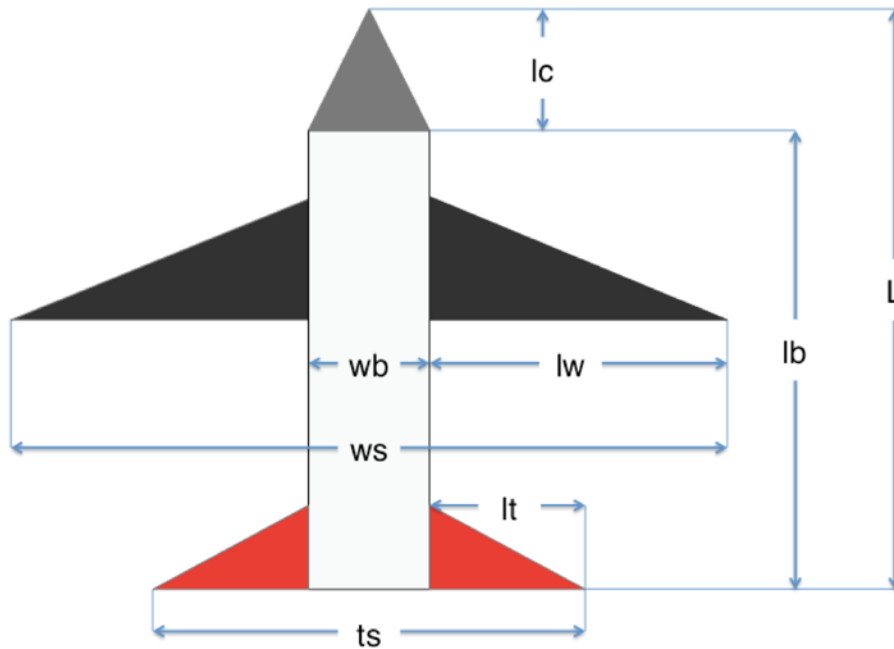




Monica Rossi
monica.rossi@polimi.it
@moni2punto0

Let's design an airplane!

Airplane Dimensions



lb: Length of Body
wb: Width of Body
lw: Length of Wing
lt: Length of Tail
lc: Length of Cockpit

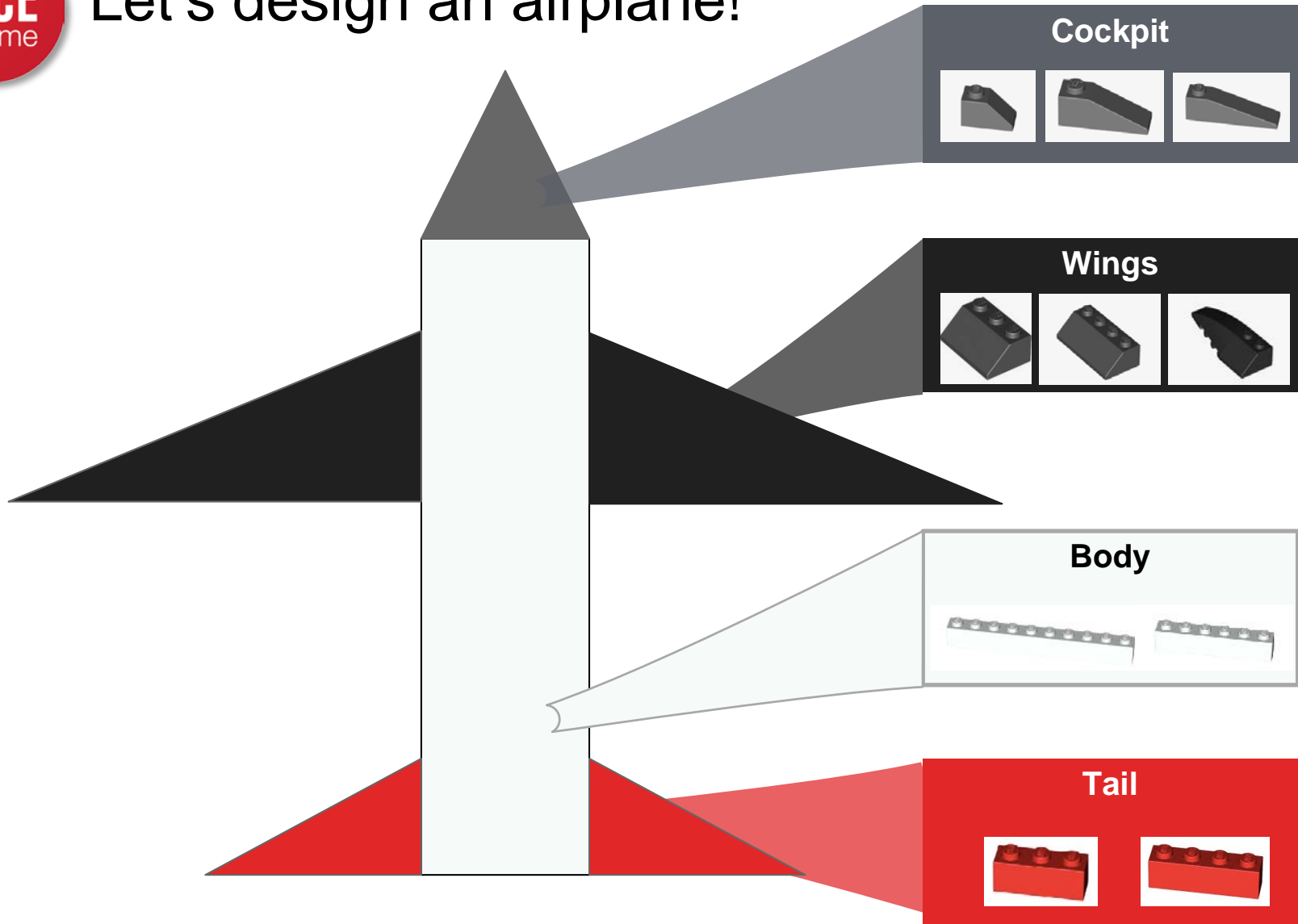
Length of Airplane (L) = Length of Body + Length of Cockpit = lb + lc

*Wing Span (ws) = 2 * (Length of Wing) + Width of Body = 2 * lw + wb*

*Tail Span (ts) = 2 * (Length of Tail) + Width of Body = 2 * lt + wb*

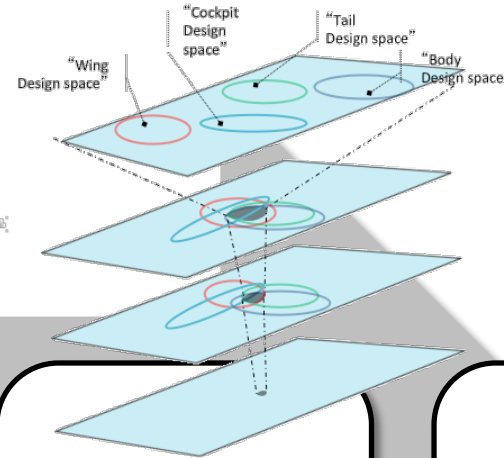


Let's design an airplane!





Introduction to the SBCE Game Session

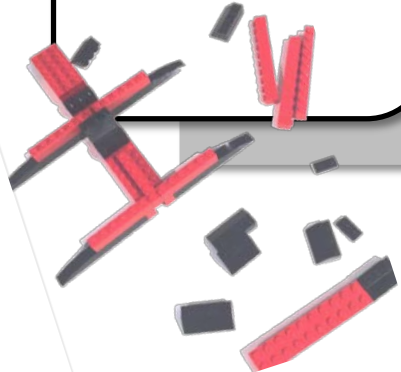


1.
Stage one

2.
Testing

3.
Stage two

4.
Discussion





SBCE Game: Stage 1

Build team &
Form function



Customer and
supplier



Design



Deliver to
testing



Number of tests	Airplane Specifications							Mark
	Body Spec.		Wing Spec.		Tail Spec.		Cockpit Spec.	
	th	th	th	th	th	th		
1								
2								
3								

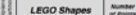










Body

Wing

Tail

Cockpit











CUSTOMER 1		
Ranges	Min	Max
Number of Passengers	91	110
Length of Airplane	10	22
Weight of Airplane	9500	14500
Wing Span	7	20
Tail Span	7	15

Components Specifications		
Category	LEGO Shapes	Number of Points
Body		6
		18
Wing		3
		4
		6
Tail		3
		4
		6
Cockpit		3
		4
		6

Note:
The weight (100 Kg) is not considering a passenger!
The weight of a single passenger is assumed to be 80 Kg. And, only the points in the body should be considered for passengers' weight calculations!



STAGE ONE: Details & Instructions

Airplane Departments	LEGO Shapes	Number of Points
Body		6
		10
Wings		3
		4
		6
Tail		3
		4
Cockpit		2
		3
		4

	Single Point
Capacity	3
Weight	100
Length	1
Width	1

Note:

The weight (100 Kg) is not considering a passenger!

*The weight of a single passenger is assumed to be 60 Kg. And, only the points in the **body** should be considered for passengers' weight calculations!*



STAGE ONE: Details & Instructions

Customer Requirements

Number of Passengers (NP): The number of people an airplane can carry during a flight

NP = Number of Points on Body * Defined Number of Seats for each Single Point (equals to 3)

Weight (W): Total weight of airplane

W = Weight of Airplane (wa) + Weight of Passengers (wp)

wa = Weight of Body (wb) + Weight of Wings (ww) + Weight of Tails (wt) + Weight of Cockpit (wc)

wp = NP * Average Weight of every Person (Considered as 60 Kg)

Length of Airplane (L)

Wing Span (Ws)

Tail Span (Ts)

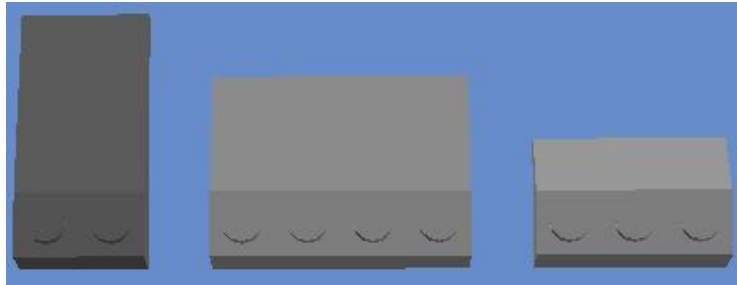
CUSTOMER 1

Ranges	Min	Max
Number of Passengers	91	110
Length of Airplane	10	22
Weight of Airplane	9500	14500
Wing Span	7	20
Tail Span	7	15

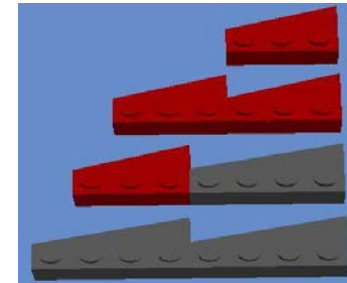


STAGE ONE: Details & Instructions

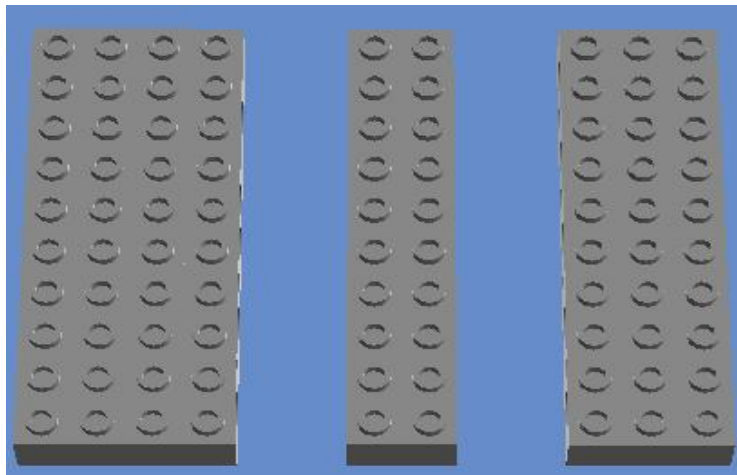
LEGO Components Combination



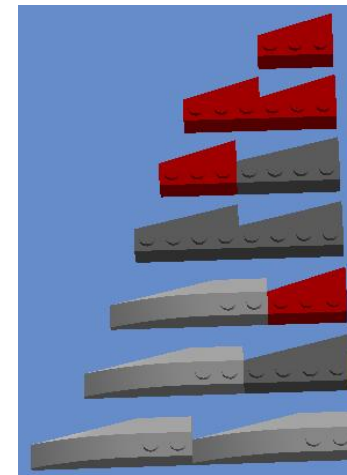
Cockpit
Combinations



Tail
Combinations



Body
Combinations



Wing
Combinations



STAGE ONE: Details & Instructions

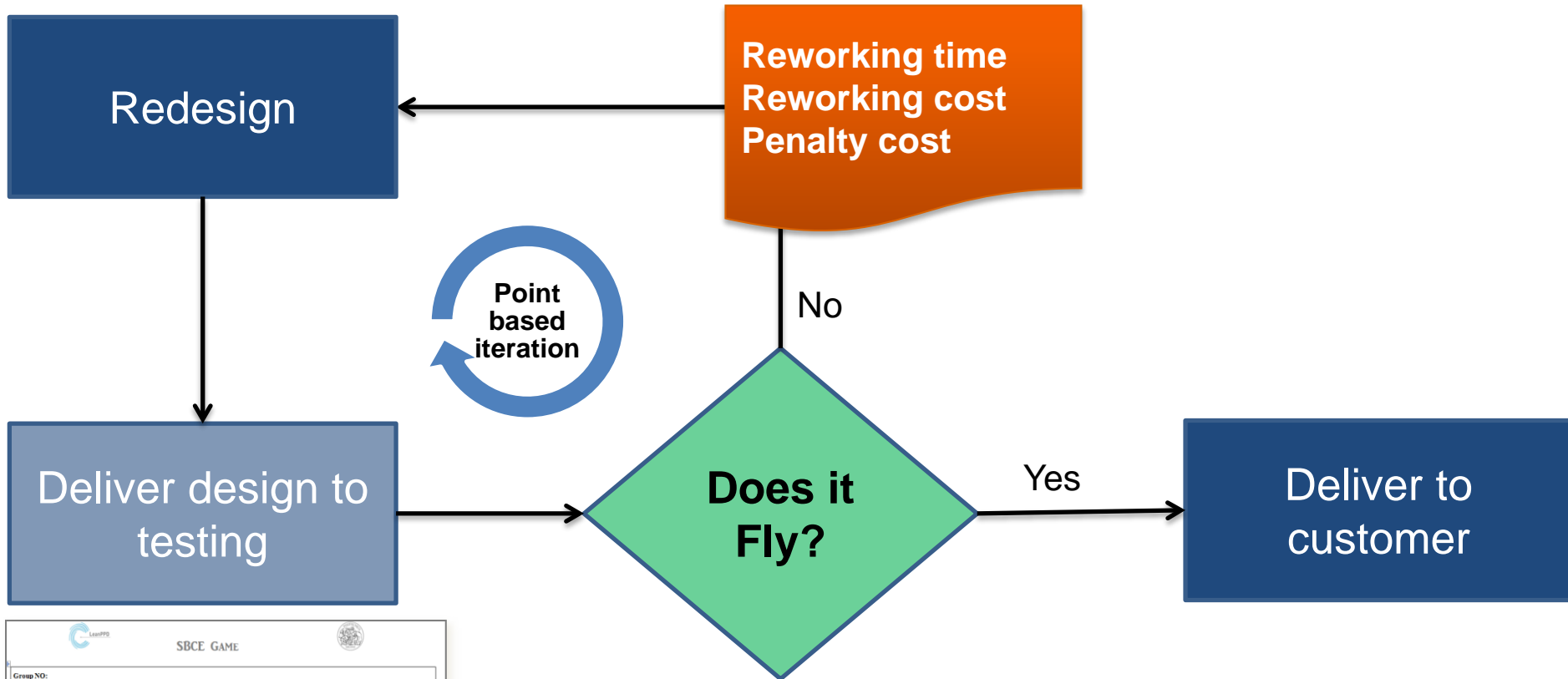
LEGO Joints




Joint for connecting the components
of your airplane.



Testing



<div>SBCE GAME<div></div></div>									
Group NO:									
Number of trials	Airplane Specifications								Status
	Body Dep.		Wing Dep.	Tail Dep.	Cockpit Dep.		Starting time	Finishing time	
	<u>lb</u>	<u>wb</u>	<u>hw</u>	<u>lt</u>	<u>lc</u>	<u>wc</u>			
1									
2									
3									
4									
5									



Before we start Stage 2...

LET'S TELL A STORY



imagine...

*the opportunity to develop a
world changing product or
solve a vexing problem...*

- Benefit to society beyond imagination
- Fame
- Fortune
- Immense personal satisfaction



but failure means...

- Possible financial ruin
- Injury or death to you or a family member
- Others have tried, failed and met these consequences.

How would you proceed?

Two brothers met the challenge...

The Challenge: manned, controlled, and powered heavier-than-air powered flight

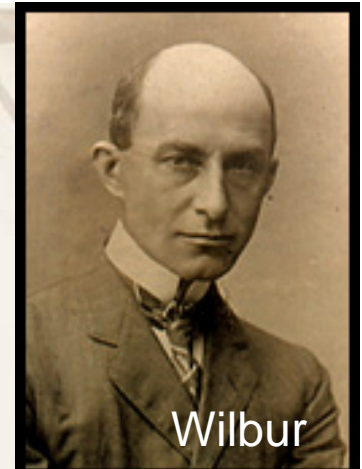
When: **1899 -1903**

Where: **Dayton, Ohio USA**

- rural
- farming

Who: ***Wilbur & Orville Wright***

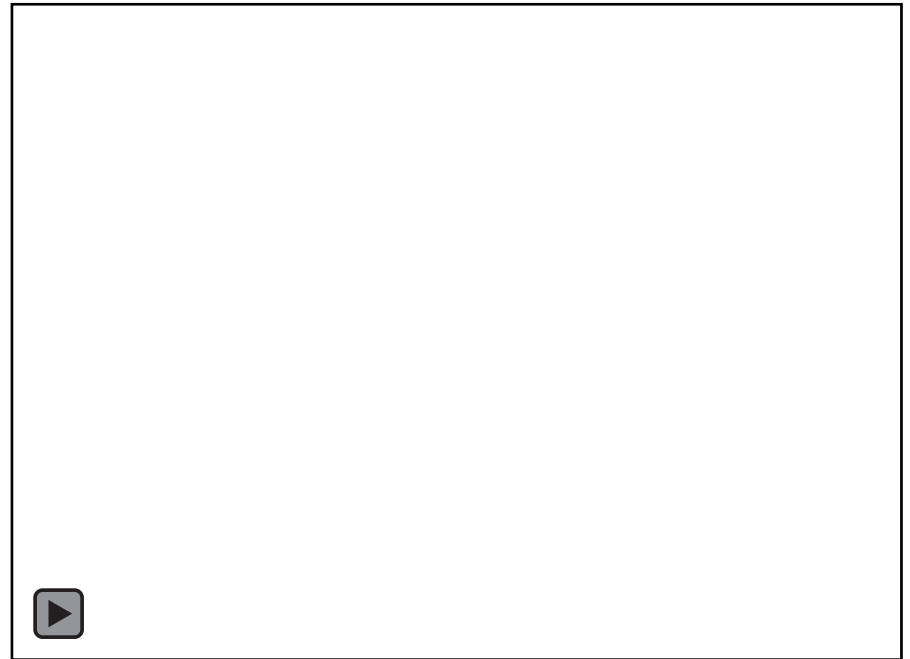
- high school education
- bicycle sales & repair





Others tried and failed...

- many previous attempts had ended catastrophically
- many concurrent efforts
 - Langley (USA)
 - Chanute (USA)
 - Pearse (New Zealand)
 - Jatho (German)
 - Whitehead (USA)
 - Kress (Austrian)
 - Others
- most were:
 - better educated
 - better funded



Why were the Wright brothers successful, and What can we learn from them?





They began by Observing

- Most other investigators were spending **thousands of hours designing** their aircraft and **5 seconds testing** it...
(before it crashed and usually killed them).
- They did not believe this was a sensible approach, so they focused their efforts on methods of **experimentation**:

“We thought that if some method could be found by which it would be possible to practice by the hour instead of by the second there would be hope of advancing the solution of a very difficult problem...and without any serious danger.”

Wilbur Wright

...and began experimenting.

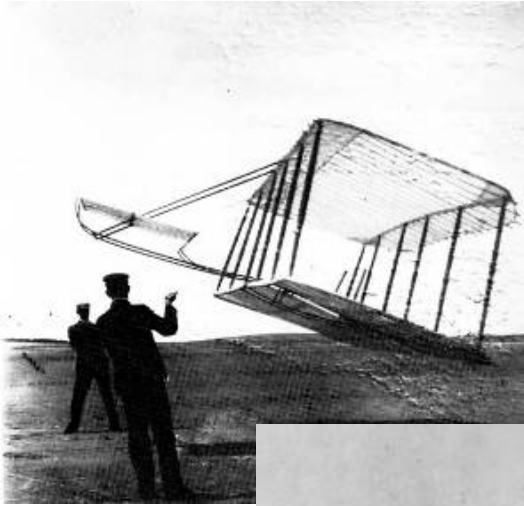


They focused their experiments

- They identified three critical knowledge gaps that need to be closed for successful flight:
 - Lift
 - Control
 - Propulsion
- They focused on each independently – and nothing else until all were closed.



before designing plane, conducted 1000's of tests...

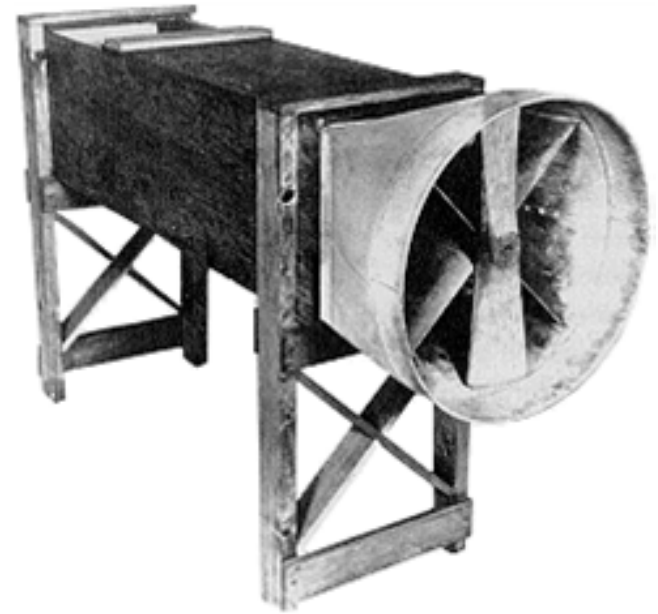


scaled kites



wind tunnel
with airfoil
models

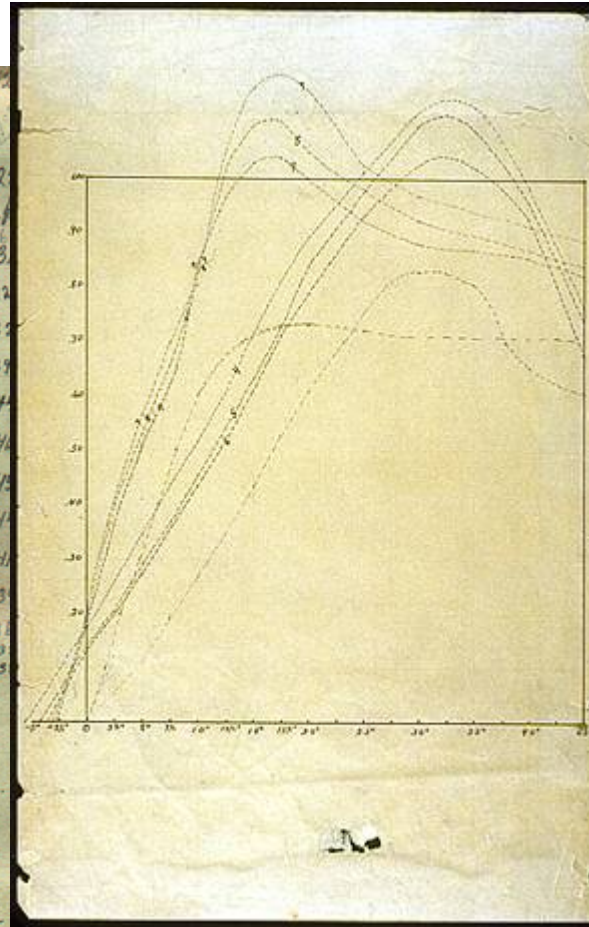
manned
gliders



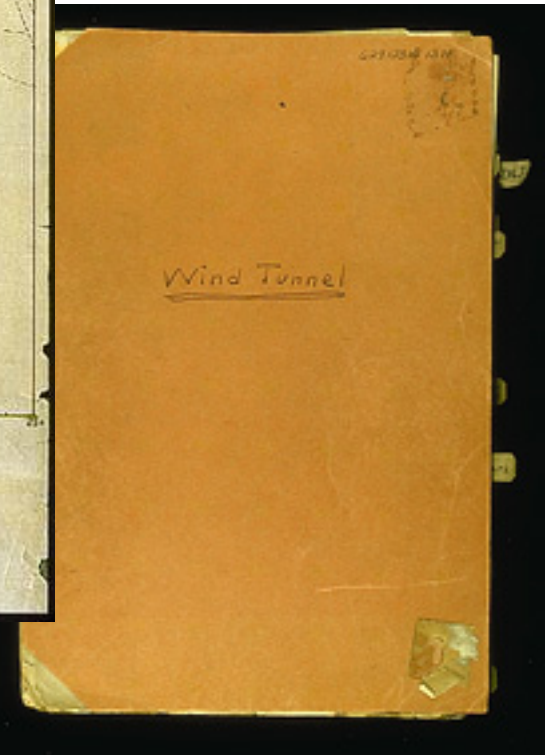
meticulously recorded results...

	1	2	3	4	5	6	7	8	9	10	11	12
0°	0	0	0	5 1/2	4 1/4	3 1/2	3	2 3/4	2 1/4	3	2 3/4	2
2 1/2°	2 1/4	5 1/2	7 1/4	11 1/2	8 3/4	8 1/2	17 1/2	17 1/2	15 1/4	18 1/4	16 1/4	13
5°	4 3/8	11 1/2	13 3/4	15	12 3/4	10 3/4	25	23 1/2	22 1/2	26 1/2	25	22
7 1/2°	8	17 1/4	20 1/4	18 1/4	16	15 1/2	31 1/2	29 1/2	27 3/4	33 1/2	32	32
10°	11 1/2	22 1/4	27	22 3/4	19 1/2	19	38 1/2	39	37	35 1/2	37	39
12 1/2°	14 3/4	27 1/2	36 1/4	27	24	22 3/4	52	49 3/4	46 1/2	35 1/2	37	44
15°	19	31 1/4	32	32 1/2	28 1/4	27 1/4	61	55 1/2	53 1/2	38	35 1/4	44
17 1/2°	23 1/4	32	32 1/2	37 1/2	38	32 1/4	63 1/2	56 1/4	51	39	41 1/2	45
20°	27	33 3/4	33 3/4	42	39	36 1/4	60 1/2	52	48 3/4	41	42	44
25°	34 1/2	38 1/2	32 1/2	49 1/2	47	44 1/2	50 1/2	47 1/2	44	44 1/2	41 1/2	41
30°	38 1/4	32	32 1/2	57 1/2	54 1/2	49 1/2	46 3/4	44	41 1/2	41	39 1/4	3
45°	27	27	32 1/2	35	38 1/2	30 1/2	41 1/2	39 1/4	36 1/4	38 1/4	37	31
60°	27 1/4	30	32 1/2	54 1/2	53 1/2	50 1/2	45	42 1/4	40 1/4	37 1/4	38 1/2	3
75°	28 1/2	28	32 1/2	47 1/2	40	38 1/2	43 1/2	41	40	39	38 1/2	3
90°	32 1/2											
Normal												
25°	518											
30	993											
36	993											
45	951											
70	869											

Preliminary Tests



in notebooks with tables and graphs





Between May 1900 and December 1903 (very intermittent, part-time effort)

- **Discovered**

- lift and drag calculations others were using were incorrect
- optimum wing shapes and control surfaces
- there was no production engine with adequate power and low enough weight

- **Invented**

- a wind tunnel / mechanisms for measuring lift and drag
- wing warping technology for controlling plane in flight
- a highly efficient propeller (even by today's standards)
- a lightweight engine
- the science of aeronautics



Comparison of Approaches

	Samuel P. Langley	Wright Brothers
Time Invested	~17 years	~22 months over four years
Money Invested	~\$70,000	~\$1,000
Approach	<i>Design Build Test Repeat</i>	<i>Test & Experiment Repeat until feasible Design Build</i>
Result	Airplane never flew	1st Design Successful



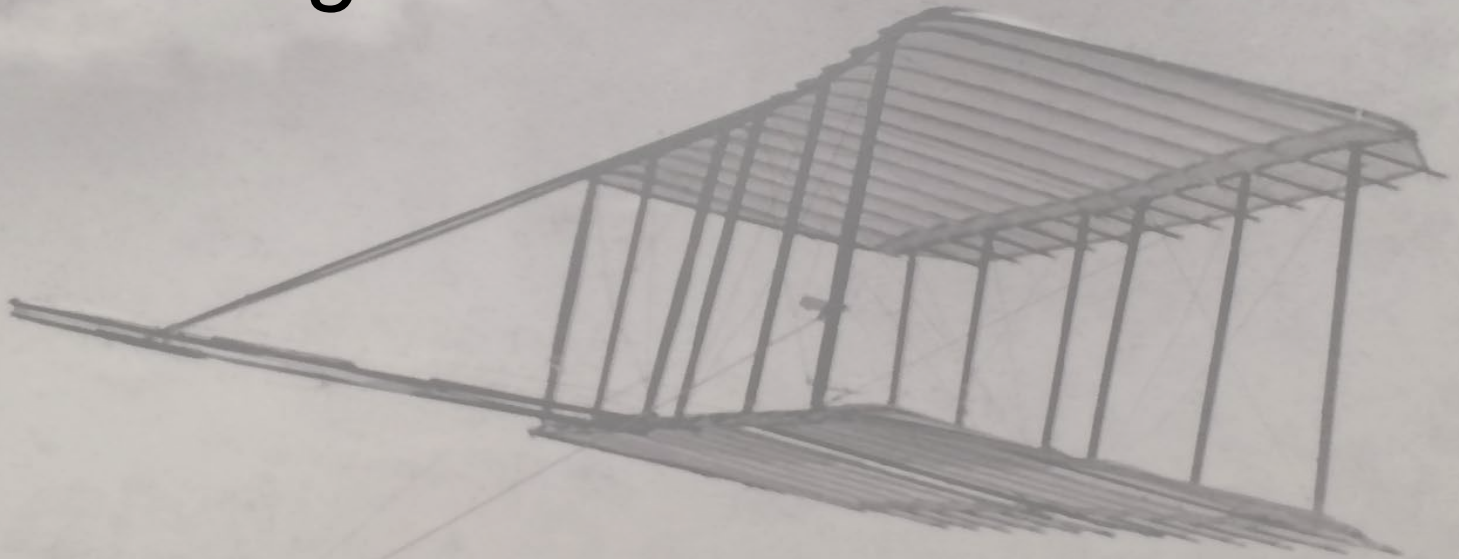
Lessons from the Wright Brothers

- Began with deep, thorough, extensive **observation**.
- Identified the key **knowledge gaps** and turned their focus to just those.
- Set an **objective**, but **not the solution**.
- **Tested** extensively using **rapid prototyping** of **alternative components and subsystems** (not the whole plane) to discover **limits** and **trade-offs**.
- The **plane design came last** – an integration of the knowledge gained from observation and testing.



The Bottom Line

The Wright brothers **learned** what they needed to be successful *before deciding* on a solution.





Let's learn before designing then...

LET'S START STAGE 2!



SBCE GAME – STAGE TWO

Integrate customer value and Explore sub-system alternatives



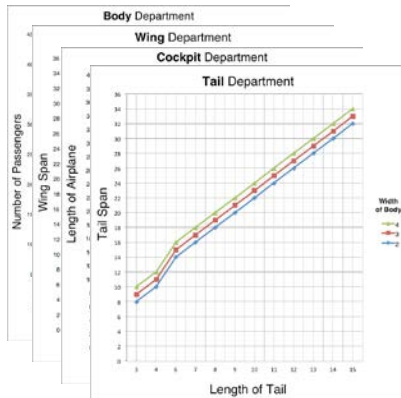
Map design space and integrate



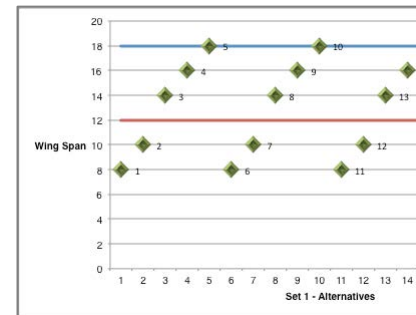
Eliminate inferior design



Converge to optimal design



Department	Dimensions	Possible Design Alternatives		
		Width of Body		
		2	3	4
BODY	Length of Body			
COCKPIT	Length of Body			
WINGS	Length of Wings			
TAIL	Length of Tail			





SBCE GAME – STAGE 2

Customer Requirements

Ranges	Min	Max
Number of Passengers	91	110
Length of Airplane	10	22
Weight of Airplane	9500	14500
Wing Span	7	20
Tail Span	7	15



SBCE GAME – STAGE 2

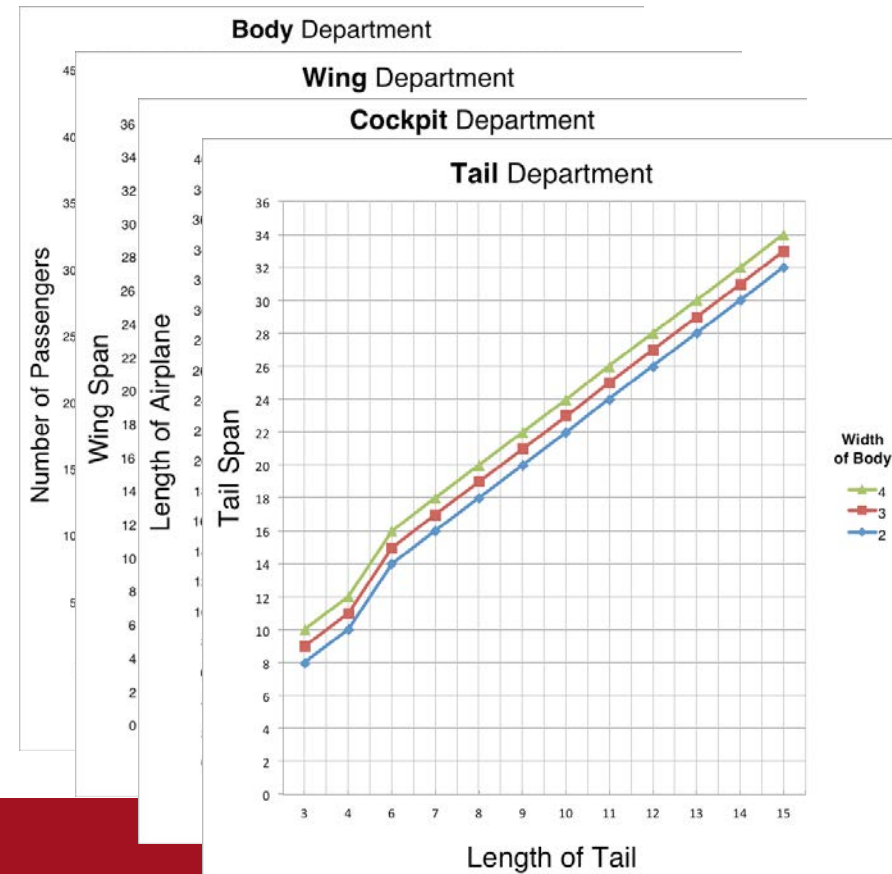
Customer Requirements

1

Ranges	Min	Max
Number of Passengers	91	110
Length of Airplane	10	22
Weight of Airplane	9500	14500
Wing Span	7	20
Tail Span	7	15

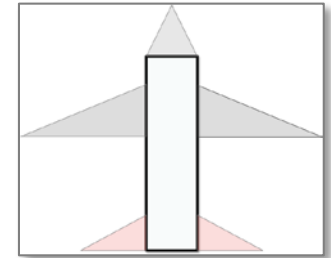
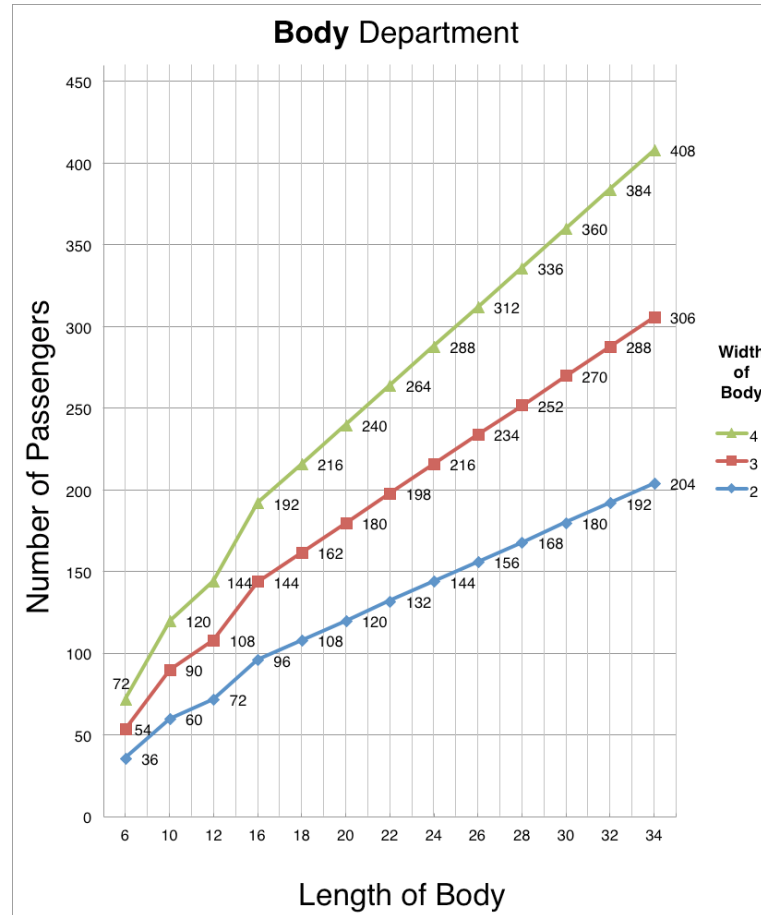
2

Trade-off Curves







SBCE GAME – STAGE 2

Trade-off curve BODY DEPARTMENT



SBCE GAME – STAGE 2

Define your design space

Department		Dimensions	Possible Design Alternatives		
			Width of Body		
			2	3	4
BODY		Length of Body			
COCKPIT		Length of Body			
WINGS		Length of Wings			
TAIL		Length of Tail			

SBCE GAME – STAGE 2

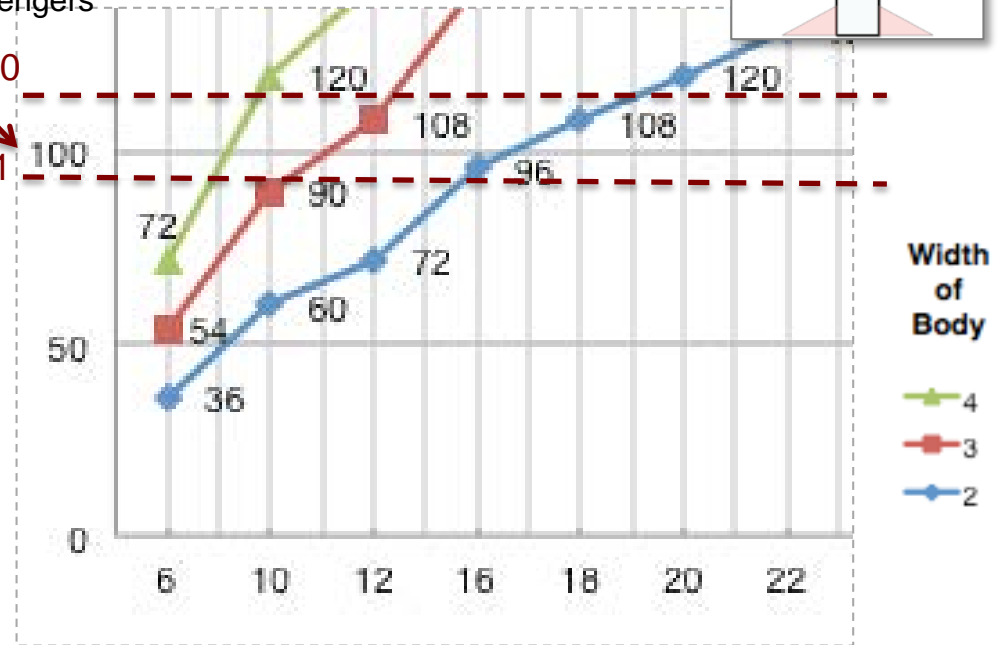
CUSTOMER 1

Ranges	Min	Max
Number of Passengers	91	110
Length of Airplane	10	22
Weight of Airplane	9500	14500
Wing Span	7	20
Tail Span	7	15

Trade-off curve
BODY DEPARTMENT

Number of Passengers

110
91



Length of Body

SBCE GAME – STAGE 2

Customer Requirements

Ranges	Min	Max
Number of Passengers	91	110
Length of Airplane	10	22
Weight of Airplane	9500	14500
Wing Span	7	20
Tail Span	7	15





1

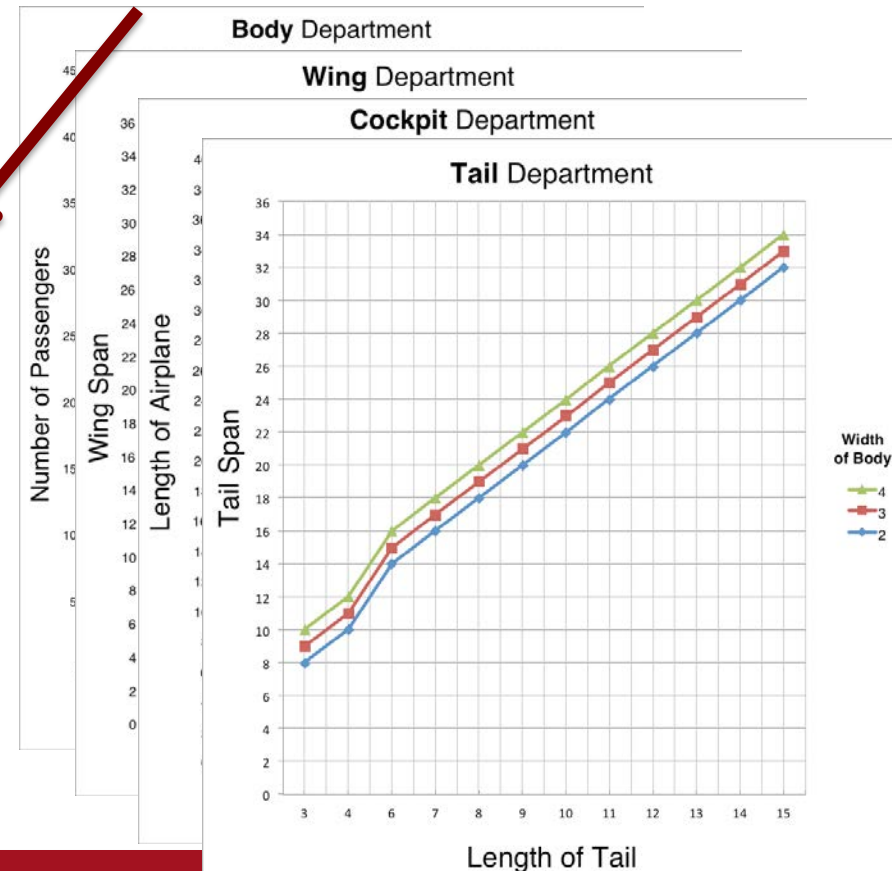
2

Trade-off Curves

3

Design Space

Department		Dimensions	Width of Body		
			2	3	4
BODY		Length of Body			
COCKPIT		Length of Body			
WINGS		Length of Wings			
TAIL		Length of Tail			



SBCE GAME – STAGE 2

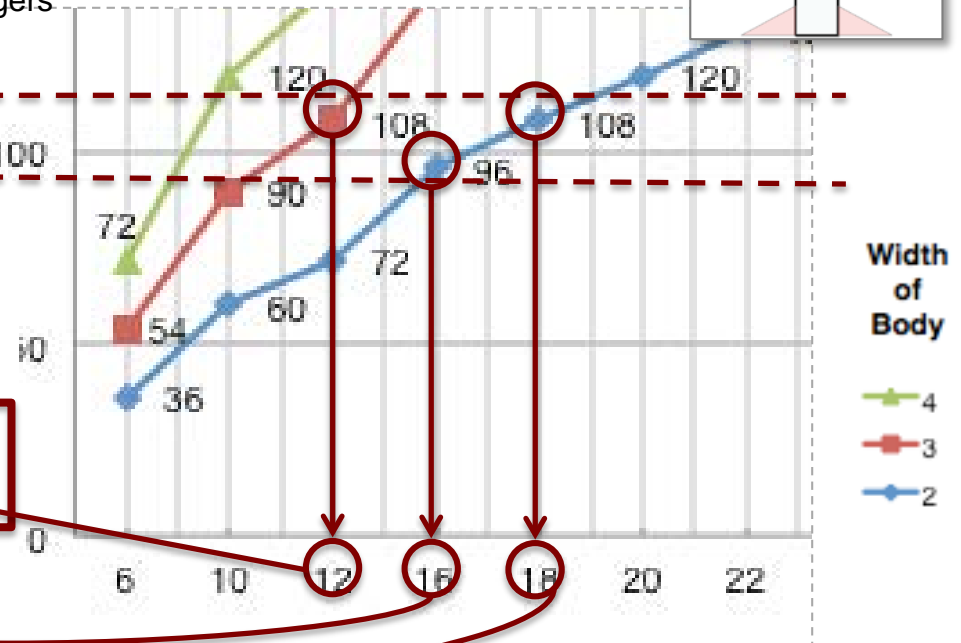
CUSTOMER 1

Ranges	Min	Max
Number of Passengers	91	110
Length of Airplane	10	22
Weight of Airplane	9500	14500
Wing Span	7	20
Tail Span	7	15

Trade-off curve BODY DEPARTMENT

Number of Passengers

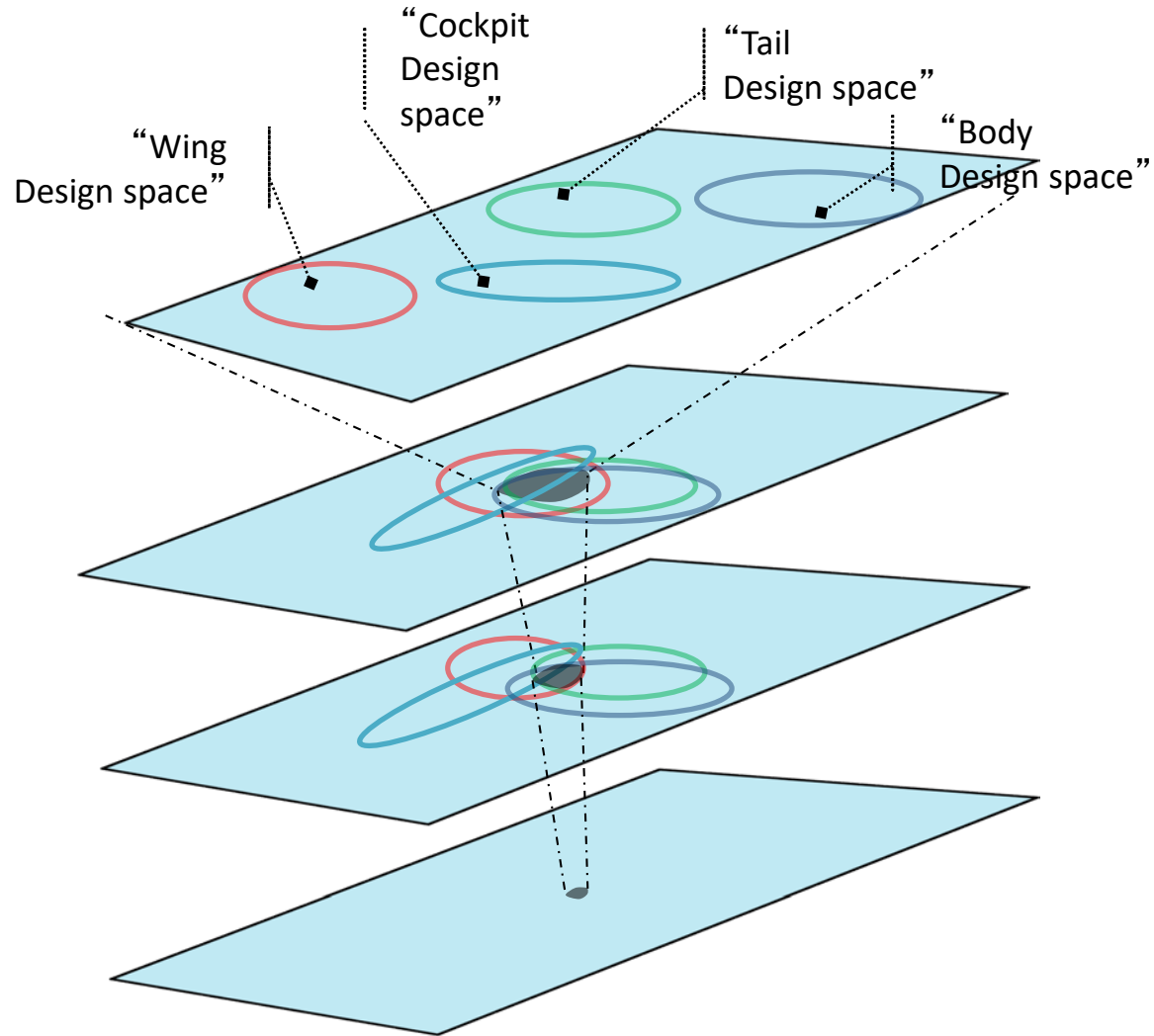
110
91



Length of Body

Department	Dimensions	Possible Design Alternatives		
		Width of Body		
		2	3	4
BODY	Length of Body	18 16	12	X
COCKPIT	Length of Body			X
WINGS	Length of Wings			X
TAIL	Length of Tail			X

Set-Based Concurrent Engineering

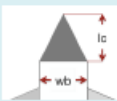
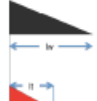






SBCE GAME – STAGE 2

Team Name:

Customer #:

# Opt.	# Set	Length of Body (lb)	Width of Body (wb)	Length of wings (lw)	Length of tail (lt)			 ($2/3L \leq ws < L$)			 ($Rw < 1.25$)					
						$wb=lc=wc$	$lw \geq lt$	$2/3L$	ws ($2*lw+wb$)	L ($lb+lc$)	Check C_3	P_{body} ($lb*wb$)	P_{rest} ($(lw+lt)*2+lc^2$)	Rw (P_{body}/P_{rest})	limit value	Check C_4
1															1.25	
2															1.25	
3															1.25	
4															1.25	
5															1.25	
6															1.25	
7															1.25	
8															1.25	
9															1.25	
10															1.25	
11															1.25	
12															1.25	
13															1.25	
14															1.25	
15															1.25	
16															1.25	
17															1.25	

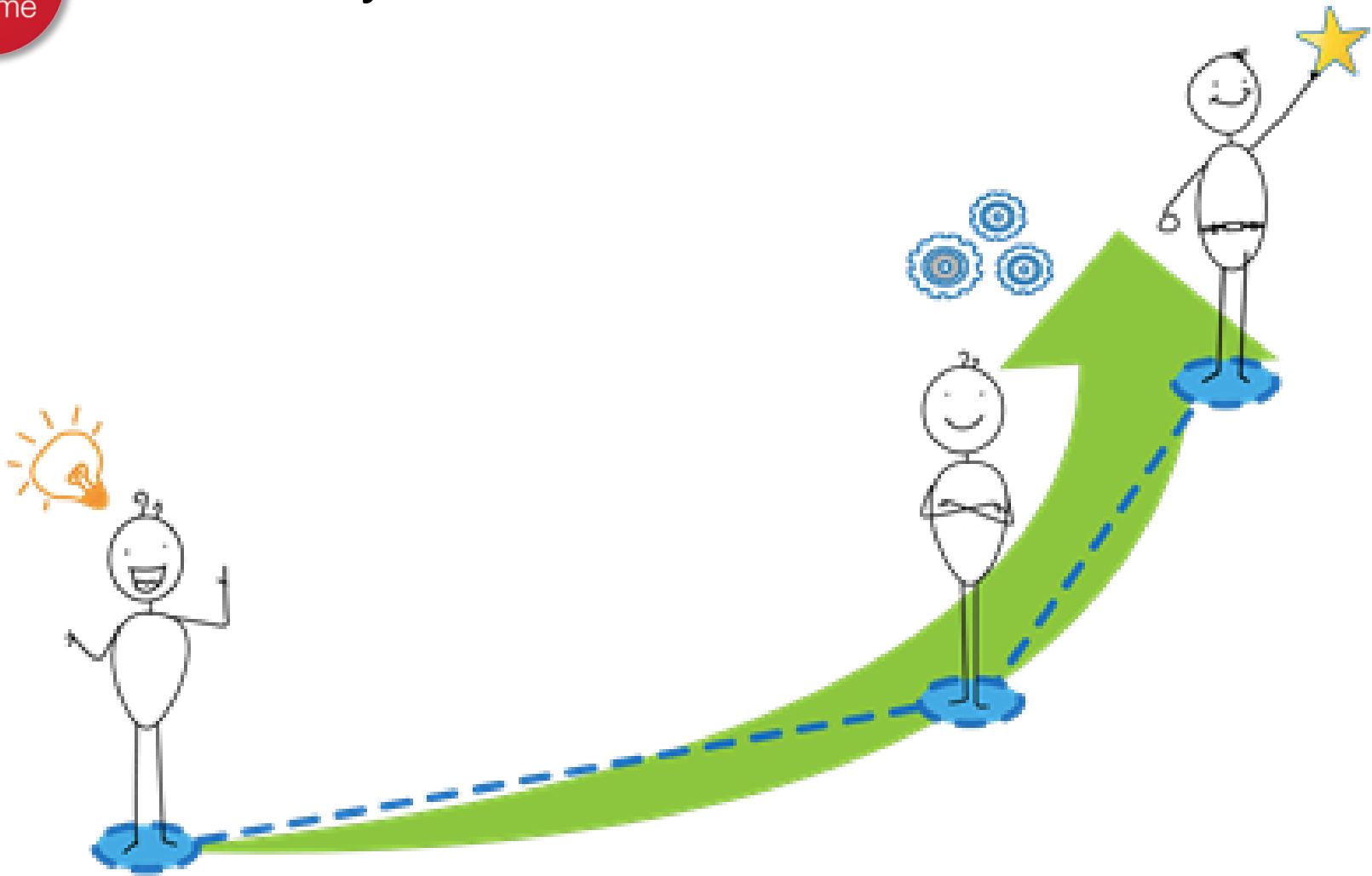




Stage 2 Summary of Instructions

1. According to the **customer requirements**, find different design alternatives from the curves and fill your **design space sheet**.
2. Share your alternatives and fill the Possible Design Alternatives Sheet together. Some of you might **not have common alternatives!**
3. Using **template sheets**, try to create sets of possibilities. Each **set** represents a number of combinations which are using **same «lb» and «wb»**.
4. Narrowing the possible solutions by using given **constraints/limit curves**.
5. Optimum solution can be found by comparing **development time** and **cost** of feasible solutions.
6. **LEGO** your optimum solution!

What did you learn?





Lessons Learned -Phase 1-

(Answer some of these) Questions?

- Which **strategy** did you follow?
- Which was the main **challenge** you faced?
- What did you do **wrong**?
- Were you **successful**? Why?
- Do you know **how many options** you have, if any?
- Was it **difficult**? Why?
- How would such a behavior **impact product development**? (*Time, cost..*)
- *Further comments...*



Lessons Learned –Phase 2-

(Answer some of these) Questions?

- Do you know **how many options** you have, if any?
- Was it **more difficult/easy**? Why?
- Which are the **main differences** with Phase 1?
- How would such a behavior **impact product development**? (*Time, cost..*)
- What if you have to satisfy a **different customer**?
- Why do you think is important to have/use/reuse **formal knowledge** (e.g. *Trade off curves*)?
- *Further comments...*

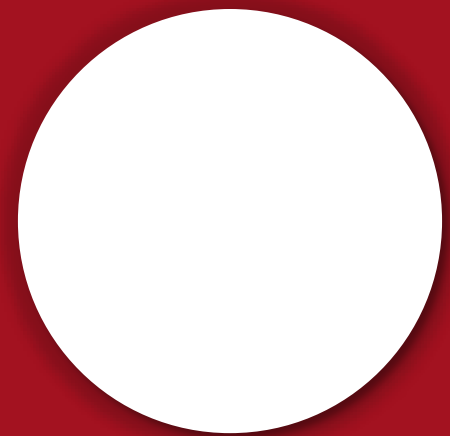
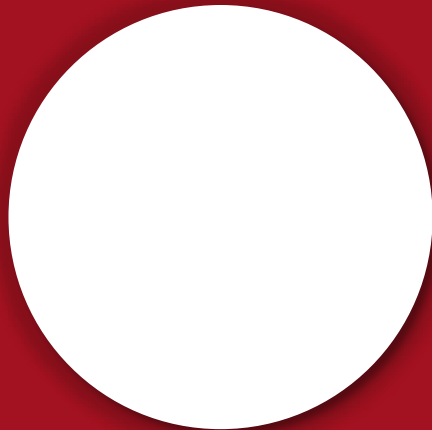


Learning Objectives

- Demonstrate the challenges of **meeting customer and design requirements**
- Introduce the **concept of SBCE** and its application to design management
- Demonstrate the importance of **common tools** and **leanPD enablers** used to execute SBCE process (**Trade-off curves & Limit curves**)
- Demonstrate the importance of proper **Knowledge Management** initiatives

Thank You!

<http://www.sbcegame.polimi.it>



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