Innovation in Aircraft complex systems integration

Presented by:
Sebastien REMY
SVP Head of Airbus Group Innovations
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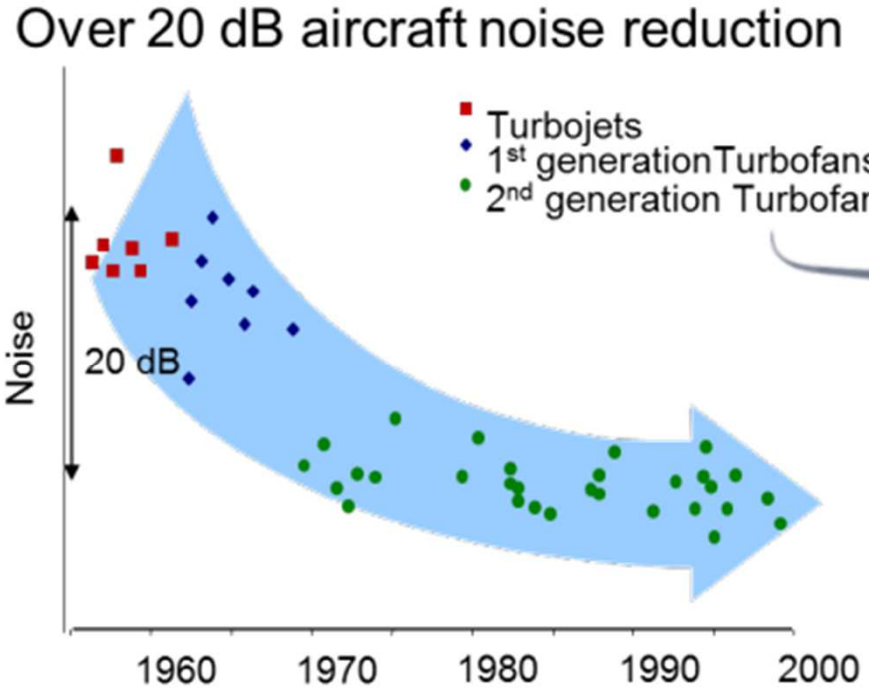
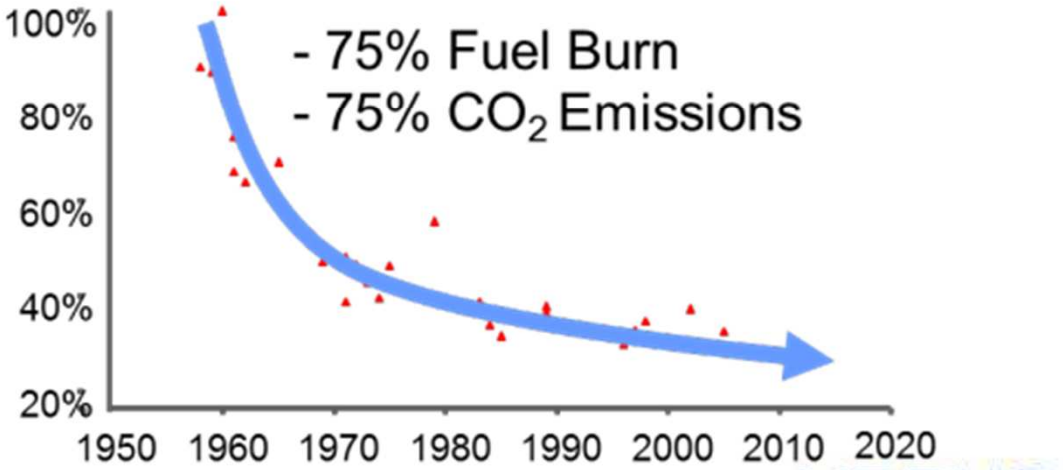
AIRBUS GROUP

Aviation has improved a lot over the past 50 years…





State of the Art Airliners feature excellent systems integration, resulting from multiple requirements

Our industry will face higher expectations and more competition

Safe

Fuel price

Growth

Simple

Regulations

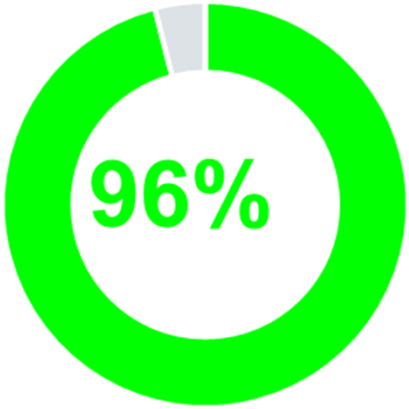
Competition

Eco-efficient

Affordable

… so we have to do more

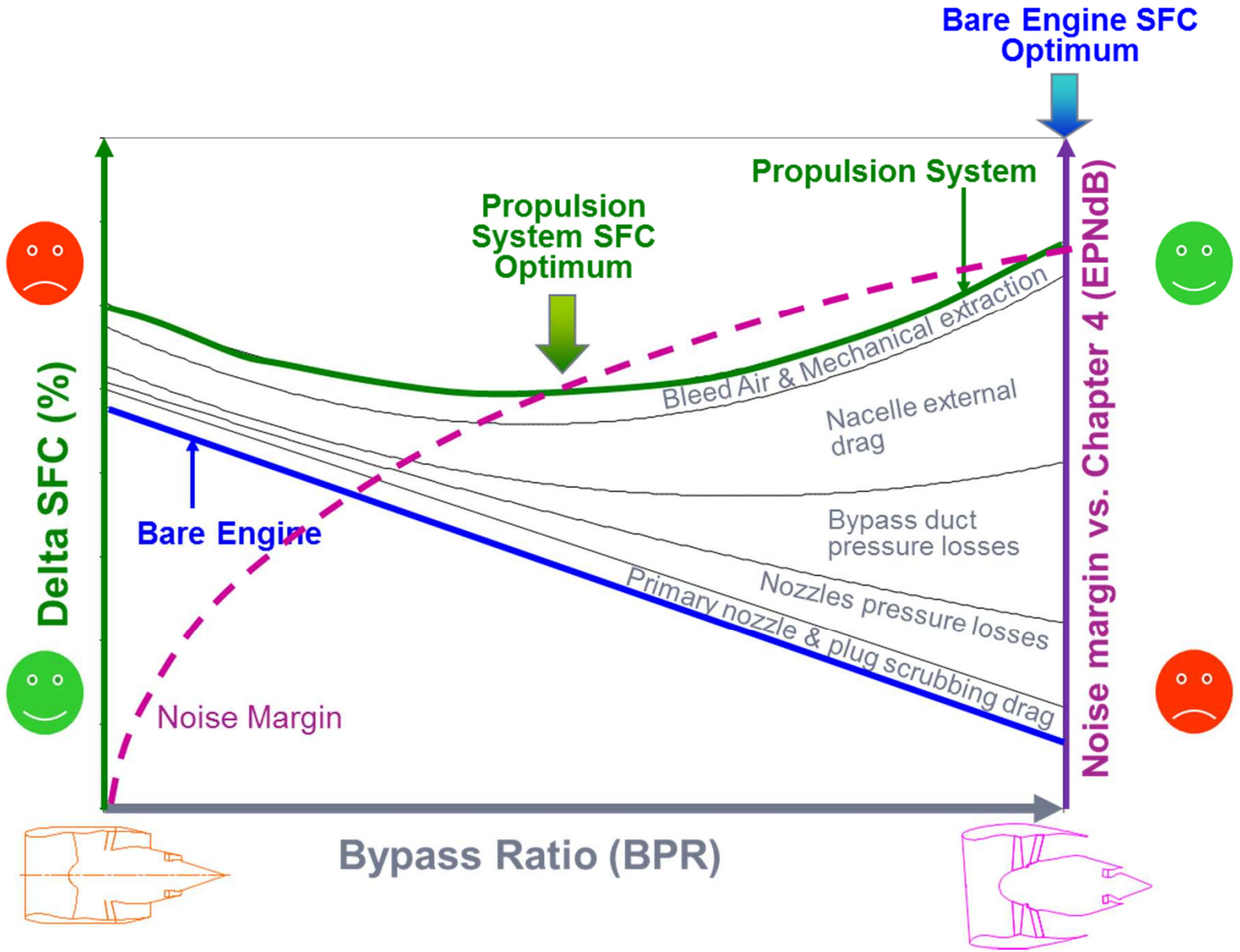
The Passenger of 2050 (2012 Survey)



of respondents believe that aircraft in the future will need to be **more environmentally sustainable**

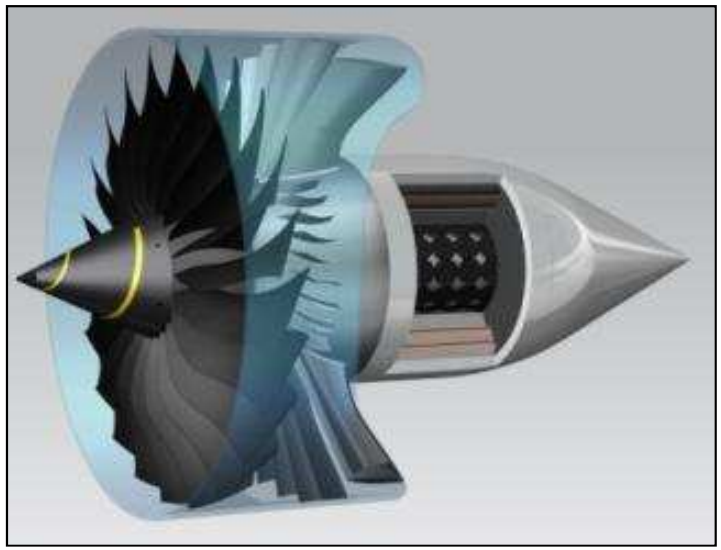
Ambitions:
-75% CO_2
-90% NOx
-65% Noise
vs 2000

Traditional optimization has limits…



… and NOx increases with BPR (due to OPR and T3)

… new options can be considered

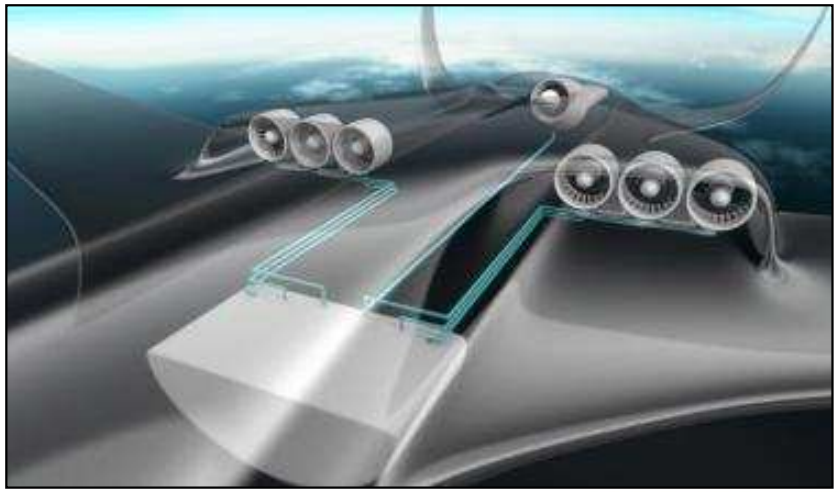


Full Electric Propulsion:

- No CO2
- No NOx / Emissions
- Significantly reduced Noise
- Weight? Drag? Cost? Reliability?

Hybrid Electric Propulsion:

- Reduced CO2
- Reduced NOx / Emissions
- Reduced Noise
- Weight? Drag? Cost? Reliability?



What others say…

Electric Propulsion is a Bigger Change than Going from Piston to Turbine Engines

Electric Propulsion Penalties

Energy Storage Weight (60x worse than aviation fuel)
Energy Storage Cost (Tesla 65 kWhr battery is ~$25,000)
Certification?

Electric Propulsion Benefits

~2x efficiency of turbine engines, 3-4x efficiency of piston engines
High efficiency across 50% rpm range
6x the motor power to weight of piston engines
None air breathing - No power lapse with altitude or on hot days
Extremely Quiet
Zero vehicle emissions
10x lower energy costs

Electric Propulsion Integration Benefits

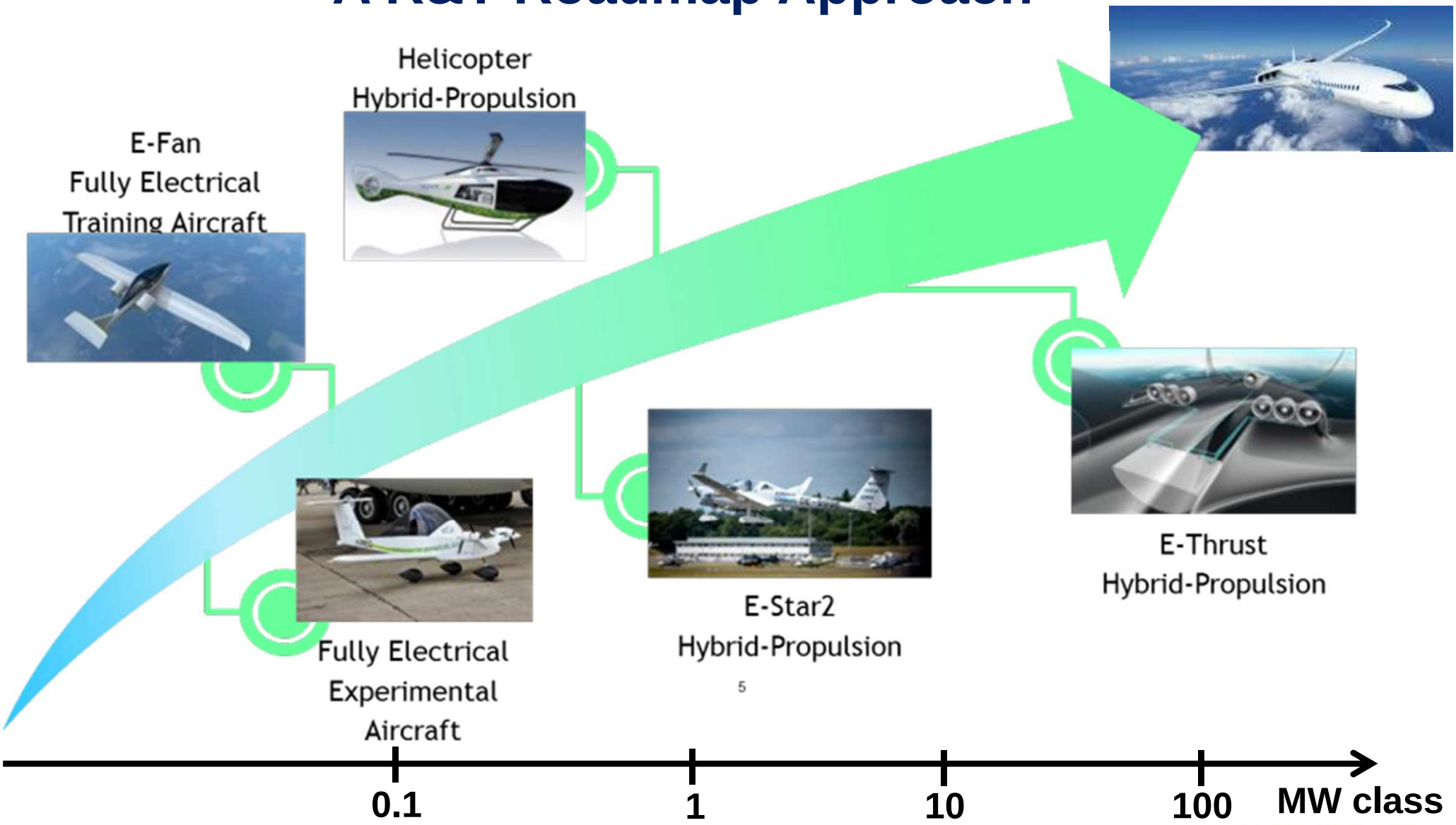
Scale independent
Power to weight and efficiency don't degrade at smaller sizes
Extremely compact
High Reliability – Few moving parts

Hydrocarbon fuel cost has tripled in constant year dollars since 1999 with constant energy density, while batteries have tripled in energy density.

3

Abstract from:
"Misconceptions of Electric Aircraft and their Emergent Aviation Markets"
Mark D. Moore and William J. Fredericks , AIAA SciTech, Jan 12-15, 2014

A R&T Roadmap Approach



What others do…

Porsche Panamera Hybrid

0.07 MW / 5500 rpm

1 to 2 kW/kg

Liebherr Mining Truck

3 MW

0.25 kW/kg

Queen Mary 2

20 MW / 180 rpm

0.2 to 0.4 kW/kg

New challenges & requirements

- **Energy storage distribution & Power generation**
  - Energy density >350Wh/Kg, batteries life & security
  - Electrical motors/generators, power electronics (> 15 kW/Kg incl. cooling)
  - High voltage electrical network & associated ancillaries

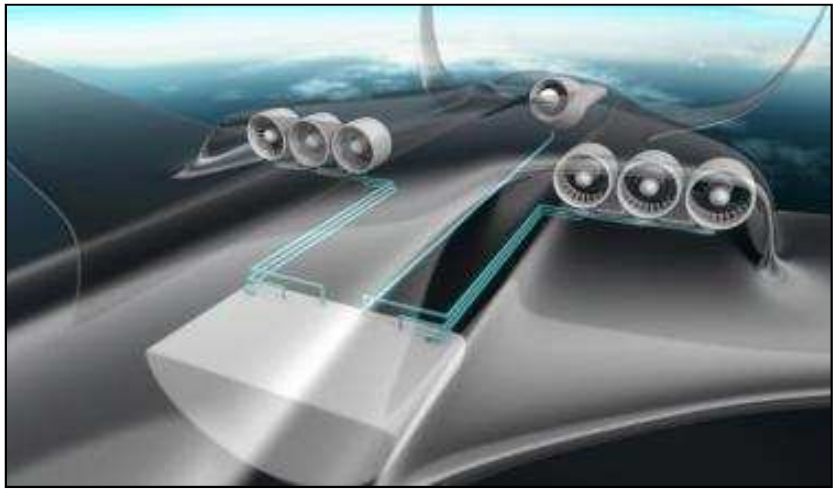
Batteries	Key performance Indicators:
	Energy/Mass ratio
Short term (5-10 years)	150 - 350 Wh/kg
Mid Term (10 to 15 years)	350 - 600 Wh/kg
Long Term (>>15 years)	500 - >>1000 Wh/kg

- **Propulsion system integration**
  - Control system, Thermal management, ECM compatibility

Superconducting electric machines		
	Power / mass ratio	efficiency
Short term (5-10 years)	7-10 kW/kg	99,20%
Mid Term (10 to 15 years)	10-20 kW/kg	99,50%
Long Term (>>15 years)	20 -50 kW/kg	99,90%

New challenges & requirements

- **Novel configurations**
  - Explore potential benefits of hybrid / electric propulsion (e.g. distributed propulsion, aircraft sizing…)



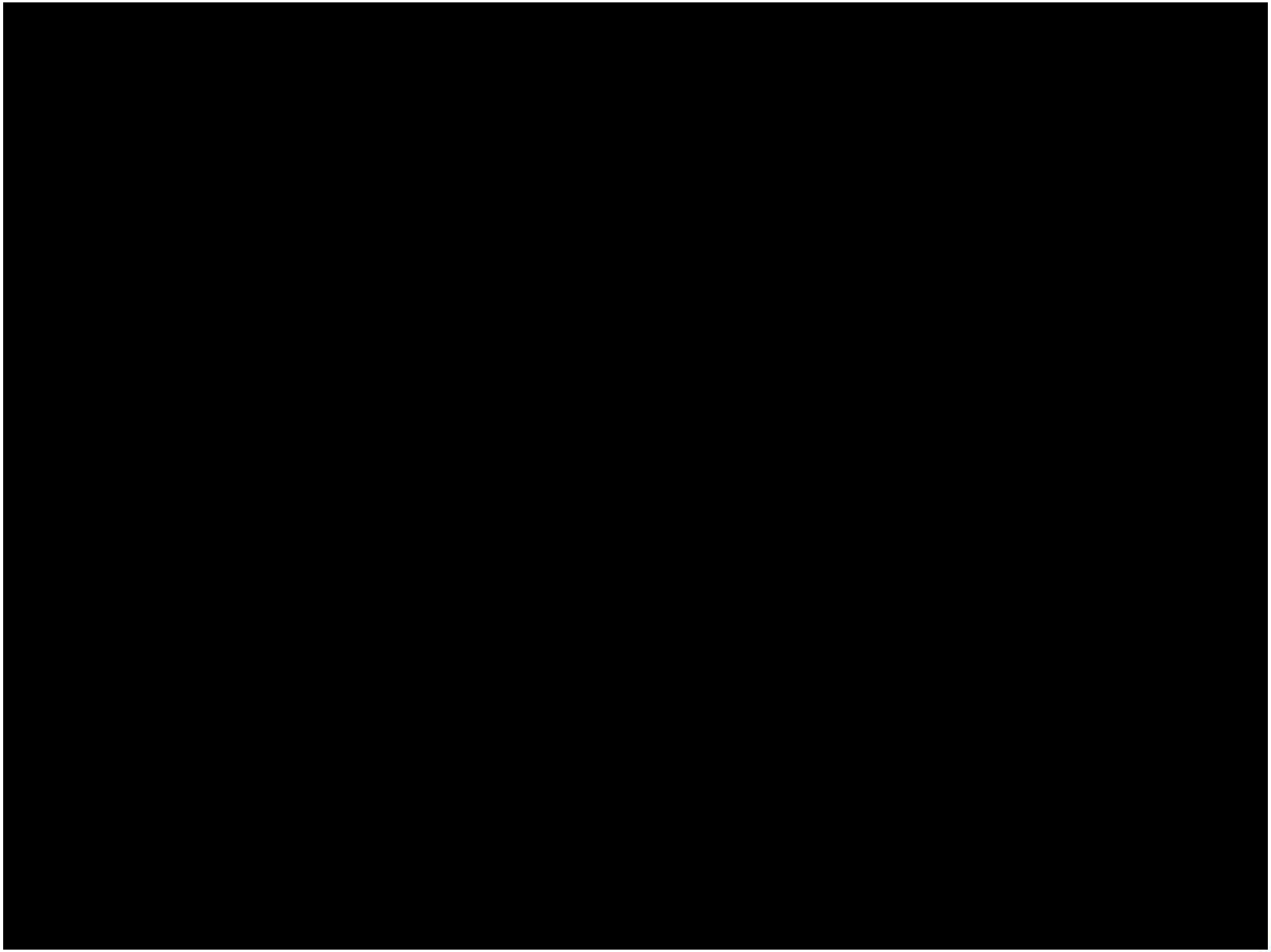
- **Scalability & Modeling**
  - Systems level performance & economics, Transients, Failure cases
- **Certification & Operations**

Innovation based on in-flight experience…

… starting by in-flight demonstration, with DGAC support

100th Flight performed on June 19th, 2015

E-Fan Channel Crossing (July10th, 2015)



« It always seems impossible until it's done »
Nelson Mandela