CS as Science

CSCI 8901:
Research & Evaluation Methods

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GWU

These slides are based on the Research Methods course by David Jensen, UMass

Edwin Smith Papyrus

Egyptian medical textbook from ~1,600 BCE

Proposes a system for learning how to treat disease

1. Examination
2. Diagnosis
3. Treatment
4. Prognosis

This is the basic form of **Empirical Research**

Empirical Method

This course will focus on *empirical* computer science

- Science where you experimentally evaluate a phenomenon

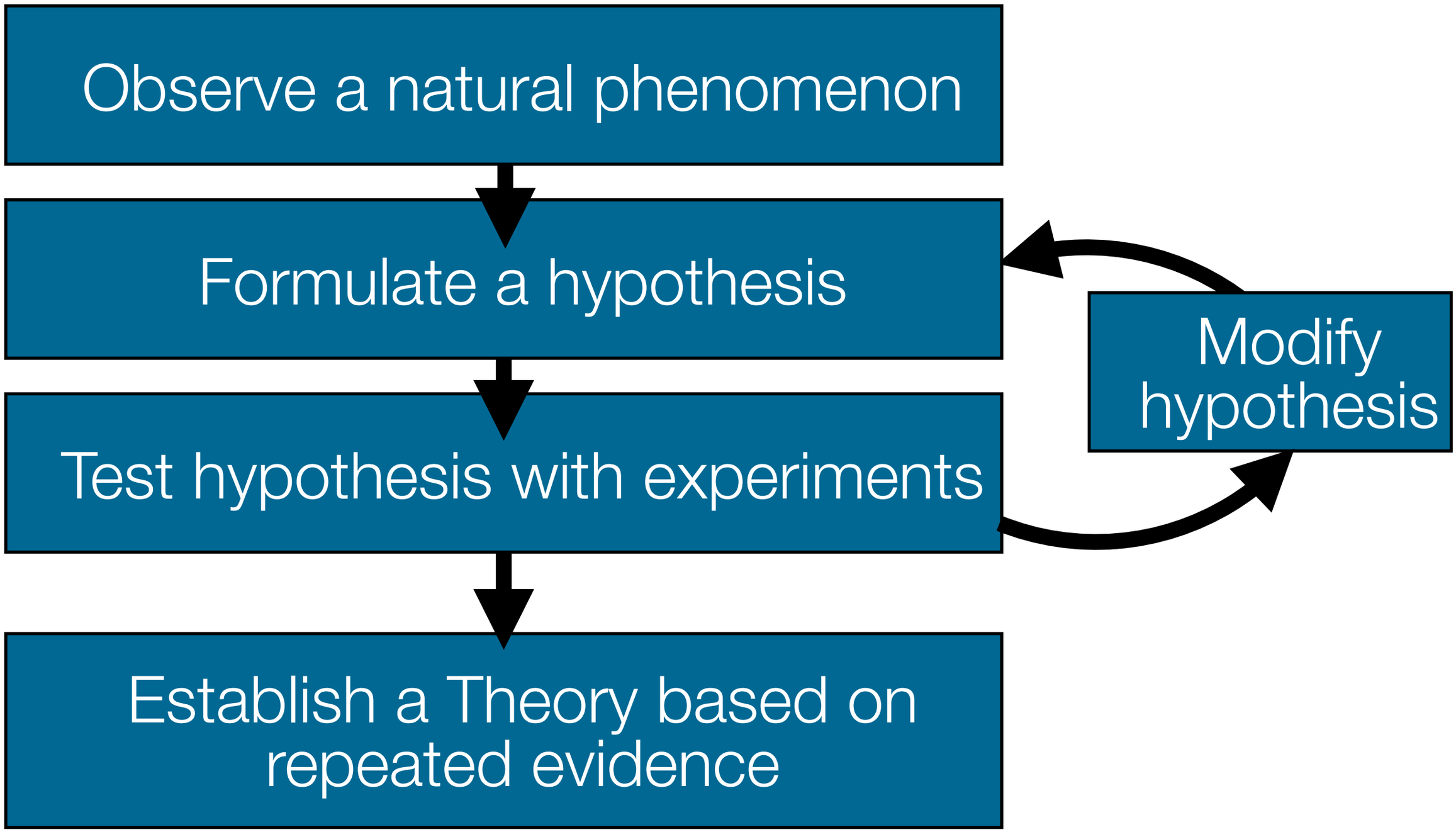
This applies to most fields of CS…

- AI: develop new algorithms and then evaluate their effectiveness
- Systems: build new architectures and evaluate performance
- HCI: design new interfaces and measure user satisfaction

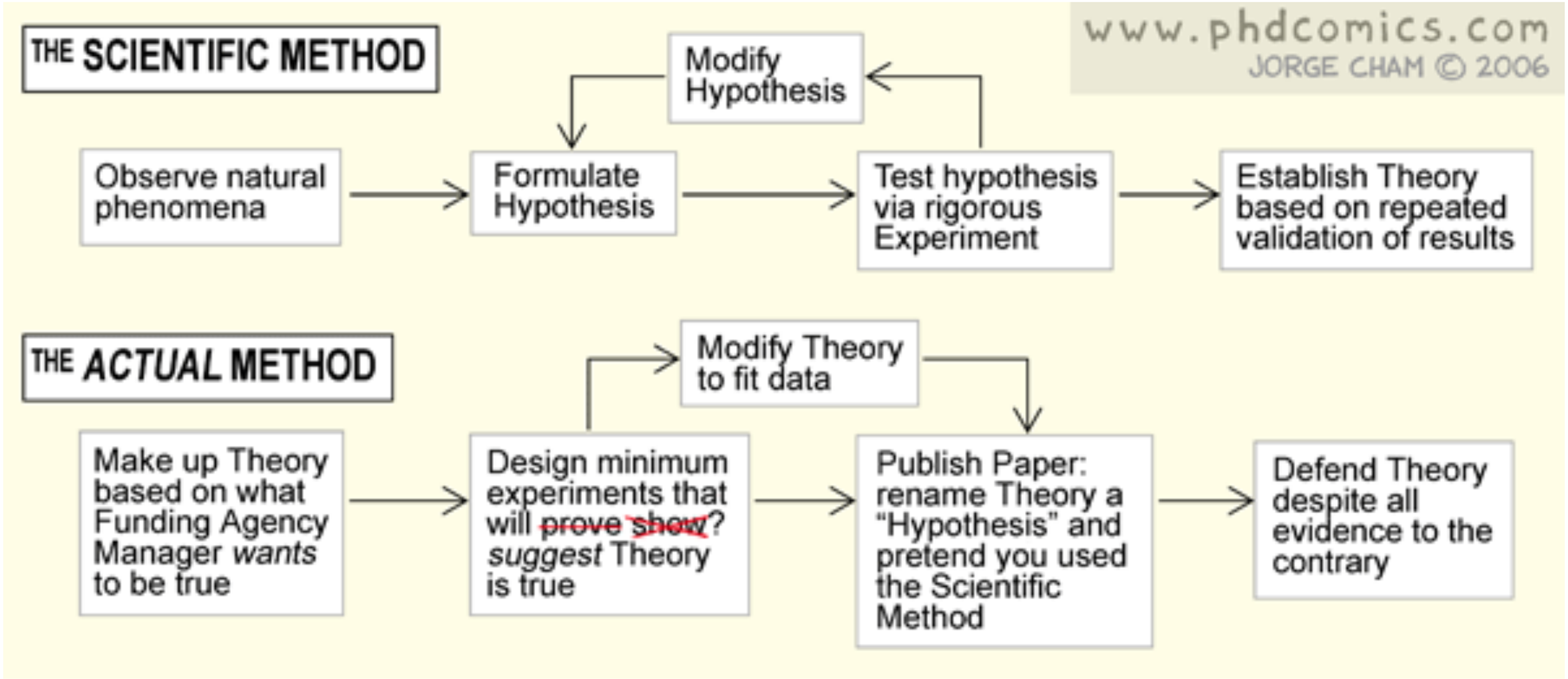
…but not so much to purely math-based fields:

- Theory of computation: prove things to be true or false
- If this is your area portions of the class may be less relevant

Scientific Method



Scientific Method



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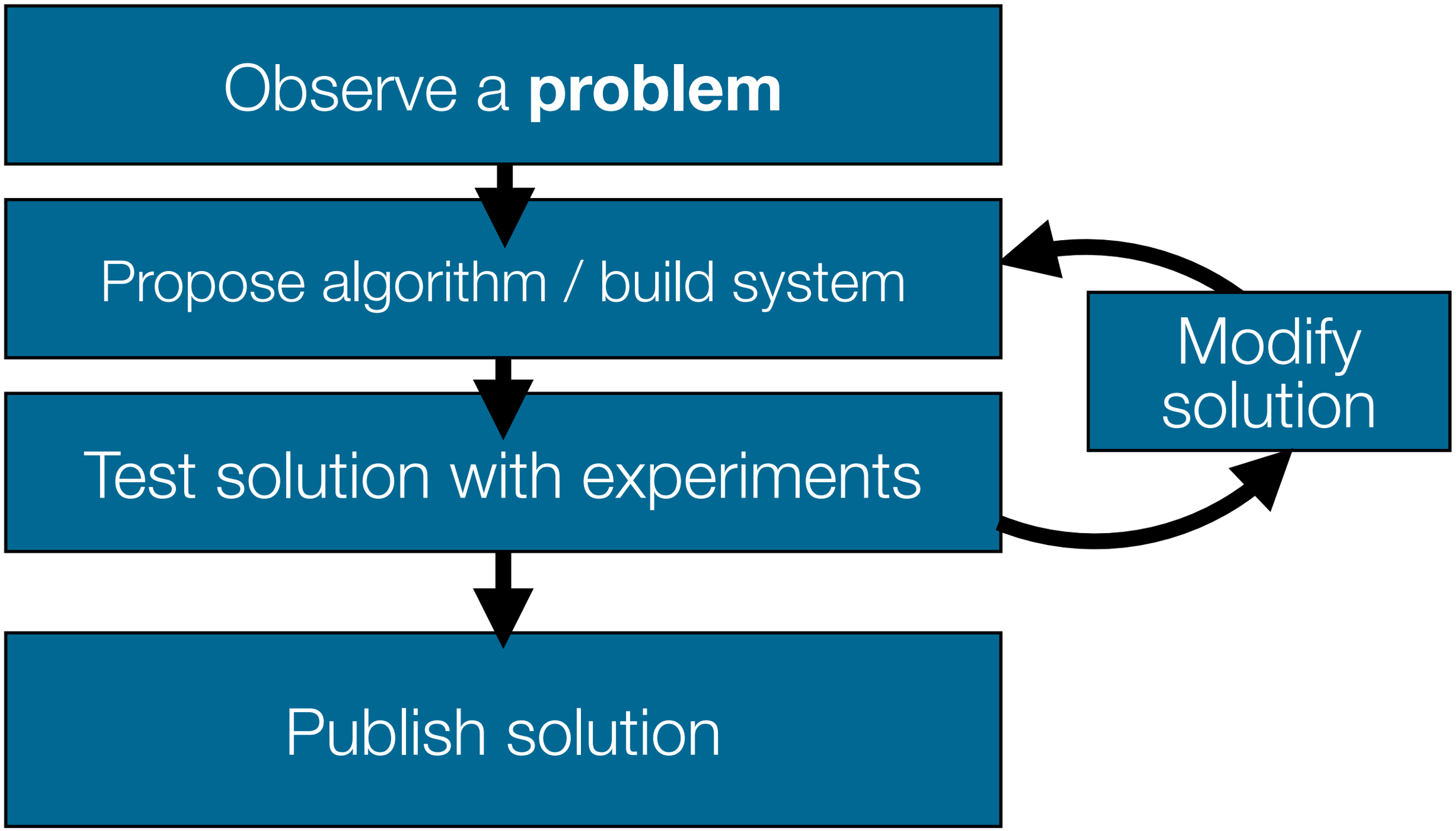
CS Scientific Method



Computer Science

"Science is not science fiction.
***It accepts the tests of observation and experiment**, acknowledges the supremacy of fact over wish or hope.*
***The smallest experiment can crash to earth the most attractive theory**."*

— Herbert A. Simon

Why think of CS as Science?

Offers a systematic approach to explore phenomenon and discover new things

Science provides a rigorous structure to ensure that new advances are significant and correct

- Provides a methodology to structure research activities
- Ensures the integrity of results

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176 C KA CS 33 Paid. Via Norfolk Va

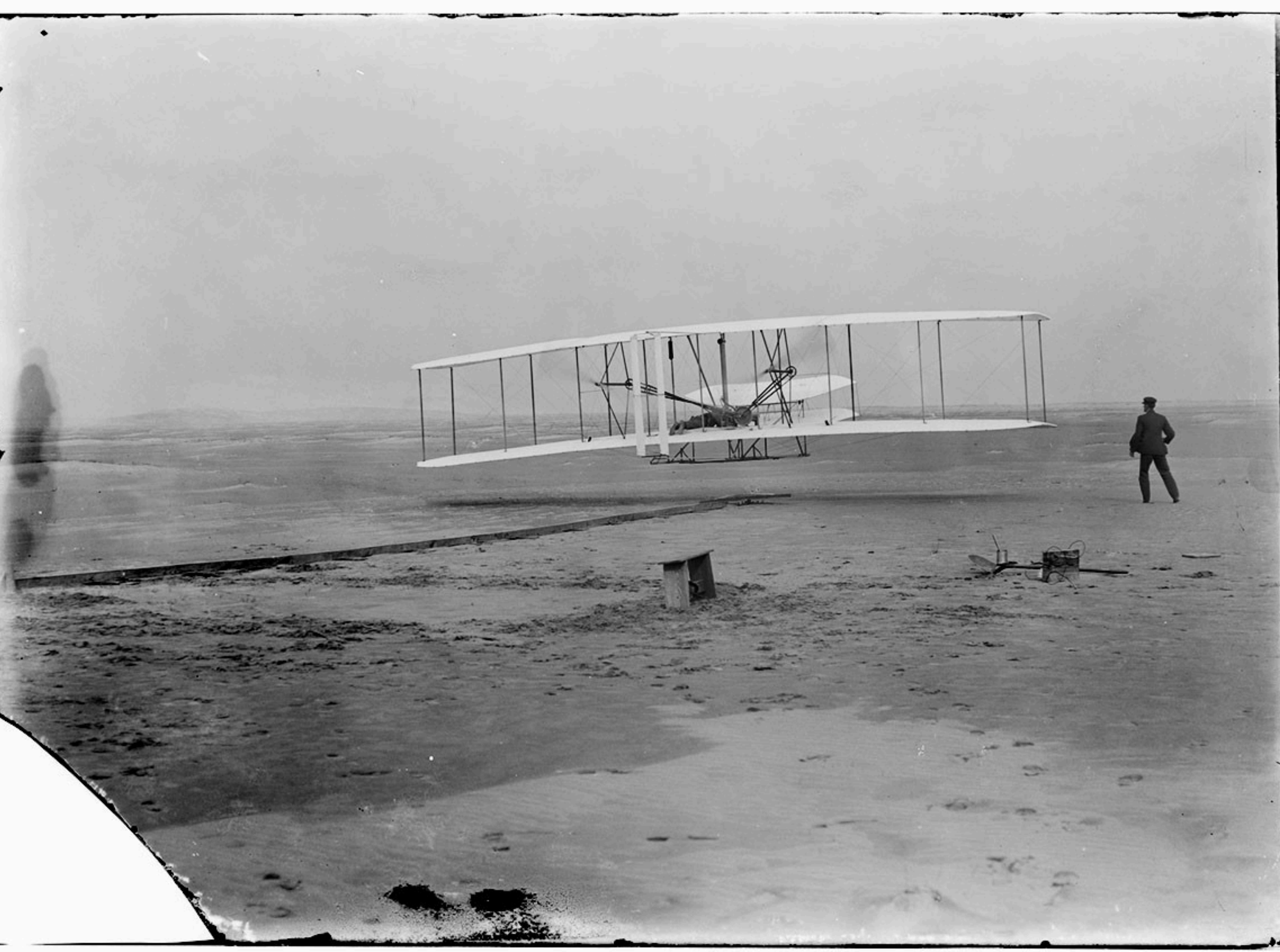
Kitty Hawk N C Dec 17

Bishop M Wright

7 Hawthorne St

Success four flights thursday morning all against twenty one mile wind started from Level with engine power alone average speed through air thirty one miles longest 57 seconds inform Press home ~~#####~~ Christmas .

Orevelle Wright 525P

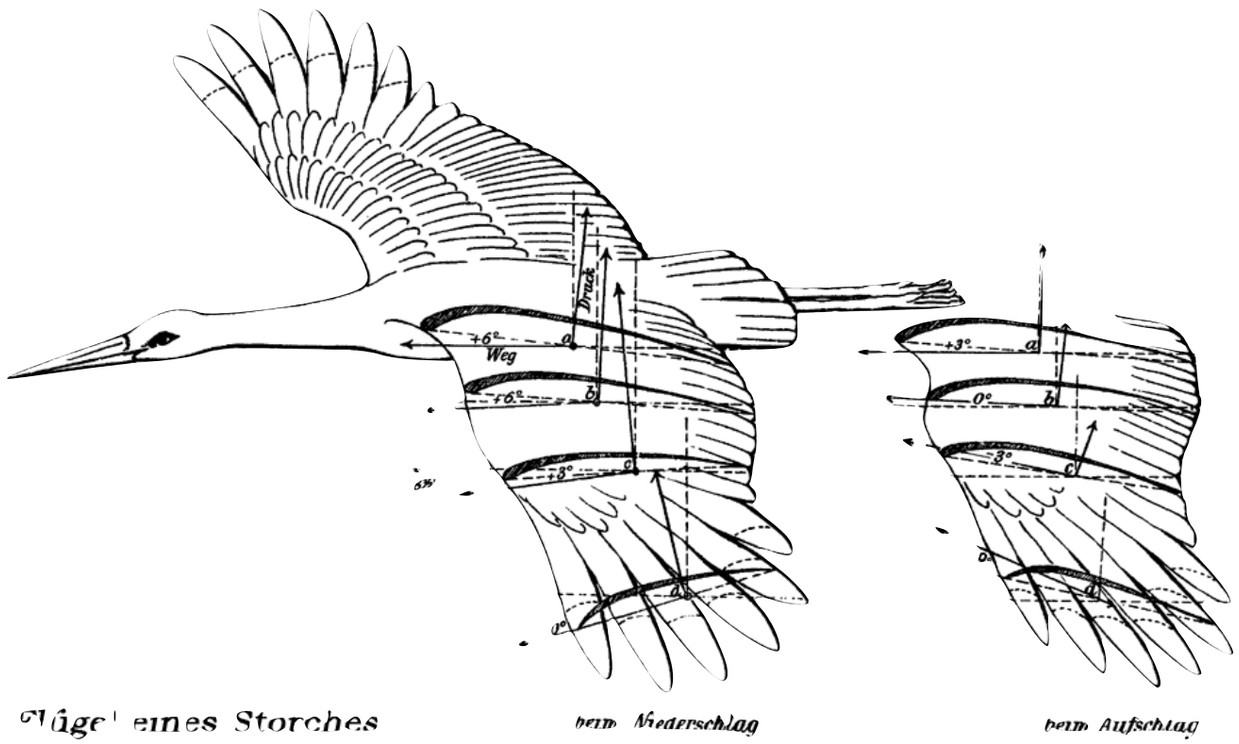


Otto Lilienthal

German engineer

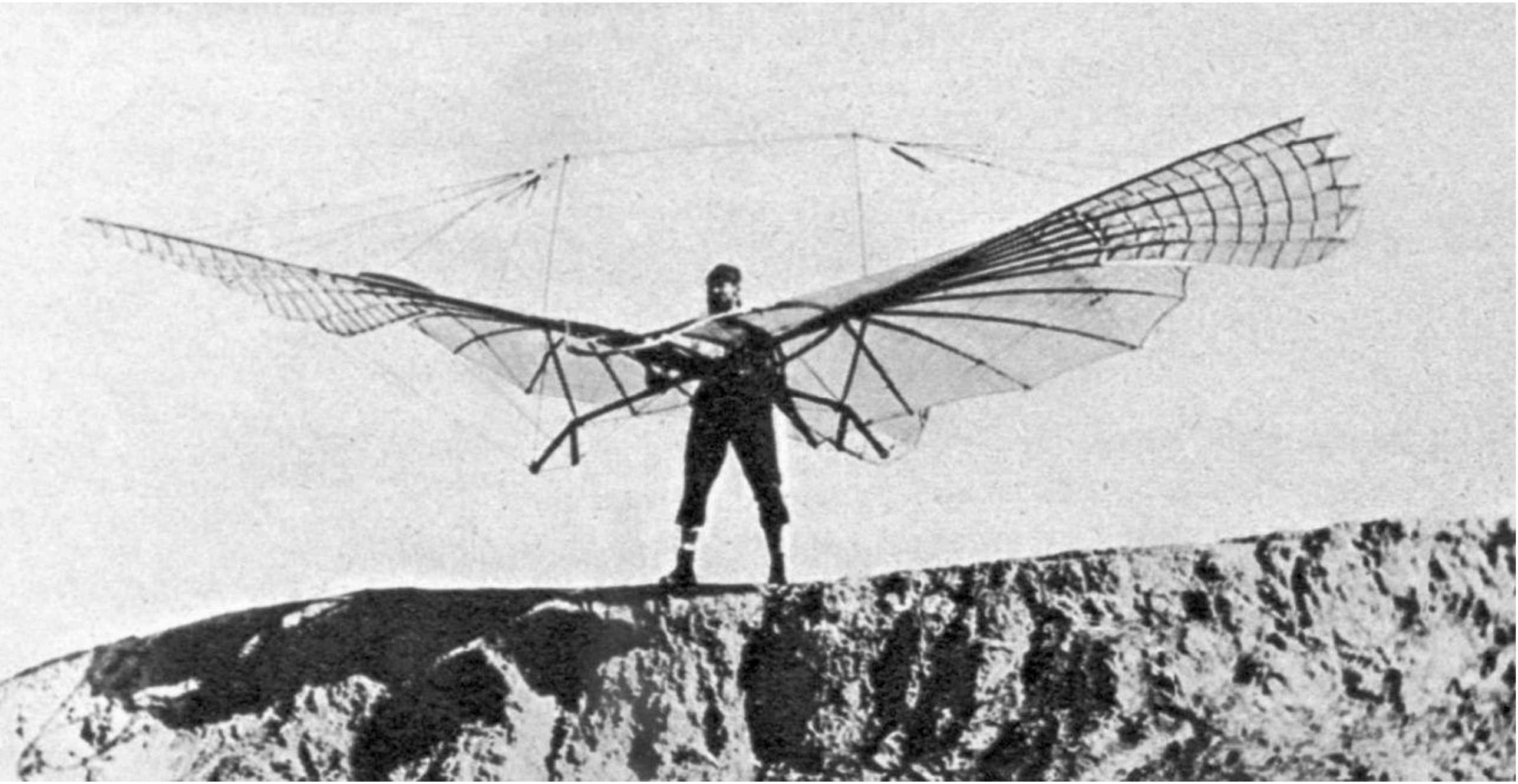
Published *Birdflight as the Basis of Aviation* in 1889

Gathered extensive aeronautical data



Flügel eines Storches beim Niederschlag beim Aufschlag

Bird-inspired Glider



Lilienthal's Legacy

Successes

- Flew 820 feet, which was a record until after his death
- Provided extensive data about aerodynamics

> **"Of all the men who attacked the flying problem in the 19th century, Otto Lilienthal was easily the most important. ...many others were reported to have made feeble attempts to glide, but their failures were so complete that nothing of value resulted."**
> **—Wilbur Wright**

Failures

- Died in 1896 when his glider crashed
- Thought birds would give us the secret to flight

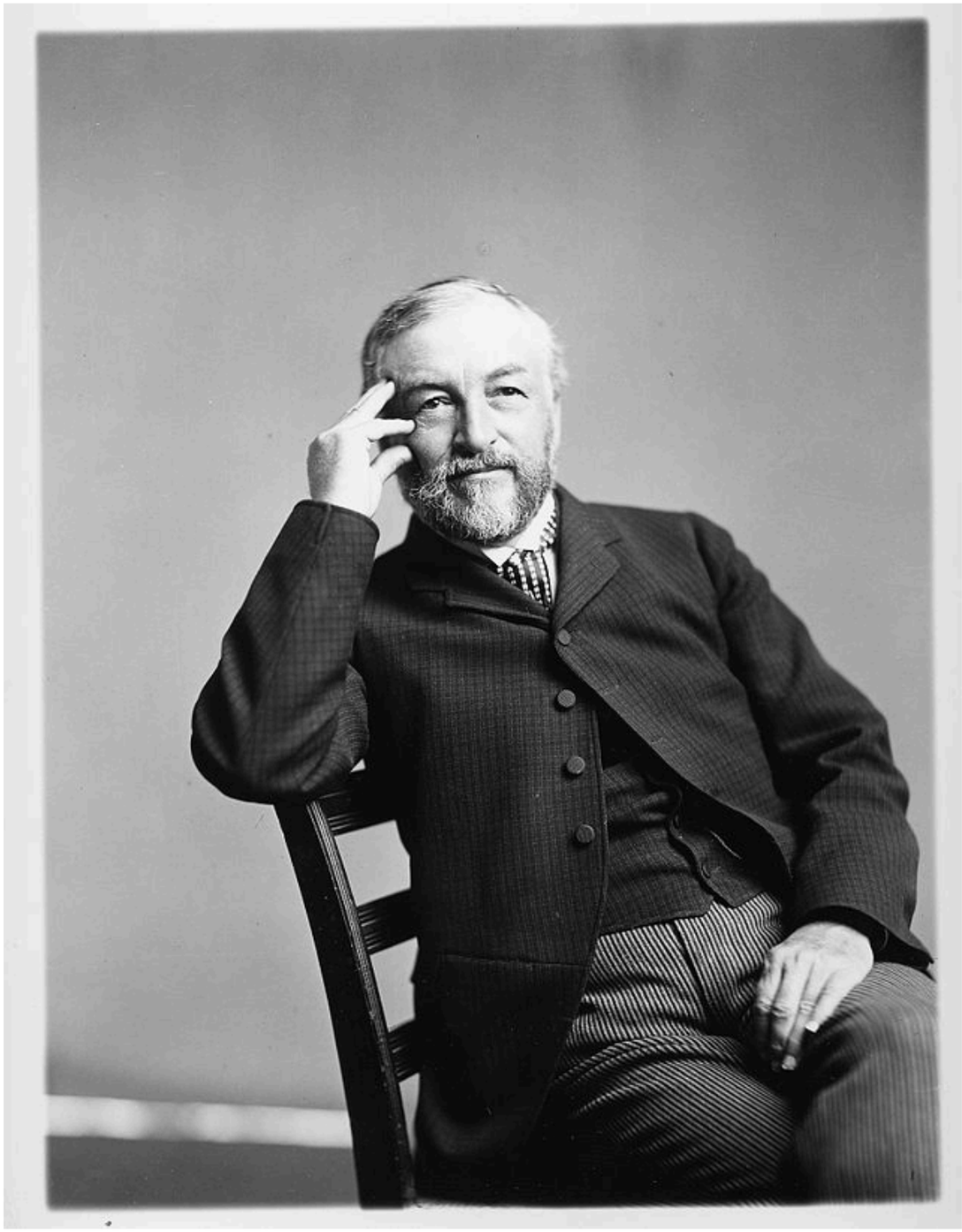
Samuel Langley

Astronomer and physicist

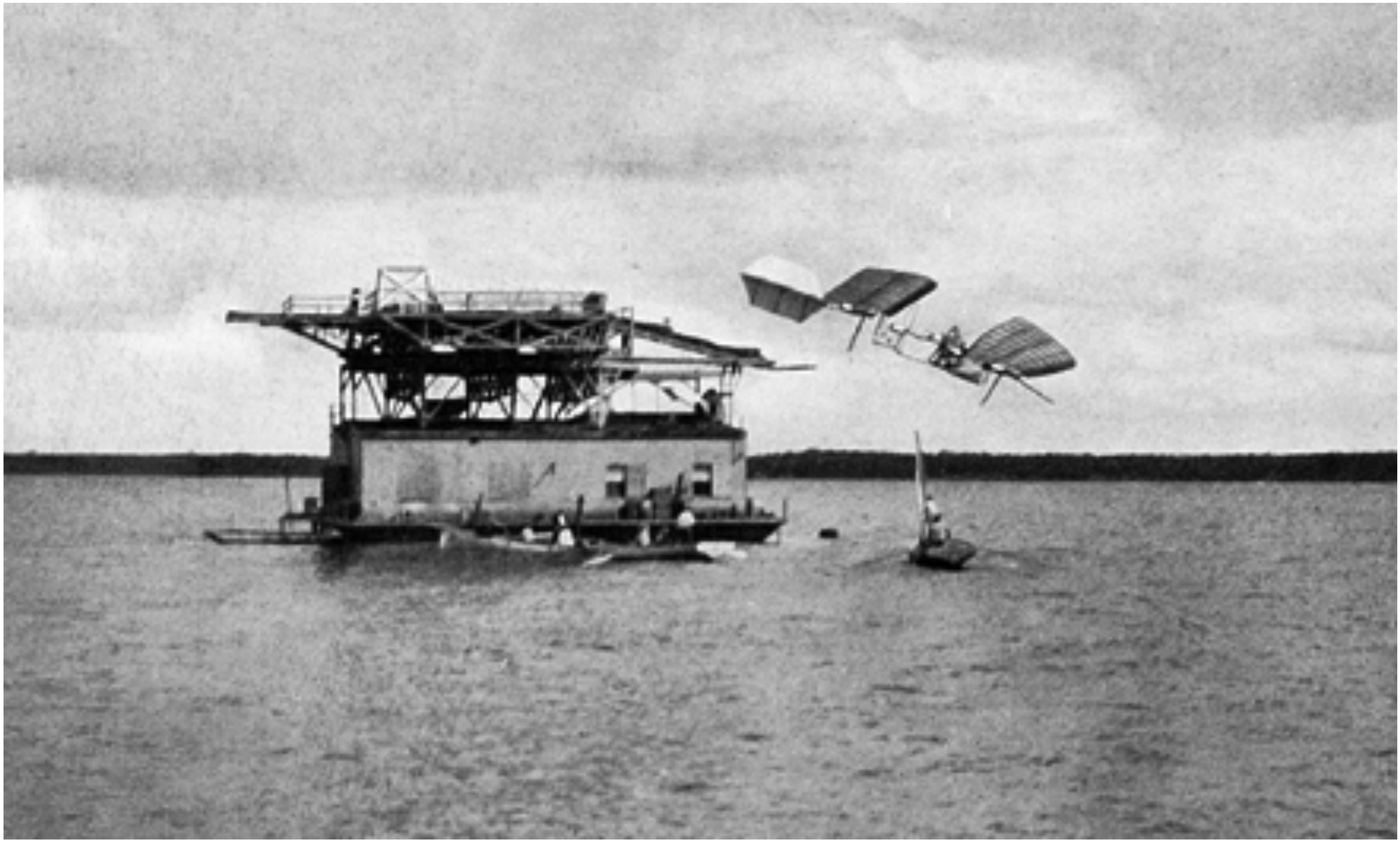
Head of the Smithsonian Institution

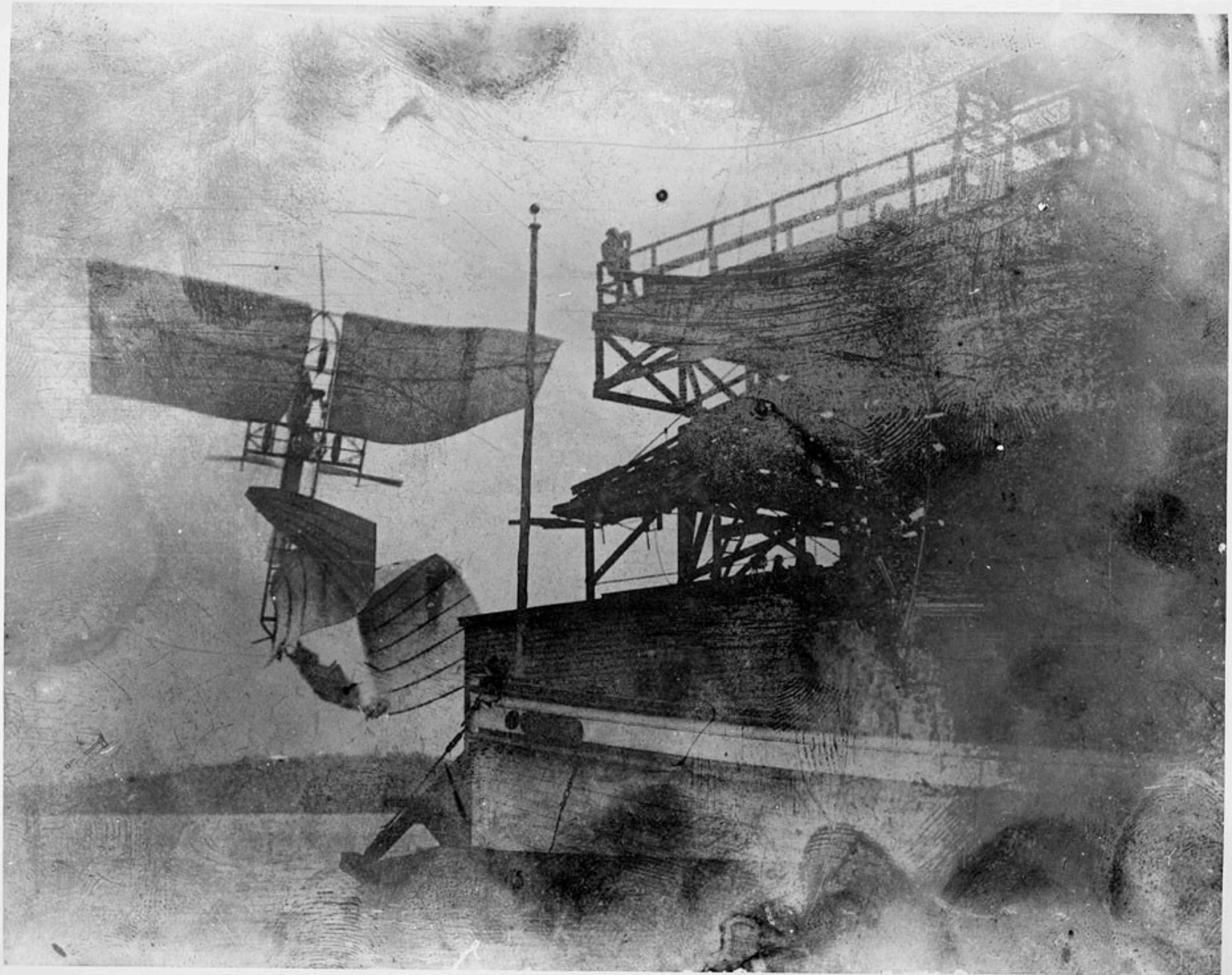
~$100,000 in funding to pursue “heavier than air flight”

- Equal to $78 million in today’s currency



Langley's Aerodrome, 1903





Langley's Legacy

Failures

- Massive media presence at failed launches hurt his reputation
- Too focused on the "craft" of airplanes, motors, etc. Didn't worry about *how* they would be flown

Successes

- His unmanned models set records and established much of the early science for aeronautics
- Aerodrome was displayed in the Smithsonian in 1914 as the first manned vehicle "capable" of flight
  - Suspicious story involving a Wright brother's competitor who was attempting to get lawsuits thrown out

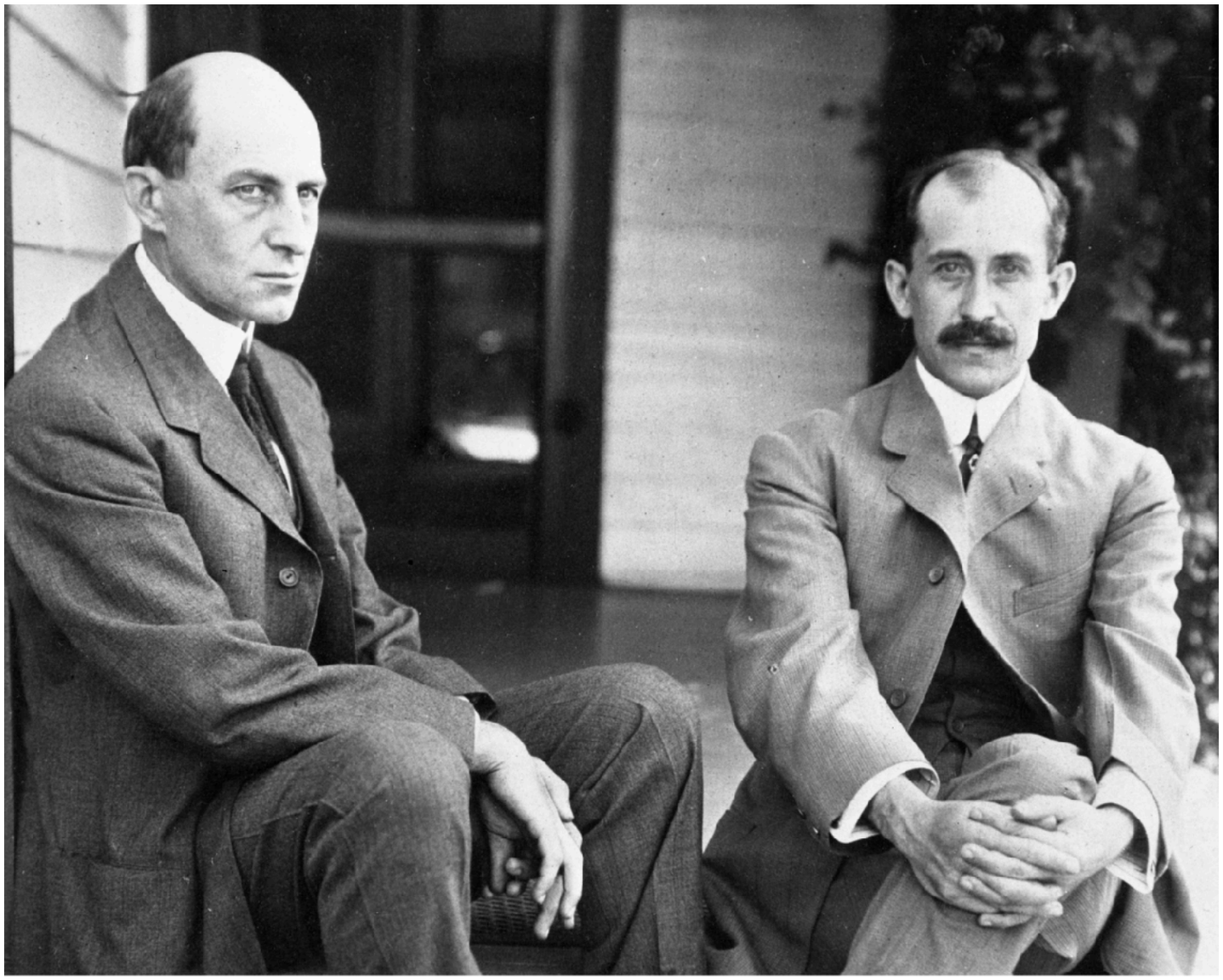
Wright Brothers

Didn’t graduate high school

Owners of Wright Cycle Company

Self financed

No experience prior to 1899



Why did the Wright Bro's get it right?

The perfect combination of…

Meticulous experimental research

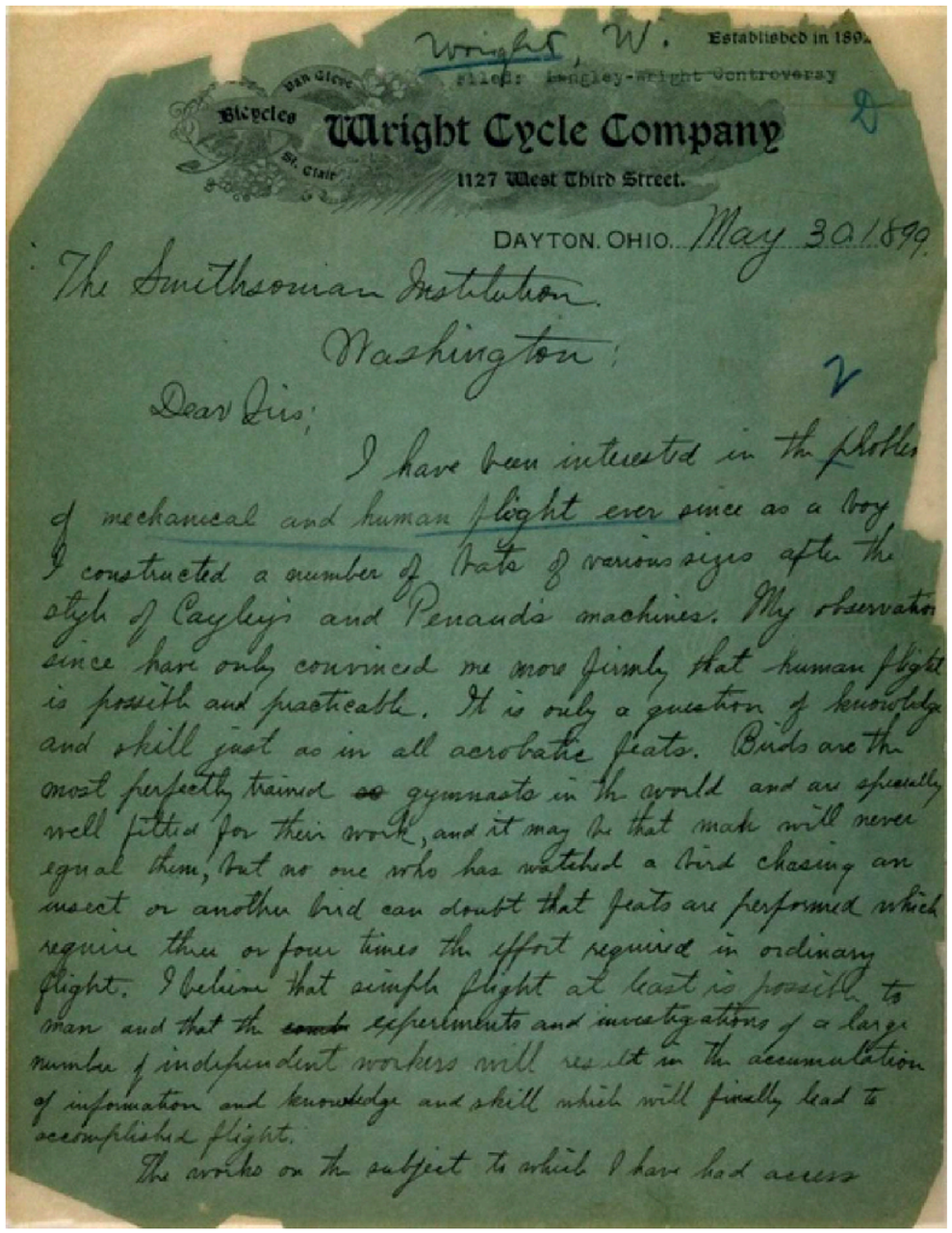
+

A transformative approach

1) Survey the Literature

Wrote to the Smithsonian to ask about relevant literature

"I am an enthusiast, but not a crank in the sense that I have some pet theories as to the proper construction of a flying machine. I wish to avail myself of all that is already known and then if possible add my mite to help on the future workers who will attain final success." —Wilbur Wright


Wright, W. Established in 189
Filed: Langley-Wright Controversy
Bicycles Van Cleve St. Clair
Wright Cycle Company
1127 West Third Street.
DAYTON, OHIO. May 30 1899.
The Smithsonian Institution.
Washington.
Dear Sirs:
I have been interested in the problem of mechanical and human flight ever since as a boy I constructed a number of kats of various sizes after the style of Cayley's and Penaud's machines. My observation since have only convinced me more firmly that human flight is possible and practicable. It is only a question of knowledge and skill just as in all acrobatic feats. Birds are the most perfectly trained ~~as~~ gymnasts in the world and are specially well fitted for their work, and it may be that man will never equal them, but no one who has watched a bird chasing an insect or another bird can doubt that feats are performed which require three or four times the effort required in ordinary flight. I believe that simple flight at least is possible to man and that the ~~conclu~~ experiments and investigations of a large number of independent workers will result in the accumulation of information and knowledge and skill which will finally lead to accomplished flight.
The works on the subject to which I have had access

Got back 2 book, 3 journal issues, and 4 pamphlets

- This was everything known at the time about flight!

2) Focus on a problem

How should you control an aircraft?

Why did this seem like an important problem?

Because glider operators kept dying!

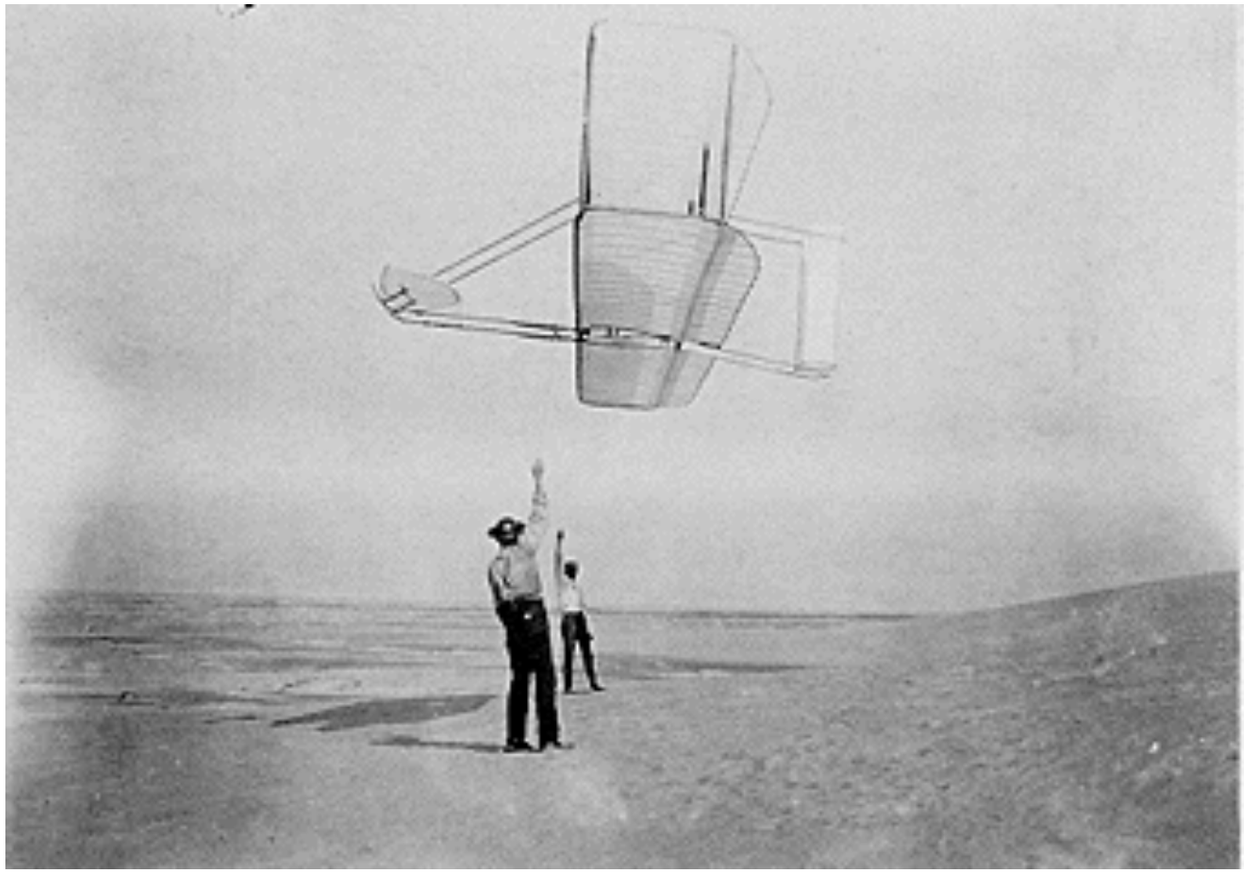
- Otto Lilienthal in 1896, Percy Pilcher in 1899

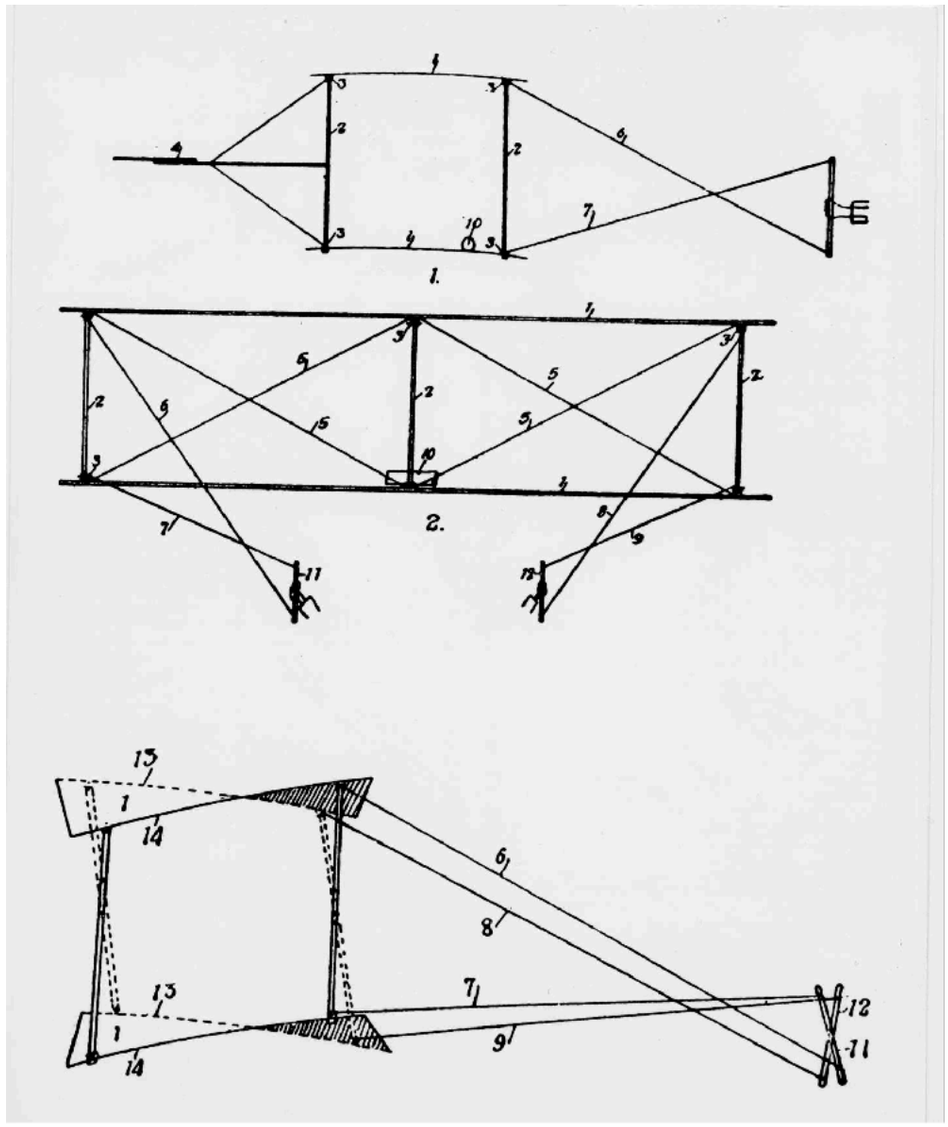
Lilienthal showed the importance of practice

- But clearly they needed better control mechanisms than he had or they would share the same fate!

3) Build Prototypes

Spent 1900-1902 building unmanned prototypes to test their theories

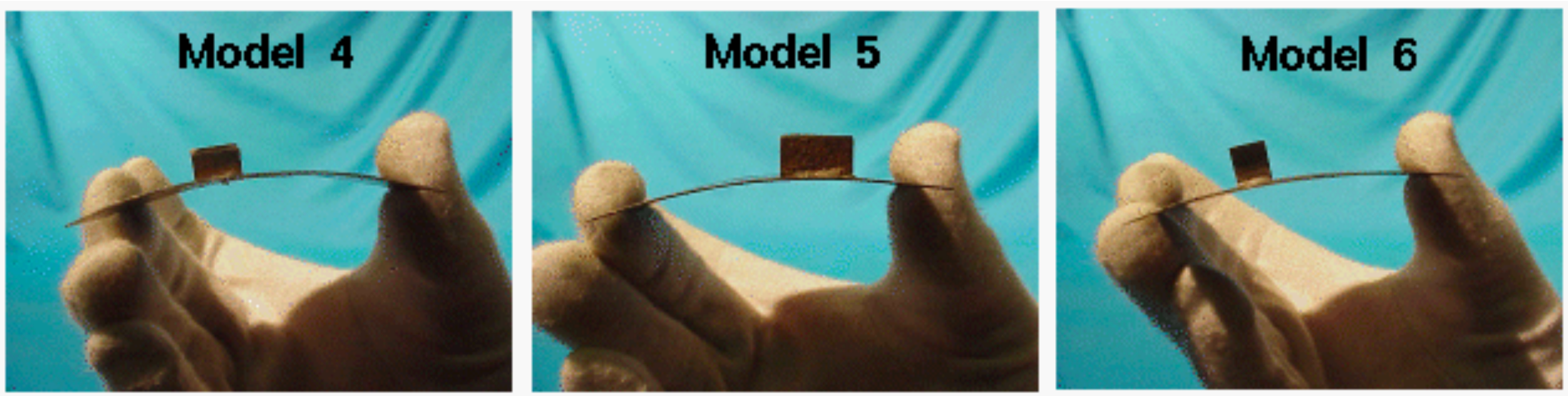




4) Conduct Experiments

Designed wind tunnels and other experimental apparatus to help them run experiments

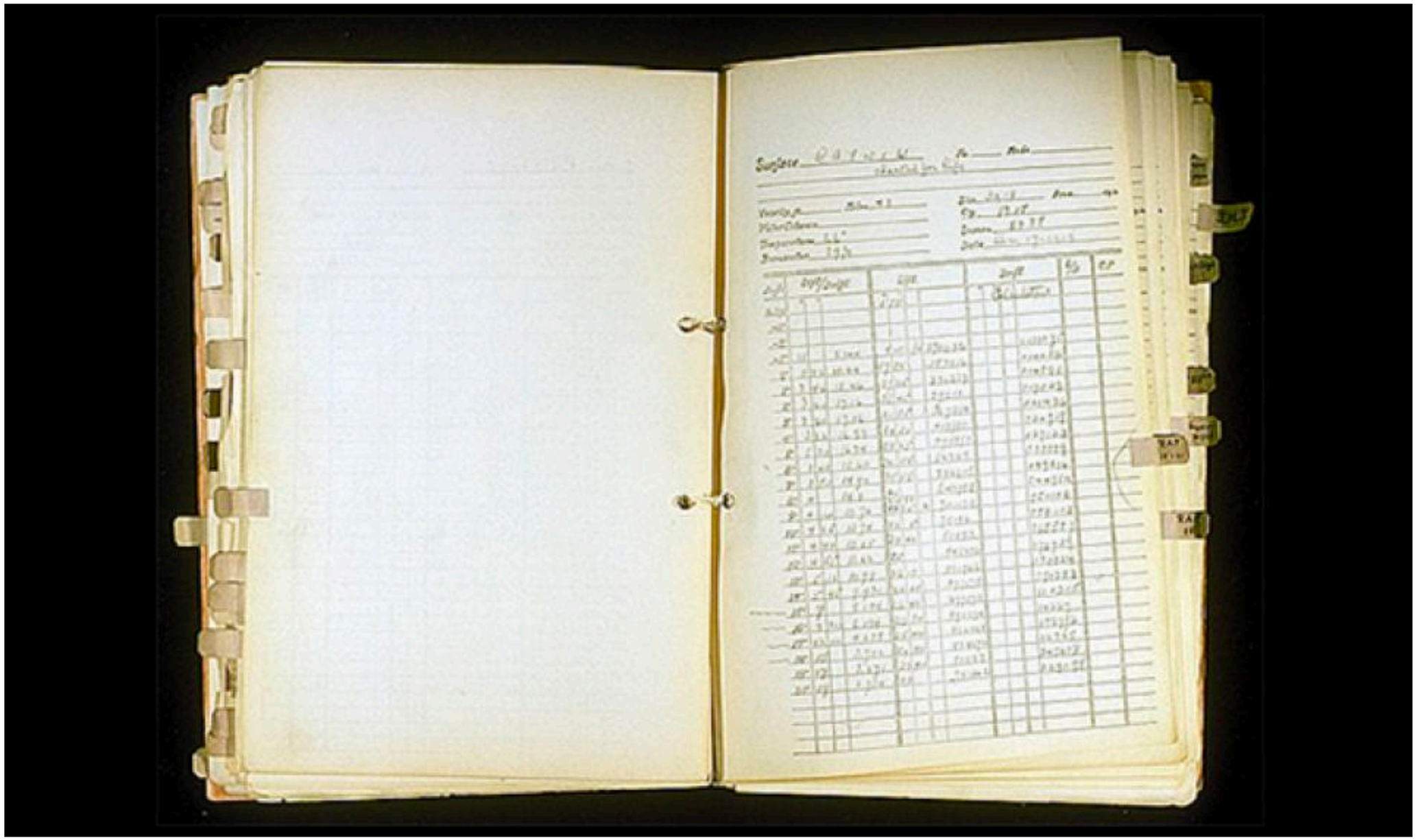
- Tested 200+ different wings and airfoil models



Camber test, arc foils, low aspect ratio

5) Analyze Results

Recorded detailed performance data for hundreds of variations



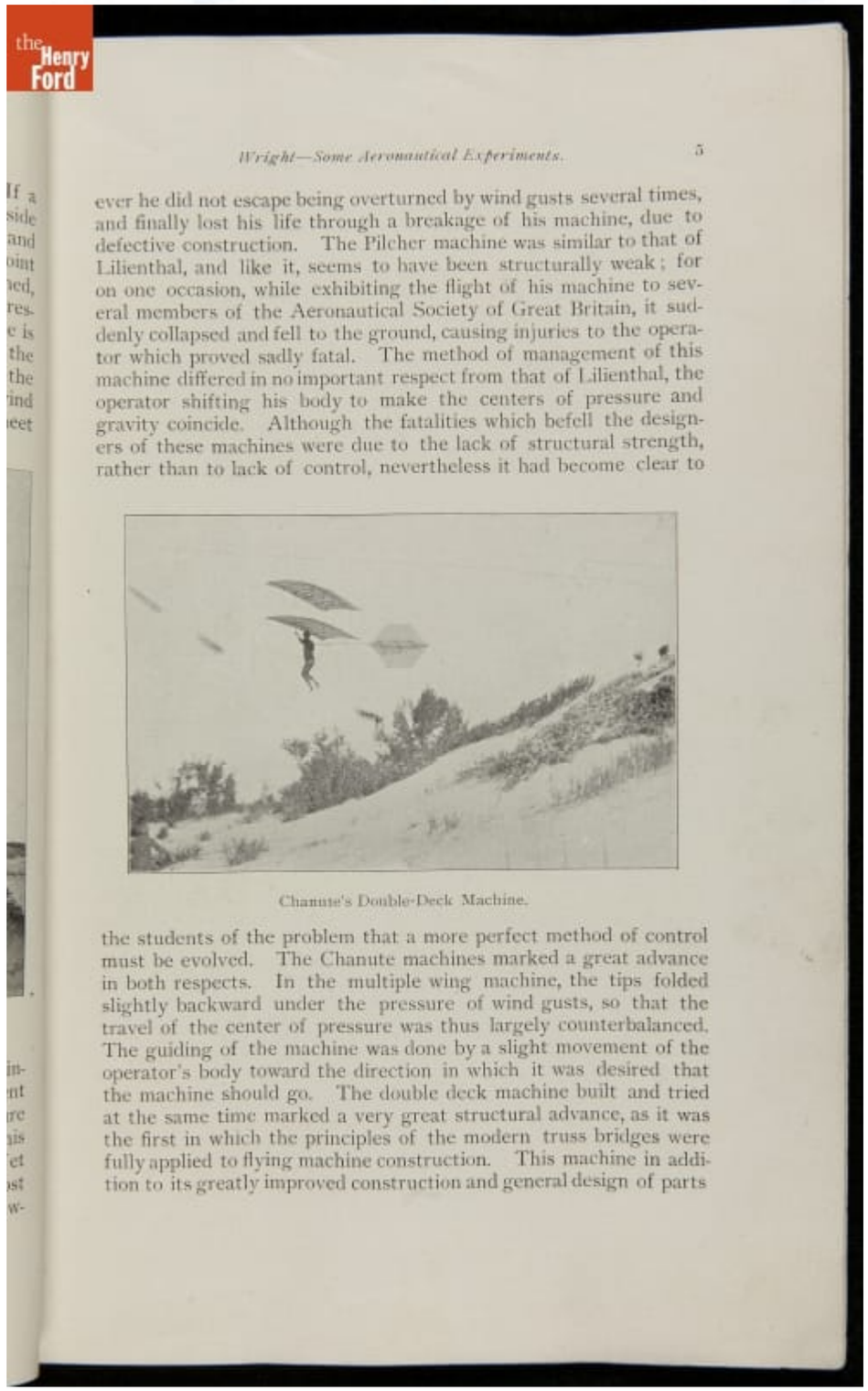
6) Compare to Prior Results

Built tools to let them evaluate and falsify other's research

7) Publish Results

Published “Some Aeronautical Experiments” in Western Society of Engineers September 18,1901

Challenged prior wing designs



Wright—Some Aeronautical Experiments. 5

ever he did not escape being overturned by wind gusts several times, and finally lost his life through a breakage of his machine, due to defective construction. The Pilcher machine was similar to that of Lilienthal, and like it, seems to have been structurally weak; for on one occasion, while exhibiting the flight of his machine to several members of the Aeronautical Society of Great Britain, it suddenly collapsed and fell to the ground, causing injuries to the operator which proved sadly fatal. The method of management of this machine differed in no important respect from that of Lilienthal, the operator shifting his body to make the centers of pressure and gravity coincide. Although the fatalities which befell the designers of these machines were due to the lack of structural strength, rather than to lack of control, nevertheless it had become clear to

Chanute's Double-Deck Machine.

the students of the problem that a more perfect method of control must be evolved. The Chanute machines marked a great advance in both respects. In the multiple wing machine, the tips folded slightly backward under the pressure of wind gusts, so that the travel of the center of pressure was thus largely counterbalanced. The guiding of the machine was done by a slight movement of the operator's body toward the direction in which it was desired that the machine should go. The double deck machine built and tried at the same time marked a very great structural advance, as it was the first in which the principles of the modern truss bridges were fully applied to flying machine construction. This machine in addition to its greatly improved construction and general design of parts

8) Iterate

Repeated this process until eventually they flew!

1) Learn the background material and prior work

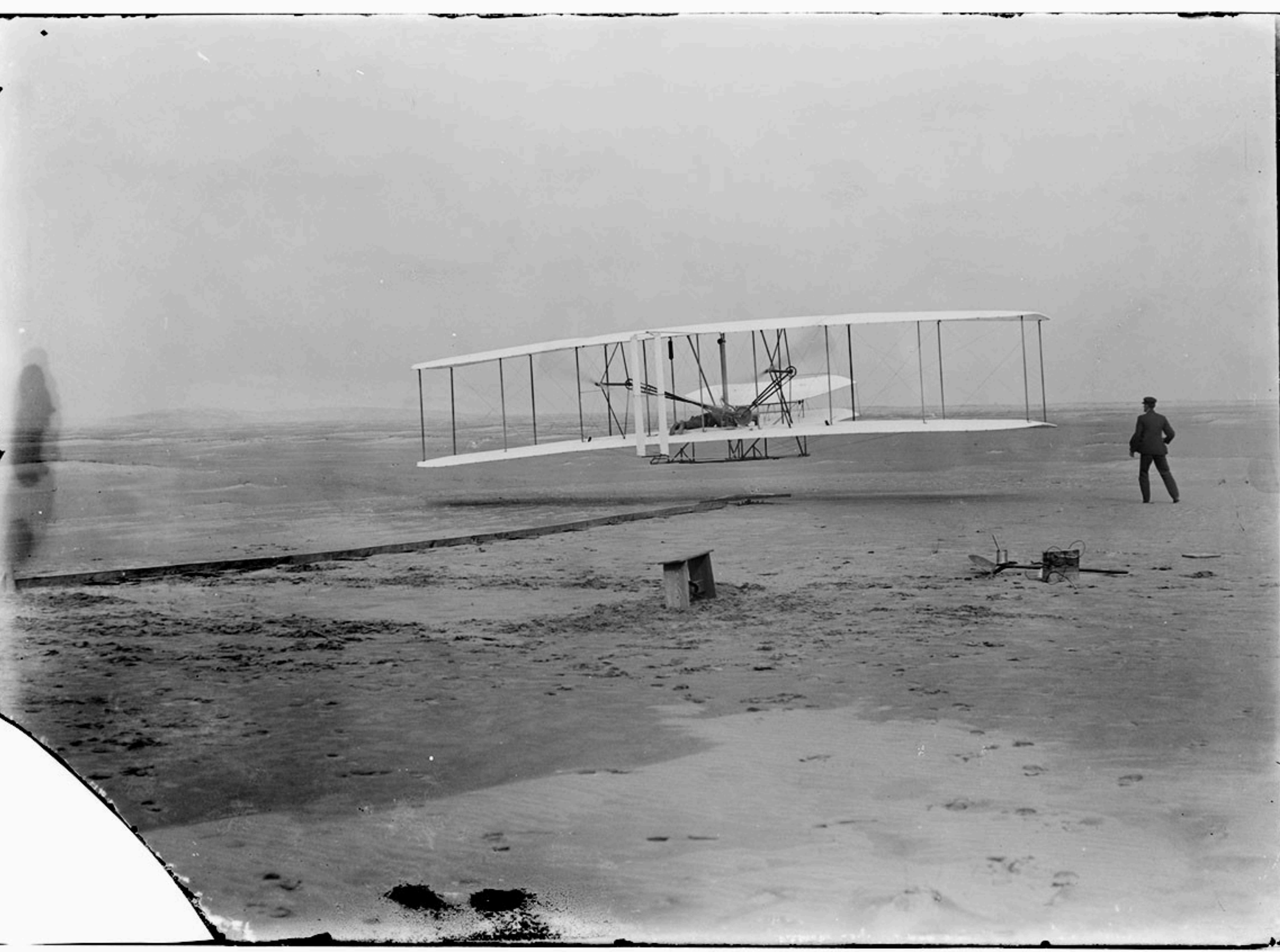
2) Determine the most important problem

3) Build prototypes

4) Conduct experiments

5) Analyze results

6) Compare against other approaches



Secret Ingredient

Why focus on control and why were they good at solving that problem?

Langley was a “Skilled Insider”

Orville and Wilbur were “Passionate Outsiders”

- Their history as cyclists may have been what let them fly!

Learn More…

https://wright.nasa.gov/overview.htm

https://medium.com/@ade3/zombies-in-flight-f0bd6c1c3ba4

The Smithsonian Air and Space museum!

Public Speaking 1

Speak for 1-2 minutes

Pick one of these topics:

Hidden because I don't want you to plan ahead…

I will record you!

- Don't worry, it won't go on youtube
- Homework: watch your own presentation and think about how you can improve upon it

Probably next week!

Reading 1

A Guide to Increased Creativity in Research — Inspiration or Perspiration?

by C. Loehle, in Bioscience February 1990

A guide to increased creativity in research— inspiration or perspiration?

There are four requirements for a successful career in science: knowledge, technical skill, communication, and originality or creativity. Many succeed with largely the first three. Those who are meticulous and skilled can make a considerable name by doing the critical experiments that test someone else's ideas or by measuring something more accurately than anyone else. But in such areas of science as biology, anthropology, medicine, and theoretical physics, more creativity is needed because phenomena are complex and multivariate.

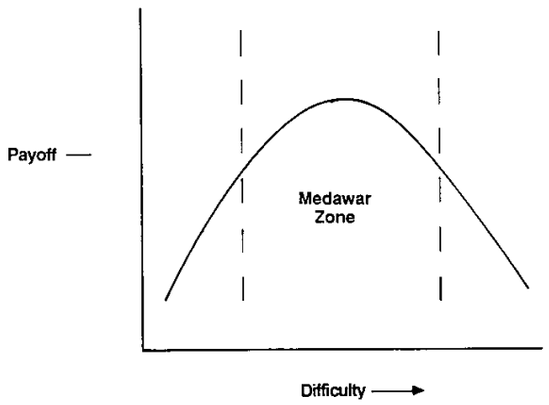


Figure 1. Relationship between degree of difficulty and payoff from solving a problem. Solving problems that are too easy

and work intensely. After you have finished writing your paper, you can go back and remove the comments about what an imbecile the other person is. The effort to refute someone can even lead to evidence supporting them or to a different topic altogether. Intensive rivalries, as in the race to discover DNA (Watson 1968), can also provide this essential intensity. Thus whereas the finished product may appear dispassionate, truly creative work is often driven by strong passions.

File on website

Acknowledgements

Much of the slide content, and almost all of the amazing quotations, are derived from the *Research Methods for Empirical Computer Science* course taught by **David Jensen**

- http://dx.doi.org/11084/10002
- https://people.cs.umass.edu/~jensen/courses/index.html
- https://people.cs.umass.edu/~jensen

- Many thanks for allowing me to make use of his materials!