



How the Wright Brothers Learned!

Andrew Wagner

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8/8/24

Why Attend this Workshop?

- This story we are about to share with you is the foundation for the workshop we will be holding at the LPPDE Conference in Milwaukee in the end of September
- We are using the Wright Brother's Invention of the airplane to illustrate the creation of a product development learning plan in an environment with high uncertainty, requiring new innovation
- The learning plan process sets the stage for reusable knowledge and visual management, two key components of Lean Product and Process Development, by creating artifacts which link critical design decisions to the technical knowledge base, to enable project planning

Introductions

Carolyn Carter

Education:
• BSME

Places Lived/worked



New England
Georgia
Texas
Wisconsin

Work Travel:
Across US
UK
Argentina
Mexico

Research/Production Engineering
Analytical Instrumentation



Consumer Products Manufacturing/
Product Development



Lean Consulting



Kimberly-Clark

The LEAN MACHINE | ARGO EFESO
MANAGEMENT CONSULTANTS

THE SCIENCE OF
IMPROVING INNOVATION

Career Coaching

Leadership, Manufacturing, Product Development, Lean Consulting - Coach, Change agent, Continuous Improvement

Andy Wagner

I Am Diversity: Andy Wagner

Diversity
BLUEPRINT



• Andy Wagner

- 13-years w/Boeing: 787 QE, M&S Core, 737 PE
- 3-yr automotive, 9-yr GE Aircraft Engines
- BS (Mat'l Sci) Vanderbilt '98, MS (Eng Mgt) Tufts '07
- Design, Quality, Industrial, and Manufacturing Engineering roles
- Passionate about Continuous Improvement: Lean, Theory of Constraints, etc.

• Personal Blueprint

- Grew up outside Detroit, MI; went to school in Nashville, TN; lived 10-years in Boston, MA
- Married, 13-year old daughter, 9-year old son, 1 dog, 1 cat
- Dad (engineer), mom (music teacher), 1 sister (librarian), 1 brother (architect)

• Anything additional you want others to know about you

- Love to travel, hike, read, fix my old house, occasional woodworking

• What Diversity & Inclusion means to me

- Everybody is treated with dignity. Assume positive intent.
- "Seek first to understand, then to be understood."

YAZAKI



Adapted with permission from "Implementing Diversity" by Marilyn Lobon and "Diverse Teams at Work" by Lee Gardenswartz and Anita Rowe.

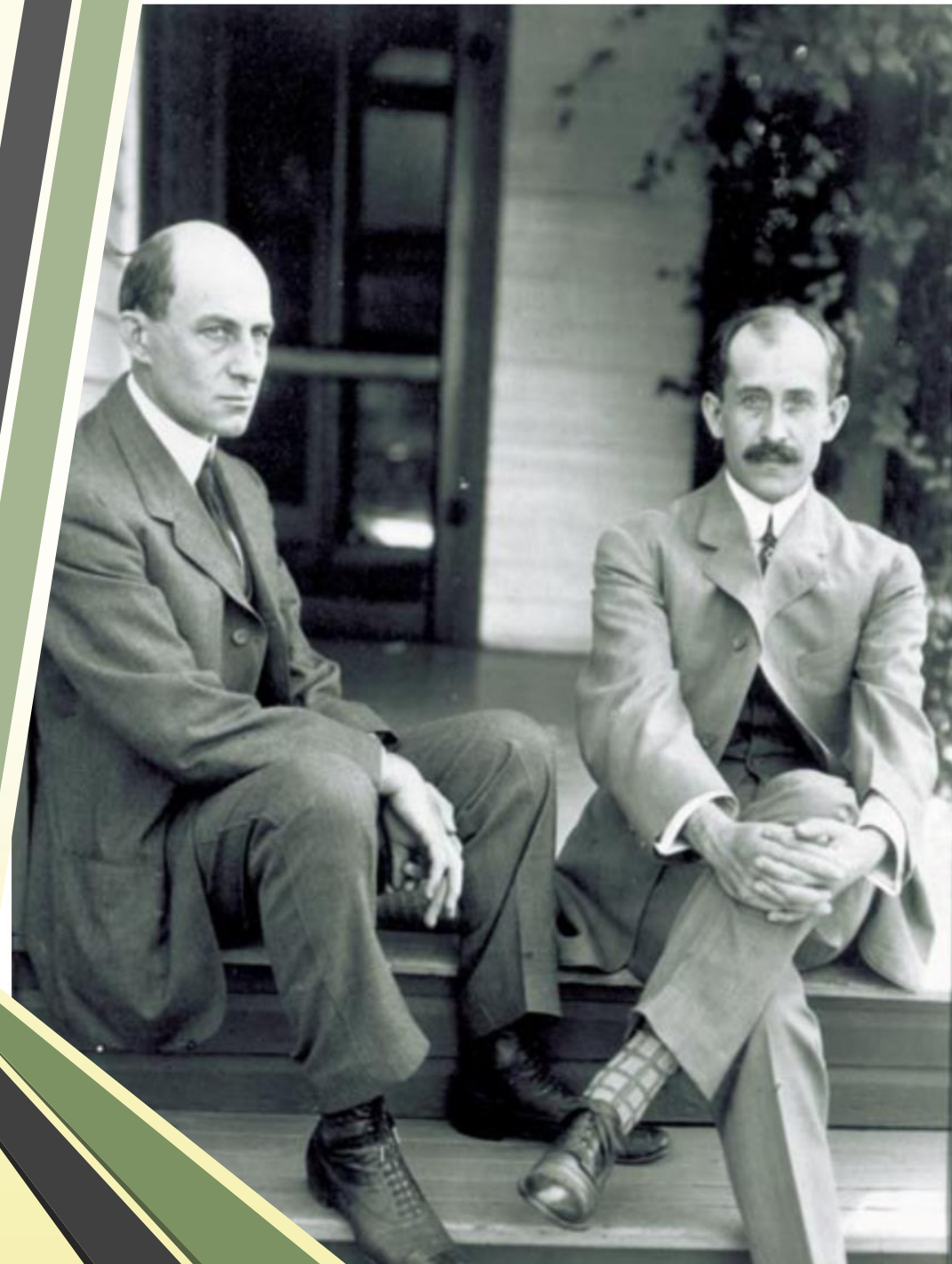
DIVERSITY
BLUEPRINT
ONE SIZE DOES
NOT FIT ALL

Agenda

- Backstory
- Learning Plan
- Knowledge Management
- Key Take Aways
- Invite to the conference

Why the Wright Brothers?

- Serial Entrepreneurs
 - Team of Knowledgeable Experts
 - Strong Technical Intuition
- Humility
- Psychological Safety
- Passion & Commitment
 - Learning
 - Flying



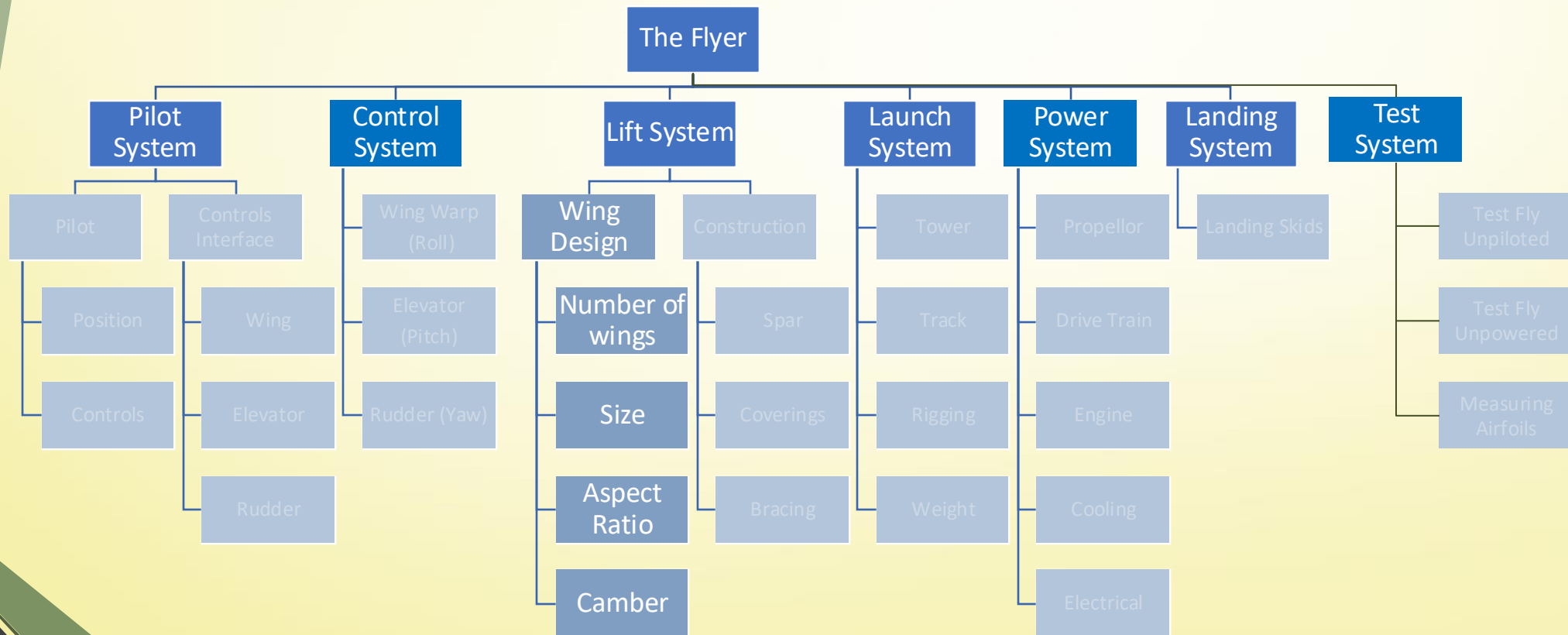
Learning Plan

- Hypothesis
- Functional Block Diagram
- Decision Network
- Causal Diagram
- Knowledge Gaps
- Learning Plan
 - Visual Management
- Trade-off Curves
 - Reusable Knowledge

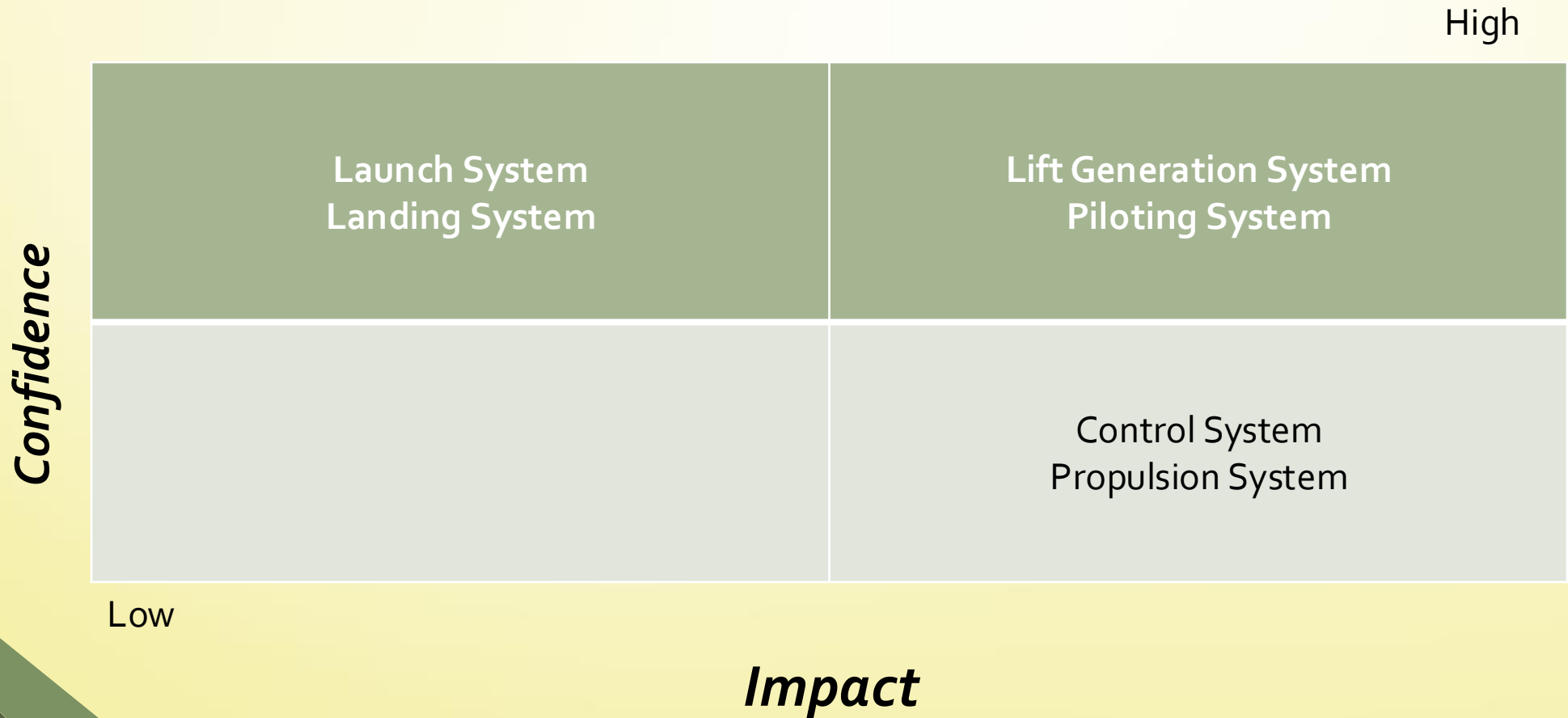
Hypothesis

- If: We start with the knowledge we have, **research what others have done**, build hypotheses, do the analysis on paper, conduct experiments **around lift, control, and power**, build test equipment as needed, gather and document the data and integrate the learning,
- Then: We will be able to provide an effective solution **for controlled, powered, heavier than air flight, for all, enabling us to do demonstration flights and educate the population, to create a viable business**
- Because: We will have successfully designed an aircraft that **all types of customers** can safely fly

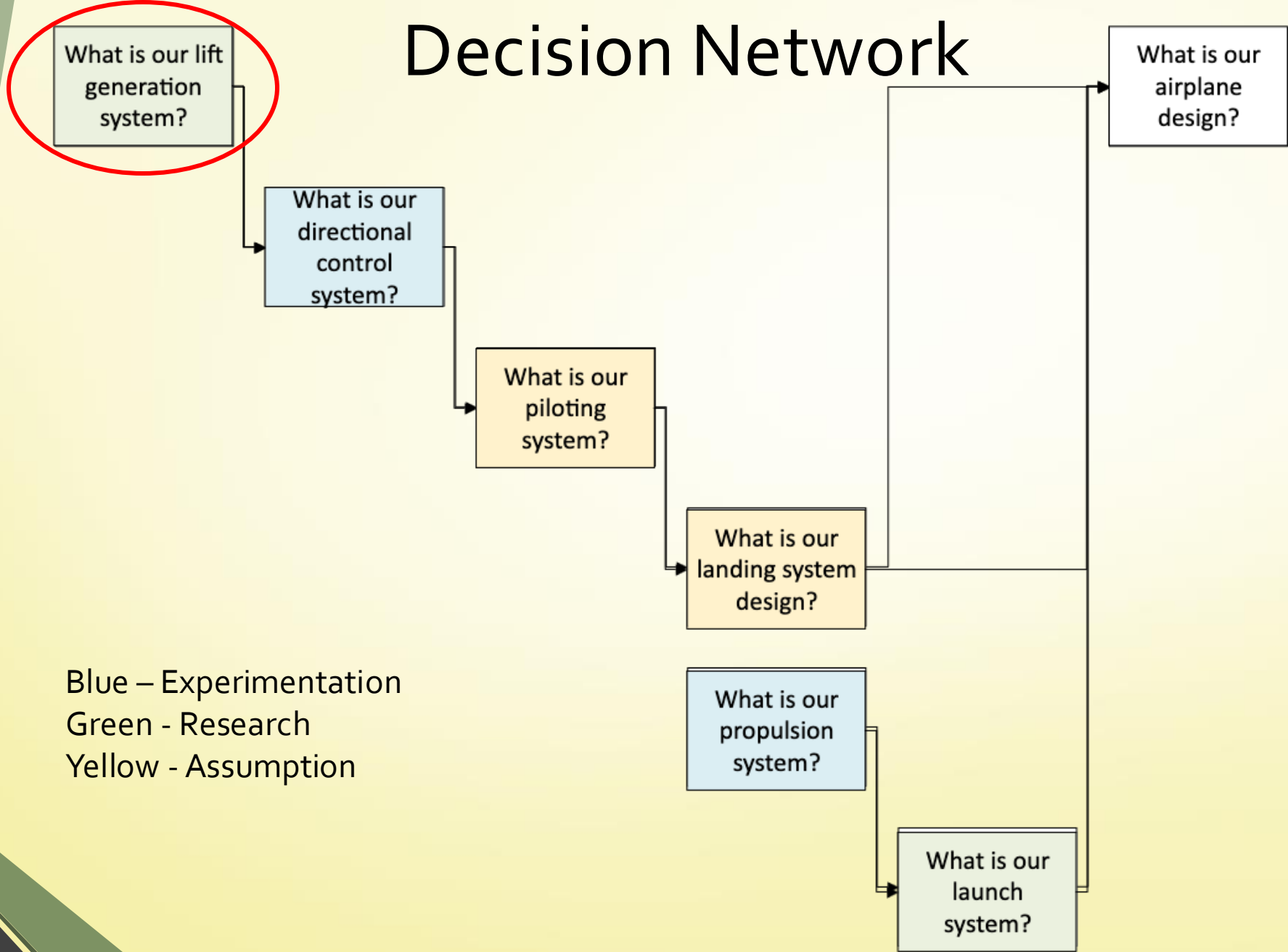
Functional Block Diagram



What did they know? What did they need to learn?

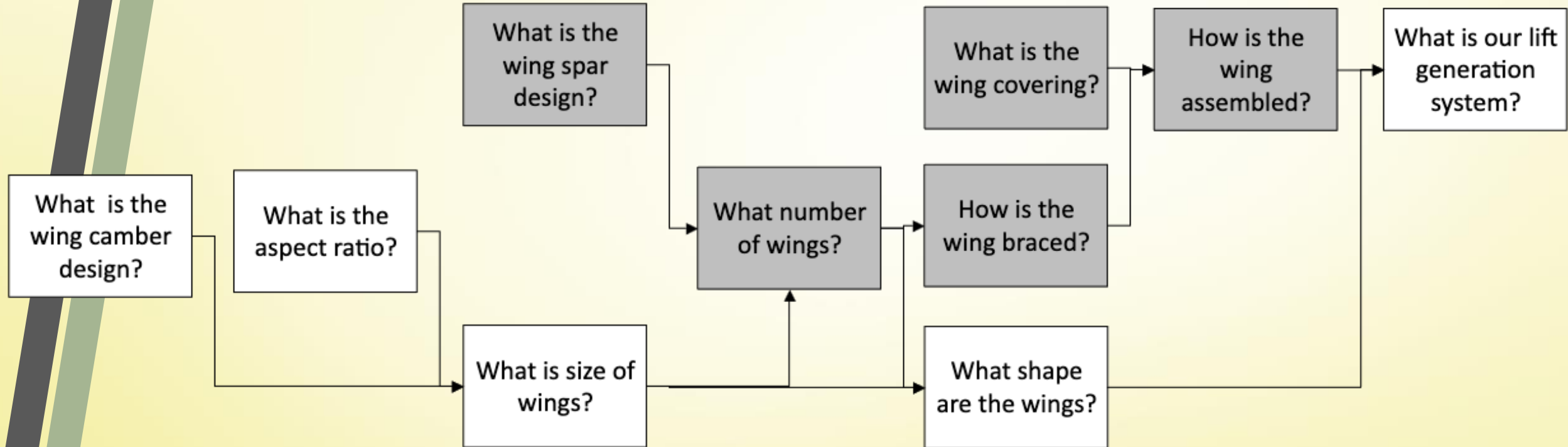


Decision Network



Blue – Experimentation
Green - Research
Yellow - Assumption

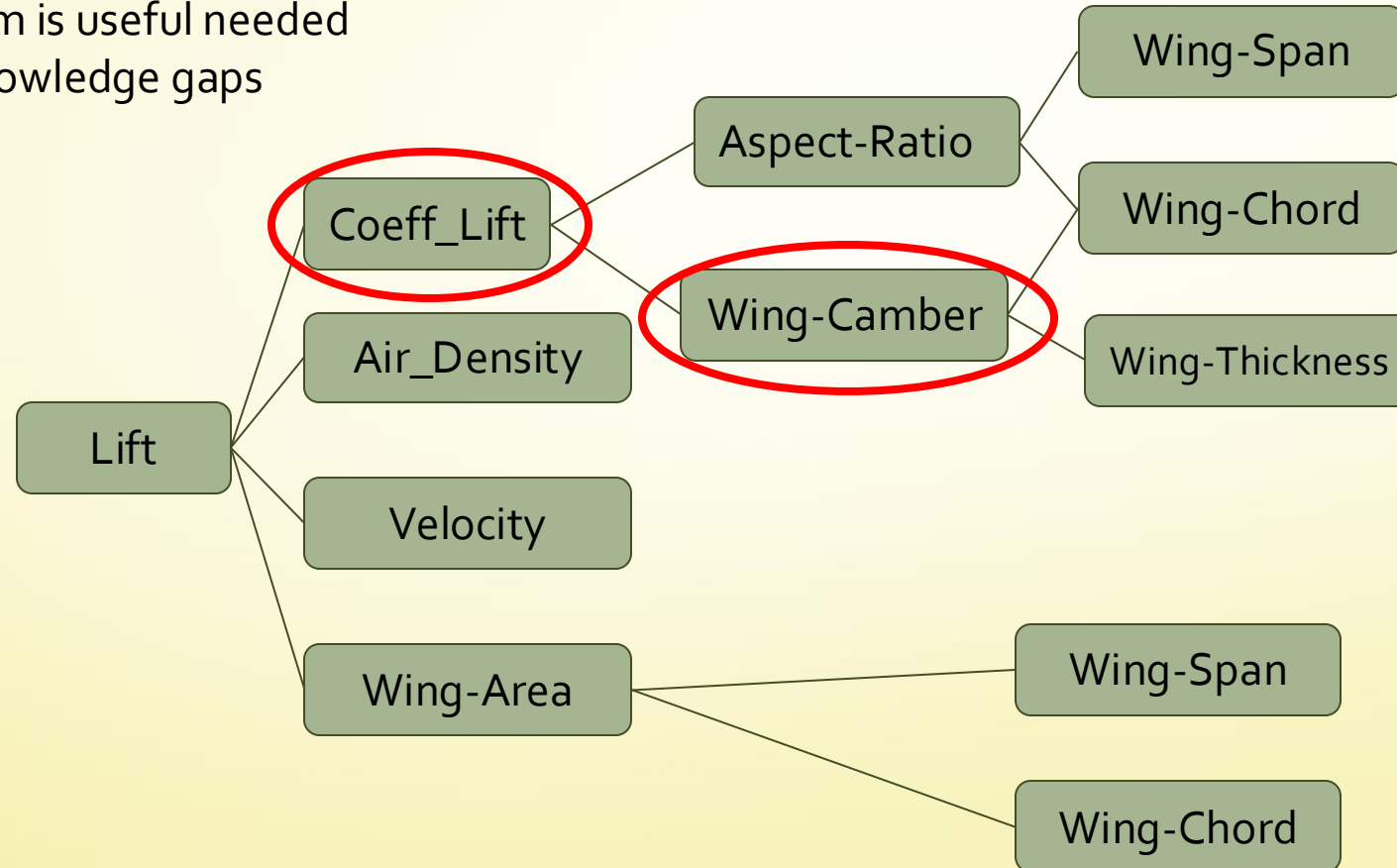
What are the lower tier decisions?



Let's set aside the structural elements, for now, and focus the shape alone...

Causal Diagram

Causal diagram is useful needed to identify knowledge gaps



$$L = C_l * r * 0.5 V^2 * A$$

Knowledge Gaps

LEARNING PLAN

What is the range of thicknesses to test?

What is the range of chords to test?

What is the range of cambers to test?

What is the Coefficient of Drag across the range of cambers?

What is the Coefficient of Lift across the range of cambers?

What is the wing camber design?

Jan

Feb

Mar

Apr

Research & Validation

- The Wrights had data from Otto Lilienthal's pioneering glider flights

Glider	Camber	Performance
1900	1:22	Bad
1901	1:12	Worse
1901 (rev)	1:19	Just Bad, again

- Three data points, three failures
- "Not in a thousand years, will man every fly."

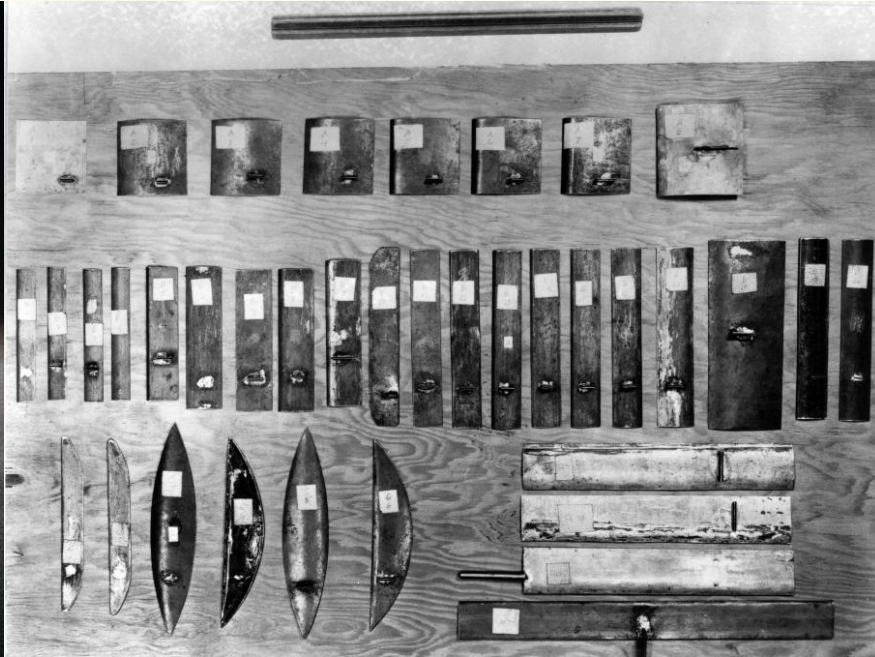
-Wilbur Wright, after 1901 gliding at Kitty Hawk

THE AERONAUTICAL ANNUAL.

TABLE OF NORMAL AND TANGENTIAL PRESSURES
Deduced by Lilienthal from the diagrams on Plate VI., in his book "Bird-flight as the Basis of the Flying Art."

α Angle.	η Normal.	ϑ Tangential.	α Angle.	η Normal.	ϑ Tangential.
-9°	0.000	+ 0.070	16°	0.909	- 0.075
-8°	0.040	+ 0.067	17°	0.915	- 0.073
-7°	0.080	+ 0.064	18°	0.919	- 0.070
-6°	0.120	+ 0.060	19°	0.921	- 0.065
-5°	0.160	+ 0.055	20°	0.922	- 0.059
-4°	0.200	+ 0.049	21°	0.923	- 0.053
-3°	0.242	+ 0.043	22°	0.924	- 0.047
-2°	0.286	+ 0.037	23°	0.924	- 0.041
-1°	0.332	+ 0.031	24°	0.923	- 0.036
0°	0.381	+ 0.024	25°	0.922	- 0.031
+ 1°	0.434	+ 0.016	26°	0.920	- 0.026
+ 2°	0.489	+ 0.008	27°	0.918	- 0.021
+ 3°	0.546	0.000	28°	0.915	- 0.016
+ 4°	0.600	- 0.007	29°	0.912	- 0.012
+ 5°	0.650	- 0.014	30°	0.910	- 0.008
+ 6°	0.696	- 0.021	32°	0.906	0.000
+ 7°	0.737	- 0.028	35°	0.896	+ 0.010
+ 8°	0.771	- 0.035	40°	0.890	+ 0.016
+ 9°	0.800	- 0.042	45°	0.888	+ 0.020
10°	0.825	- 0.050	50°	0.888	+ 0.023
11°	0.846	- 0.058	55°	0.890	+ 0.026
12°	0.864	- 0.064	60°	0.900	+ 0.028
13°	0.879	- 0.070	70°	0.930	+ 0.030
14°	0.891	- 0.074	80°	0.960	+ 0.015
15°	0.901	- 0.076	90°	1.000	0.000

Accelerating Learning

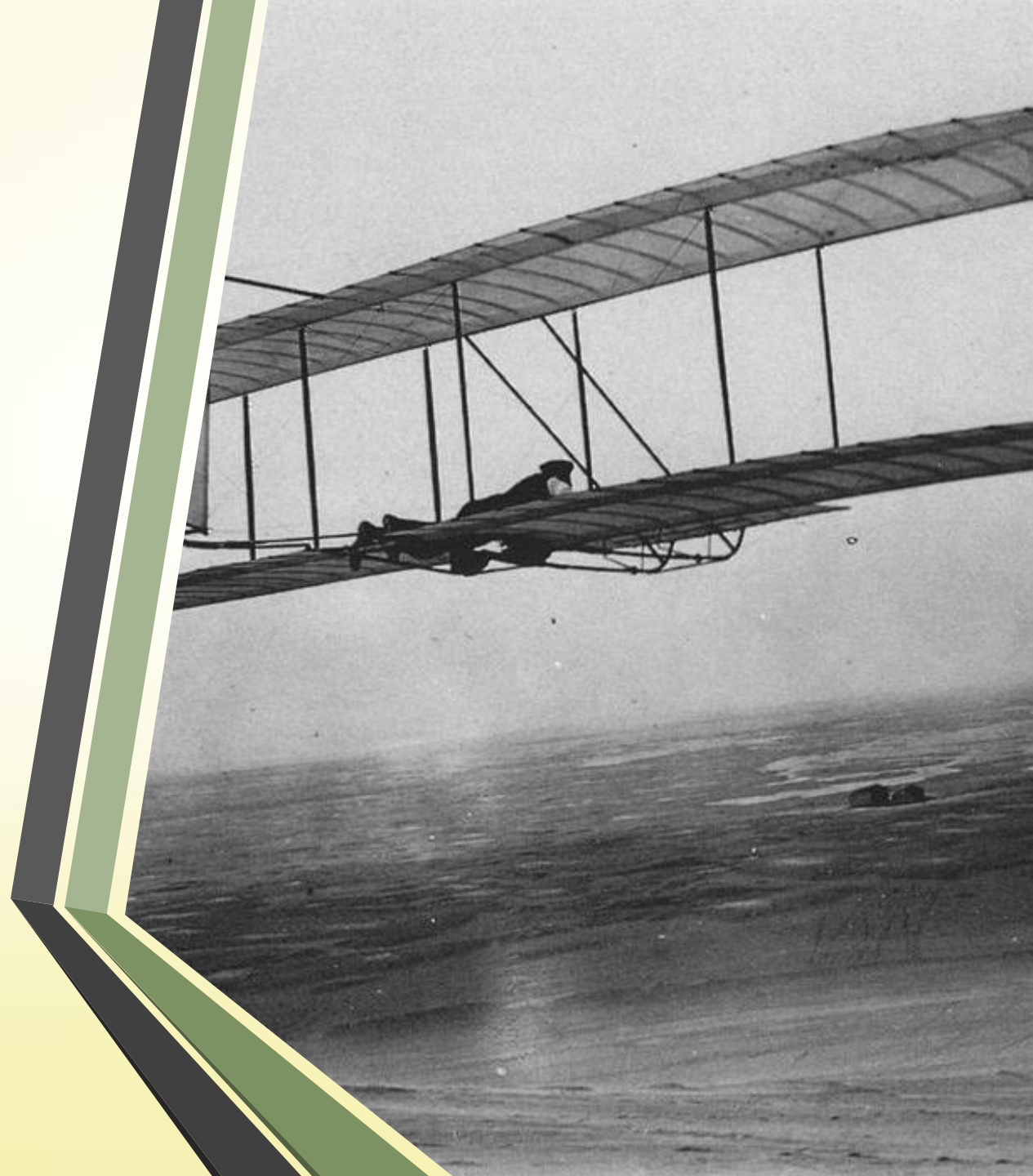


In the Winter 1902:

- Built a wind tunnel
- Invented a lift balance
- Tested 200 shapes
- Collected detailed data on 50 shapes

“Success Assured”

- In many respects, it was the 1902 Glider that was most significant.
- The lift problem was solved.
- Integration testing focused on
 - Learning to pilot
 - Mastering control in all three dimensions
- In 1903, solving for power was straightforward
 - Wind tunnel gave them a highly efficient propellor
 - Which allowed a smaller, lighter engine



Key Takeaways

- Identify sequenced key decisions, knowledge gaps, needed experiments
- Leverage what you know, make some assumptions, understand competence/impact
- Swipe learning from previous research – experiment, understand competence/impact
- Experiment with multiple data points and test to the limits to fill the gaps
- Document Knowledge for Reuse
- This is a key approach to building a learning plan for development of new technology!!

A night-time photograph of the Milwaukee skyline, featuring the Pabst Pavilion and other buildings. The image is overlaid with a semi-transparent dark blue rectangle containing text. The background also features faint digital patterns and light effects.

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Questions???

