Presented by

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Future Projects Airbus France

Why do all airplanes look the same ?

Colloque JBHU 2010

AIRBUS

A Children Question :


Airbus A320 (1988)


Airbus A330 (1992)


Boeing 777 (1995)


Embraer 190 (2004)

Even if Some side steps occurred along the ~~gradient~~ glide path,

none of them have been selected by new projects.


Lockheed TriStar (1972)


Airbus A340 (1991)


Airbus A380 (2005)


Boeing 787 (2011 ?)


Bombardier C series (2013 ?)


Mitsubishi MRJ90 (2013 ?)

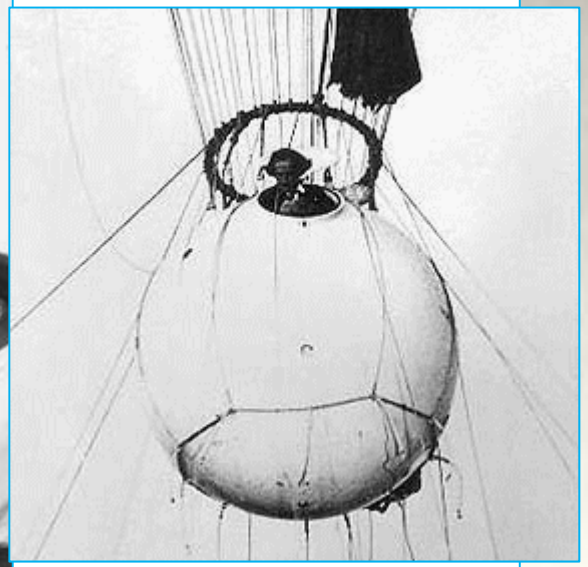

Airbus A350 (2013 ?)

- In the domain of passenger air transport, a big majority of aircraft manufacturers are adopting the so called classical configuration to design their future products.
- It seems that it is not only a fashion but the result of a technical convergence which leads to some sort of topological optimum of the general arrangement of the aircraft.
- Finding a real global optimum of a system as complex as a passenger transport aircraft is not so obvious and deserves some explanations.

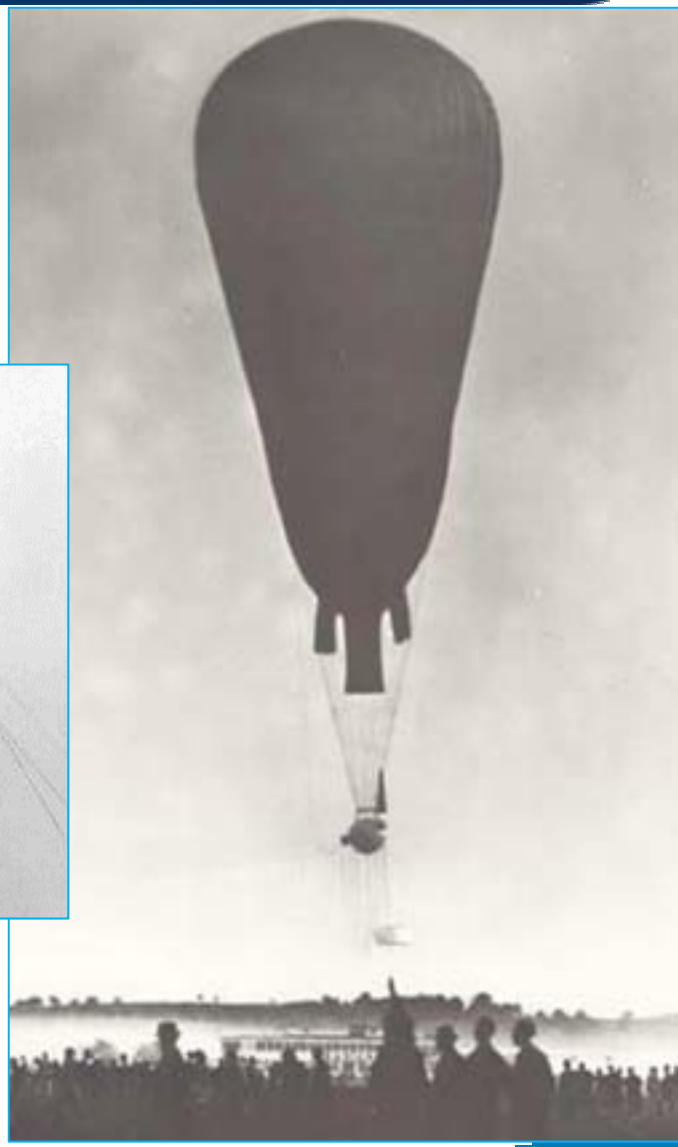

Boeing 737 (1965)

Best shape for pressurisation

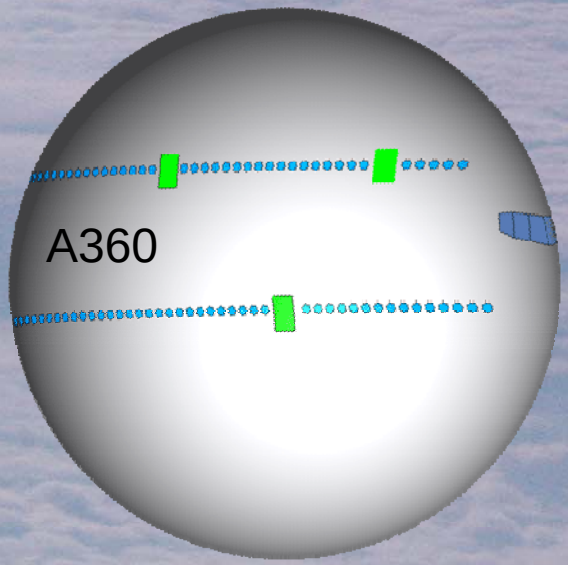
- The Best way to package a payload at high altitude



Auguste Picard (1932)



But how to fly it ?



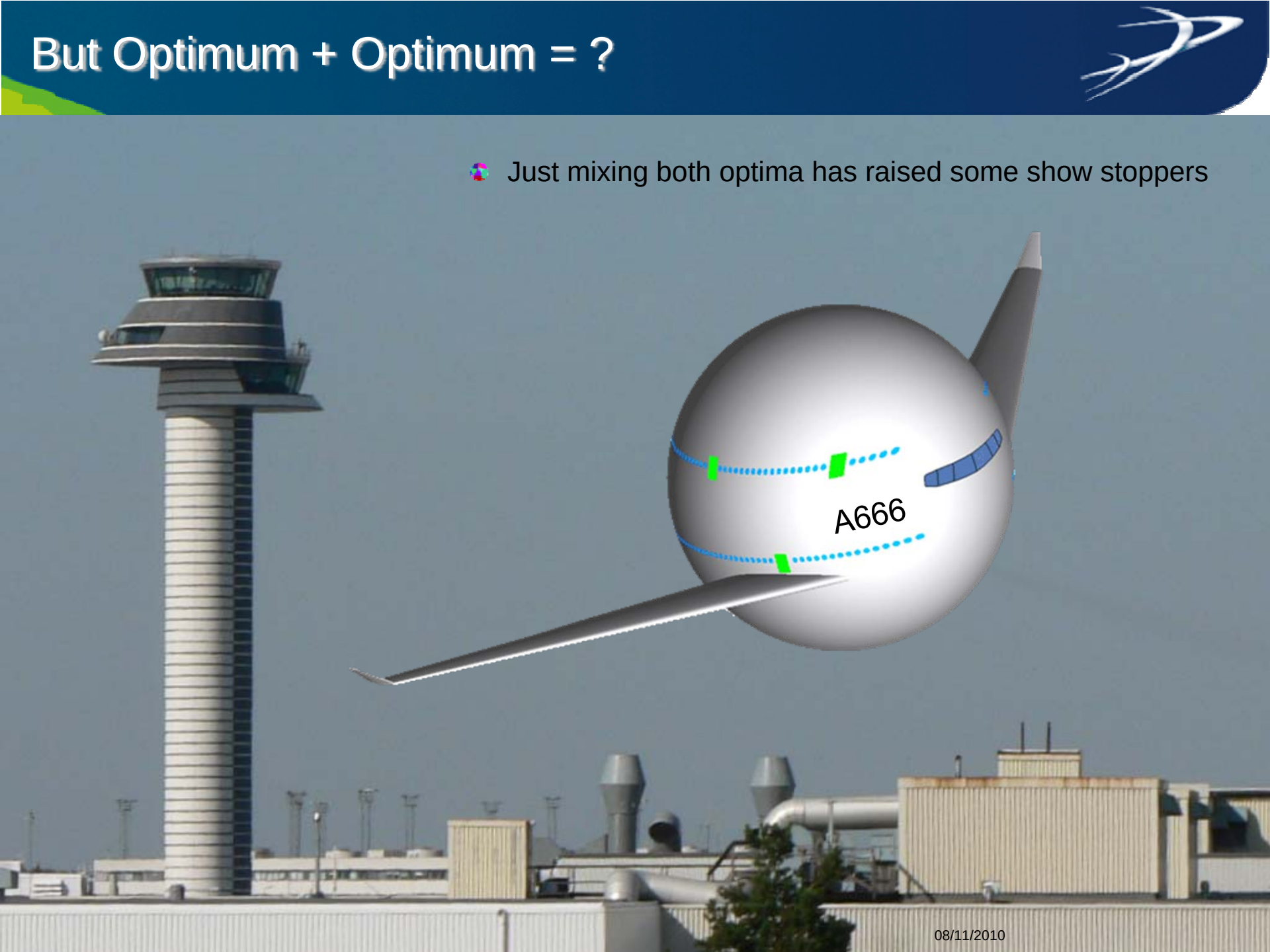
- Unfortunately, it appeared that this could not fly without antigravity system which is not yet “off the shelf”

Best shape for lift

- The best way to use velocity in order to produce lift

But Optimum + Optimum = ?

- Just mixing both optima has raised some show stoppers



Main problem : interactions

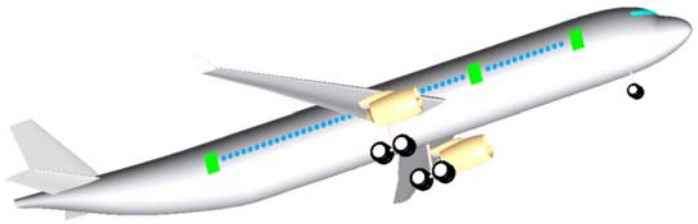
$$\min f(X) = Y \qquad R^{1\,000\,000} \quad R^{100}$$

$$G(X) = Z = 0$$

$$H(X) = U \leq 0$$

$$R^{100\,000}$$

- It is not possible to design an aircraft without taking into account the problem as a whole
- The overall problem is Multi-disciplinary, Multi-Objective, Multi-scale, Evolves all along the project life



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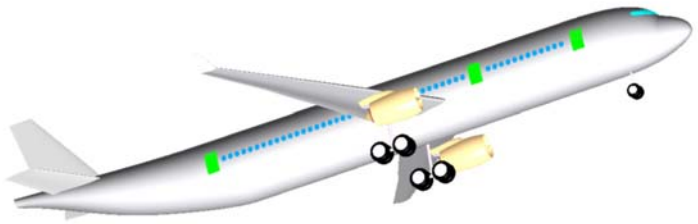

$X \in R^{100}, Y \in R$
$\min f_1(X) = Y$
$f_{1c}(X) = U \leq 0$

$X \in R^{100}, Y \in R$
$\min f_2(X) = Y$
$f_{2c}(X) = U \leq 0$

$X \in R^{100}, Y \in R$
$\min f_3(X) = Y$
$f_{3c}(X) = U \leq 0$

$X \in R^{100}, Y \in R$
$\min f_4(X) = Y$
$f_{4c}(X) = U \leq 0$

$X \in R^{100}, Y \in R$
$\min f_5(X) = Y$
$f_{5c}(X) = U \leq 0$

$X \in R^{100}, Y \in R$
$\min f_6(X) = Y$
$f_{6c}(X) = U \leq 0$

Main problem : interactions

- It is not possible to design an aircraft without taking into account the problem as a whole
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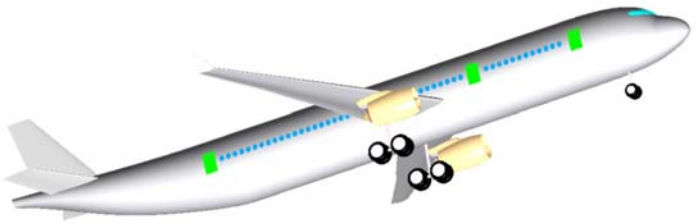

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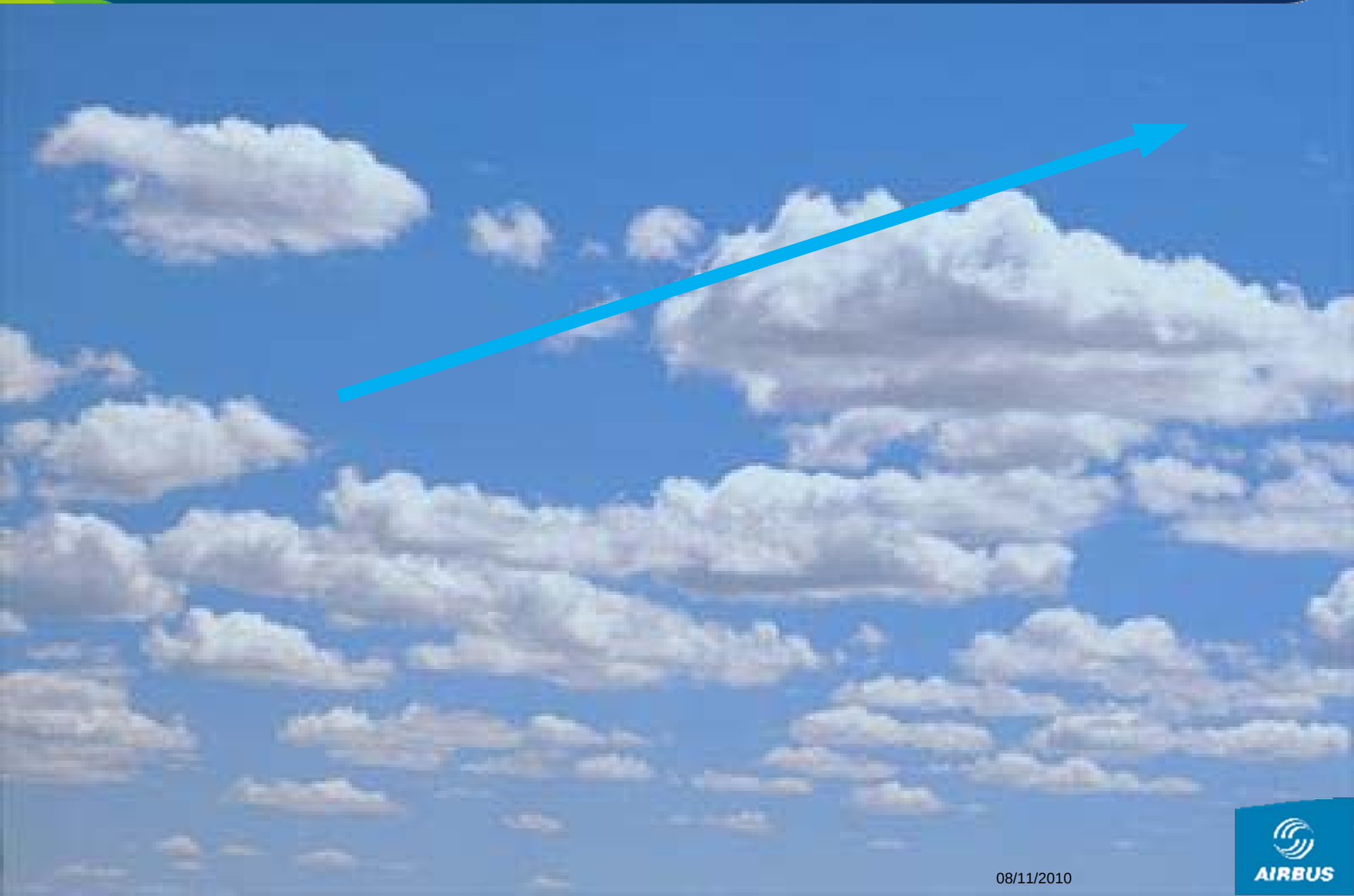
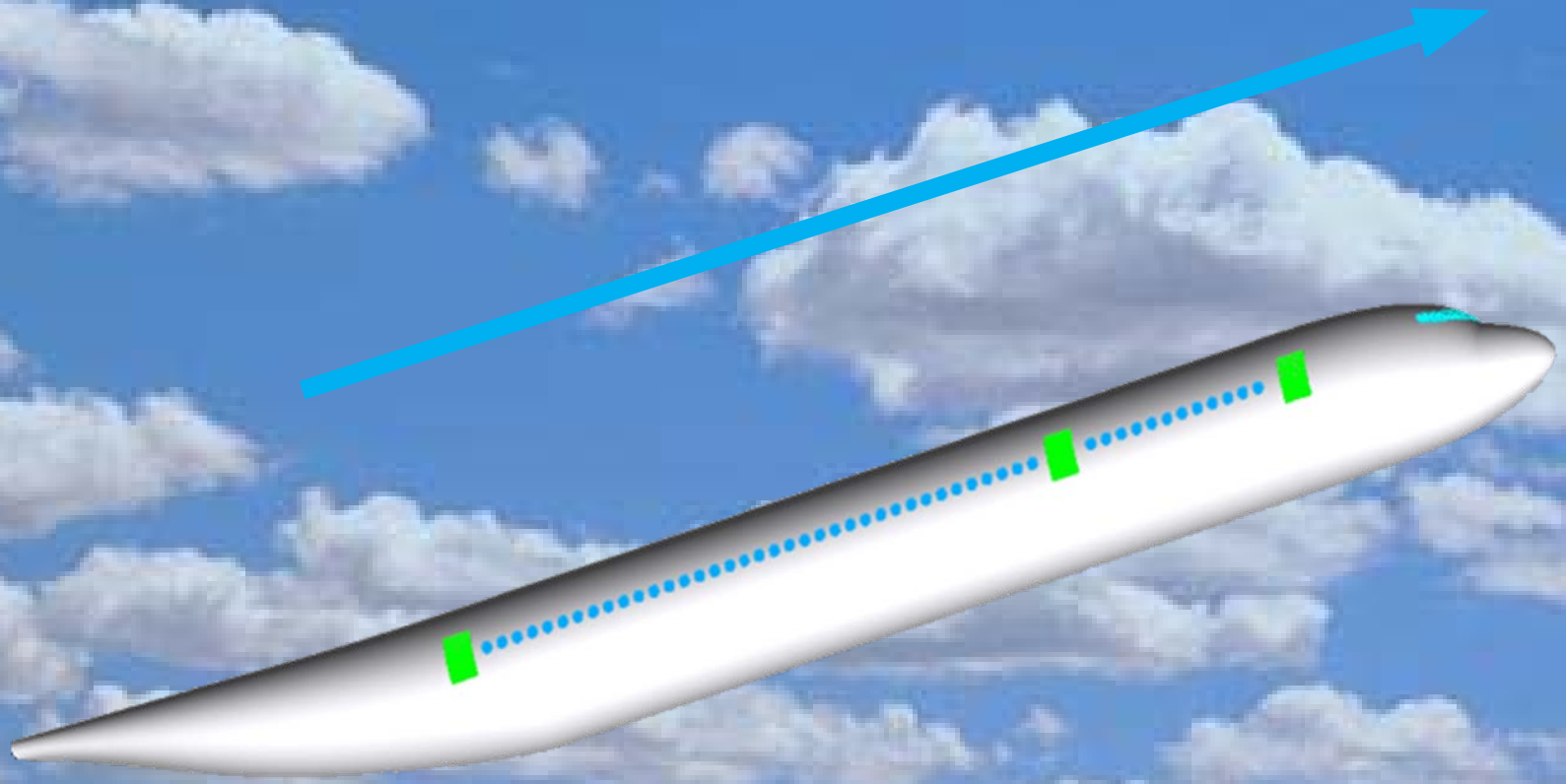
Let’s play with Legos



Another solution for payload : the can

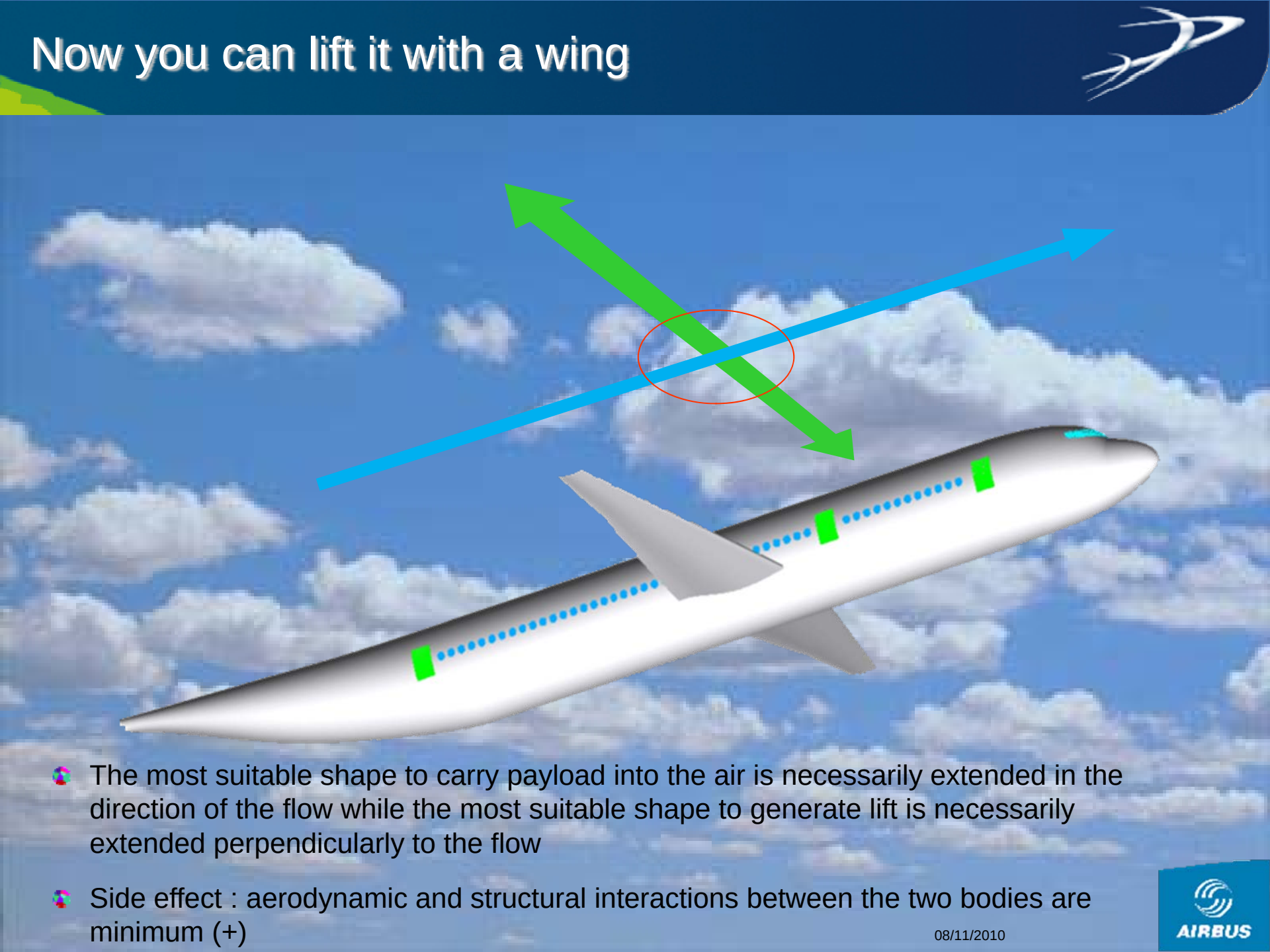
- From an aerodynamic point of view, the cost of main cross section is much higher than the cost of areas parallel to the air flow (friction drag)

Even better with some accommodations



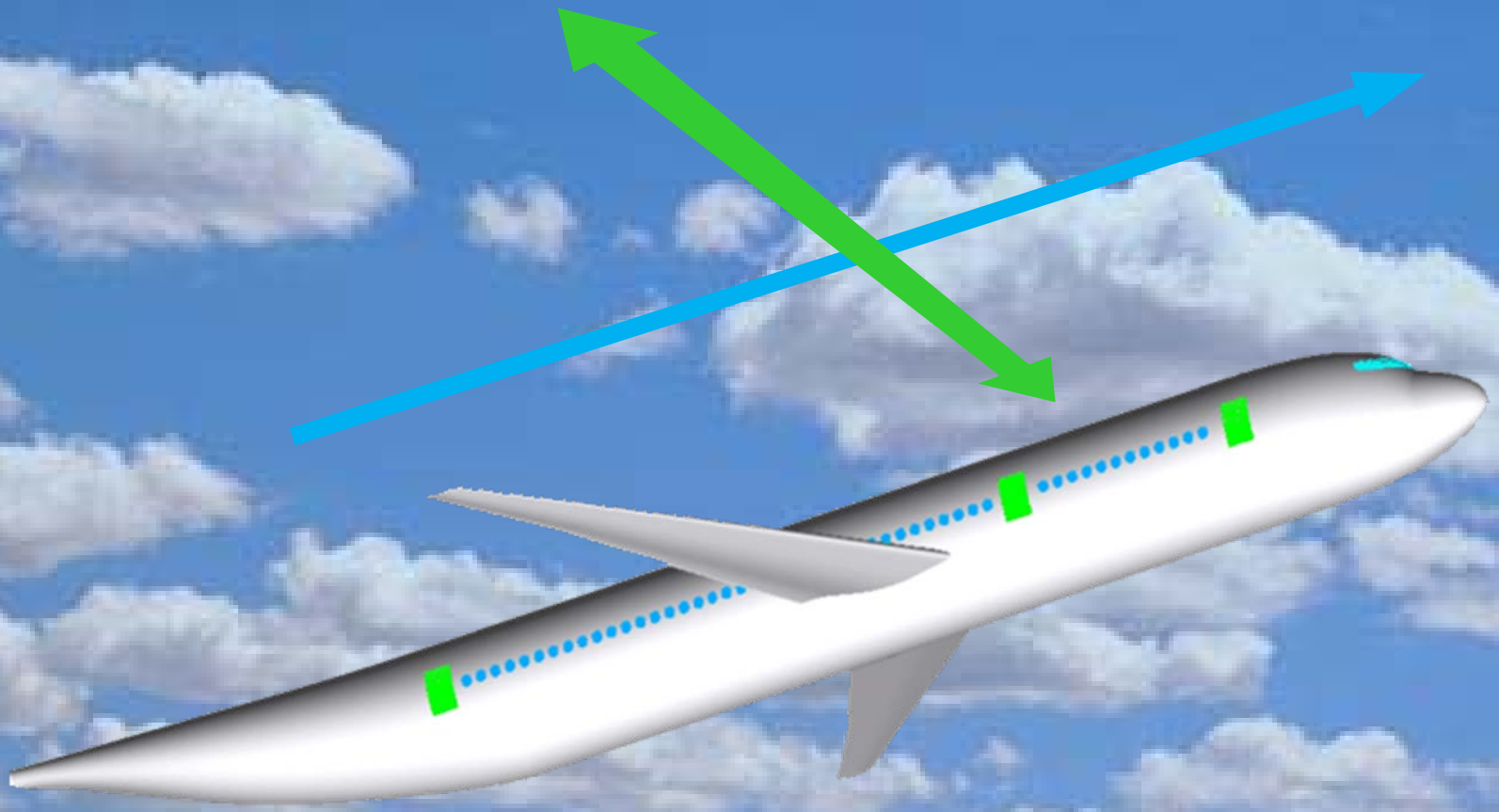
- Fortunately, from a structural point if view, a cylinder with rounded tips is as efficient as a sphere
- Side effect : passenger are never far from a door (+)

Now you can lift it with a wing



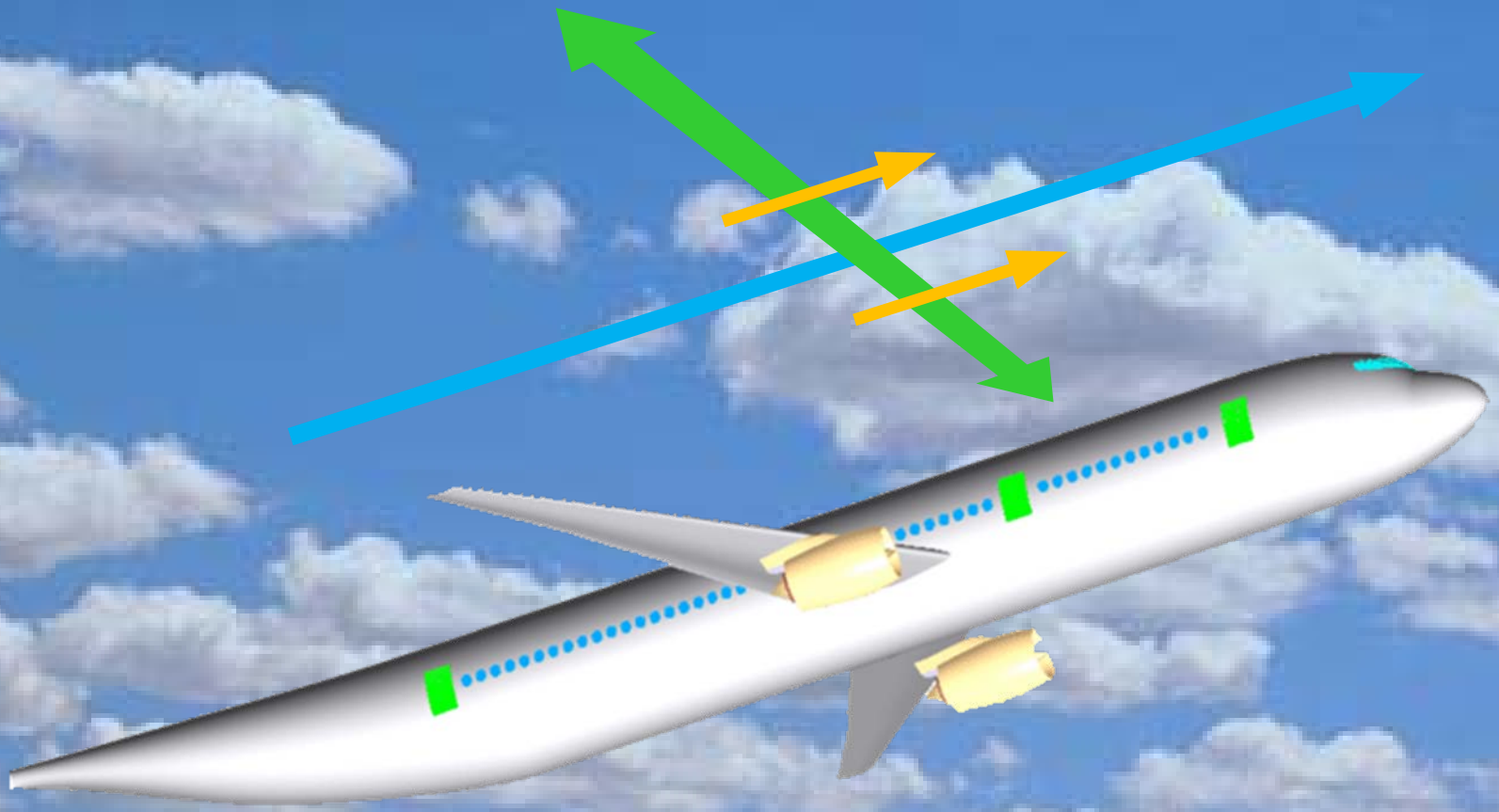
- The most suitable shape to carry payload into the air is necessarily extended in the direction of the flow while the most suitable shape to generate lift is necessarily extended perpendicularly to the flow
- Side effect : aerodynamic and structural interactions between the two bodies are minimum (+)

Wing local optimisation



- The wing sweep angle just allows to go faster
- Side effect : accessibility to forward doors is greatly improved (+)

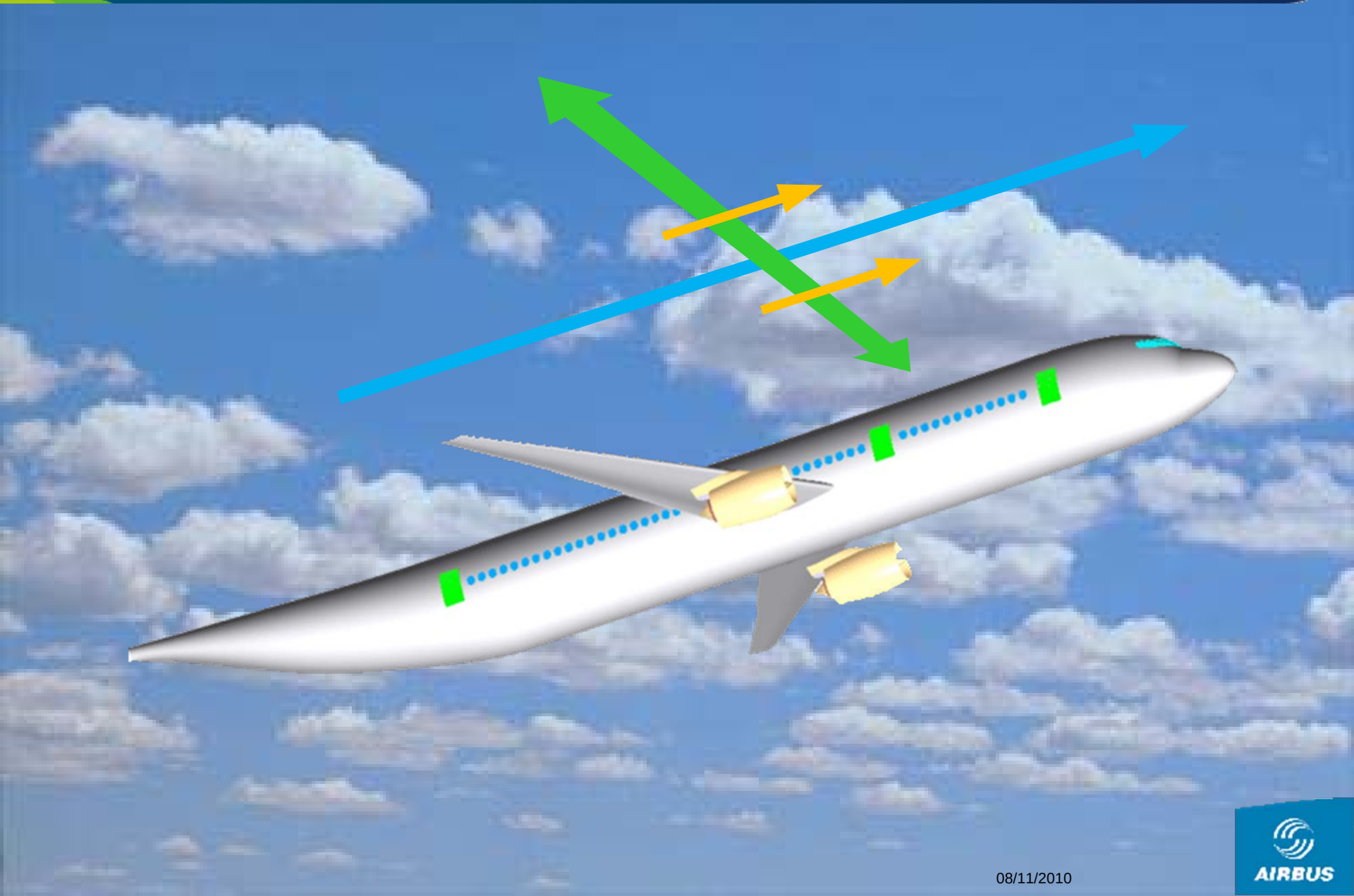
Lift and friction drag has to be balanced



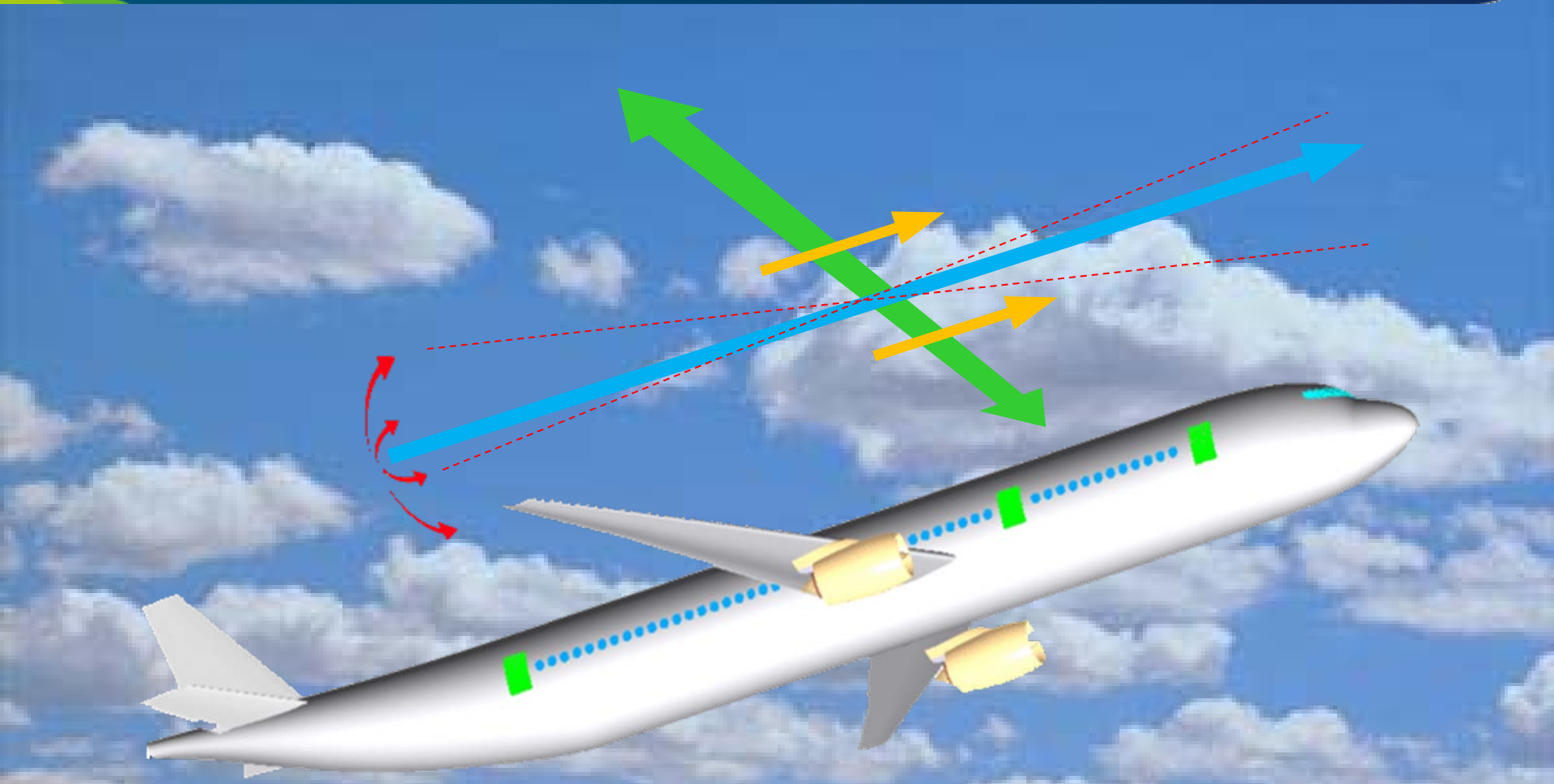
- In comparison to rear fuselage mounting, under wing position for engines provides about 1or 2% of global efficiency, improves security and makes easier in flight longitudinal equilibrium.
- Side effect : In comparison to fuselage mounting, wing mounting gives good accessibility for maintenance (+)

Engine maintenance

Lift and friction drag has to be balanced

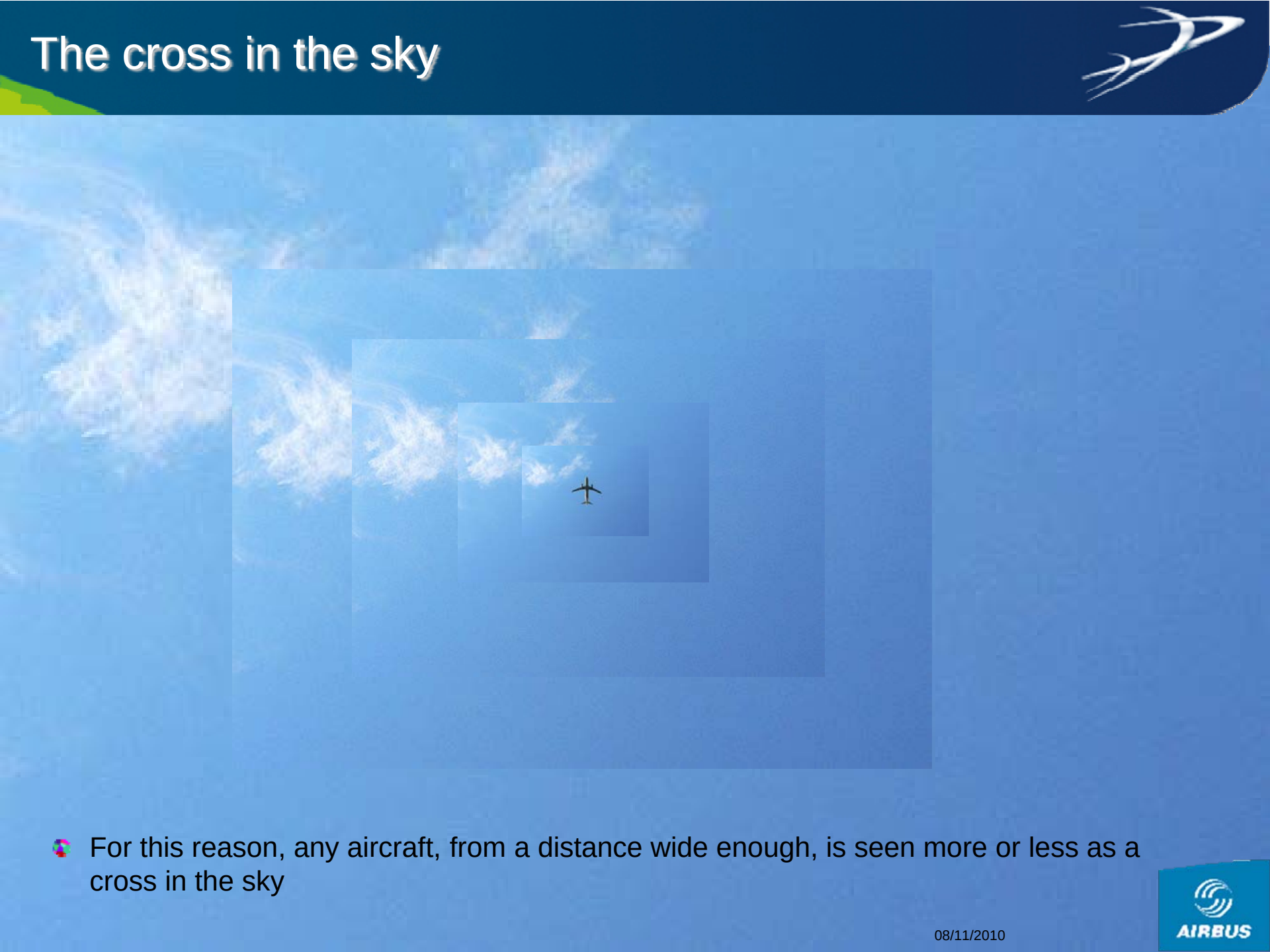


Lift vector is controlled by wing attitude



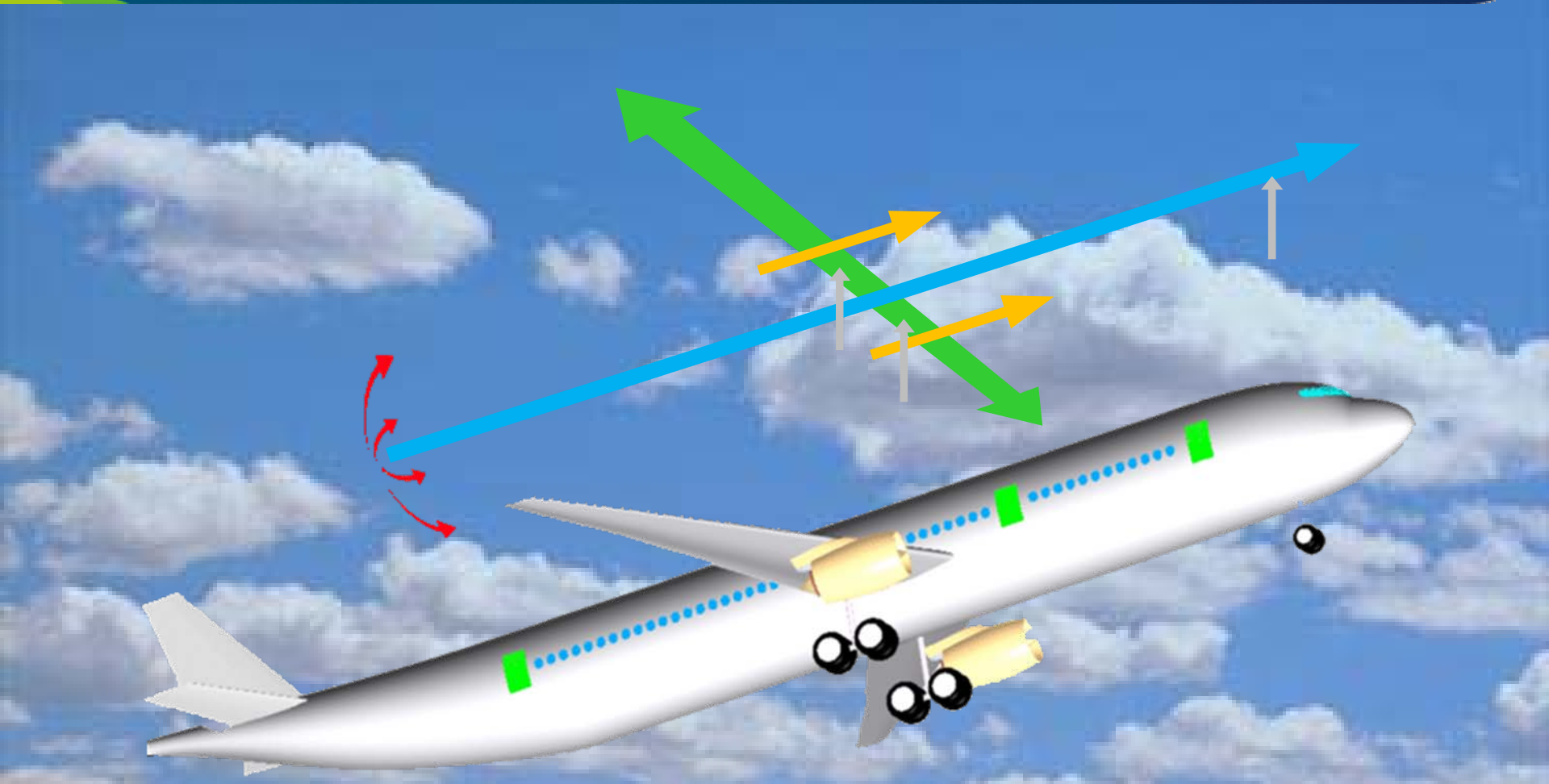
- Empennages on the top of rear fuselage provide the best lever arm to control the attitude angles of the wing versus the air flow
- Side effects: these fragile surfaces are as far as possible from the ground and from the doors (+)

The cross in the sky



- For this reason, any aircraft, from a distance wide enough, is seen more or less as a cross in the sky

Landing gears : the smallest you can do



- Main landing gears are generally attached to the wing (no far from the most backward CG position) and hidden in the fuselage during the flight
- Side effects: the design of the central section of the fuselage is a real nightmare (-) (but nobody cares)

But rear engines are still flying !


Douglas DC9 (1965)


MC Donnell Douglas MD80 (1979)

MC Donnell Douglas MD90 (1979)


Boeing B717 (1998)

- That's true, but all these aircraft are certified as evolutions of old aircraft which is much less painful regarding regulatory constraints.

Conclusion

- As we have seen above, all main choices in term of configuration layout (let's say topology) have also some strong positive side effects that contributes to make them robust to many significant technical evolutions.
- As a result of this, current available technologies do not allow to escape from the "classical configuration" which exists from 1936.

Douglas DC3 (1936)

- So the question : what have done engineers during more than 70 years ?

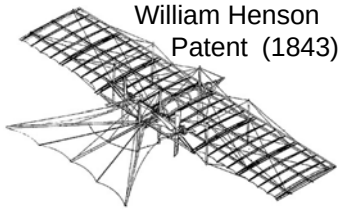
Air transport in 3 steps :

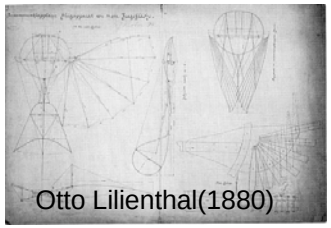
- Understand
- Maturate
- Optimise

Step 1/3 : Understand

- Understand the subtle relations between The Shape, The Air and The Velocity.


Leonard de Vinci (1488)


William Henson
Patent (1843)

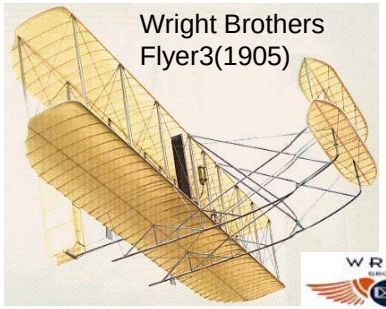

Otto Lilienthal(1880)

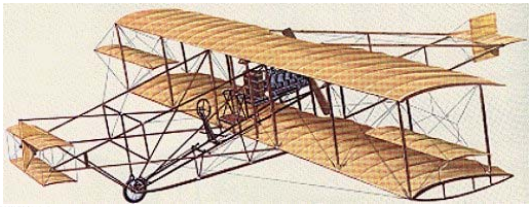

Otto Lilienthal (1889)

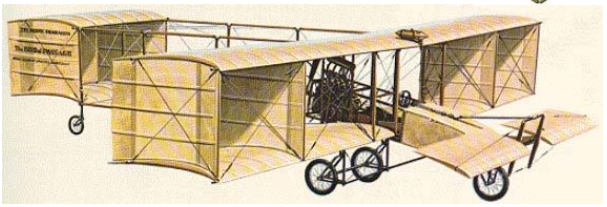

Otto Lilienthal(1889)

- Invent engines with power over weight ratio high enough for flying.

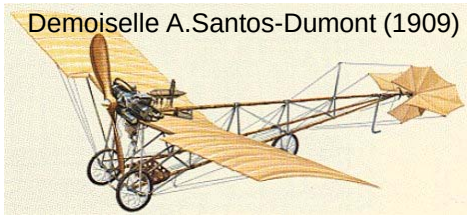

Clément Ader
Eole3 (1897)

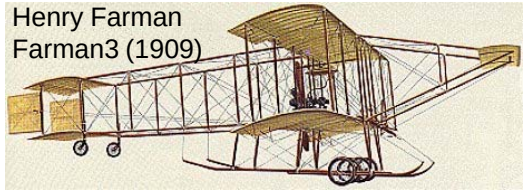

Wright Brothers
Flyer3(1905)


Curtis Rheims Flyer Glen Curtis (1909)

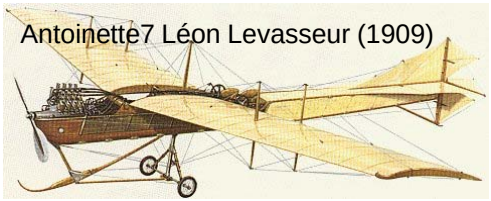

Bird of Passage Voisin Brothers (1909)

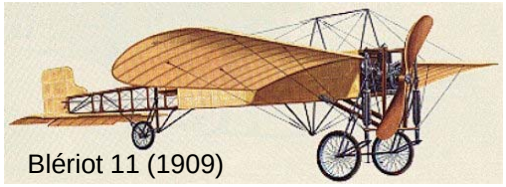

Avroplane
A.V.Roe(1909)

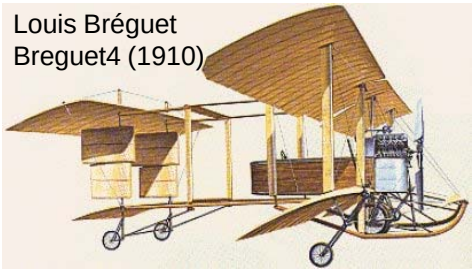

Demoiselle A.Santos-Dumont (1909)


Henry Farman
Farman3 (1909)


Taube Igo Etrich (1910)

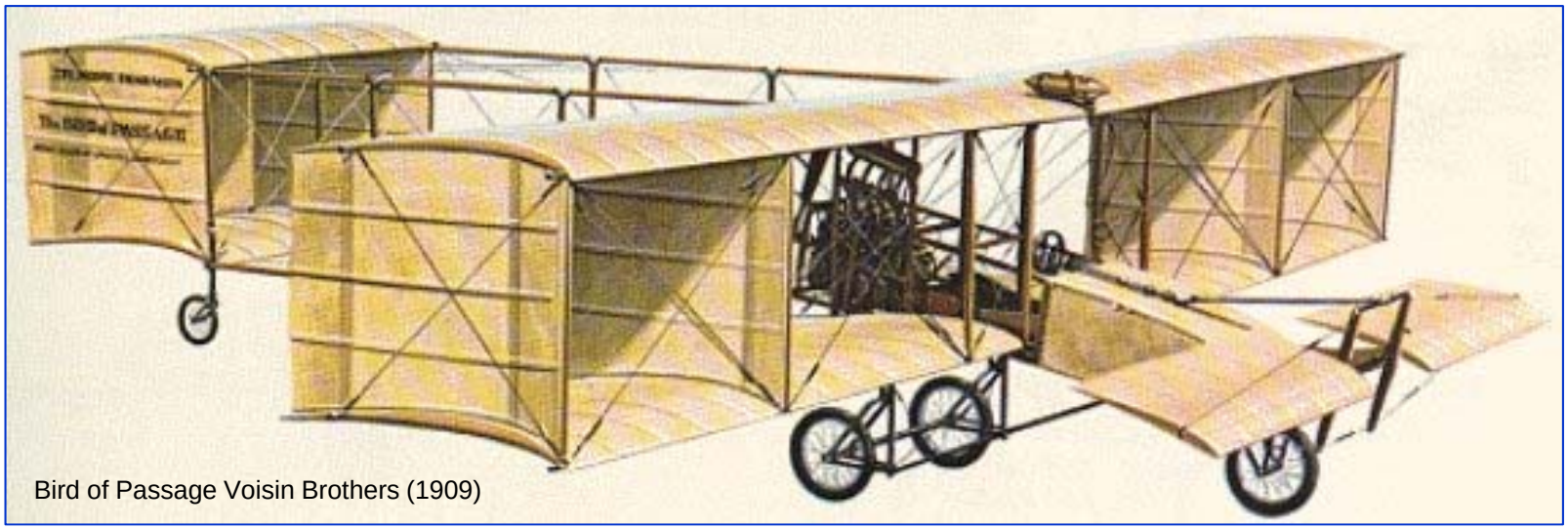

Antoinette7 Léon Levasseur (1909)


Blériot 11 (1909)


Louis Bréguet
Breguet4 (1910)

From bio-inspiration to industrial concept

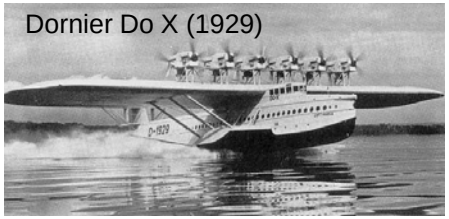
Otto Lilienthal(1889)



Bird of Passage Voisin Brothers (1909)

Step 2/3 : Maturate

- Invent structures strong enough and powerful engines to fly big airplanes.


Dornier Do X (1929)


"Dragon Rapide" (1934)
De Havilland

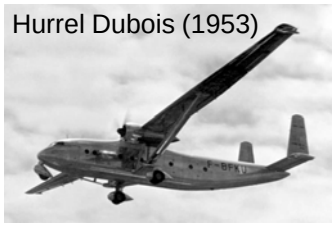

Lockheed (1943)


Spruce Goose (1945)


Douglas DC6
Constellation (1946)


Boeing 377
(1947)


Breguet "Deux Ponts"
(1949)


Hurrel Dubois (1953)


Convair NB36H (1965)


Pregnant Guppy (1962)

- Improve all components to take more passengers, further, faster.


De Havilland "Comet" (1949)


Caravelle (1955)
Sud-Aviation


Boeing 747 (1969)


Concorde (1969)
Aerospatiale BAe


Airbus A300 (1972)
Aerospatiale

Ranking the concepts

Hurrel Dubois (1953)

De Havilland DHC89 “Dragon Rapide” (1934)

De Havilland “Comet” (1949)

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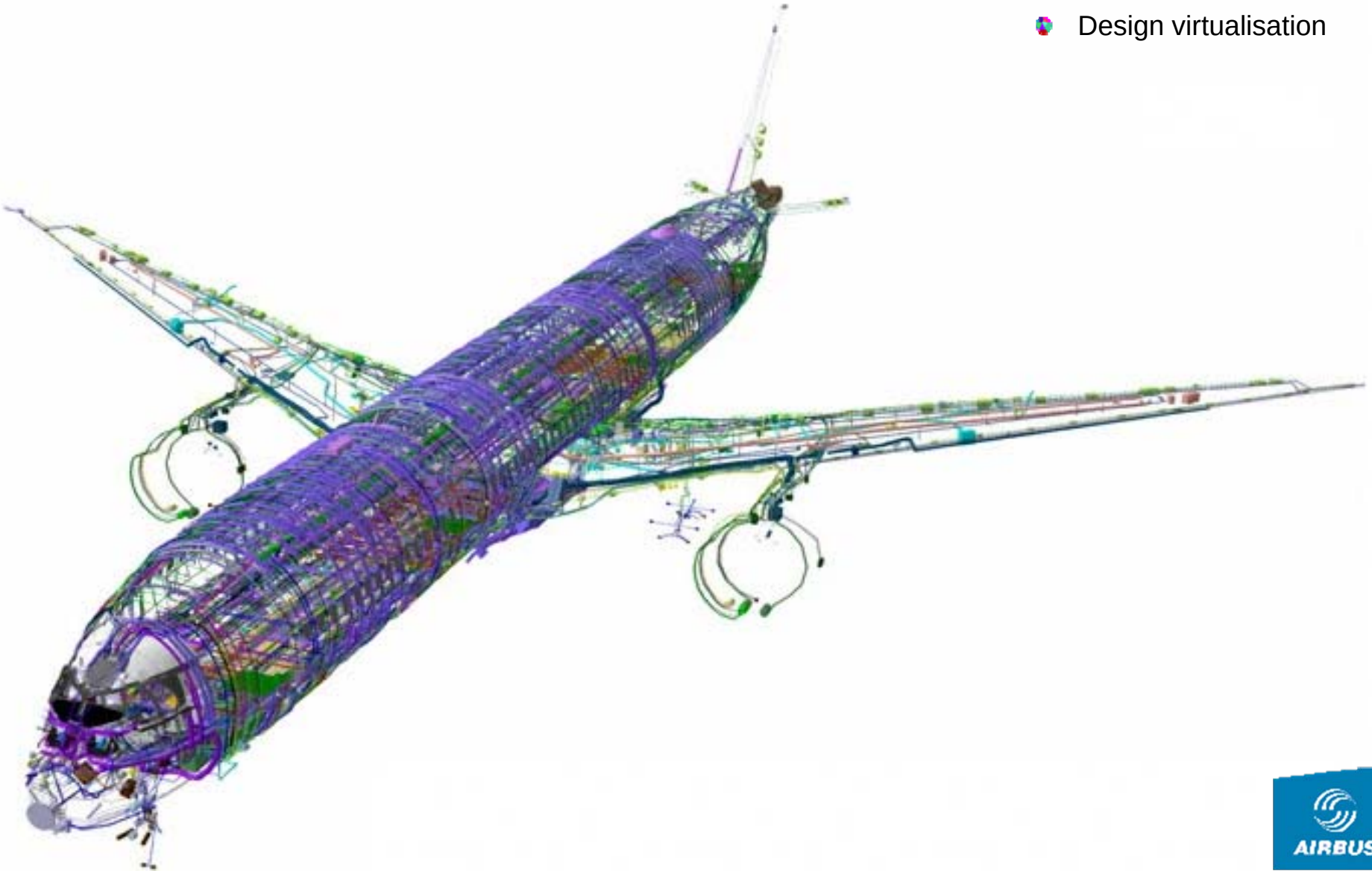
Step 3/3 : Optimise

- Make it more efficient, more secure, put a nervous system inside the airplane

- Design virtualisation



Step 3/3 : Optimise

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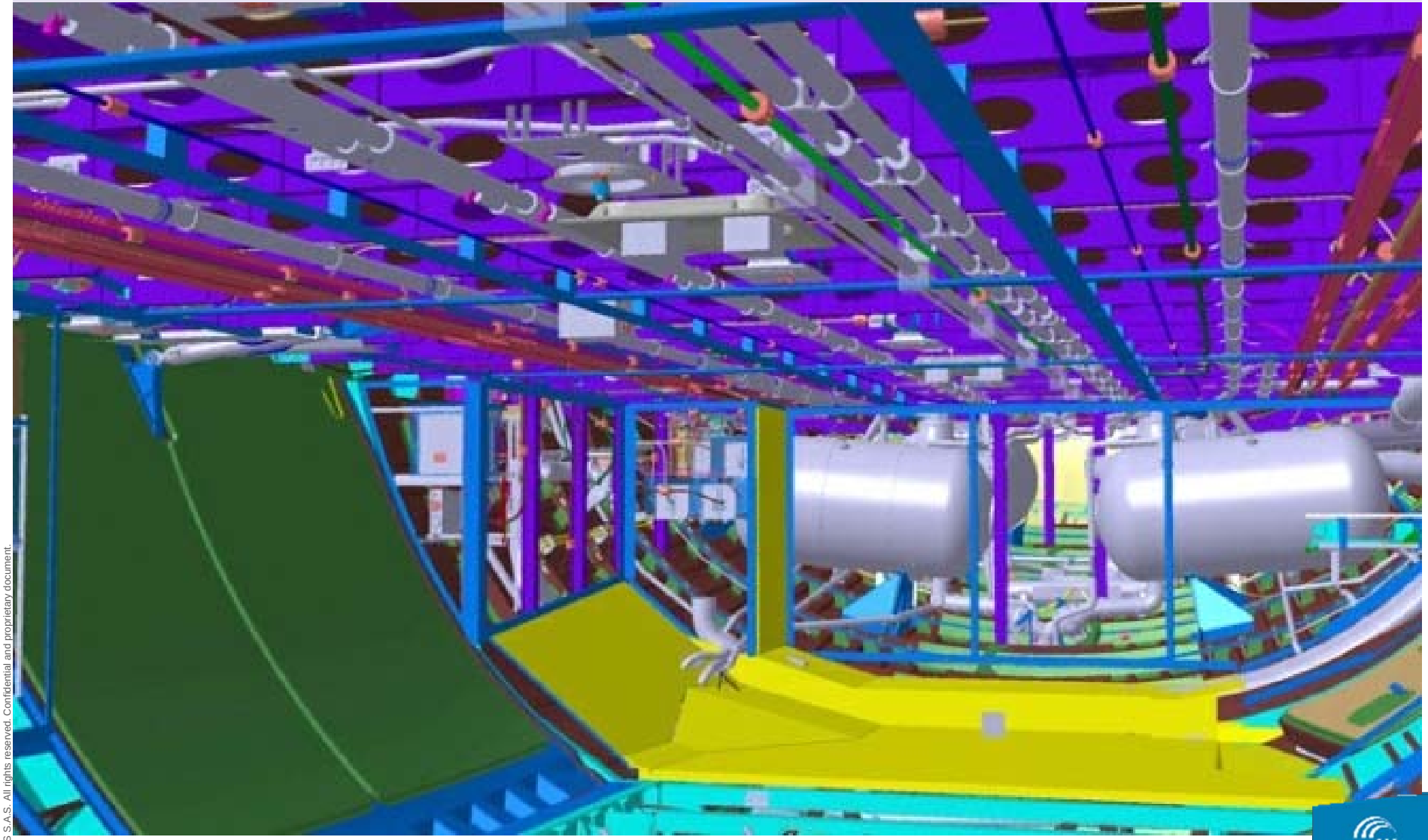

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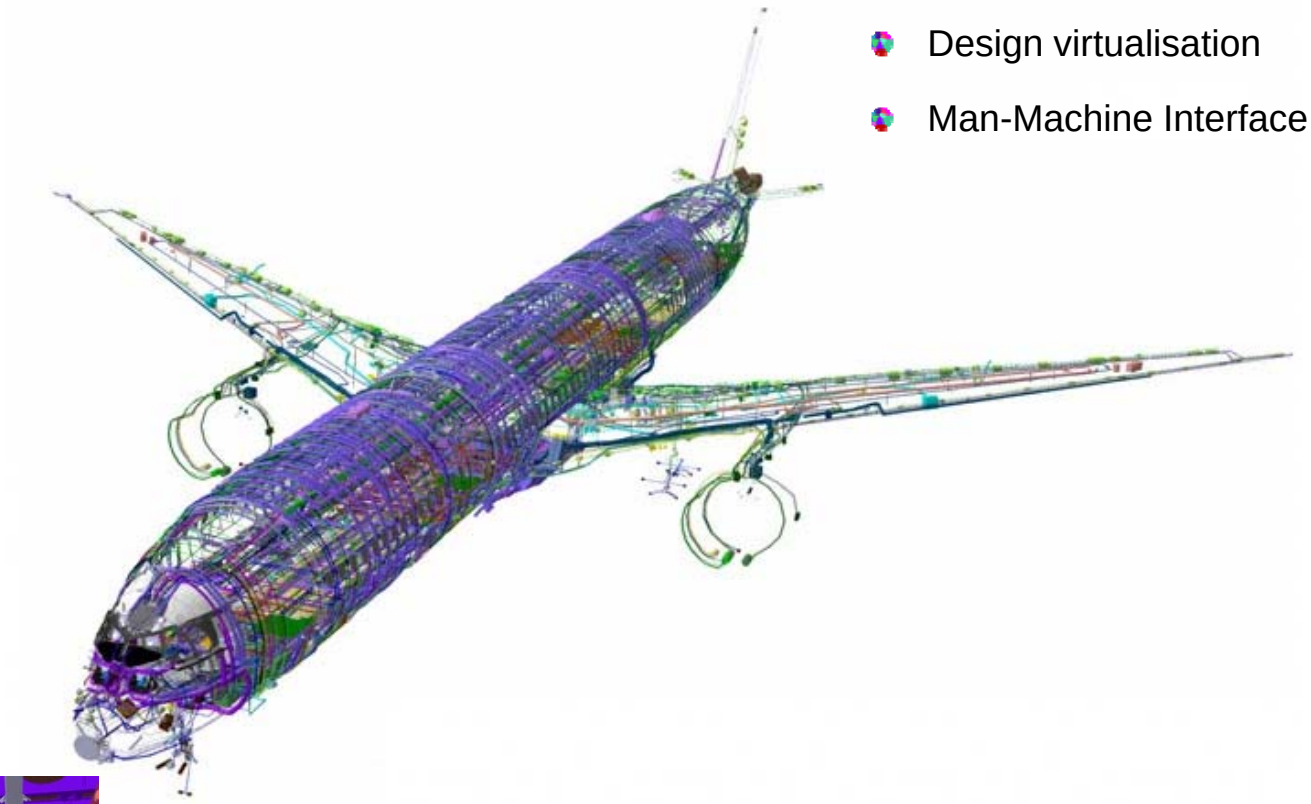
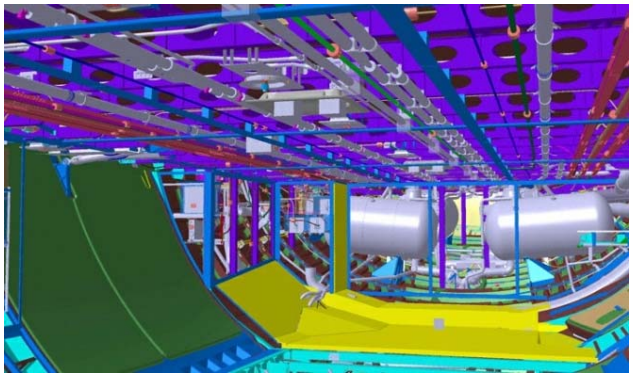


- Design virtualisation
- Man-Machine Interface



Step 3/3 : Optimise

- Make it more efficient, more secure, put a nervous system inside the airplane

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Step 3/3 : Optimise

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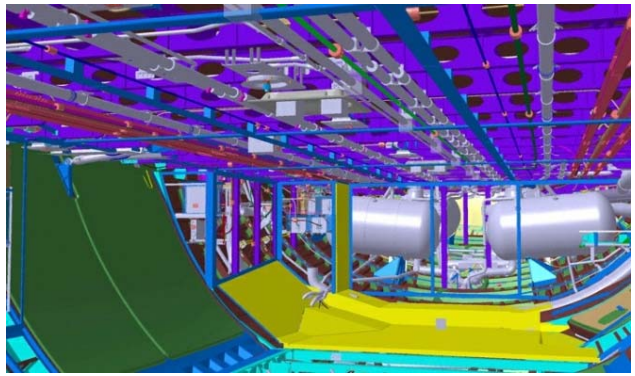

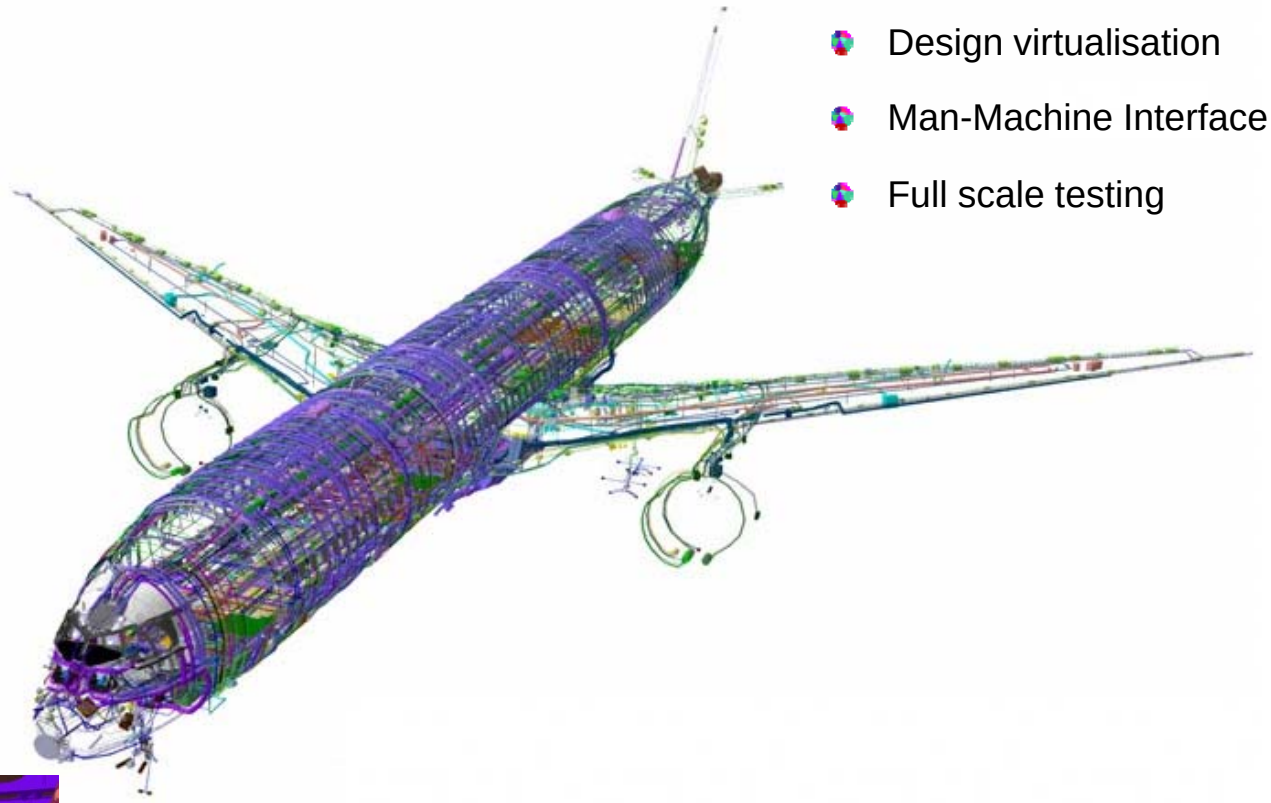

- Design virtualisation
- Man-Machine Interface
- Full scale testing

Step 3/3 : Optimise

- Make it more efficient, more secure, put a nervous system inside the airplane

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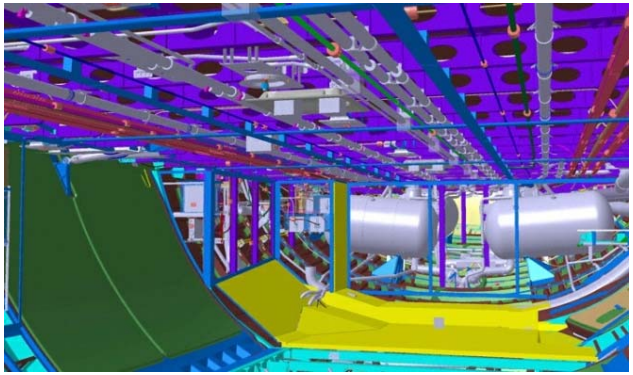
Step 3/3 : Optimise

- Make it more efficient, more secure, put a nervous system inside the airplane



- Design virtualisation
- Man-Machine Interface
- Full scale testing

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And now, what can happen ?

Fuselage-Wing Blended Body ?

An interesting problem ...

Control

Transport

Lift

Propulsion

All co-operating functions ensured by different components

All functions coupled In the body

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New configuration ?

New energies ?

Electric ?

Hydrogen ?

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Tuning old concepts

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The Optimum Optimorum

- In term of configuration it seems that it will be very difficult to evade from this:

- So the question: What kind of algorithm could provide such a deep topological optimum ?

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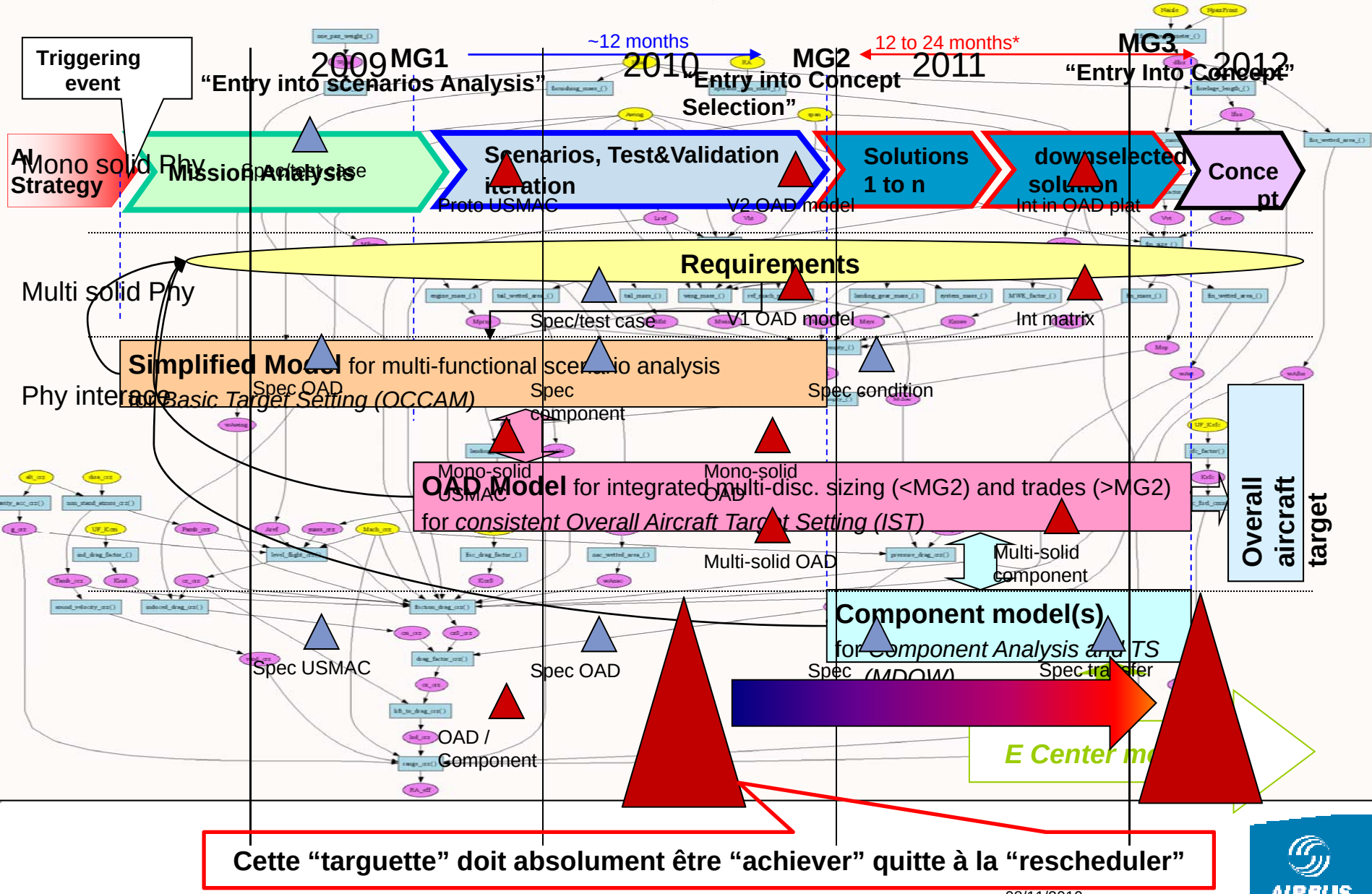
Looking for an answer



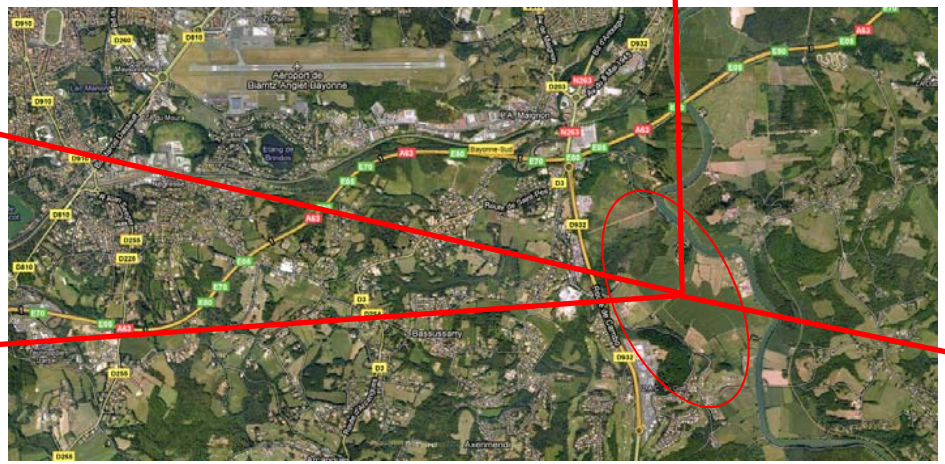
Cette "targuette" doit absolument être "achiever" quitte à la "rescheduler"

Result

- From 16 au 21 august 1910, “Une Grande Semaine de l’Aviation” has been organised at the very first airport of “Pays Basque”.

Bayonne: 4.31415926 km

Biarritz: 7.314159265 km



Guétary: 11.3141592654 km

Hasparren: 16.314159 km

Pilot / Airplane :

Tabuteau / Farman
Nieuport / Nieuport
Picard / Savary
Dufour / Voisin
Granel / Blériot
Mauvais / Sommer
Garnier / Garnier
Chateau / Letelier

- During this event, a genetic algorithm was launched with the aim to find the optimum of passenger transport aircraft
- The optimisation process has been declared converged the 27 octobre 2010 at JBHU Colloquium

Thank You

$$Let \quad F : R^4 \rightarrow R^4 \qquad \begin{bmatrix} x \\ y \\ z \\ t \end{bmatrix} \rightarrow \begin{bmatrix} x * z \\ z - y \\ z + y \\ y * t \end{bmatrix}$$

$$we \quad found \quad that : F\left(\begin{bmatrix} 2 \\ 3 \\ 5 \\ 7 \end{bmatrix}\right) = \begin{bmatrix} 10^{th} letter : J \\ 2^{nd} letter : B \\ 8^{th} letter : H \\ 21^{th} letter : U \end{bmatrix}$$

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