How to Create Visible Knowledge

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The LPPD Exchange – Ann Arbor, MI

5 October 2023

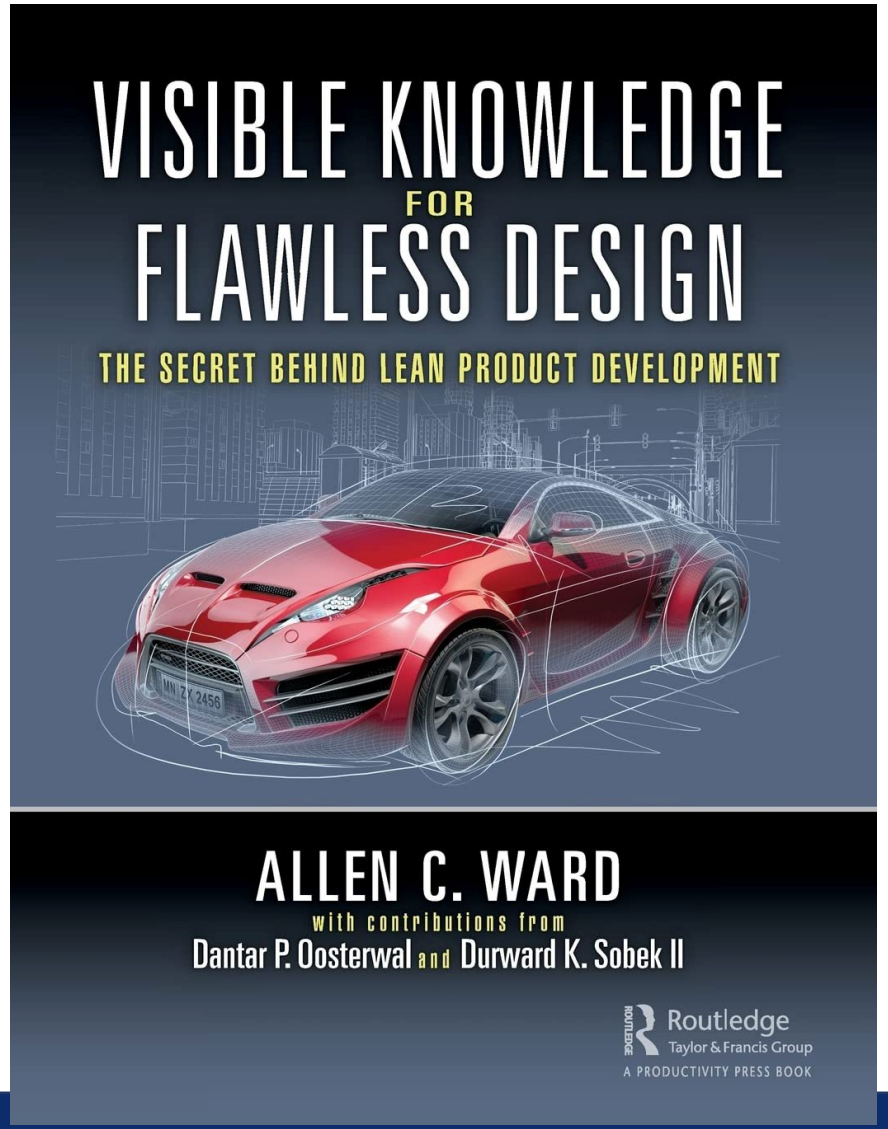
Agenda

Morning:

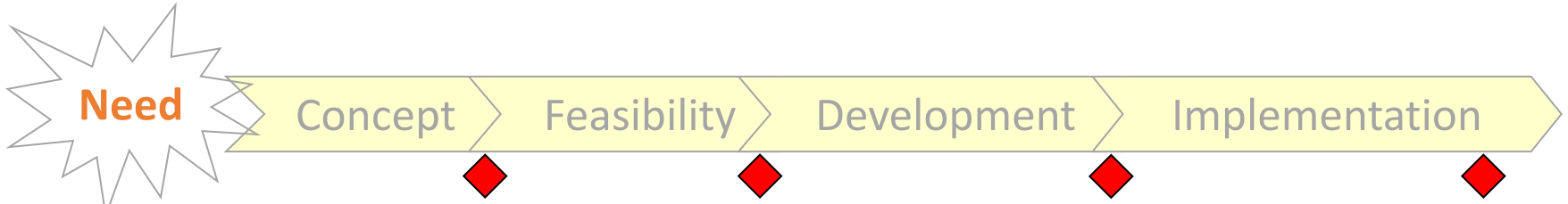
- Introductions
- Wright Brothers
- Example
- Hands-on Activity

Afternoon:

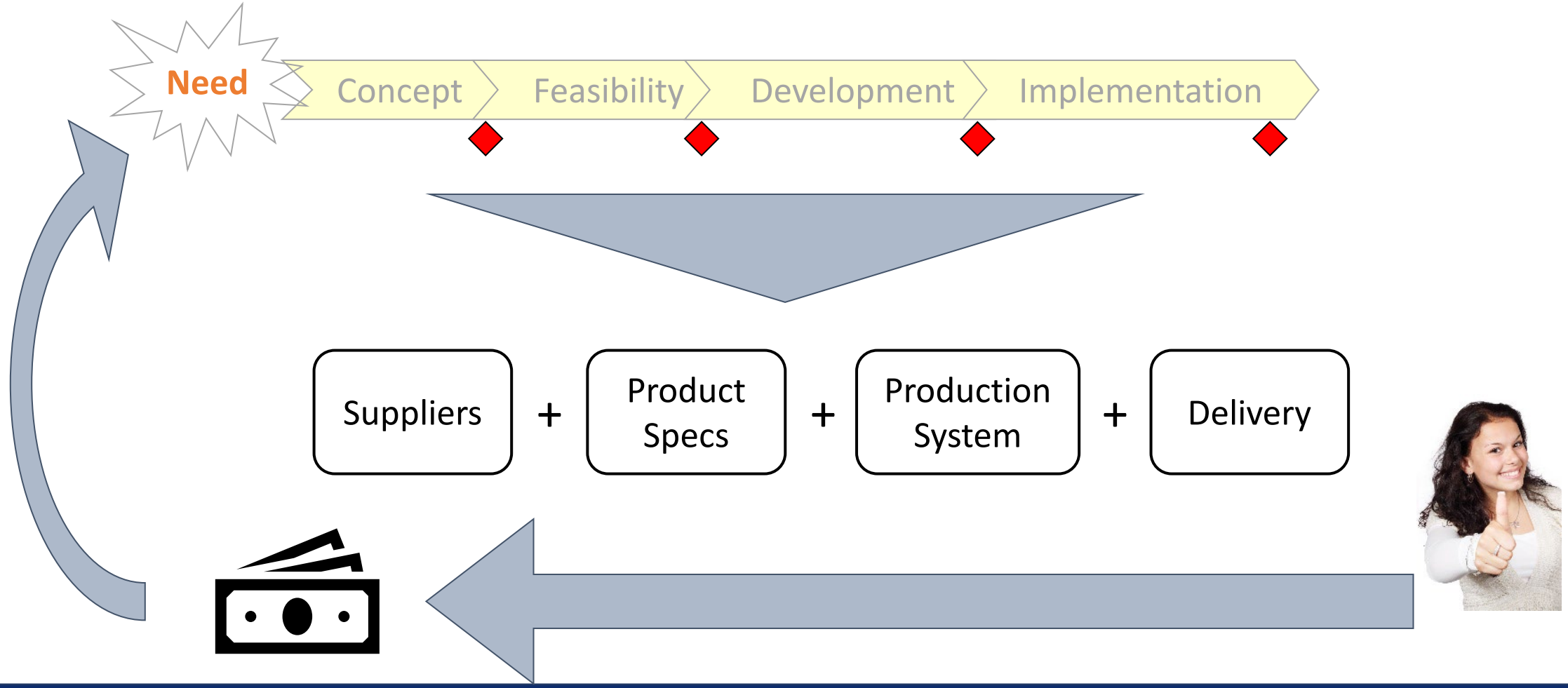
- Start your own trade-off curve



Often we see PD this way...



When it’s really more like this.



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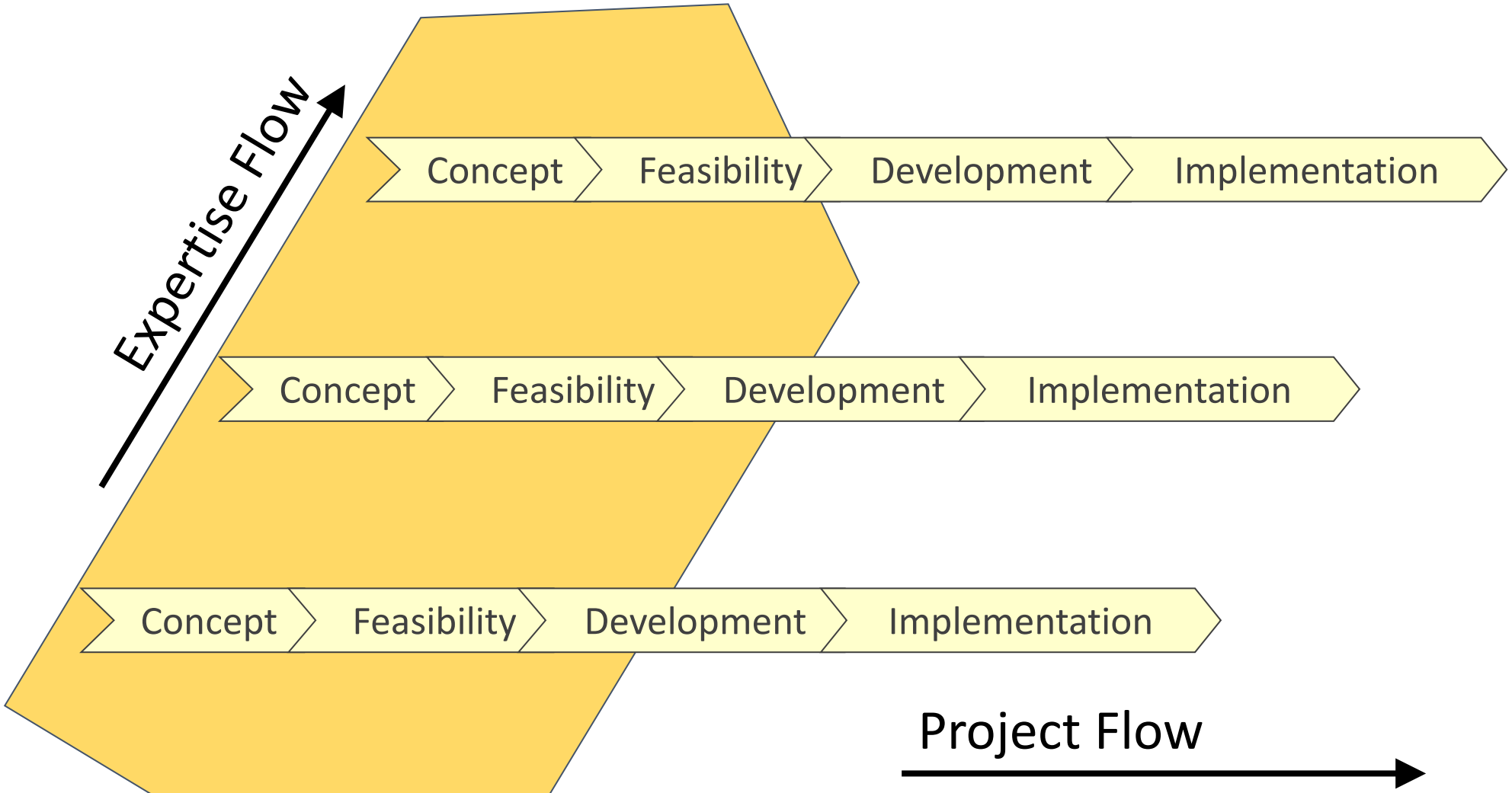
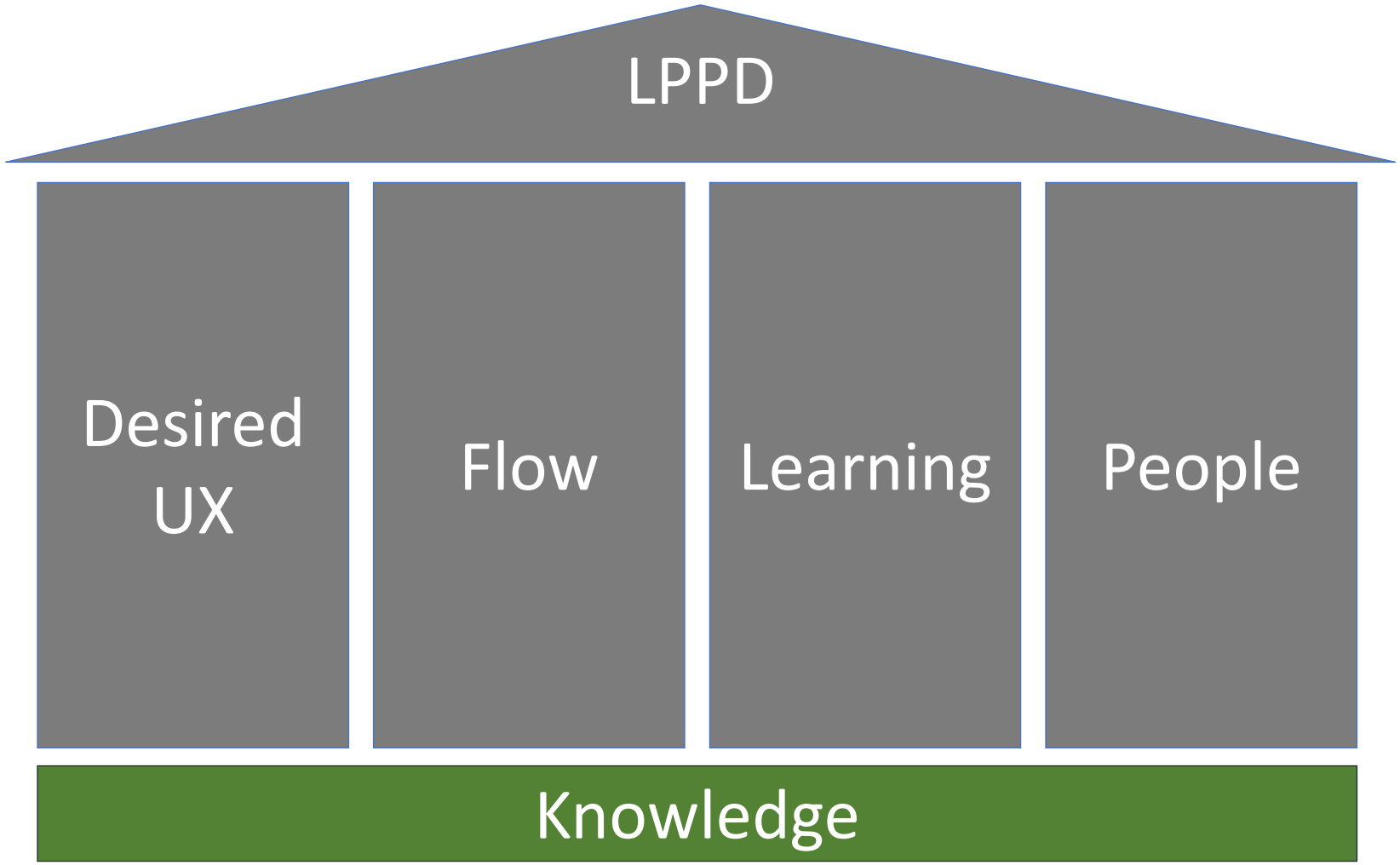


“Value added” in product development is creating **(re)useable** knowledge and hardware/software.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Flow
Learning
People
Knowledge

A Lesson From History

How to Design the First Airplane

(and live to tell about it)

Would-be Inventors of Flight

- Otto Lilienthal (Germany)
  - 18 gliders over 10 years, 2000 test flights
  - Perished in test flight crash in 1896
- Clement Ader (France)
  - $120K spent over 1872-1897 without success
- Hiram Maxim (England)
  - $200K invested in 1890's without success
- Samuel Langley (US)
  - $70K spend over 16 years; no manned flight achieved for longer than a few seconds

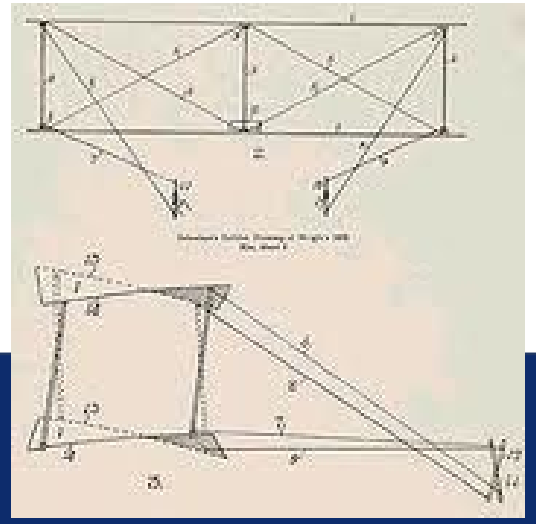
How about the Wrights?

- Never attended university.
- Spent about $1000.
- 22 months of development work, 3 people, spread over 3-4 years
- First full prototype flew.

How did they do it?

They Innovated an Entirely New Approach

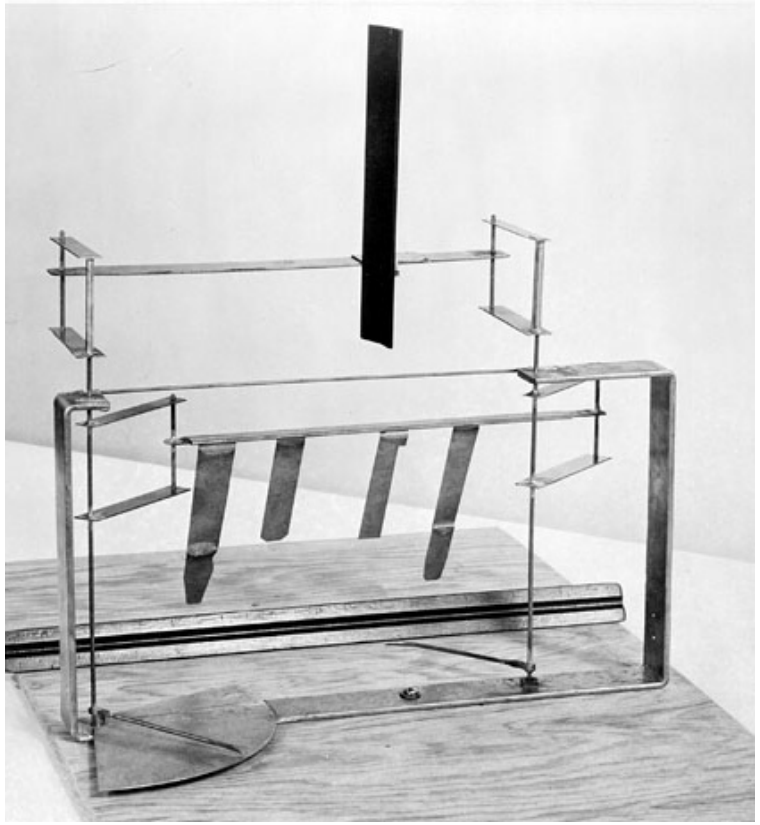
- Three knowledge gaps identified:
  - In-flight control
  - Wing design
  - Propulsion



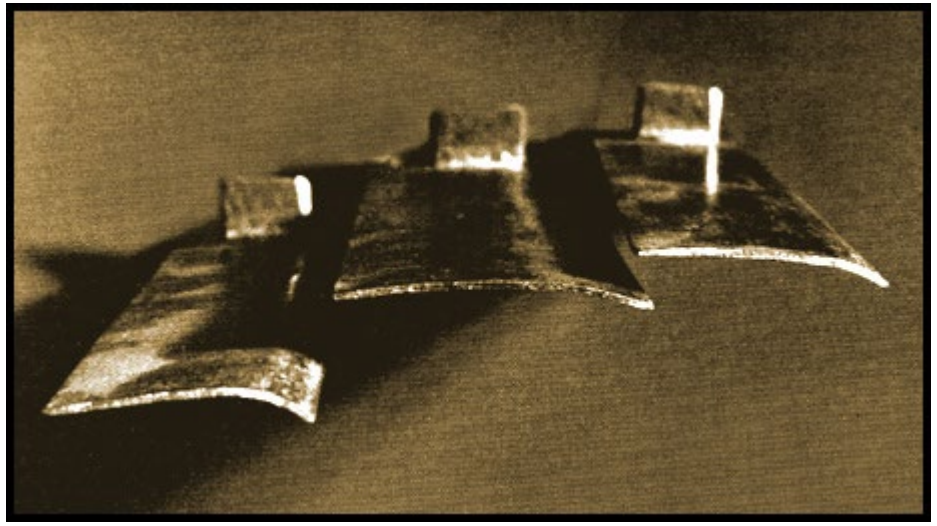
- Attacked first.
- Systemic testing of control ideas in kites, gliders.
- Discovered need to control yaw.
- Discovered that existing lift tables were wrong…

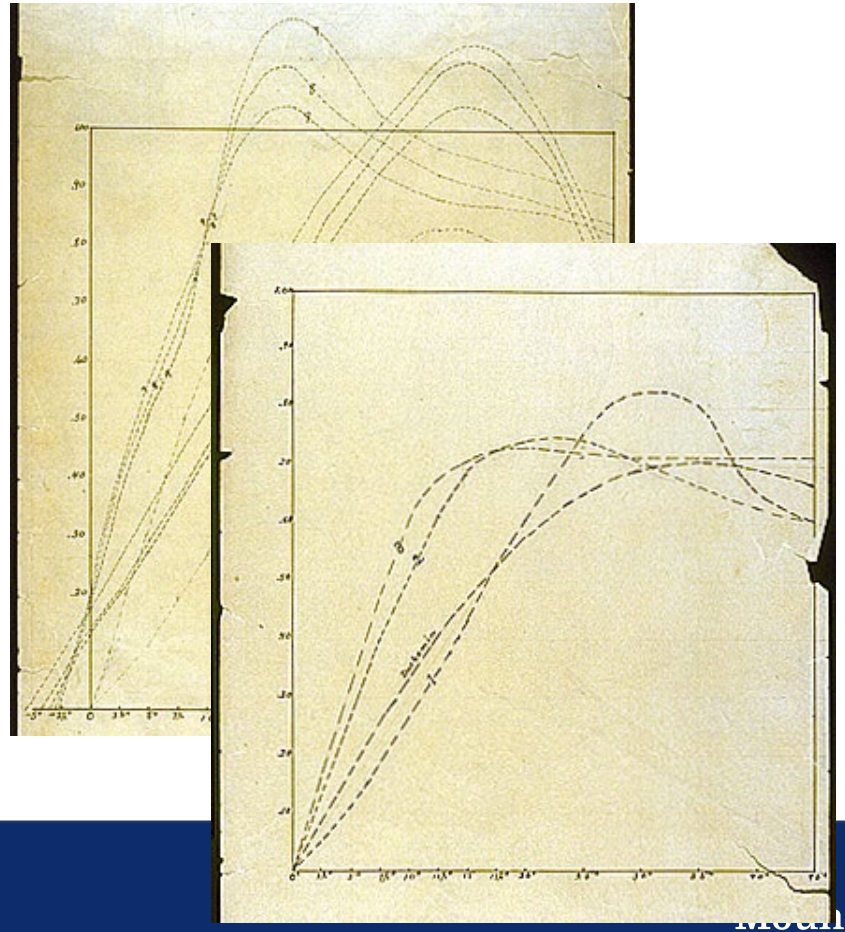
Closing the wing design gap

Wind Tunnel



Lift Balance





Wind tunnel data confirmed in a subsystem test

Closing the Propulsion Gap

Breakthrough Realization:

"It was apparent that a propeller was simply an aeroplane (wing) travelling in a spiral course. As we could calculate the effect of a wing traveling in a straight course, why should we not be able to calculate the effect of a wing travelling in a spiral course?"

Reusable Knowledge!

Reused Knowledge

- Airfoil knowledge curves used to design novel propeller.
- Highly efficient propeller allowed a small motor.

They closed the propulsion gap!

“Success assured.”

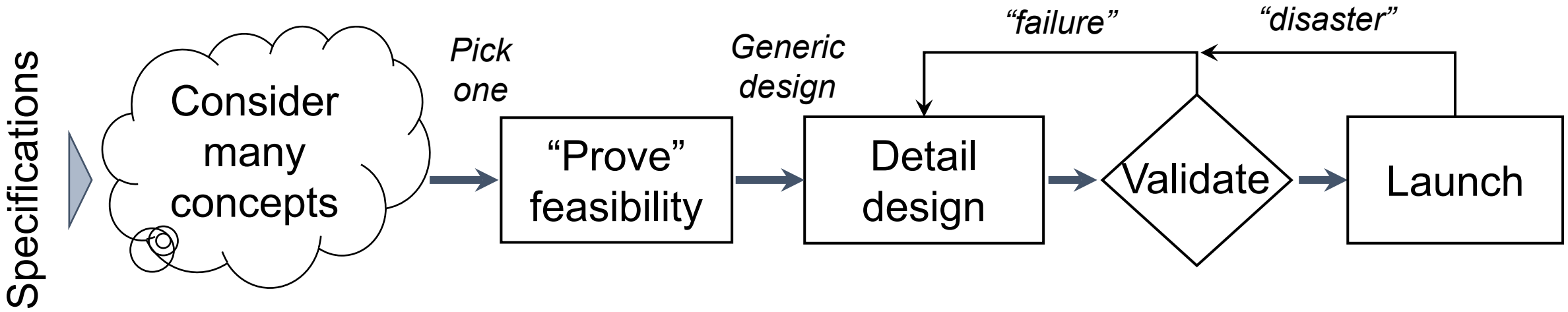
- With the knowledge gaps now closed…
- A full system prototype was built…
- Transported to Kitty Hawk…
- And flew,

  with no design changes!

Take-aways

1. Design-build-test vs. learning first

Conventional Development

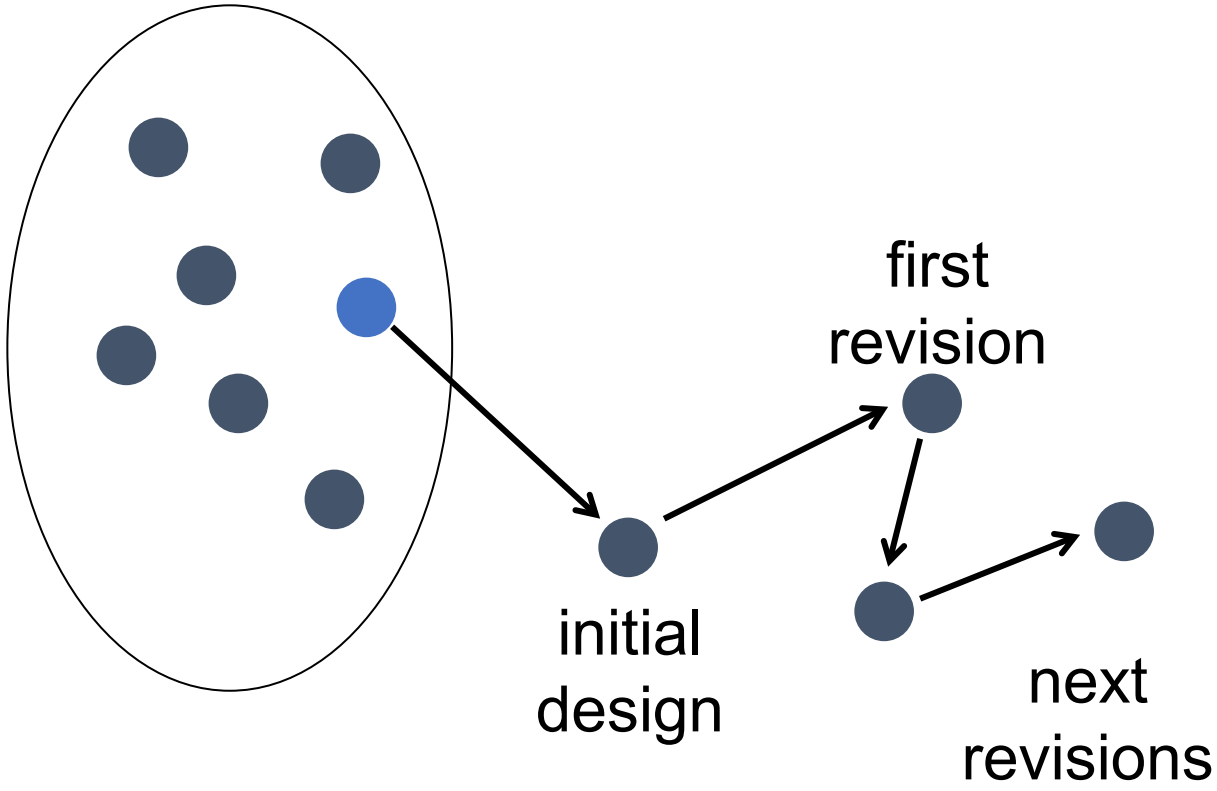


Research ("the fuzzy front end")

Advanced Development

Analyze, Simulate, Prototype & Test

Iteration on a “Point” Solution



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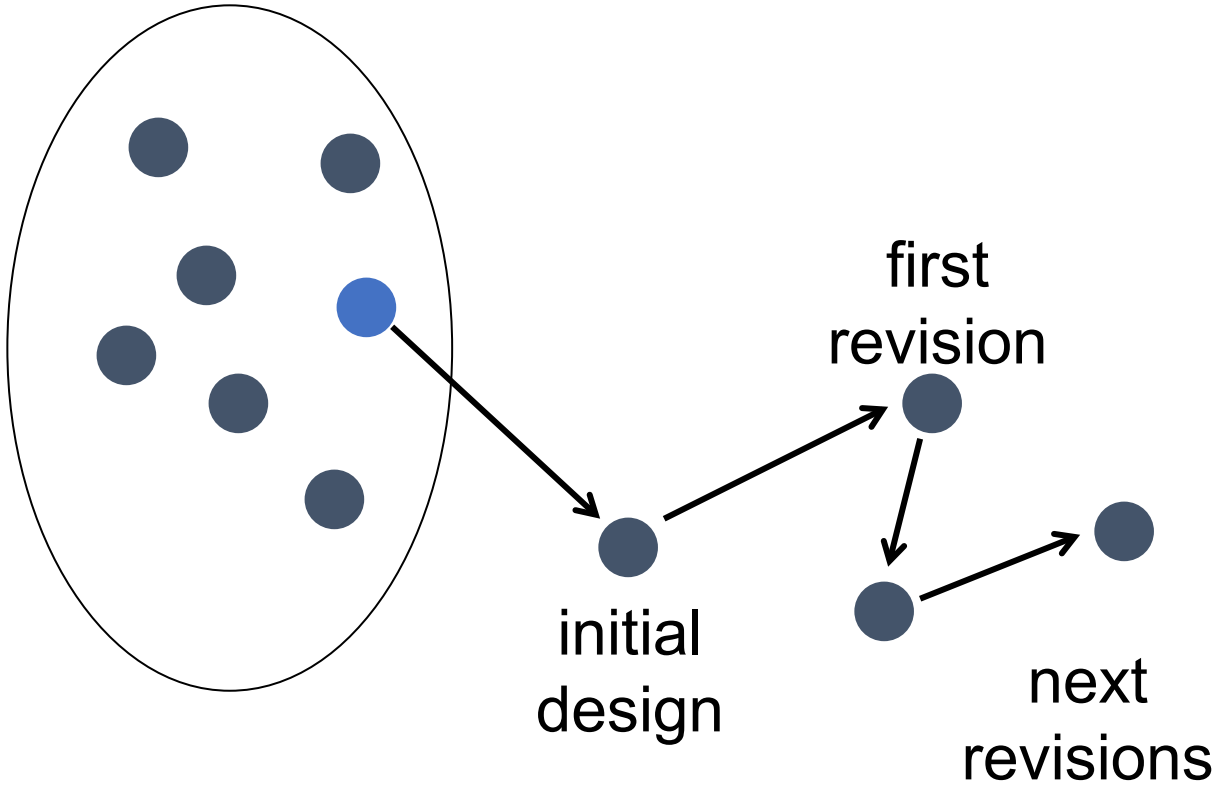


Problems

When will you find a design that works?

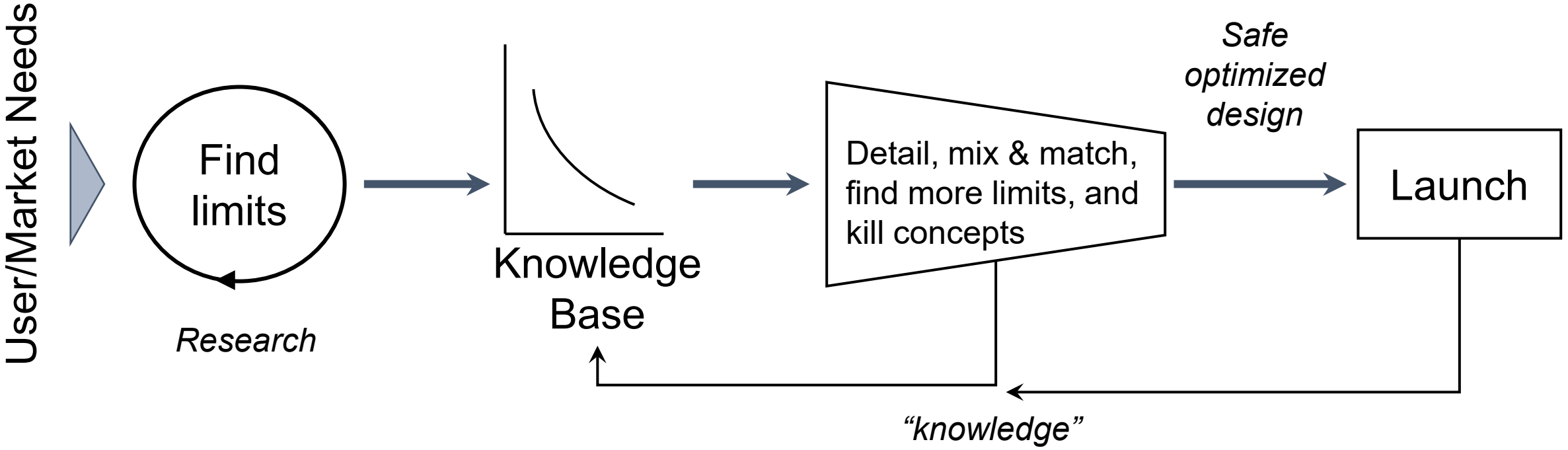
Where to go next?

How far are you from a “cliff”?

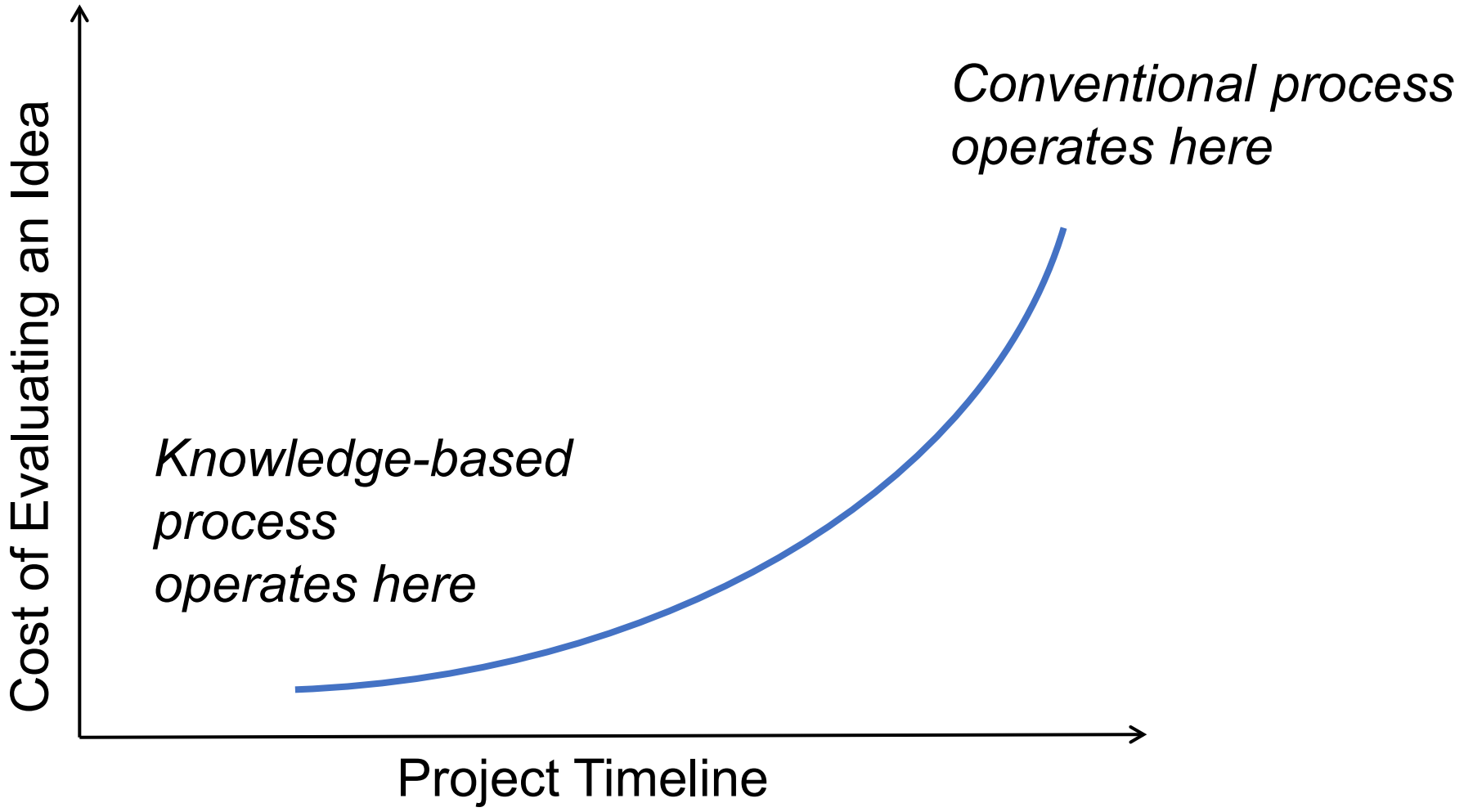
Have you produced any reusable knowledge?

How can teams work concurrently?

Knowledge-based Development

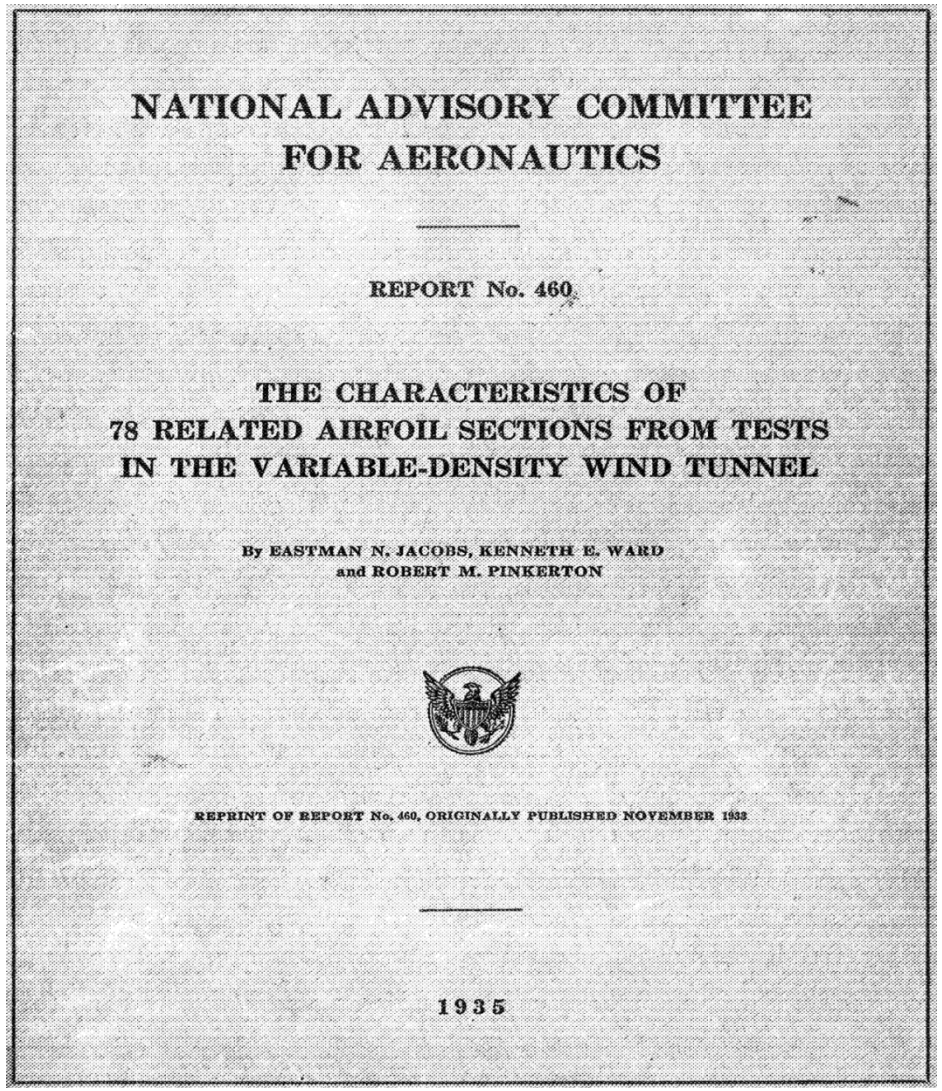


Is it More Expensive?



Take-aways

1. Design-build-test vs. learning first
2. Re-usable “visible” knowledge



NATIONAL ADVISORY COMMITTEE
FOR AERONAUTICS

REPORT No. 460

THE CHARACTERISTICS OF
78 RELATED AIRFOIL SECTIONS FROM TESTS
IN THE VARIABLE-DENSITY WIND TUNNEL

By EASTMAN N. JACOBS, KENNETH E. WARD
and ROBERT M. PINKERTON

REPRINT OF REPORT No. 460, ORIGINALLY PUBLISHED NOVEMBER 1933

1935

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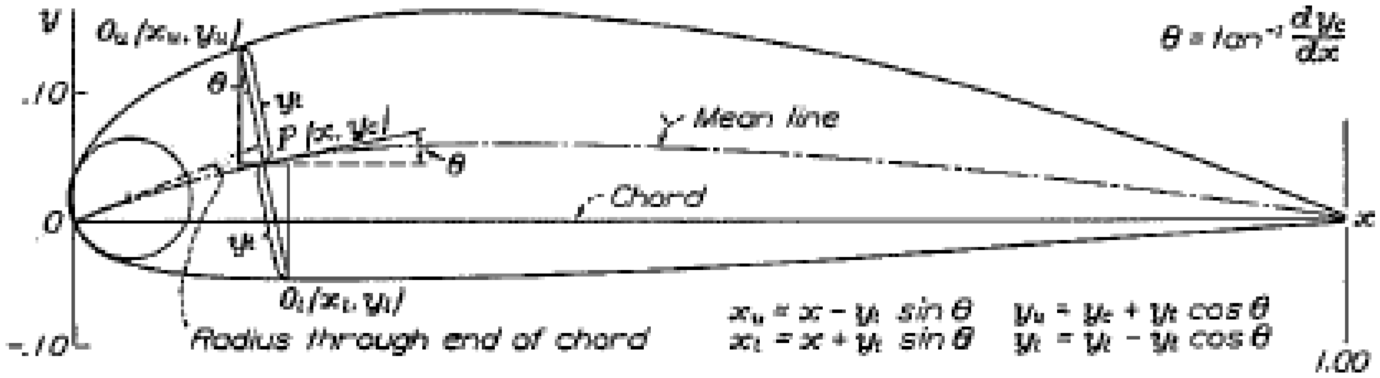

Sample calculations for derivation of N.A.C.A. 6321

x	y_t	y_c	$\tan\theta$	$\sin\theta$	$\cos\theta$	$y_t \sin\theta$	$y_t \cos\theta$	x_u	y_u	x_l	y_l
0	0	0	[1] 0.40000	0.37140	0.92848	0	0	------	------	0	0
0.01250	0.03314	0.00469	.38333	.35793	.93375	0.01186	0.03094	0.00064	0.03563	0.02436	−0.02625
.30000	.10503	.06000	0	0	1	0	.10503	.30000	.16503	.30000	−.04503
.60000	.07986	.04898	−.07347	−.07327	.99731	−.00585	.07965	.60585	.12863	.59415	−.03067
1	.00221	0	−.17143	−.16897	.98562	−.00037	.00218	1.00037	.00218	.99963	−.00218

[1] Slope of radius through end of chord.

FIGURE 2.—Method of calculating ordinates of N.A.C.A. cambered airfoils.

115 airfoils tested!

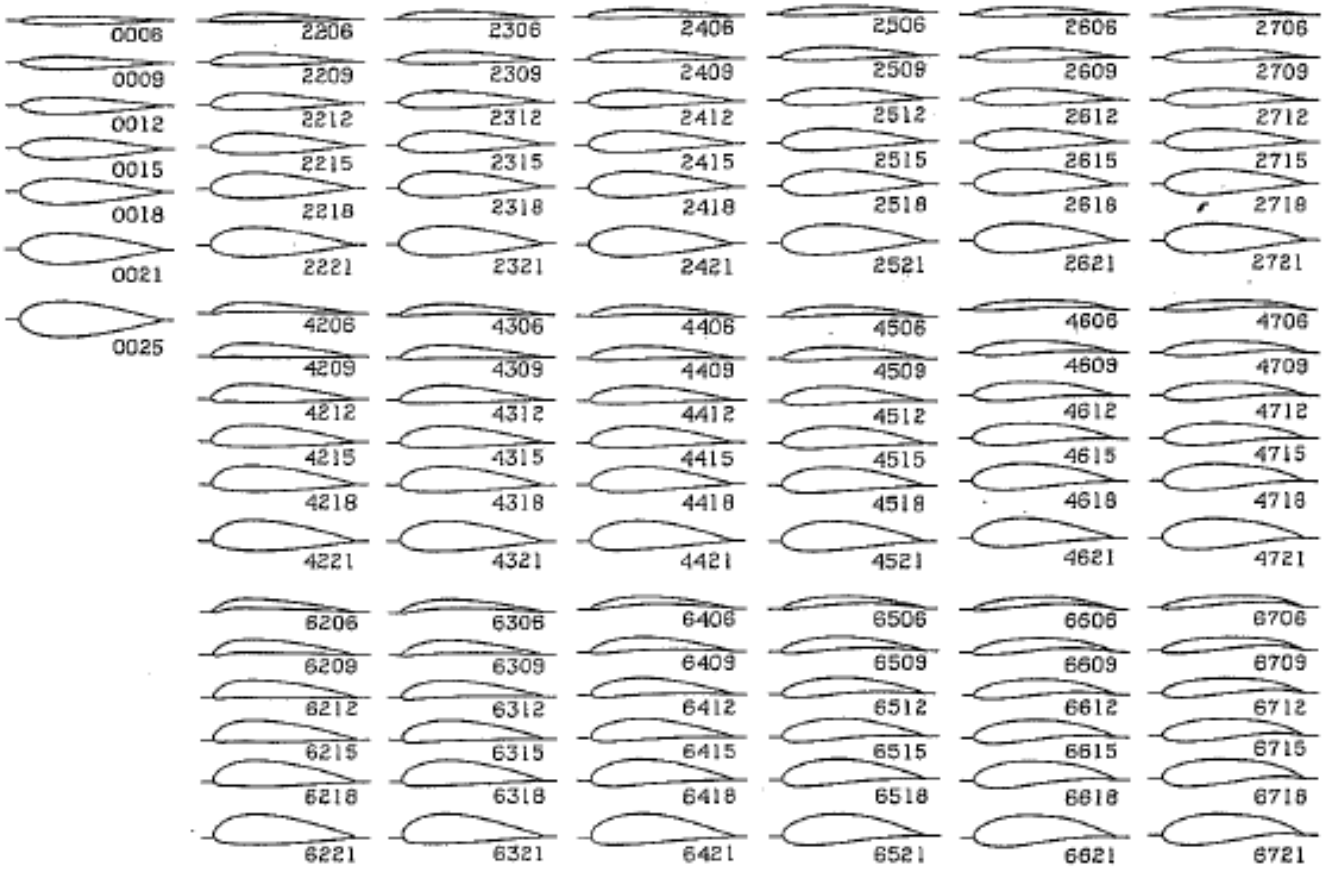

FIGURE 3.—N.A.C.A. airfoil profiles.

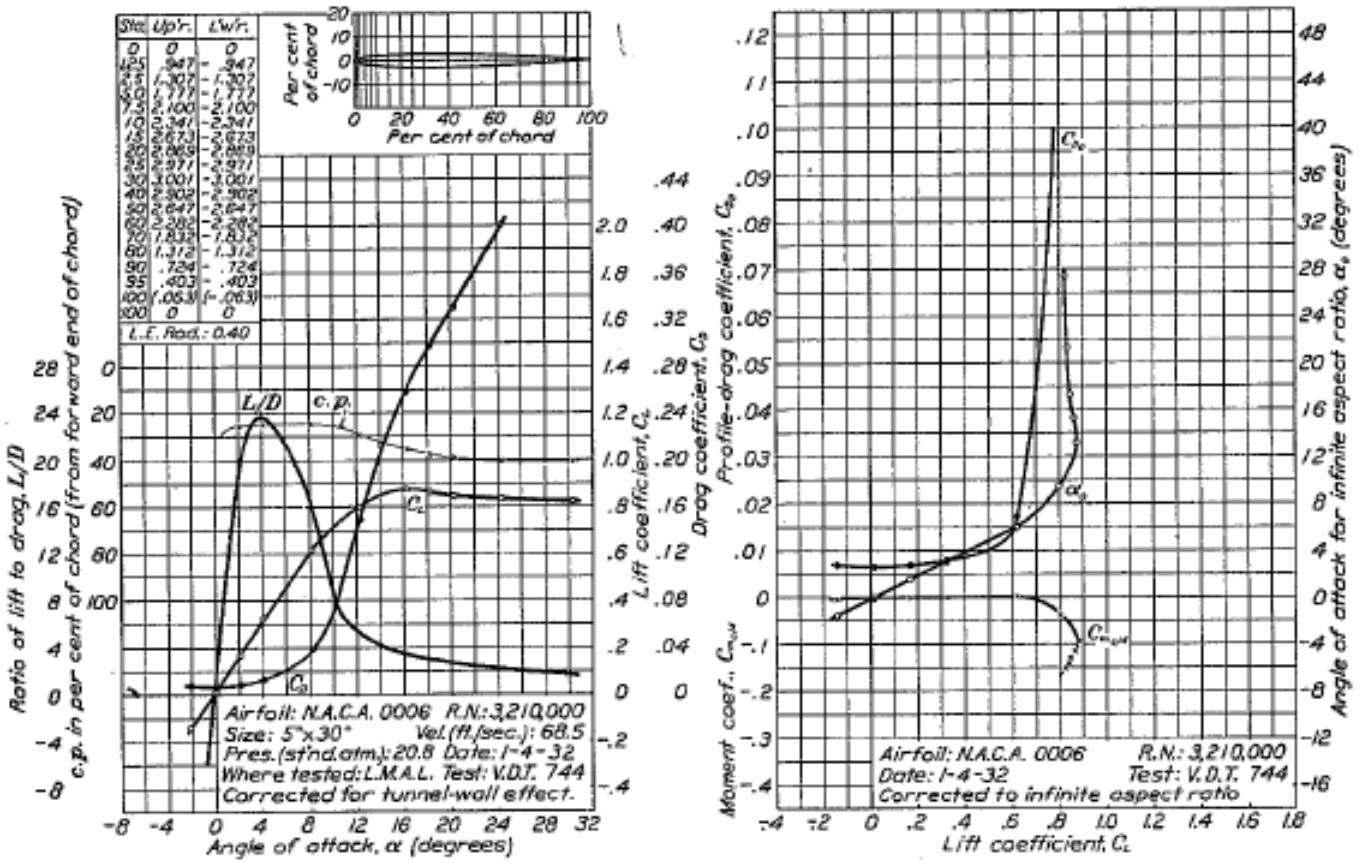

FIGURE 4.—N.A.C.A. 0006 airfoil.

P-51 Mustang

Take-aways

1. Design-build-test vs. learning first
2. Re-usable “visible” knowledge
3. Other?