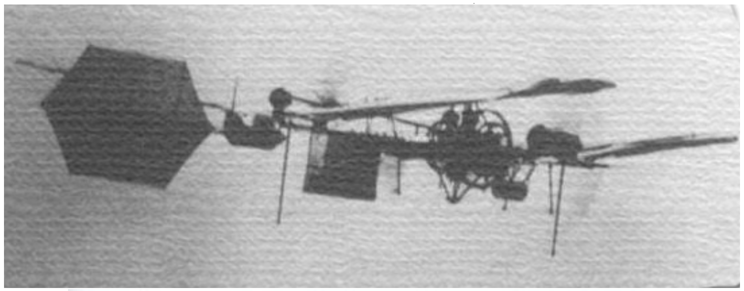
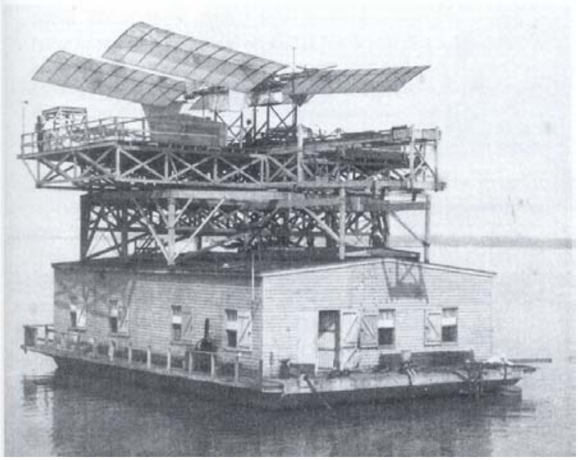


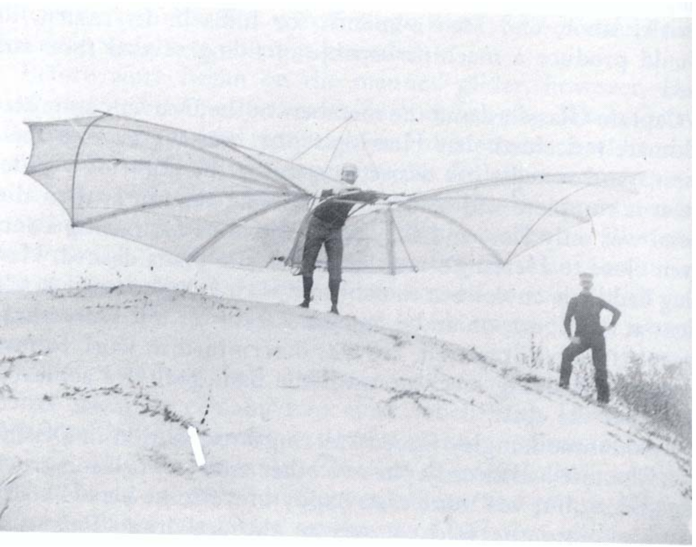
FIG. 53.—PÉNAUD—1871.



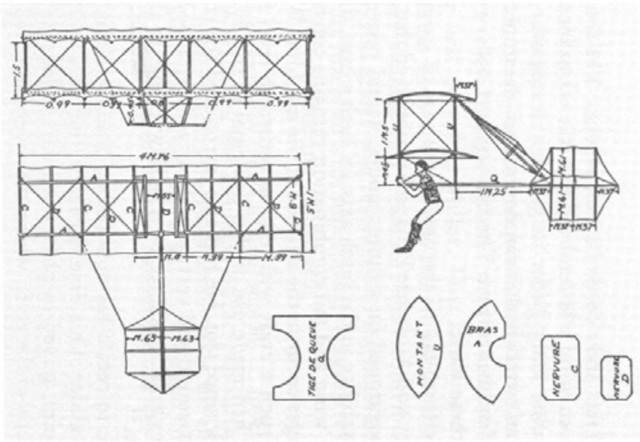


- **Alphonse Penaud (1850 - 1880)**
  - Built the first longitudinally and laterally stable glider models
- **Samuel Langley (1834 - 1906)**
  - Whirling arm lift and drag measurements of flat plates
  - Successful flights of steam powered models (the Aerodromes)
  - Unsuccessful attempt at manned, powered flight on December 8, 1903 of a full-scale Aerodrome

The earliest flights

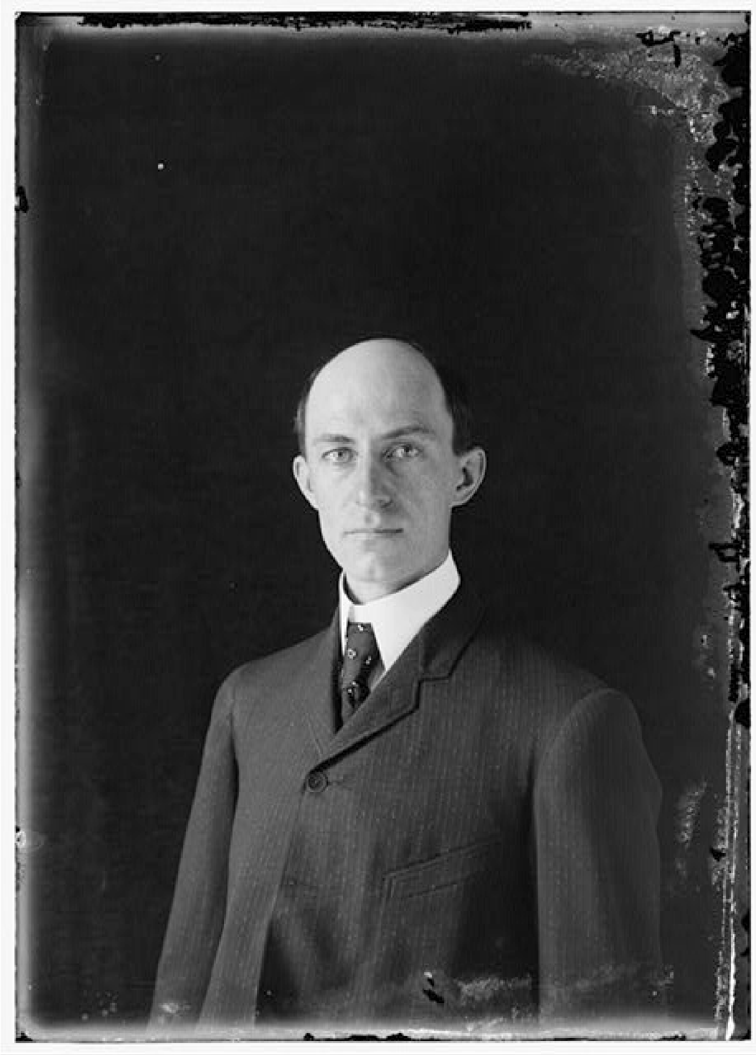


- **Otto Lilienthal (1848 - 1896)**
  - Measured lift and drag on cambered airfoils, designed, patented and flew the first person-carrying glider



- **Octave Chanute (1832 - 1910)**
  - Published *Progress in Flying Machines,* built and supervised the flights of several biplane and triplane gliders in Miller Beach, IN

And then, the Wright brothers…



Wilbur (1867 - 1912)

Orville (1871 - 1948)

Early Experiments

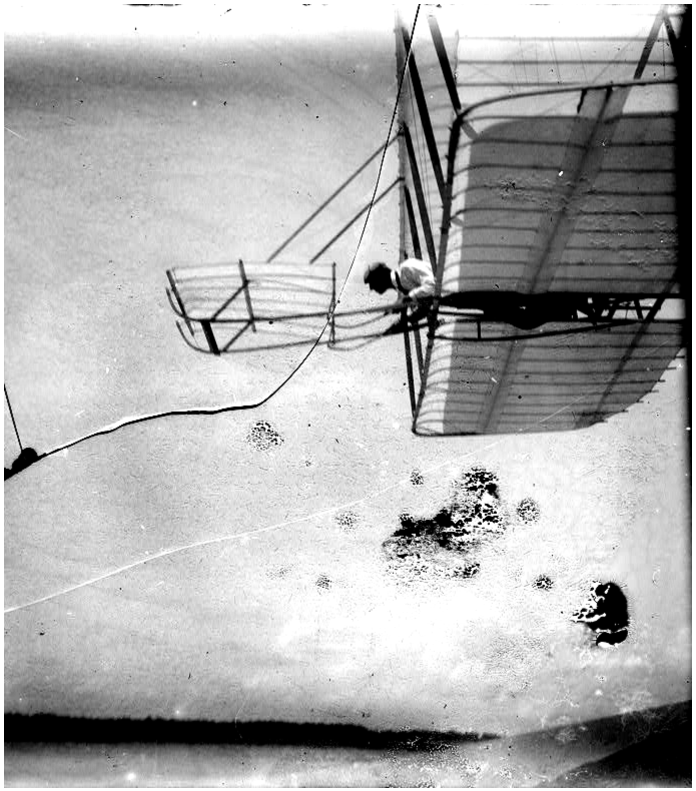
- **Flight experiments begun in 1899 with a 5' wingspan kite**
  - Proved the wing warping concept
- ***The Wrights realized that control was still an unsolved problem (unlike the majority of aerial experimentalists)***
  - Weight shift and flexible surfaces were commonly used

The 1900 - 1901 Gliding Experiments

- **First full-sized glider built in 1900 – Flew at Kitty Hawk briefly**
- ***"…hours of practice we had hoped to obtain finally dwindled down to about two minutes…"***

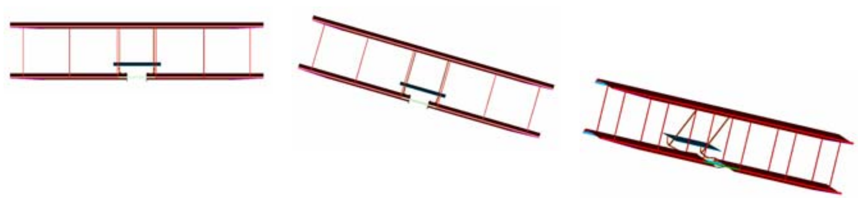
- **A larger glider was constructed in 1901 to correct the deficiency in lift found in the 1900 glider**
  - Low aspect ratio, high pitching-moment and adverse yaw = *difficult to fly!*

Some success, but not enough...



- **Pitch instability corrected by "trussing down" the wings**
- **Longest flight: 389 ft.**
- **Actual lift was much less than predicted**

And a turn to the right...

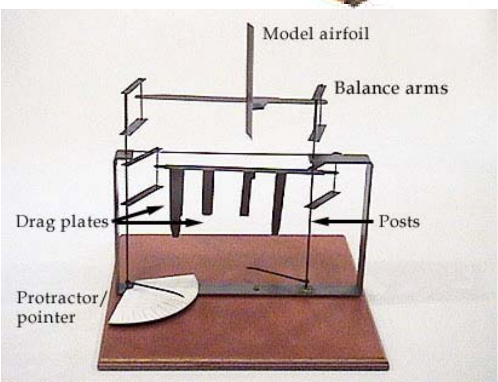


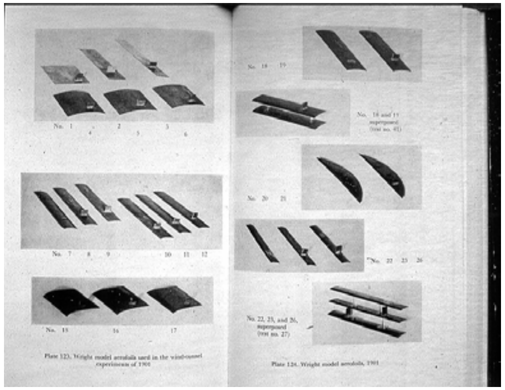
View looking Forward

...Became a turn to the left!

???

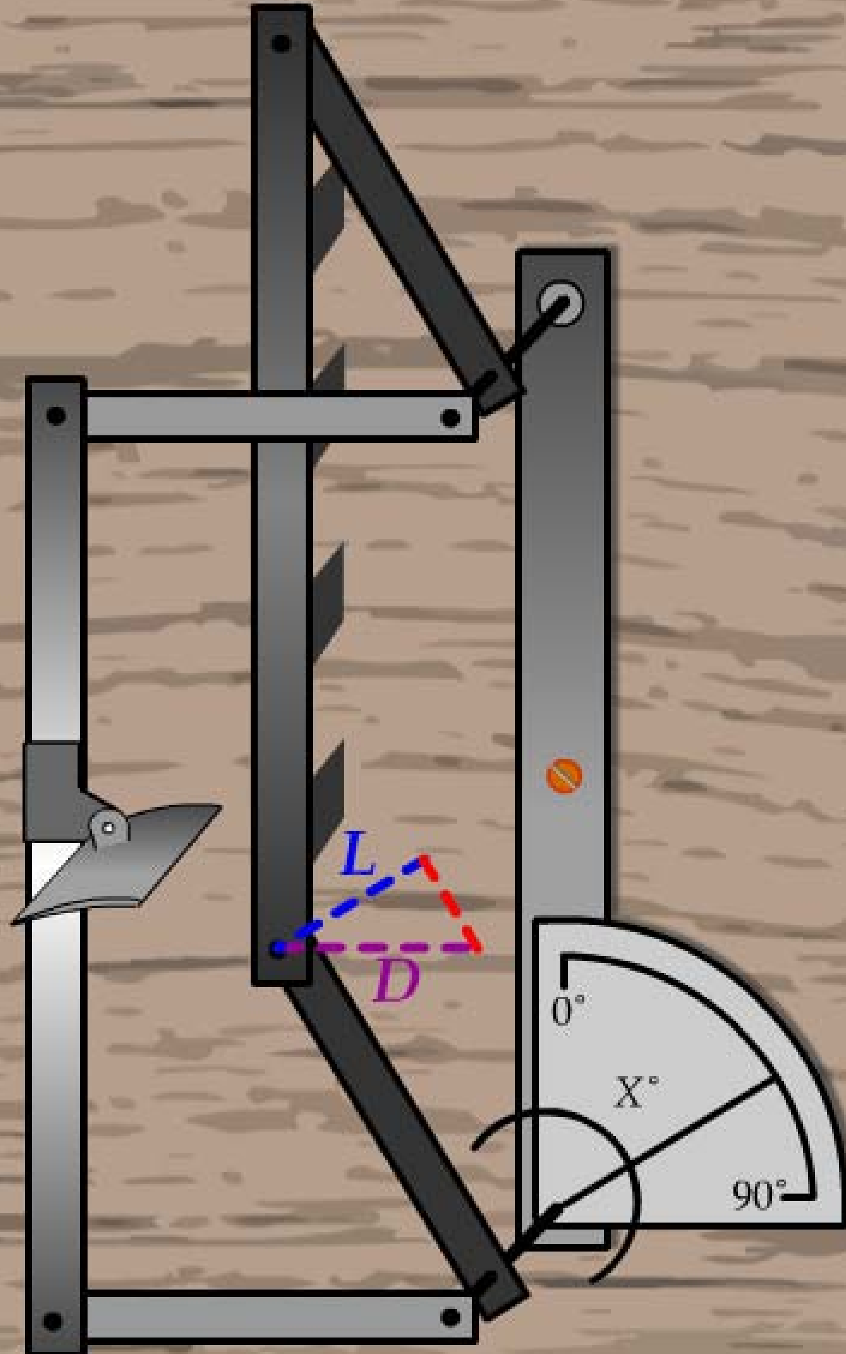
Engineering a solution



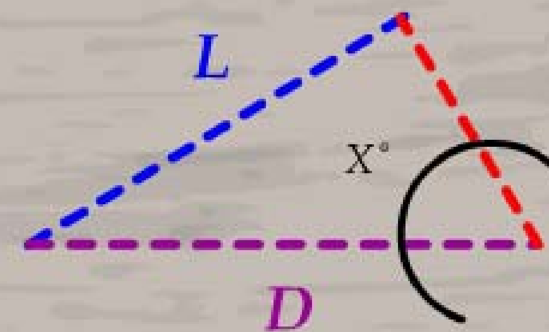


- **The Wrights' kiting experiments confirmed lift theory was incorrect**
- ***They needed to quantify airfoils, so a wind tunnel was built to determine accurate lift and drag for over 200 tested shapes***
- **Effects of camber, thickness and aspect ratio were documented as a function of angle of attack**

13



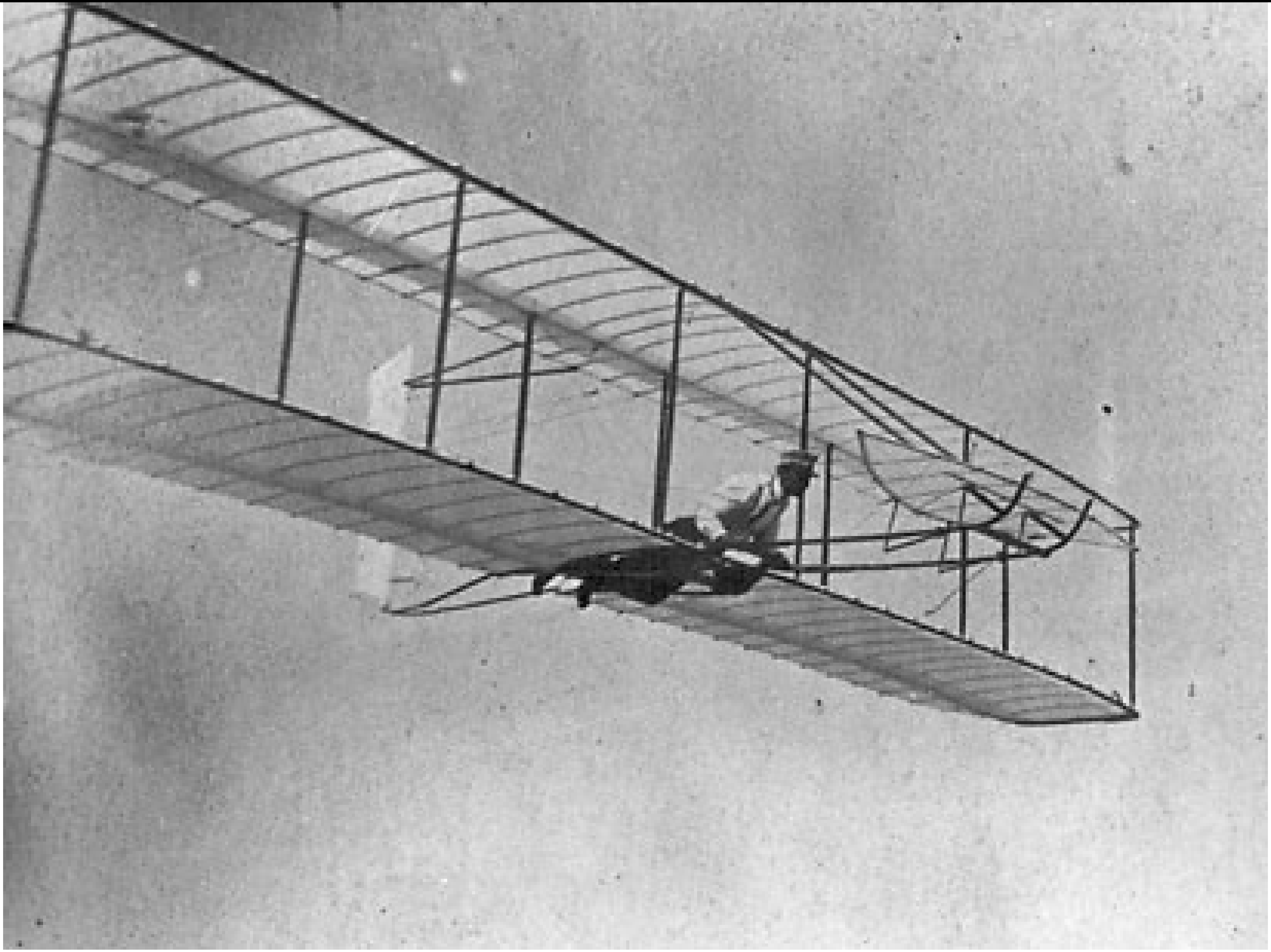
The triangle is enlarged below. The ratio of leg L to leg D is the same as the sine of angle X. This angle is the same as the angle indicated by the pointer.



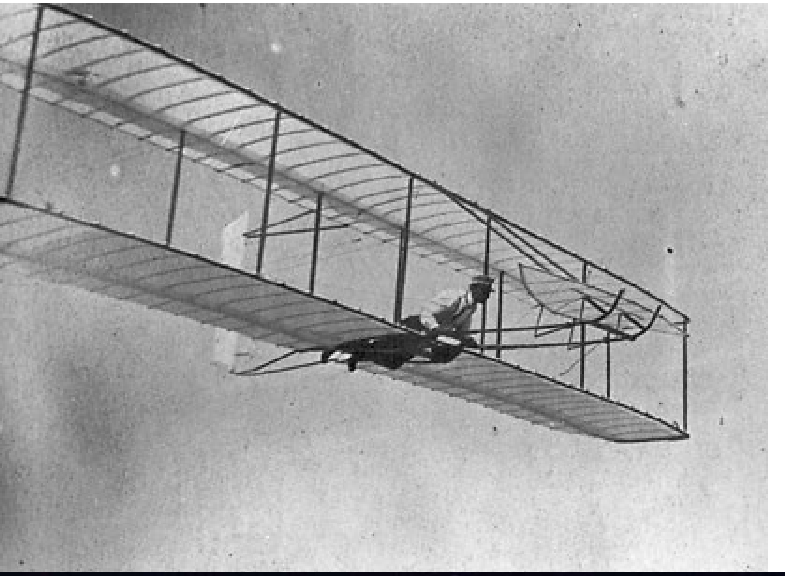
BACK

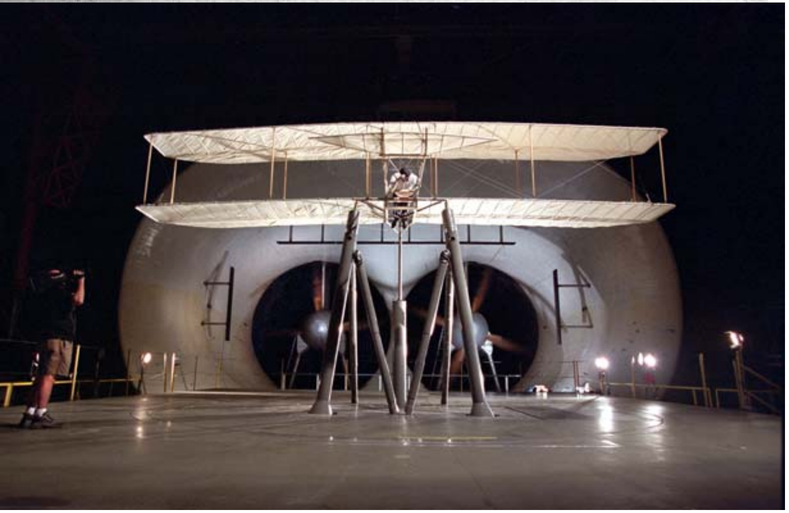
NEXT

1902 Glider



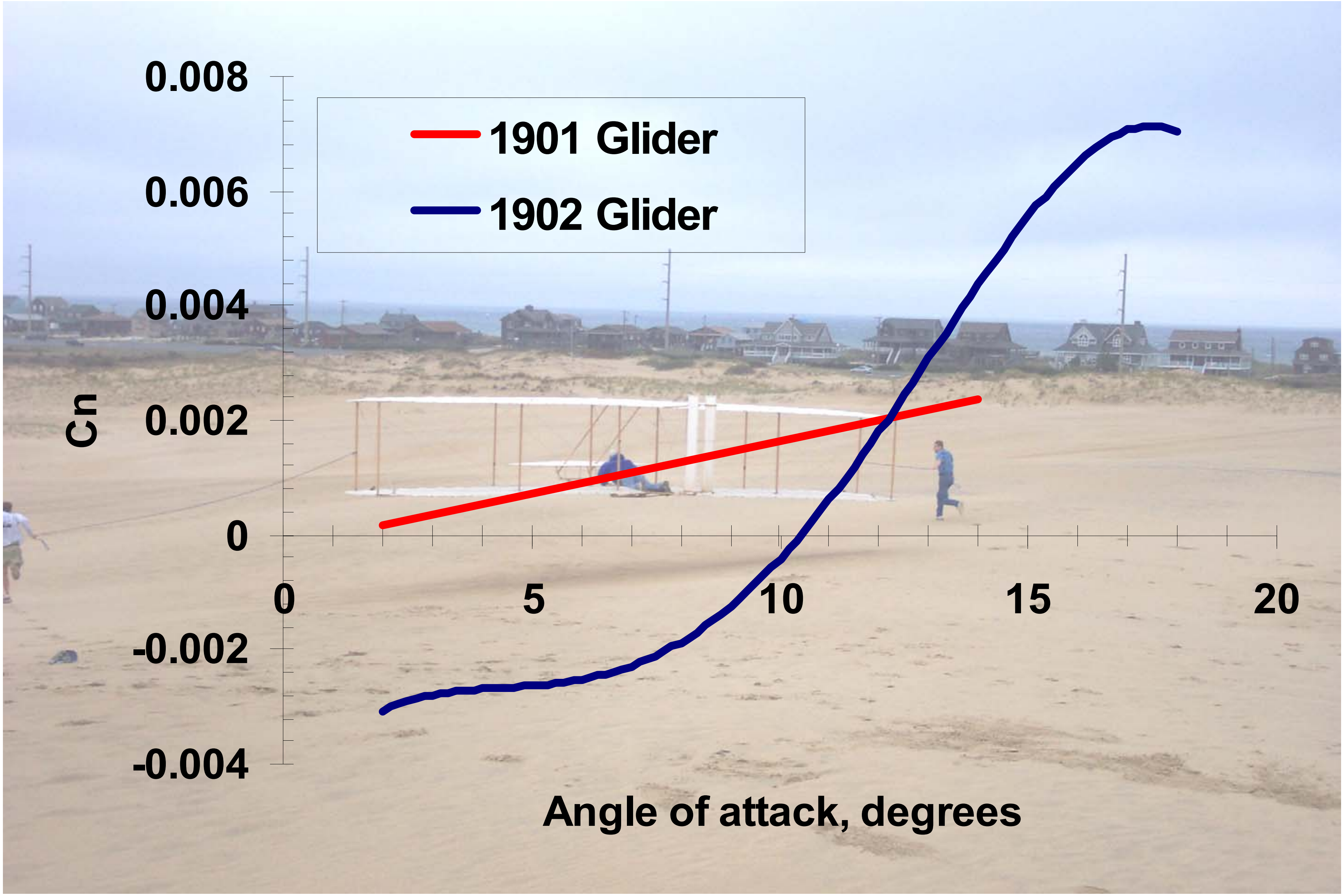
1902 glider: A modern airplane



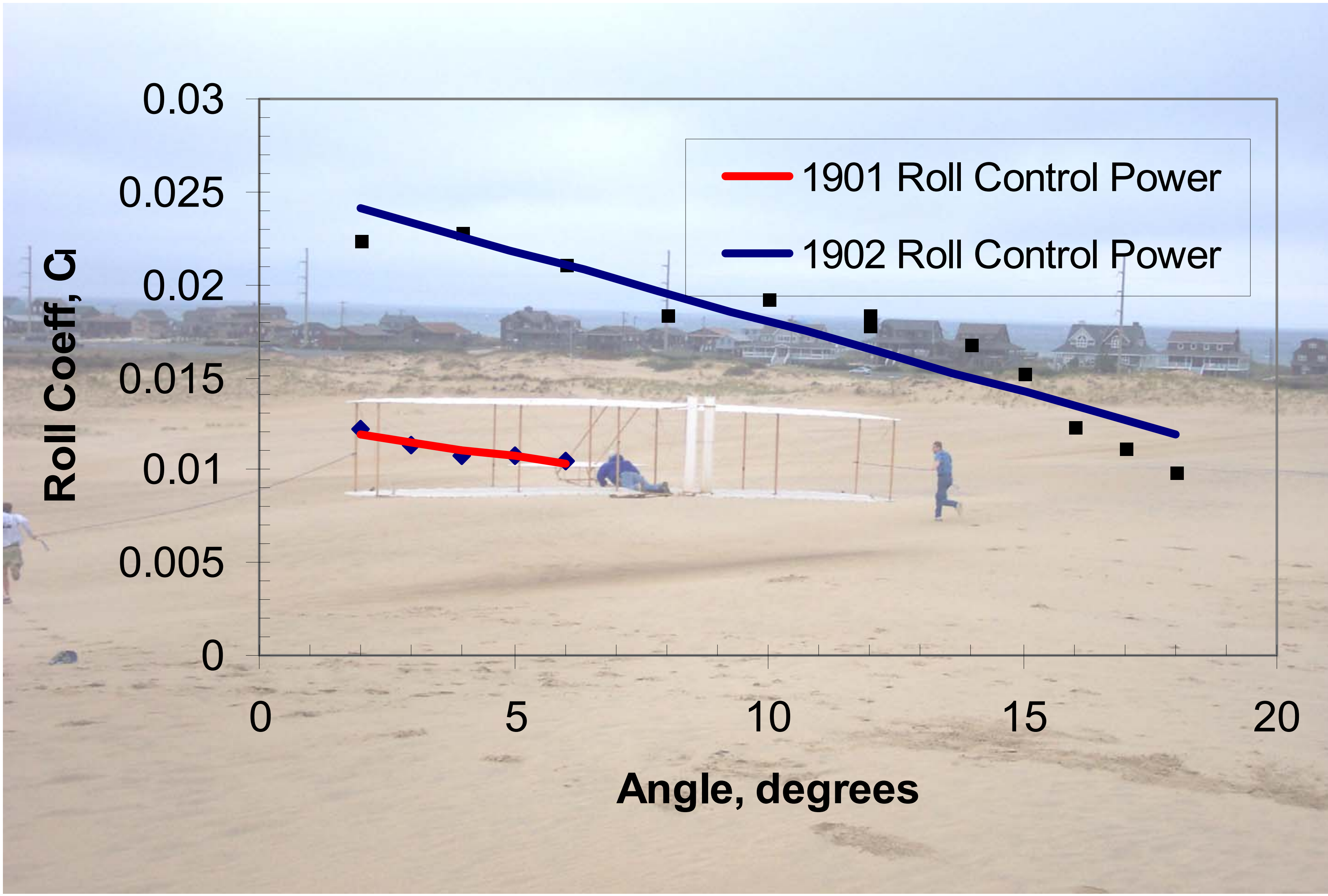


- **A high aspect ratio wing**
- **Anhedral added**
- **Improved camber (curvature)**
- **L/D increased from 5 to 7**
- **Three axis control: *with the addition of a moving tail, turns were now predictable***
- **250 flights made in a 5-day period**
- **Longest flight: 622 ft.**
- **Time aloft: 26 seconds**

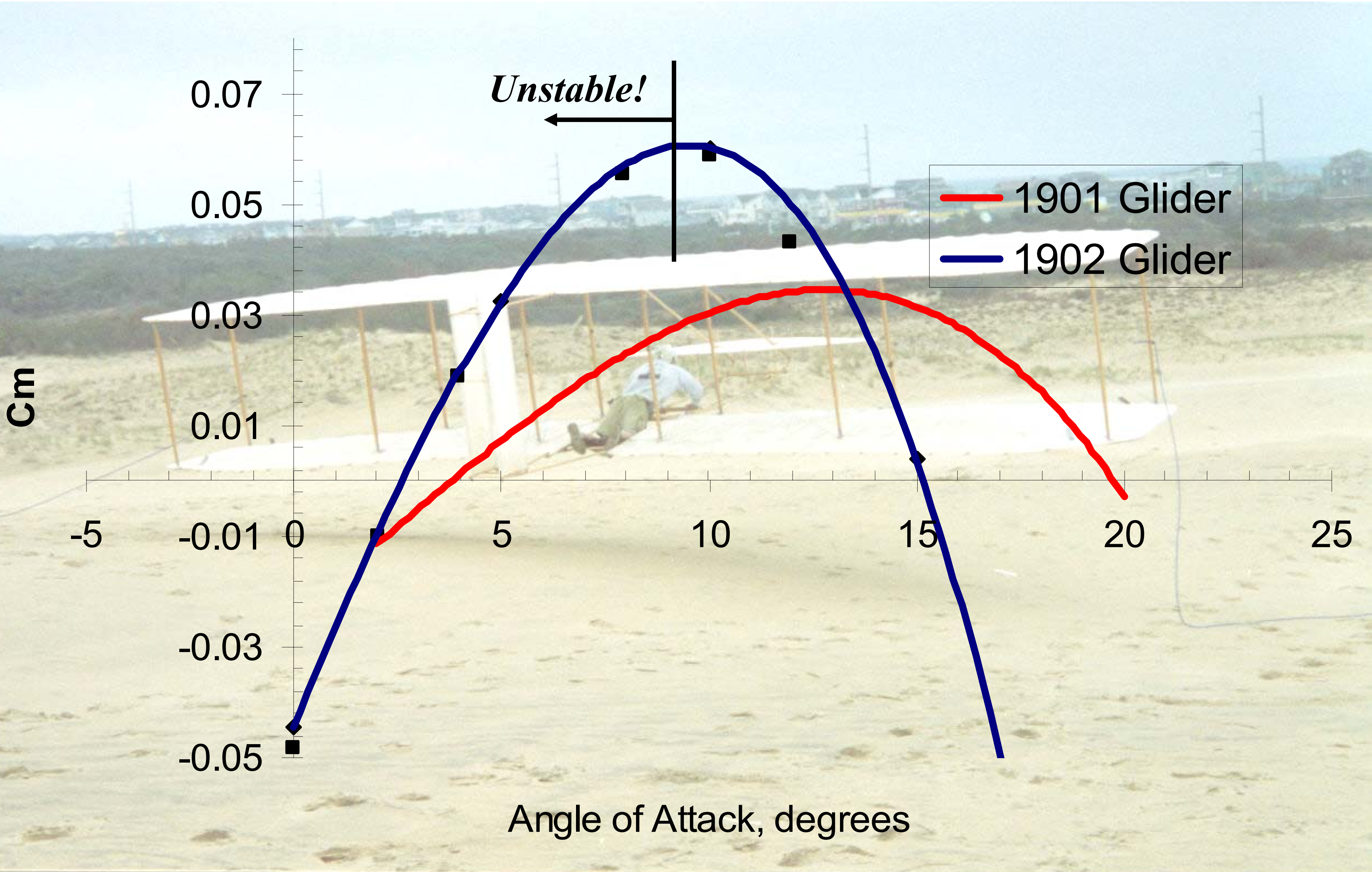
Adverse Yaw Corrected



And more warp power



But still have a variable stability aircraft



1902 / 1902 modified Flight test results

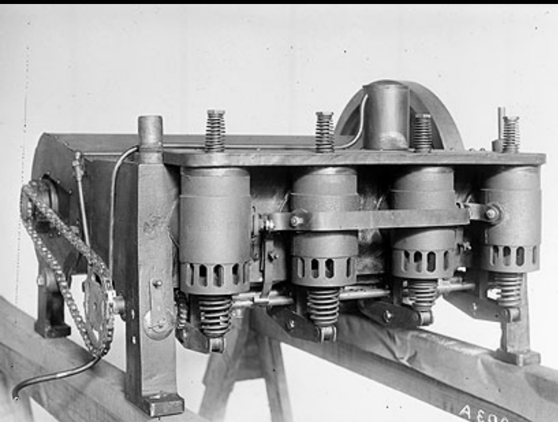
- **Aircraft very light in pitch, with a low pitch inertia and variable stability in the operating range**
  - Stable pitch up, unstable pitch down
  - Pilot must be cautious of nose-down pitch excursions
- **Roll is effective, good rate for a low-speed aircraft *but easily overpowered in a 4 kt. gust!***

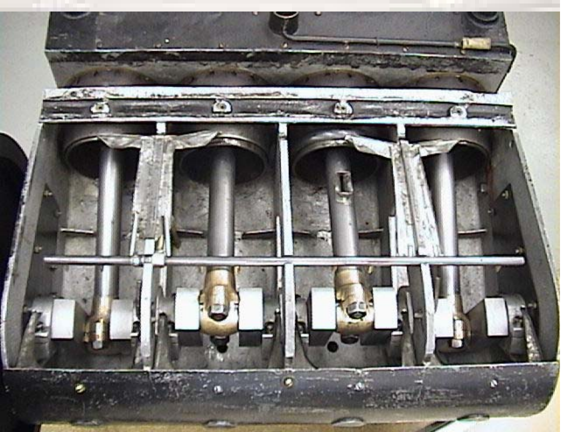
What's left?

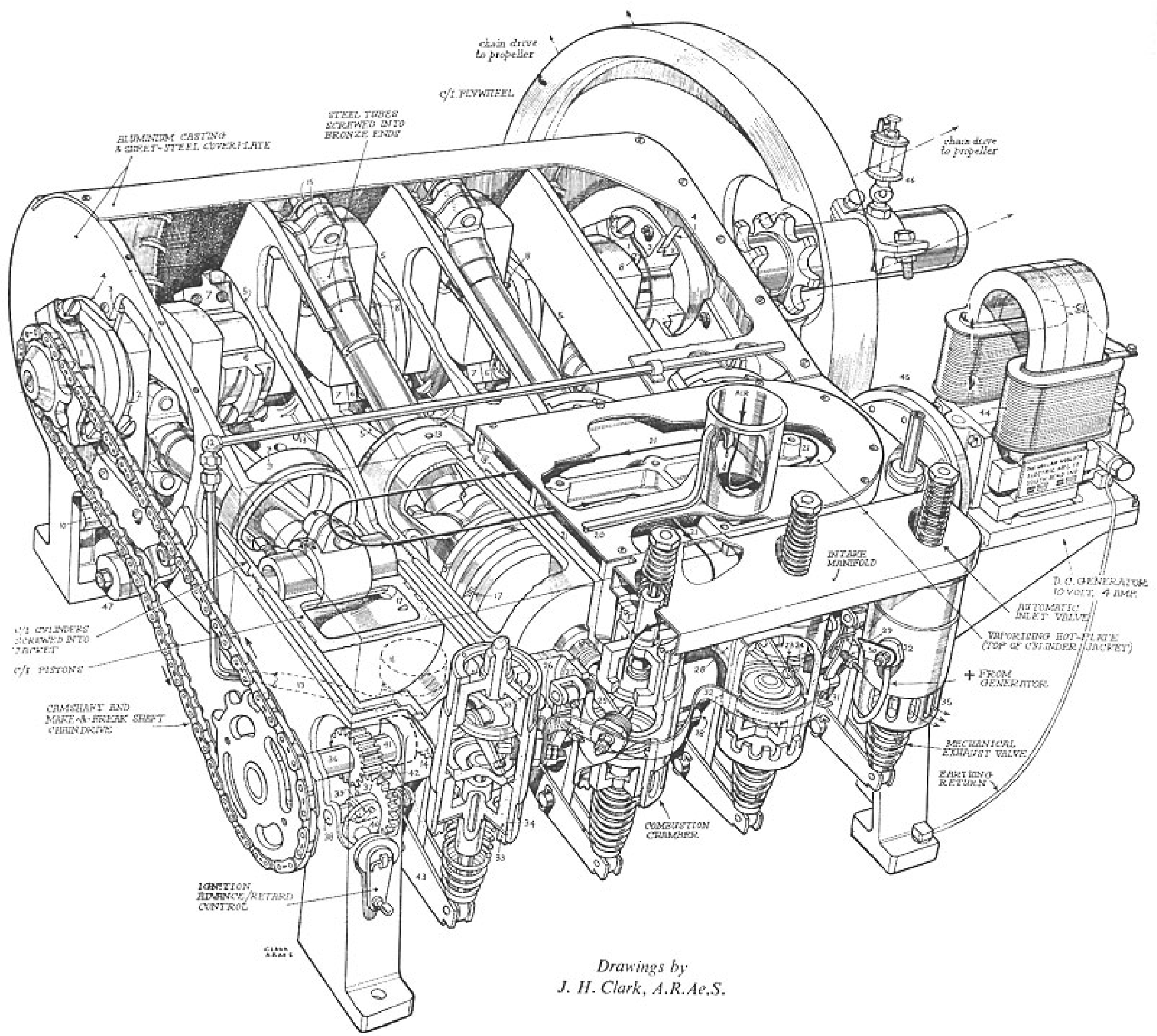
- **A reliable engine**
- **A propeller design**
- **Provision for launching on level ground**
- **The integration of the new systems into the airframe**
- ***Wind!***

The 1903 Engine

CENTENNIAL OF FLIGHT 1903-2003



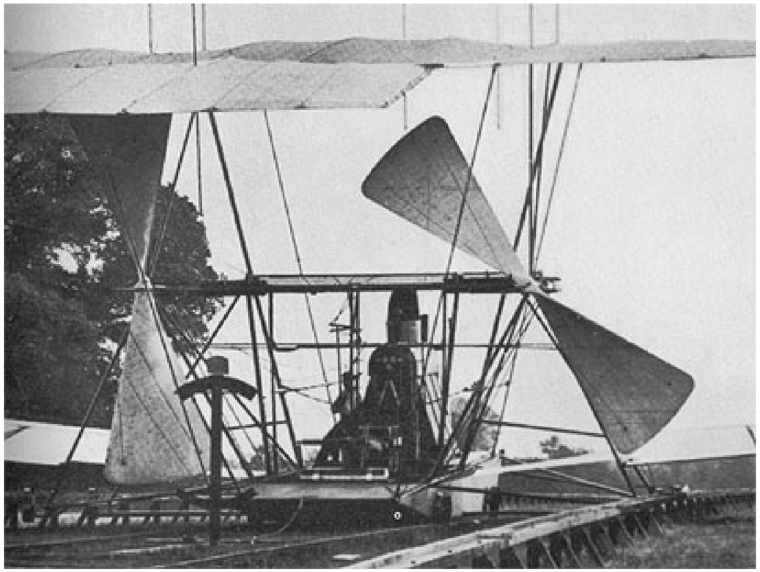




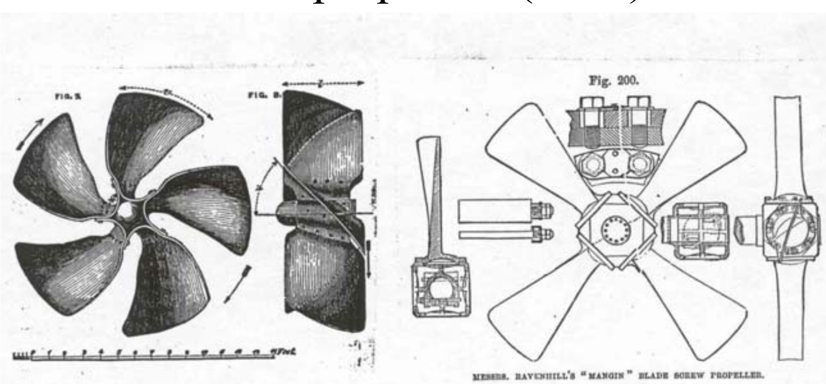
Drawings by
J. H. Clark, A.R.Ae.S.

Propeller design

CENTENNIAL OF FLIGHT
1903-2003



Maxim's propellers (1894)

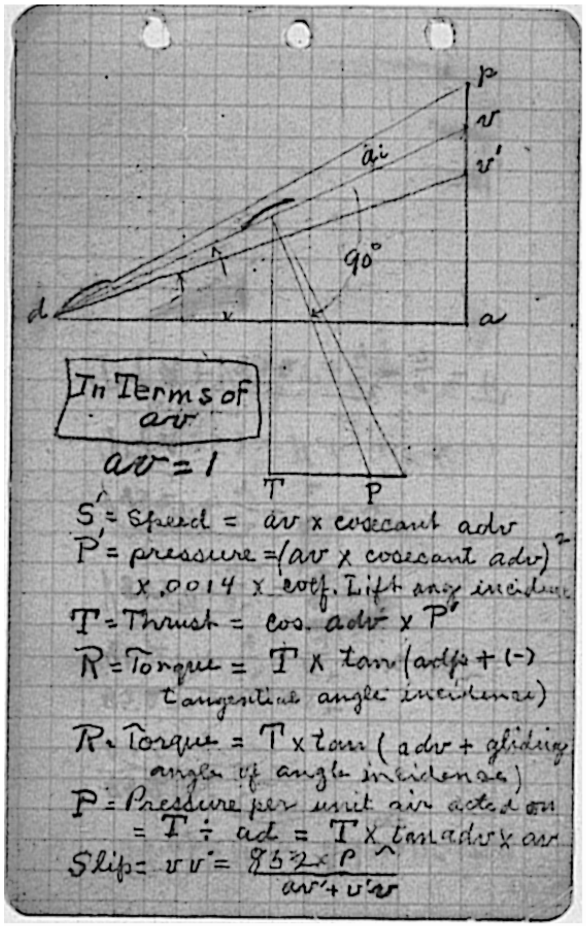


Marine screws, circa 1870

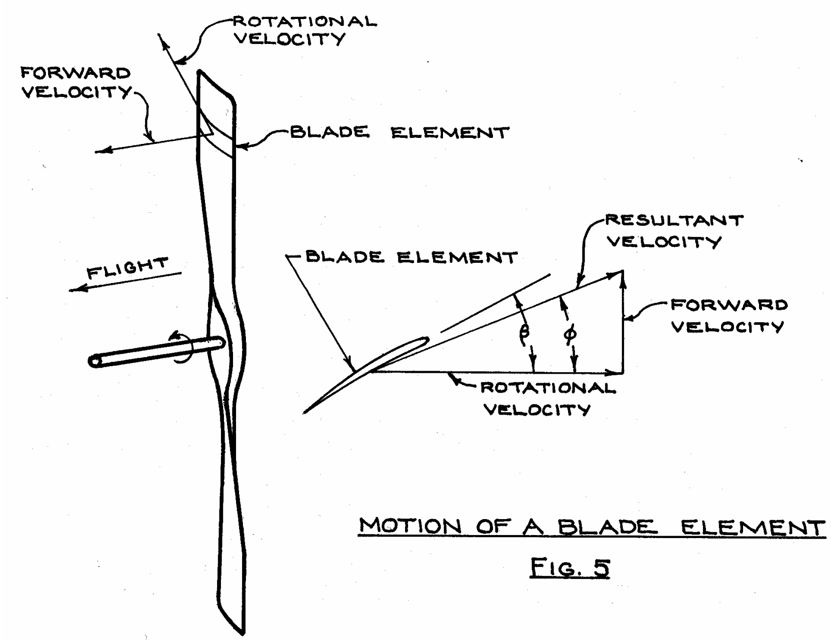
- **No theory for airscrew design existed!**
- ***"Much to our surprise, all the formulae on propellers contained in these books were of an empirical nature. There was no way of adapting them to calculations of aerial propellers."***

- Orville Wright

Propeller design



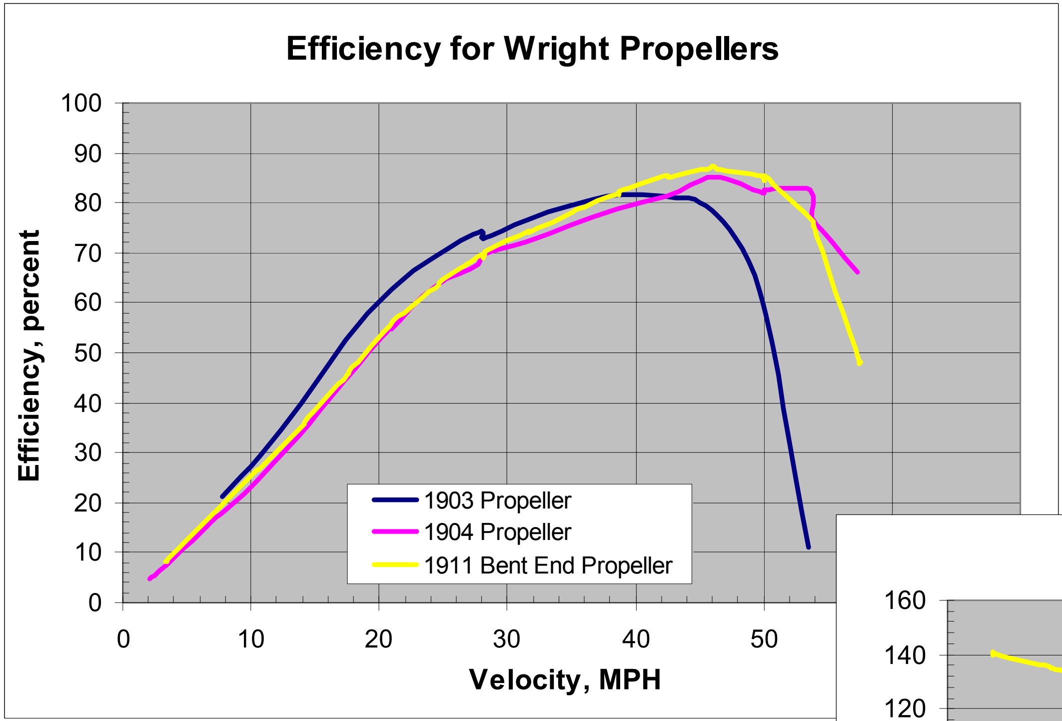
- **The Wrights applied blade element / momentum theory for the first time**
  - Newton's 2nd Law force is balanced by the lift of the rotating wing
  - They were off by a factor of 2

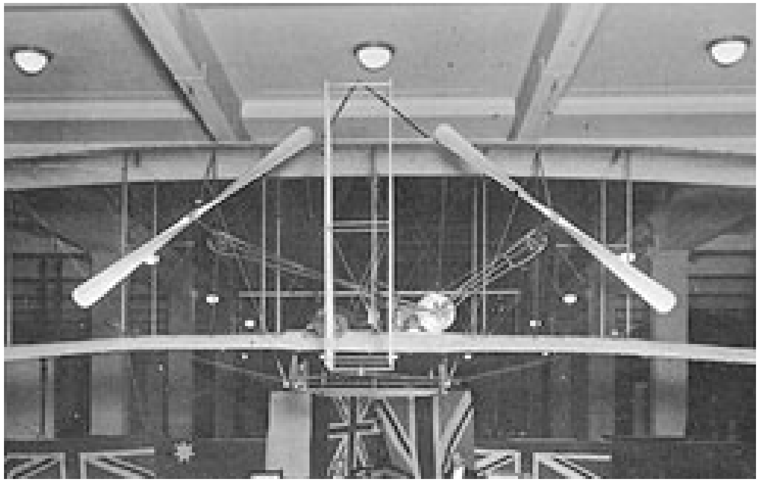


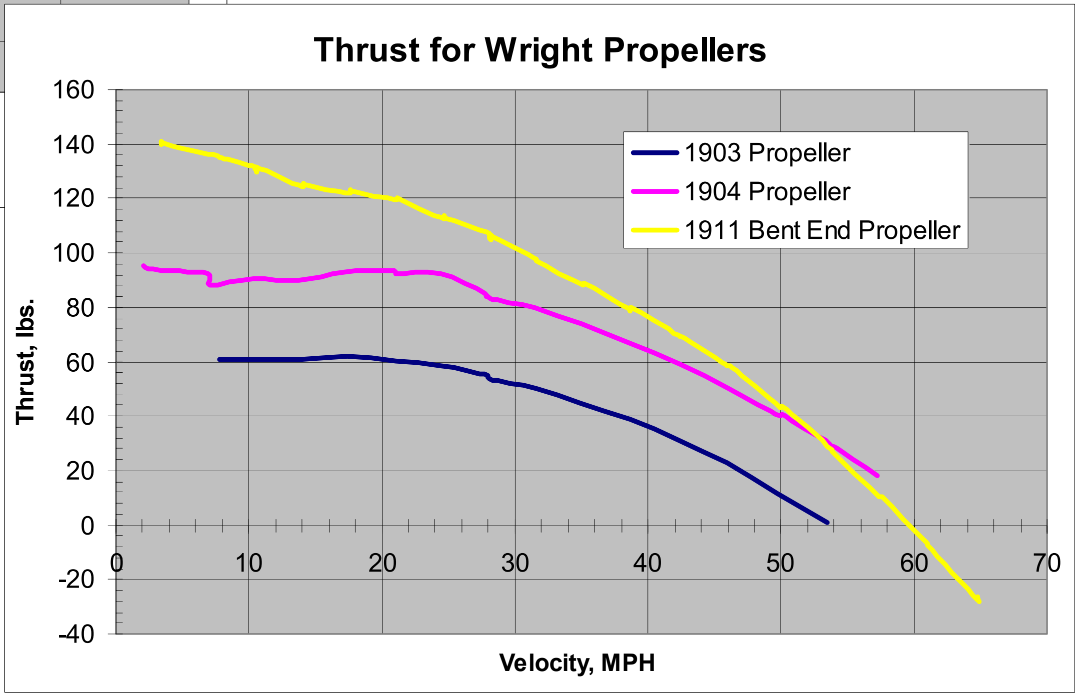
MOTION OF A BLADE ELEMENT

FIG. 5

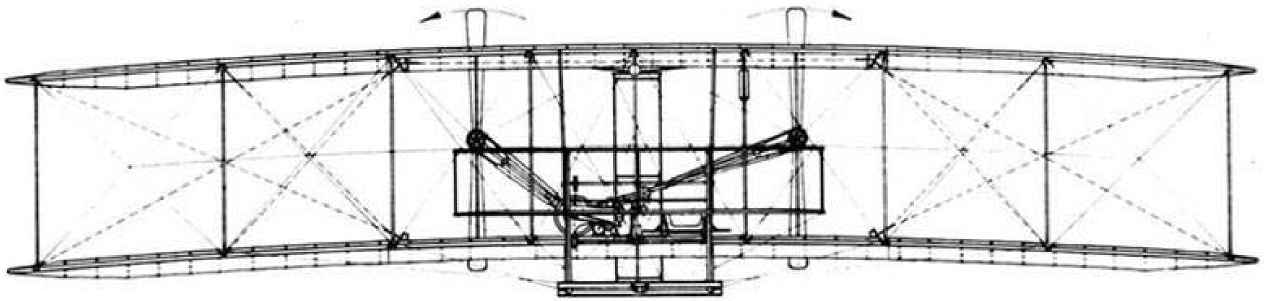
Propeller performance

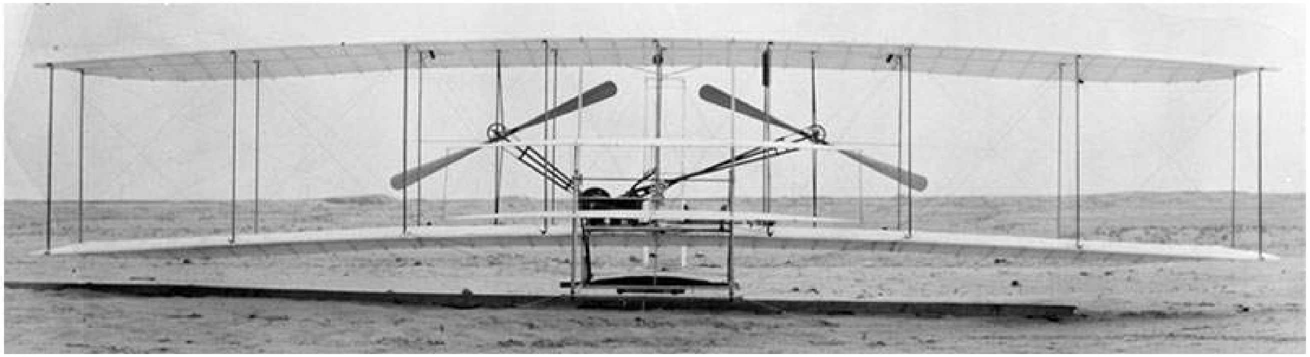


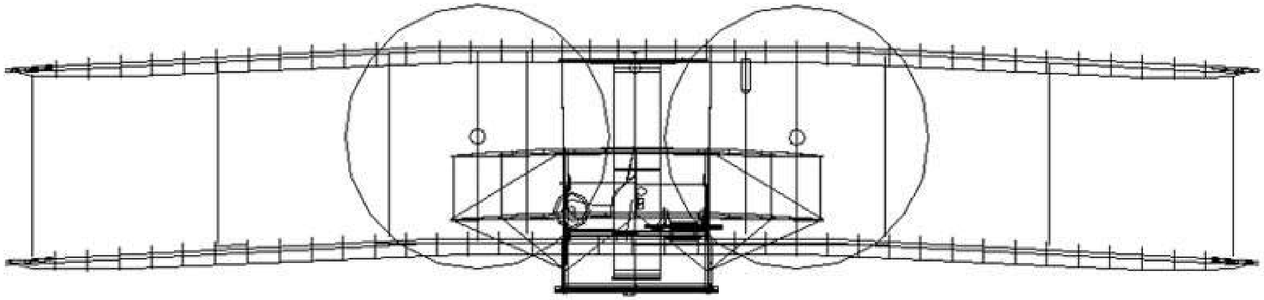




The Wright Experience Reproduction







Wing structure

Fabric

Engine

Propellers

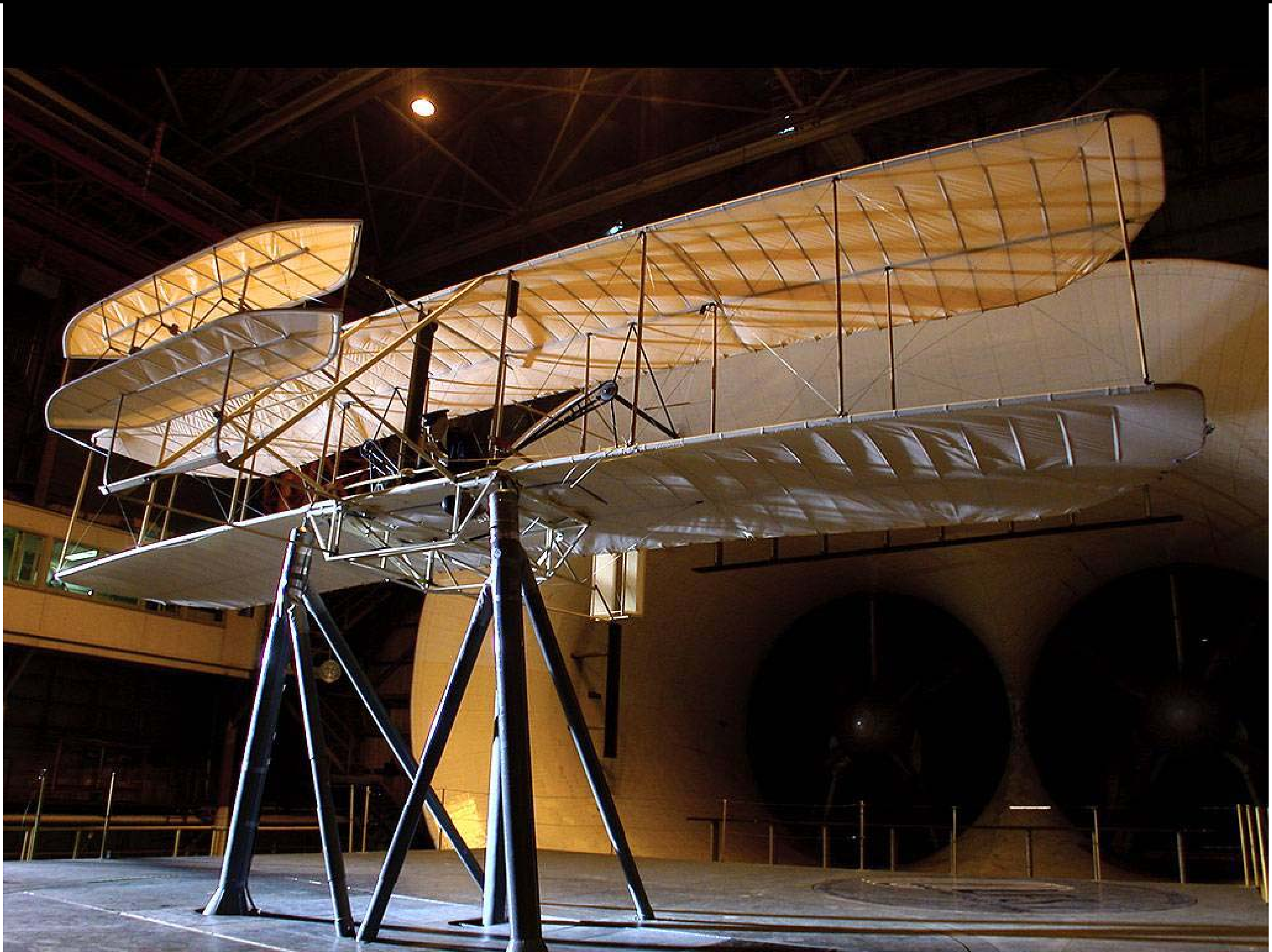
Completed 2003 Flyer

The 1903 - 2003 Flyer

- 40.3 ft. wingspan
- 510 sq. ft. wing area
- 750 lbs. gross wt.
- 15 – 20 HP 4-cylinder motor
- 8.5 ft. diameter propellers

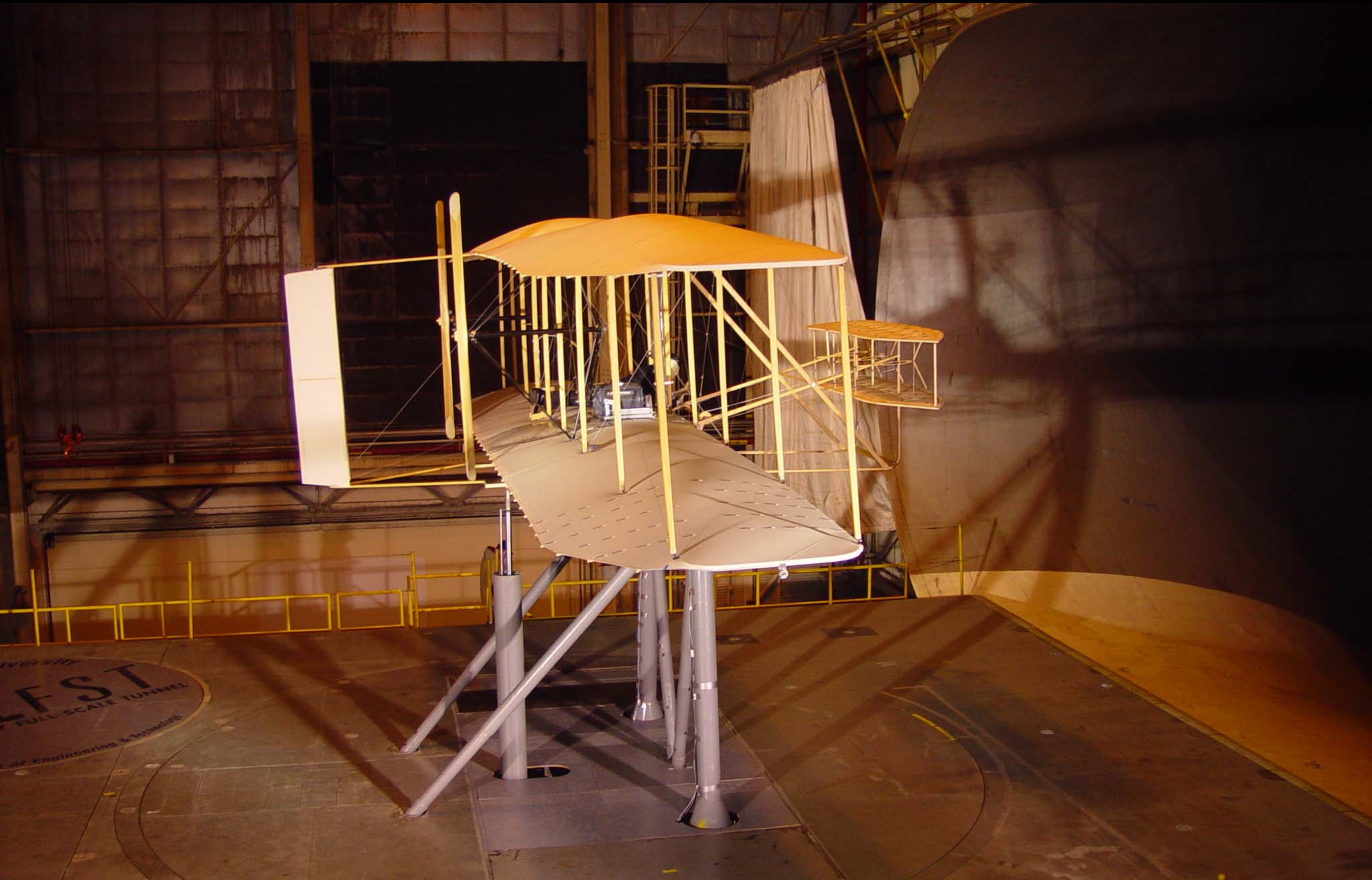
- ***Low pitch inertia, low pitch damping and instability make handling difficult***

Wind Tunnel Test – February, 2003

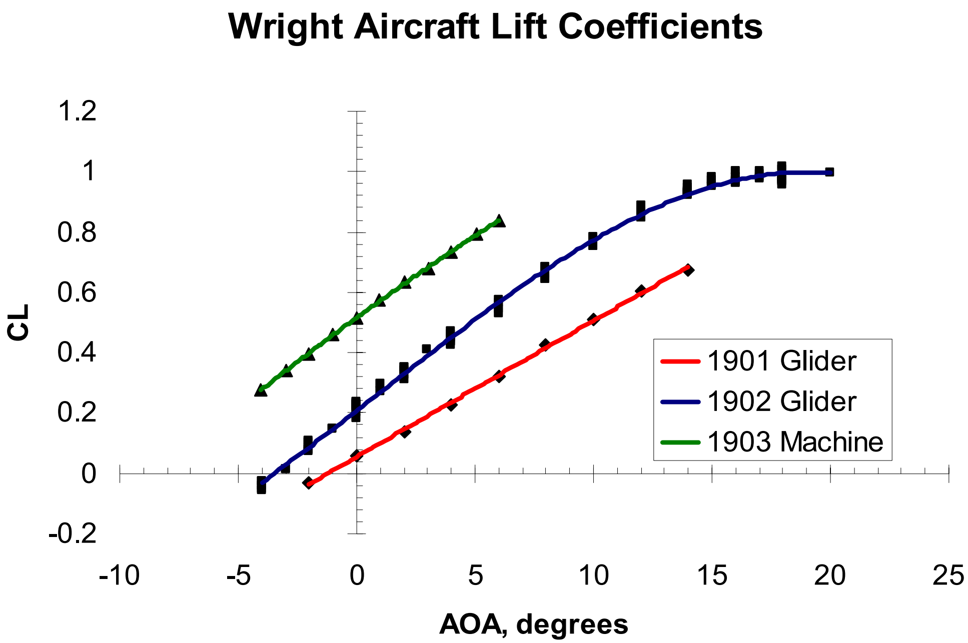


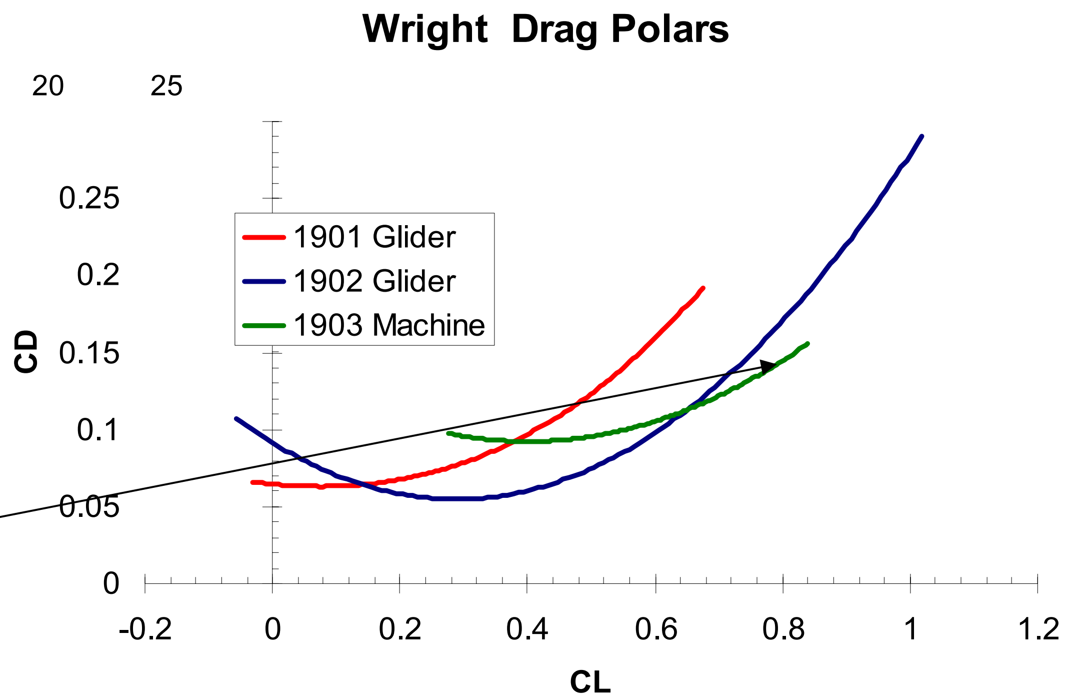
Wing billow

CENTENNIAL OF FLIGHT
1903-2003



Lift and Drag Comparisons

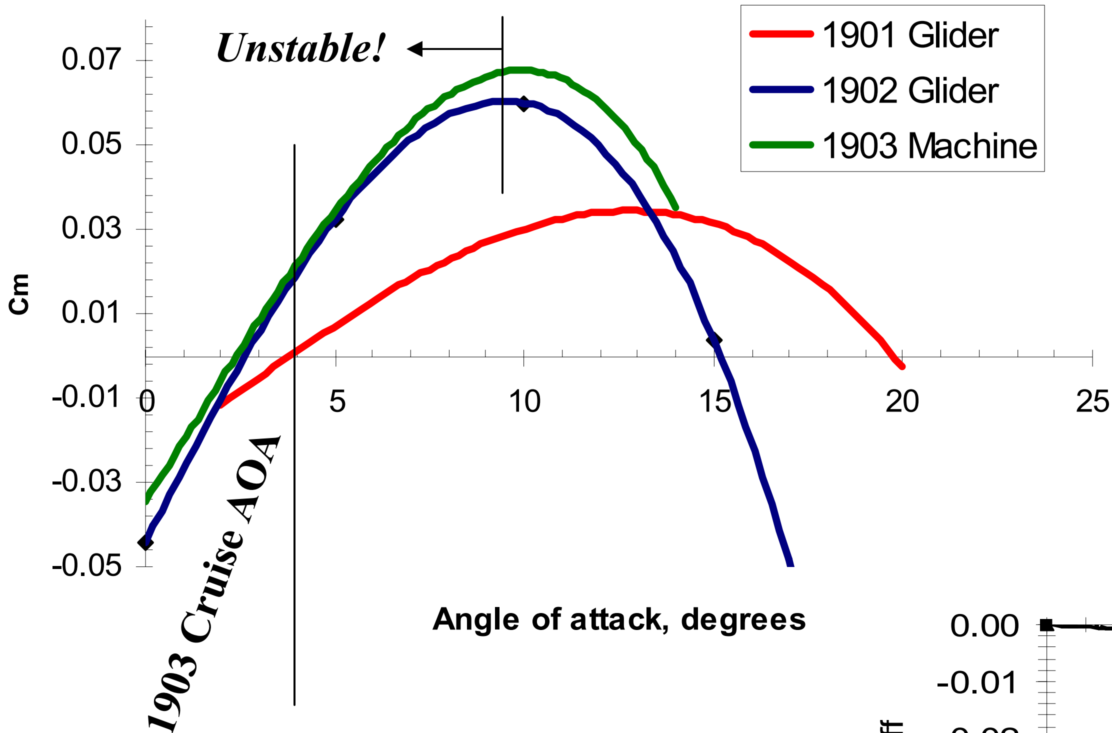




Ground effect + anhedral substantially increases lift!

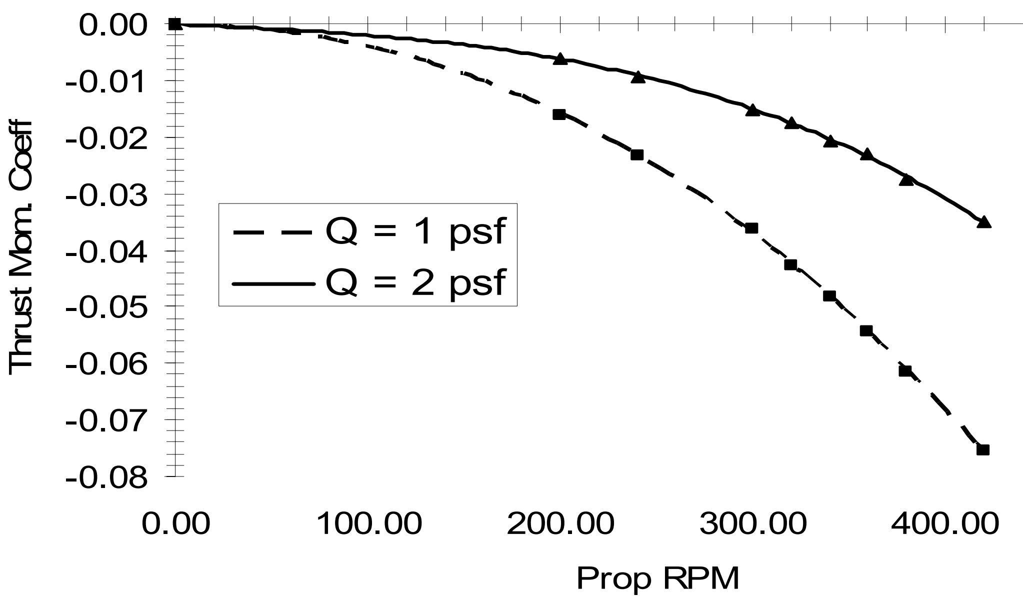
Less drag at high C_L

Pitching moment trends

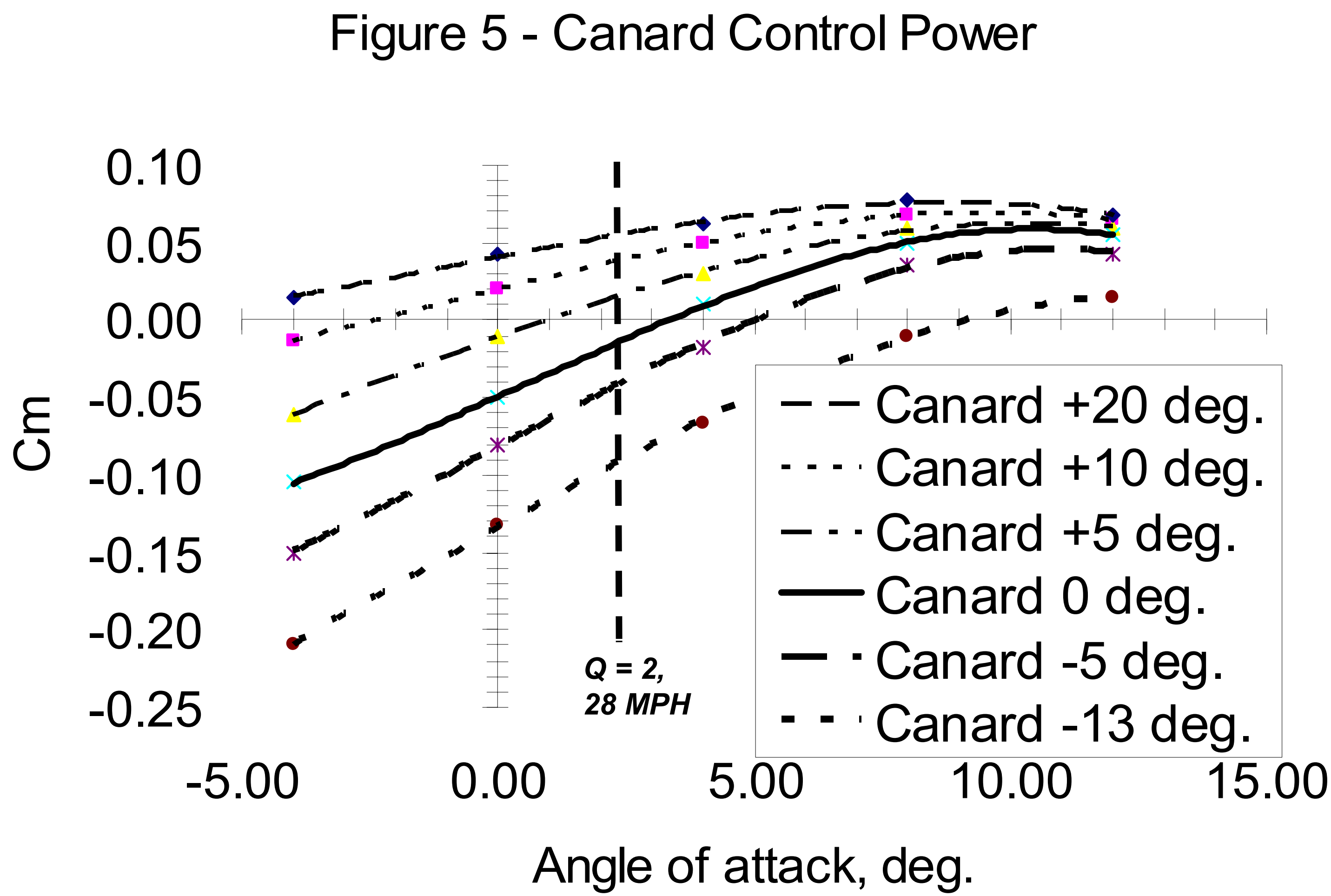


Rotation off of rail is complicated by the pitch characteristics

Figure 6 - Thrust Pitching Moment

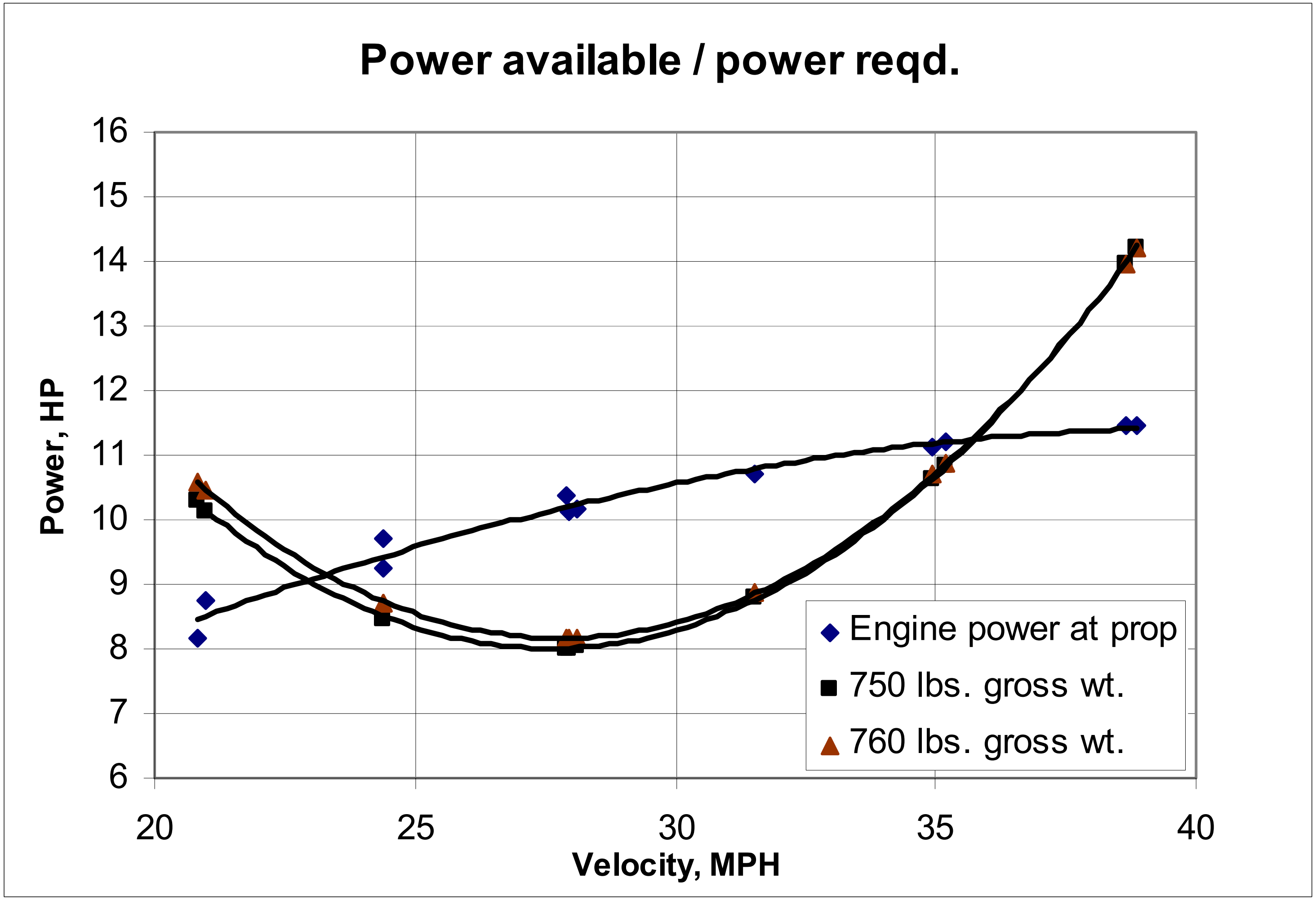


1903 Machine Pitching Moment



-17% static margin at cruise AOA!!!

16 HP motor - power available



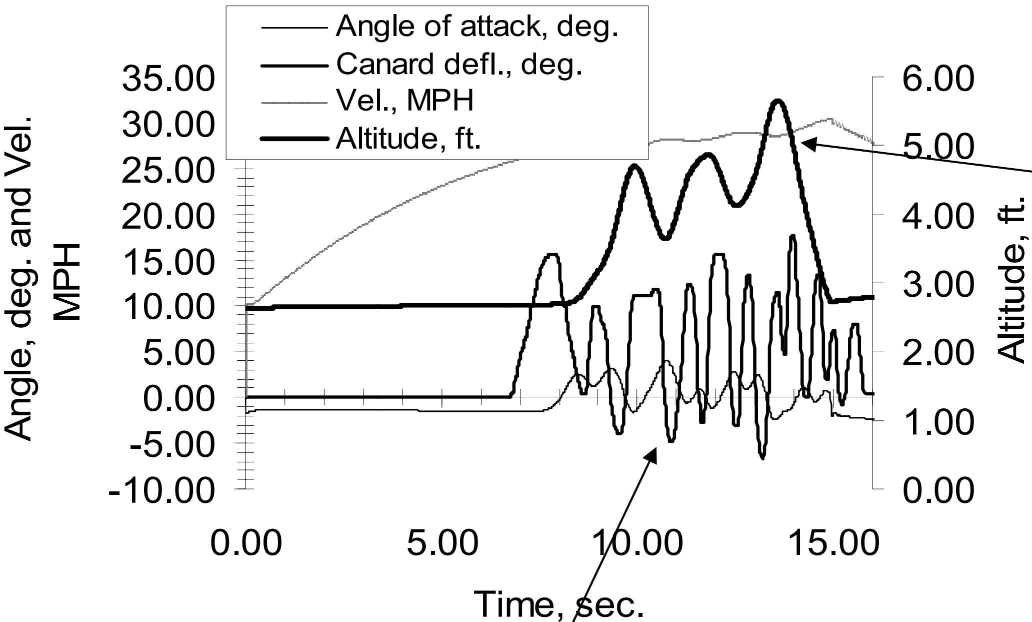
What is it like to fly the Flyer?

- **Non-ergonomic design**
  - *Canard lever and hip cradle controls awkward*
- **Back must be arched for forward visibility**
- **No throttle, fuel cut-off operated by right hand shuts down engine**
- **On rail, the pilot concentrates on keeping wings level to avoid wingtip strike**
- **No instrumentation!**

Simulator development – Bihrle Applied Research

Bihrle Simulator matched flight data well

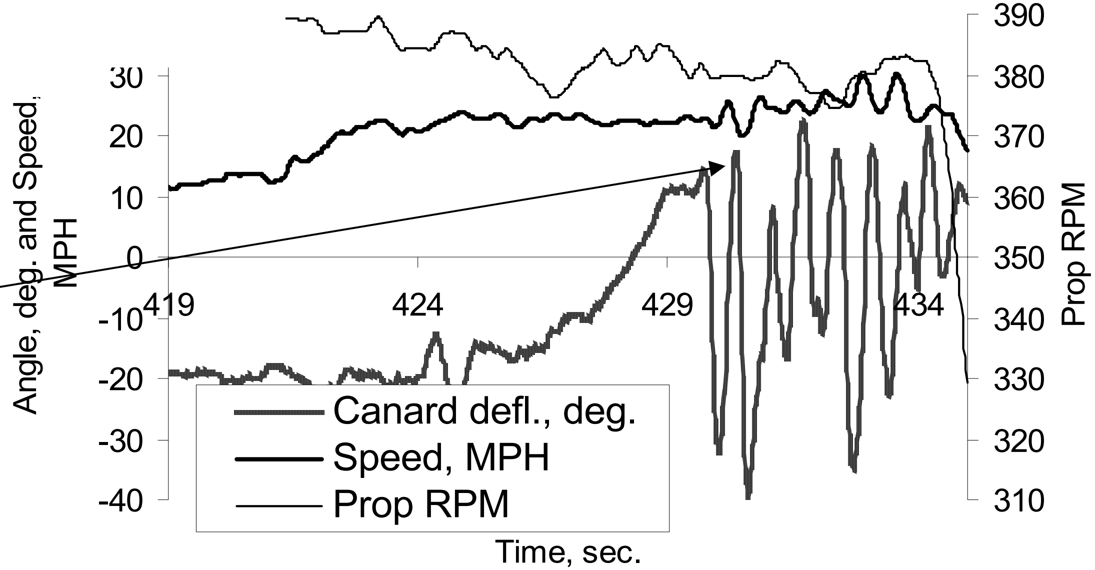
Figure 12 - Simulated Longitudinal Flight



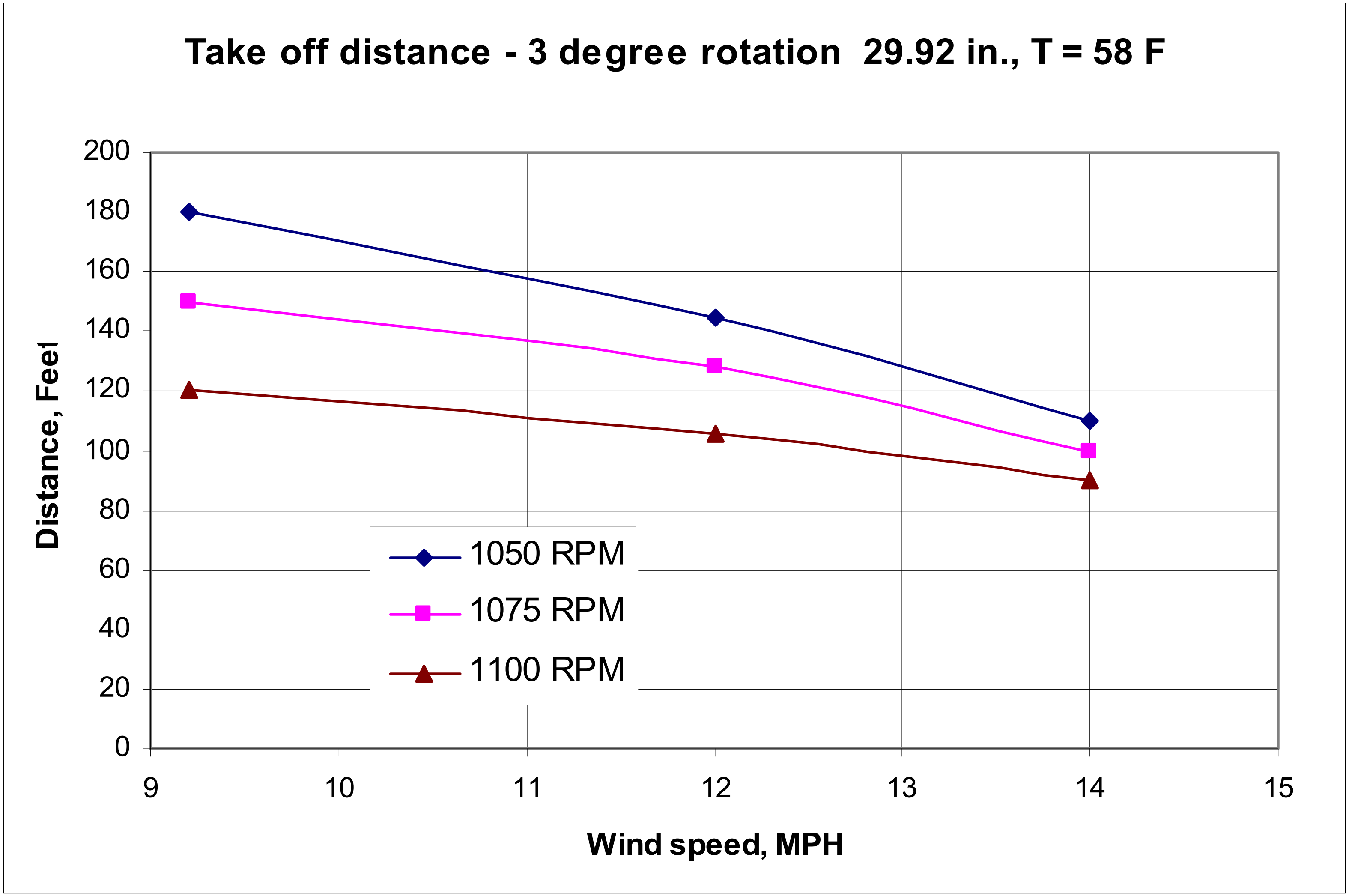
Aircraft shows pilot-in-the-loop phugoid frequency of 0.5Hz

Canard deflection frequency of 2 Hz!

Figure 13 - Flight #1 Data



Typical plot generated before each flight



What is it like to fly the Flyer?

- **Canard deflection for rotation is a function of airspeed and engine power**
  - *This is an unstable aircraft!*
- **At rotation, the workload becomes very high**
  - *Sound of engine disappears*
- **Pilot sees high frequency pitch oscillations AND low frequency altitude excursions**
  - *Canard input attempts to even out the flight path*

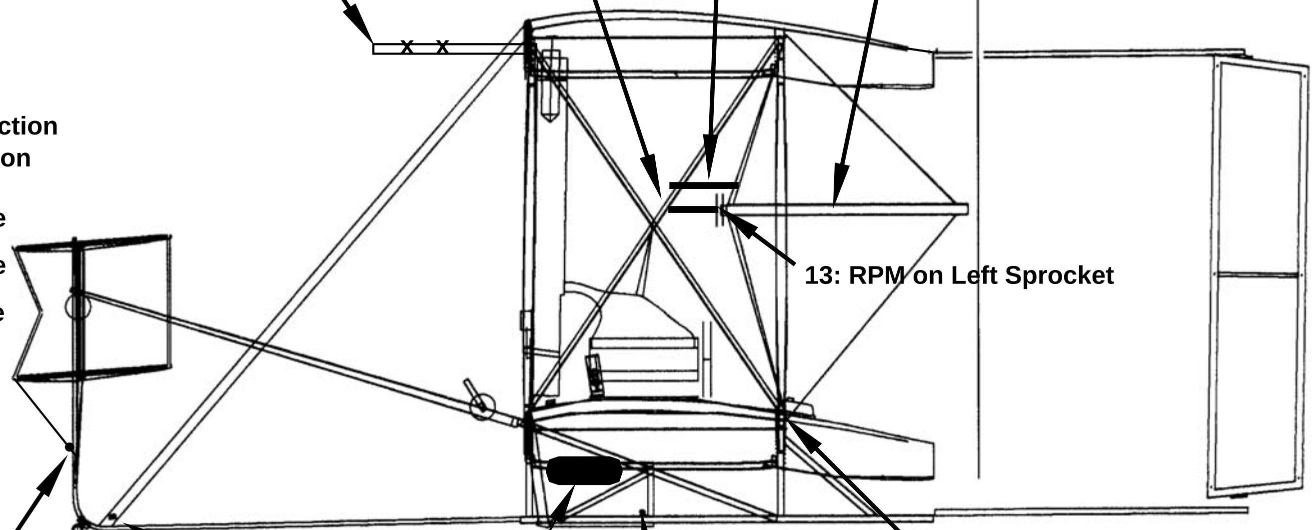
Vigyan Flight Data Recorder

Data Acquistion System Layout

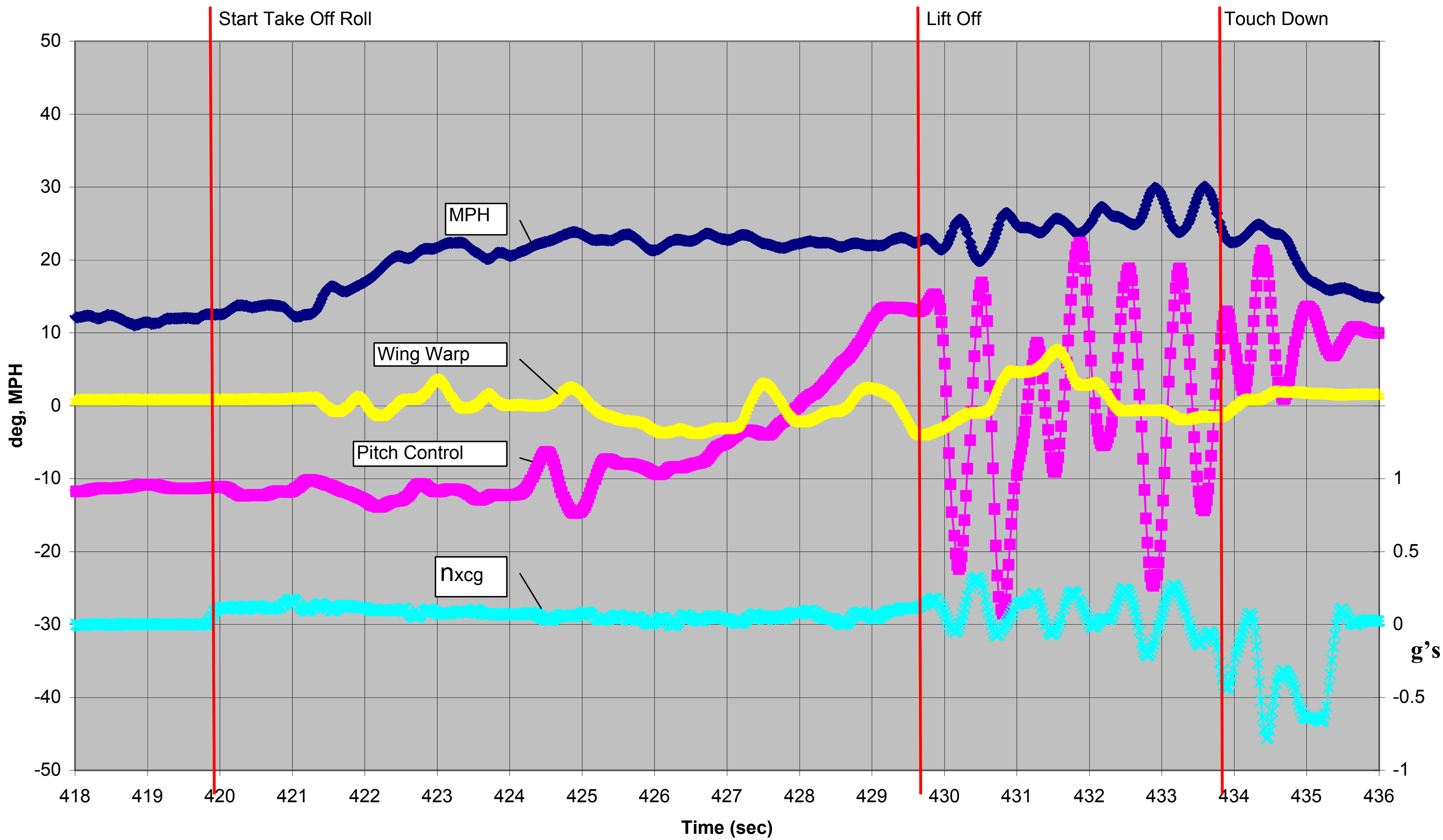
1. Pitot Pressure
2. Static Pressure
3. α
4. β
5. Pitch Control Deflection
6. Wing Warp Deflection

7. $n_{x_{CG}}$ 10. $n_{x_{nose}}$
8. $n_{y_{CG}}$ 11. $n_{y_{nose}}$
9. $n_{z_{CG}}$ 12. $n_{z_{nose}}$

13. RPM
14. Torque



FLIGHT # 1, 1903 Wright Flyer Replica Thursday 11/20/03 at 1:12 PM.

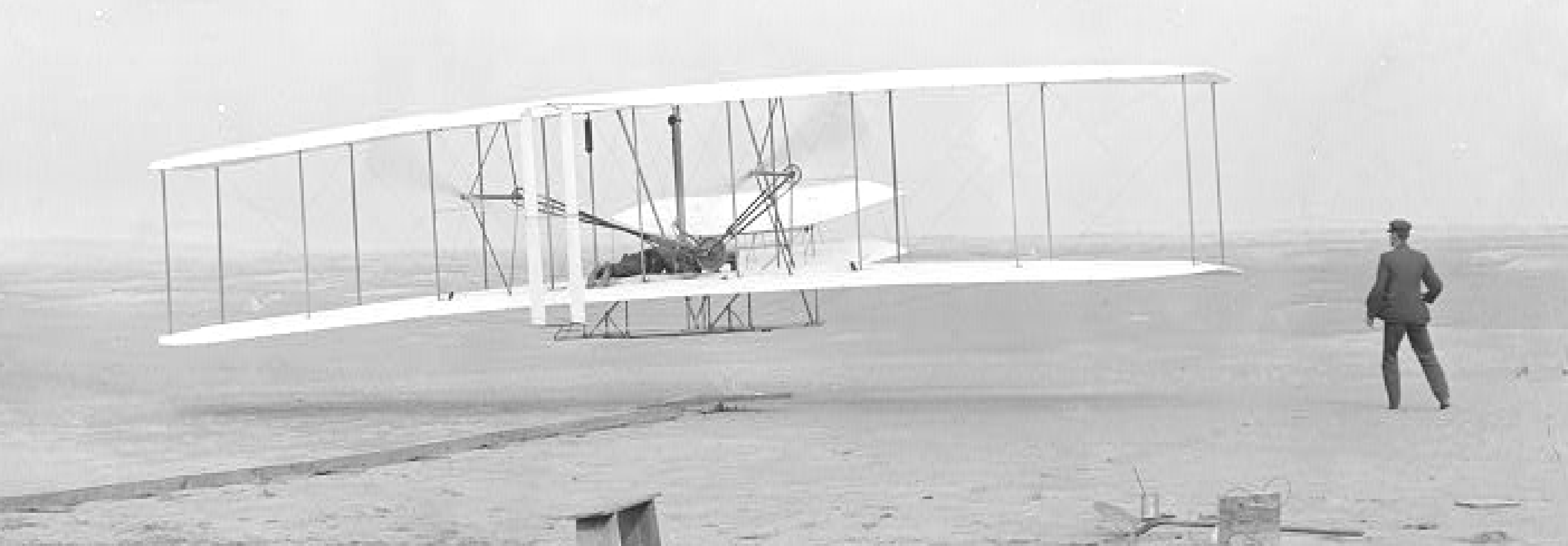


What is it like to fly the Flyer?

- **Laterally, the aircraft responds well to warp input**
- **Crosswind conditions should be ignored…keep wings level!**
  - The airplane does fine in a sideslip

Conclusions

- **The Wrights were remarkable engineers, *AND* masters at operating their machines**
- **The airplane is a functional, three-axis controlled, powered flying machine that proves powered flight is possible**
- ***The very short flight on December 17, 2003 only reinforced the brilliance shown by the Wrights in delivering a functional aircraft to the world***



THE END.