Future Aircraft Engine Design Developments

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Overview

- Intro AHEAD
- Challenges of Civil Aviation in the 21st Century
  - Developments:
    - Current & near term
    - Medium term
    - Long term:
      – Subsonic
      – Super/Hypersonic

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Why AHEAD?

Picture courtesy of TU Delft

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Challenges of Civil Aviation in the 21st Century

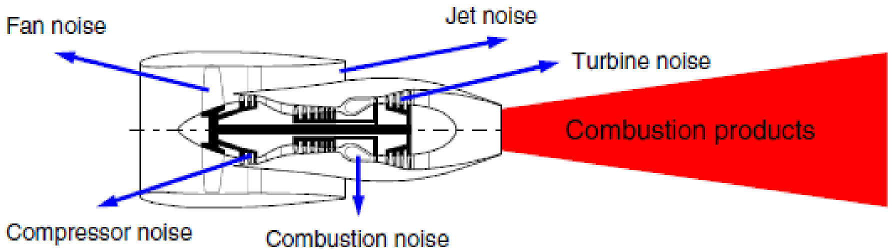
Main Challenges of Civil Aviation in 21st Century

Aircraft engines emissions

Aircraft engines emit:

- Noise: Fan noise and primary exhaust noise
- Emissions by the combustion of fossil fuels

Noise emission



Pollutant Emission

Input:

Air: $N_2 + O_2$

Fuel: $C_nH_m + S$

Combustion products:

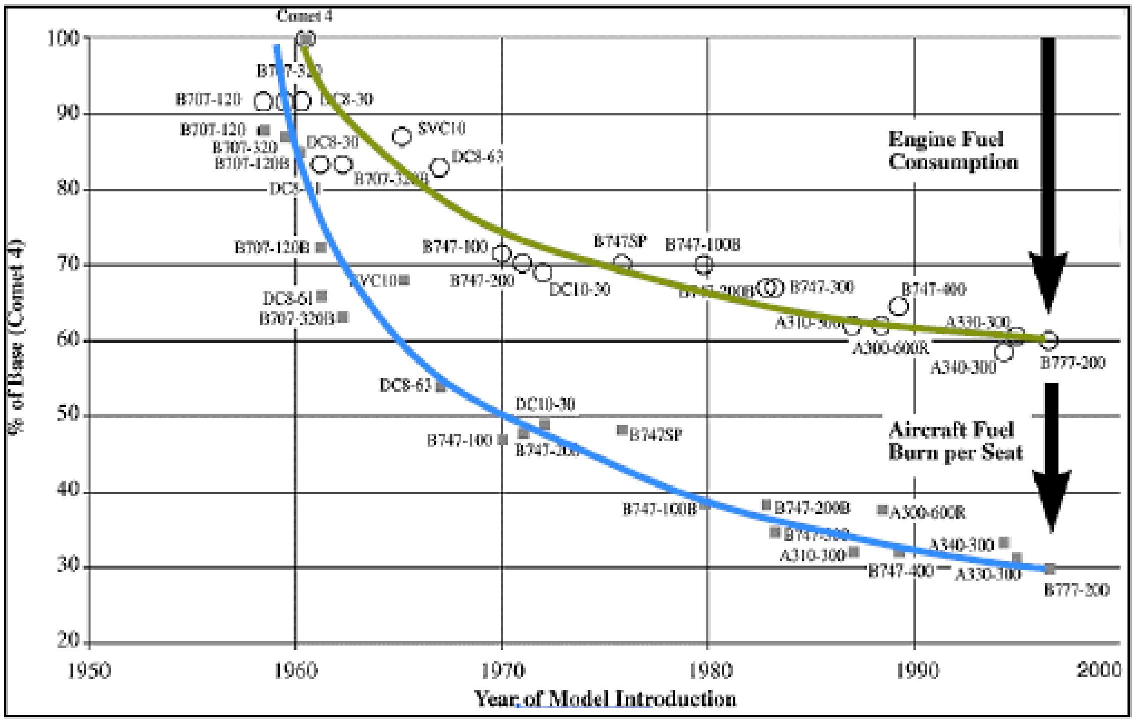
ideal: $CO_2 + H_2O + N_2 + O_2 + SO_2$

real: $CO_2 + H_2O + N_2 + O_2 + SO_X + UHC + CO + C_{Soot} + \underbrace{NO + NO_2}_{NO_x}$

Source: MTU/Airbus

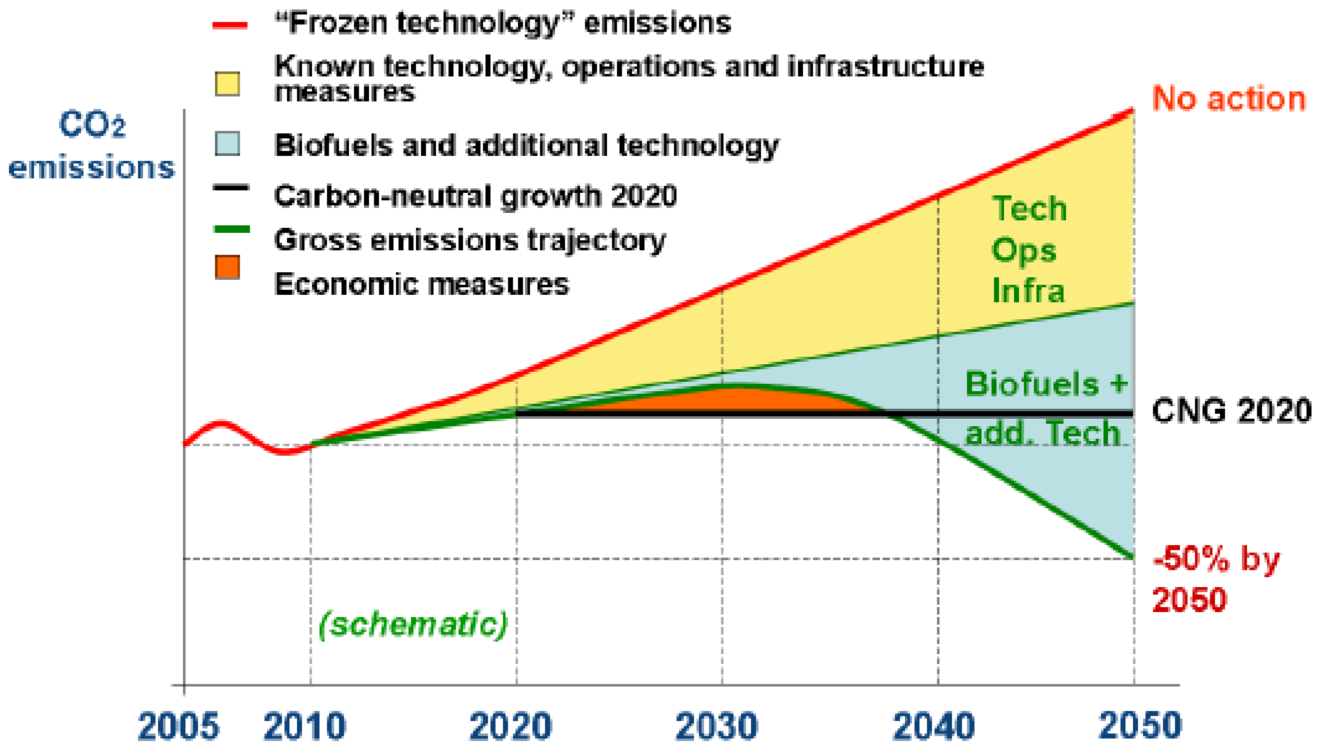
Challenges of Civil Aviation in the 21st Century

Improvement in aircraft fuel burn



http://www.grida.no/publications/other/ipcc_sr/?src=/climate/ipcc/aviation/avf9-3.htm

Challenges of Civil Aviation in the 21st Century

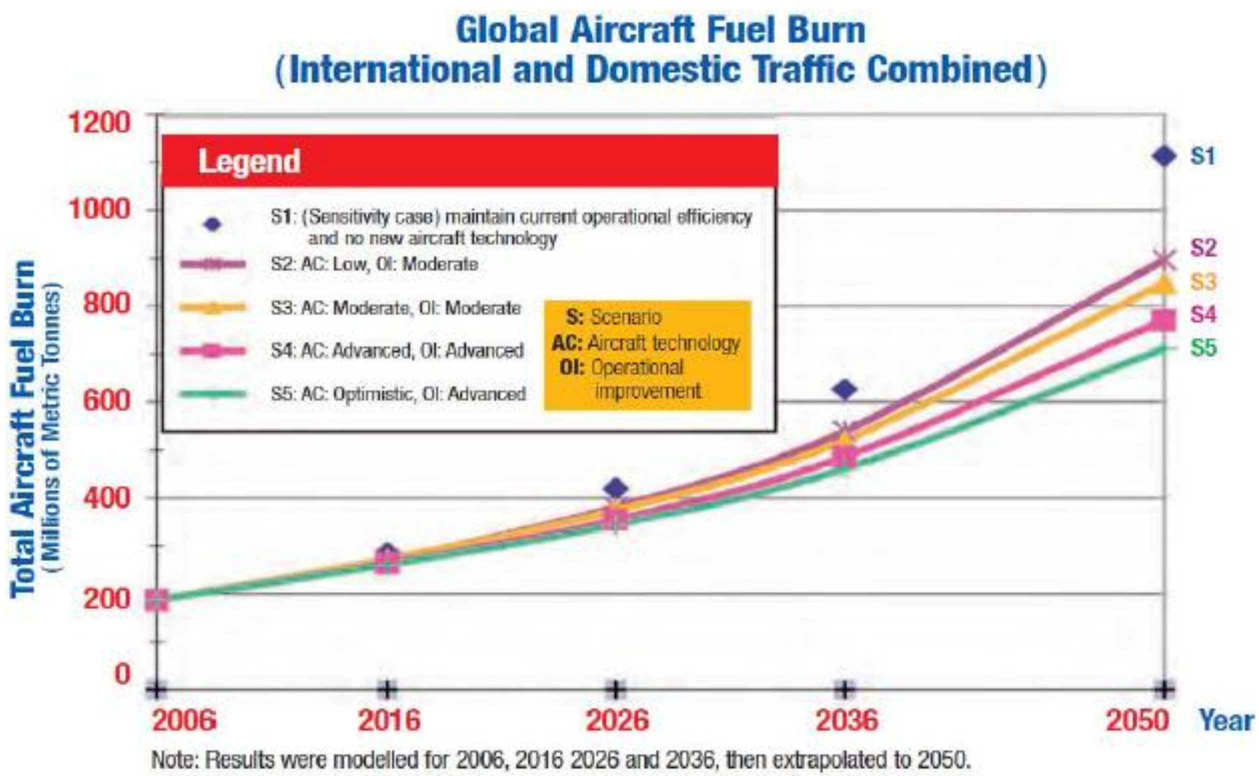


CO2 emissions development; The IATA Target

(source IATA)

Challenges of Civil Aviation in the 21st Century

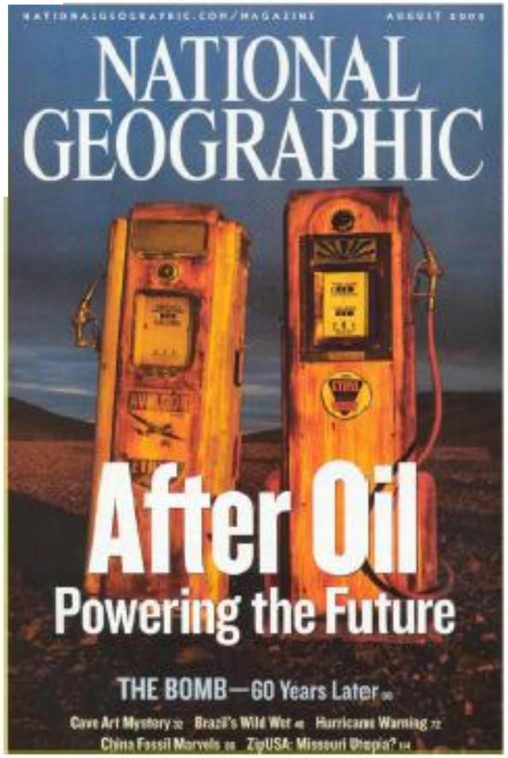
Aircraft Fuel Consumption

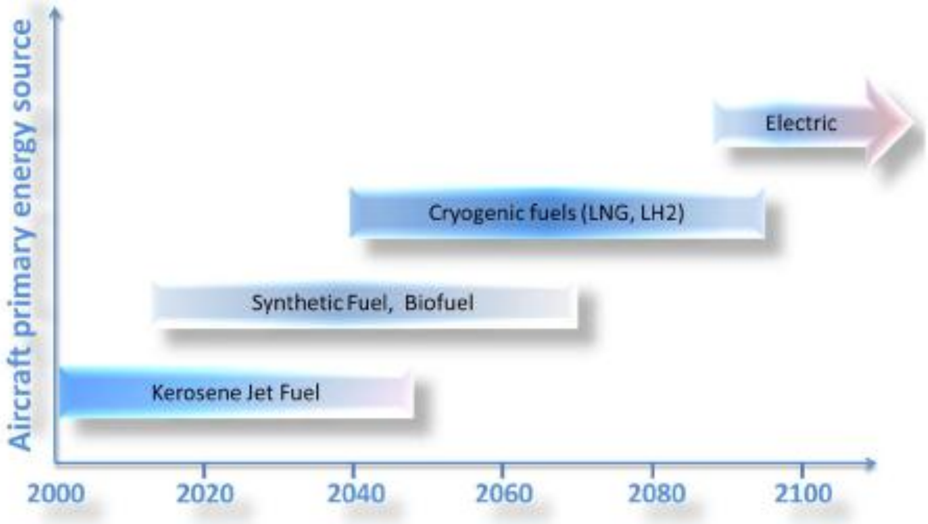


Source: ICAO Economic Briefing No.10

Challenges of Civil Aviation in the 21st Century

Future fuel Scenario for long range a/c





Picture courtesy of TU Delft

Developments of alternative fuels

In the news: development of alternative fuels

STAKEHOLDER INPUT

Alternative fuel case studies

In 2011, KLM was the first airline to use an alternative fuel based on used cooking oil for a commercial flight from Amsterdam to Paris. The BioPort Holland project and KLM Corporate Biofuel Programme aim to supply 1% of KLM's entire fleet with sustainable jet fuel in 2015-2016. Similarly, Lufthansa has been operating the domestic route from Frankfurt to Berlin using a 10% alternative fuels blend based on sugarcane, and the Frankfurt to Washington route using a 46.8% blended HEFA fuel based on jatropha, camelina and animal fats. Since 2013, Air France has been using a sugarcane based 10% blend alternative fuel on Toulouse to Paris (Orly Airport) routes. Iberia has also operated the Madrid to Barcelona route using a 25% HEFA (from camelina) alternative fuels blend.

The EU ITAKA [44] project (2013-2016) is also expected to support the development of a full value- chain to produce sustainable HEFA on a large scale based on camelina and used cooking oil. First demonstration flights were completed by KLM in 2014 with 200 tonnes of used cooking oil-based biofuel.

Biofuels: alternative fuels produced from biomass

- Significant emission reduction in production phase
- Several sources of biofuel in development
- Currently 50% blending allowed with kerosene

Challenges of Civil Aviation in the 21st Century

Development of aircraft design costs

Aircraft Model	Number built/ ordered as of 2012	Development Time in Years	Year Entered Service	Development Costs	Development Costs/Seats	Development Cost/Seat Built
				(in constant 2012 US$)		
DC-3	607	2	1936	4.8M	0.23M	3770
DC-6	704	3	1947	161M	2.88M	4084
B707	1010	6	1958	1453M	10.38M	10,276
B747	521	4	1970	5500M	12.17M	23,355
DC-8	556	7	1959	1011M	12.64M	227,299
B777	400	6	1995	7800M	19.50M	14,265
A380	253	7	2007	16,100M	30.67M	121,212
A350	555	7	2013	15,200M	55.07M	99,229
Concorde	20	9	1976	11,495M	114.95M	5,750,000
B787	873	7	2011	32,000M	121.21M	138,845
MF-BWB	800	10	2040	50,000M	167 M	208,333

Source: IATA Technology roadmap 2013

Challenges of Civil Aviation in the 21st Century

Over the last decades dramatic improvements in aircraft and aircraft engine designs have been achieved.

However if we want to cope our durability efforts with forecasted growth in air travel we need to go even more ahead with technological developments

Challenges of Civil Aviation in the 21st Century

There is a need and drive for even more significant improvements in aircraft and propulsion technology driven by:

- Environmental needs
- Fuel burn economy and availability of fuels

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Current propulsion developments

Current engine programs:

- GE/SAFRAN
- RR
- P&W

Source: Wikipedia

Current propulsion developments

Focus on:

- Fuel consumption reduction:
  - Improving aerodynamics and combustor technology
- Noise reduction:
  - Aerodynamics
  - Acoustic
  - Fan speed
- Reliability and durability improvements:
  - Technical reliability & time on wing

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Mediumterm developments

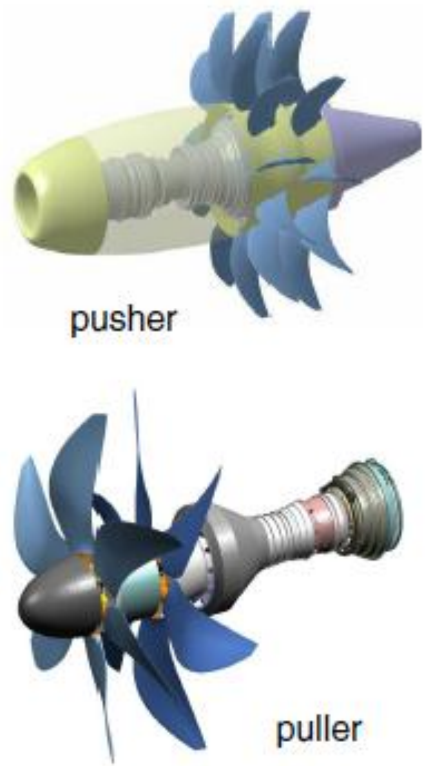
Open rotor technology

Description
- Open counter-rotating fan
- Gearbox or counter-rotating low pressure turbine
- „pusher“ or „puller“ configuration
- Very high bypass ratio

Benefits
- Very high propulsive efficiency
- 20% reduced fuel consumption *
- Technology readiness 2020+

Challenges
- Noise emission (far field + cabin)
- Installation
- High flight velocity
- Blade off, bird strike, blade pitch change mechanism
- Gearbox / counter-rotating turbine

* rel. to year 2000 engine



Source: MTU/Airbus

Source: Wikipedia

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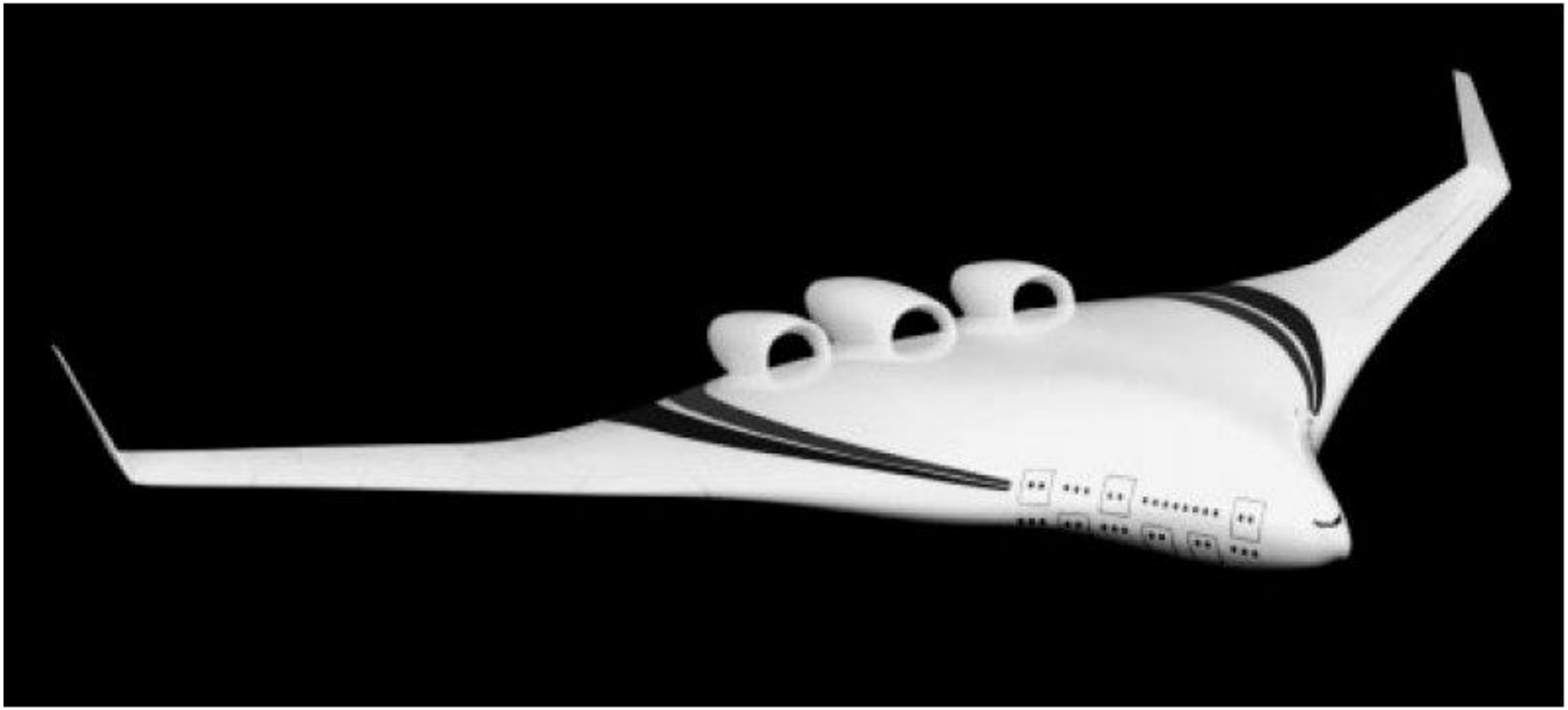
Long term developments subsonic

- Engines using fossil fuels:
  - Extreme high bypass ratio's
  - Further developments of open rotors or turbofan engines
  - Hybrid engine development operating on multiple types of fuel e.g. AHEAD design using:
    - LNG/LH2
    - Kerosene/Biofuel

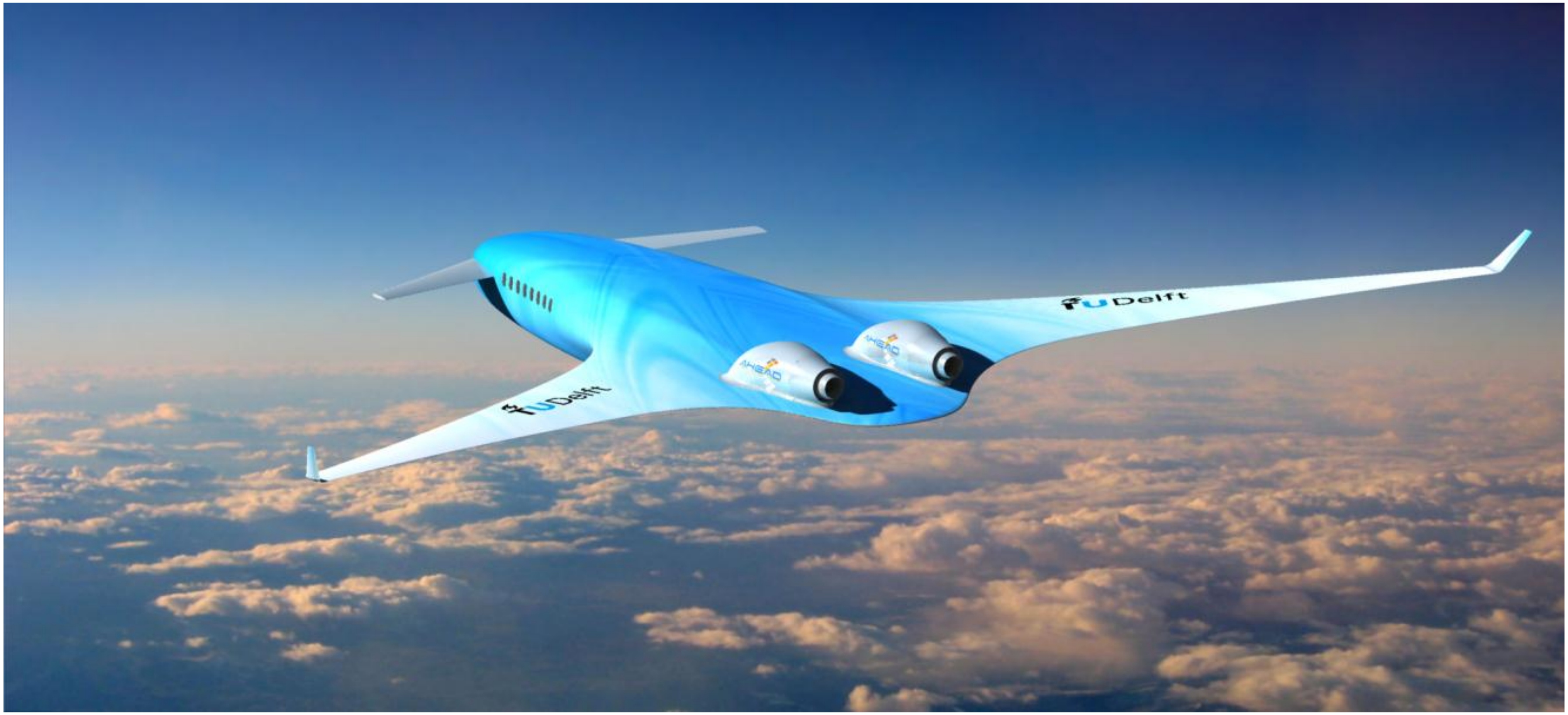
Long term developments subsonic



Boeing design concept Blended Wing Body

Source: Wikipedia

Long term developments subsonic

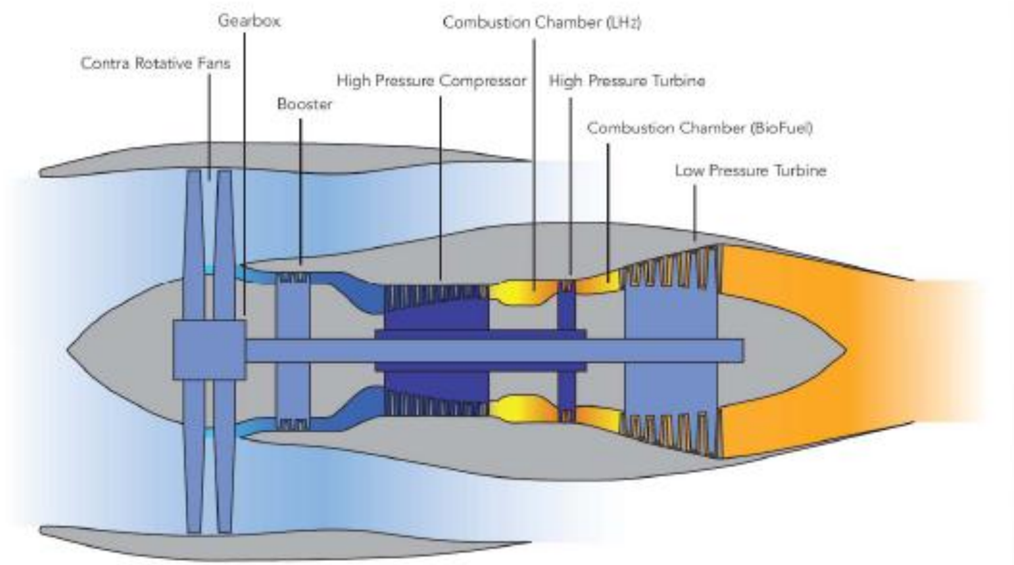


AHEAD: Advanced Hybrid Engine Aircraft Development

Picture courtesy of TU Delft

Long term developments subsonic
Advanced Hybrid Engine Aircraft Development

Next Generation Hybrid Engine



- ✓Counter rotating shrouded fans
- ✓Inter cooling and bleed cooling by LH2
- ✓High Overall Pressure Ratio (approx. 50)
- ✓ Higher Specific Thrust
- ✓Low Installation Penalty
- ✓LH2 Combustor & Biofuel / Kerosene Flameless Combustor

Picture courtesy of TU Delft

Long term developments subsonic

Electrical propulsion:

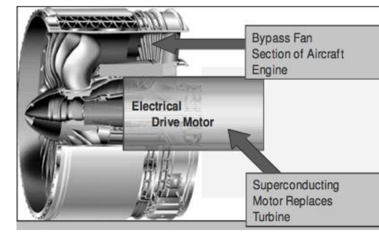
Description
- Electric driven propeller, open rotor or ducted fan
- Energy storage by batteries

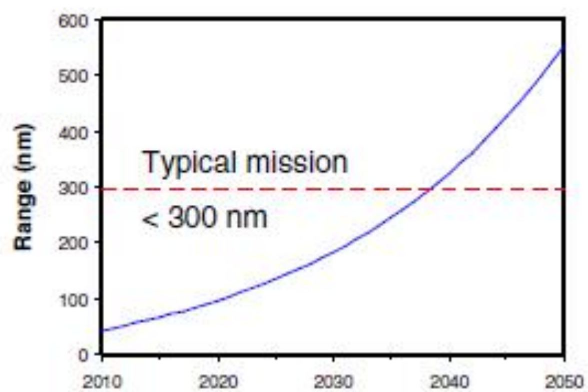
Benefits
- Zero emission (during flight)
- Independence from oil resources

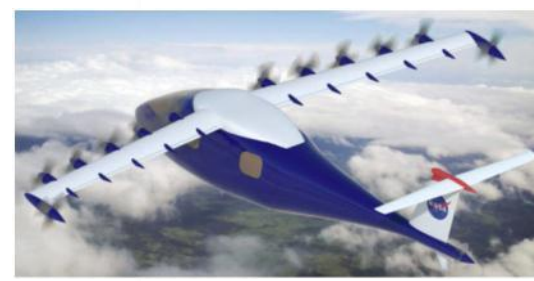
Challenges
- Specific energy of batteries (kWh/kg)
- Power to weight ratio of electric motors (high temperature superconductivity necessary)

Example: Electrification of an ATR72-600

Assumptions
- Battery capacity: 200 Wh/kg 2010, 5% p.a. improvement
- Fuel replaced by batteries (5 t)
- Electric motors using high temperature superconductivity (HTS)







Source: MTU/Airbus

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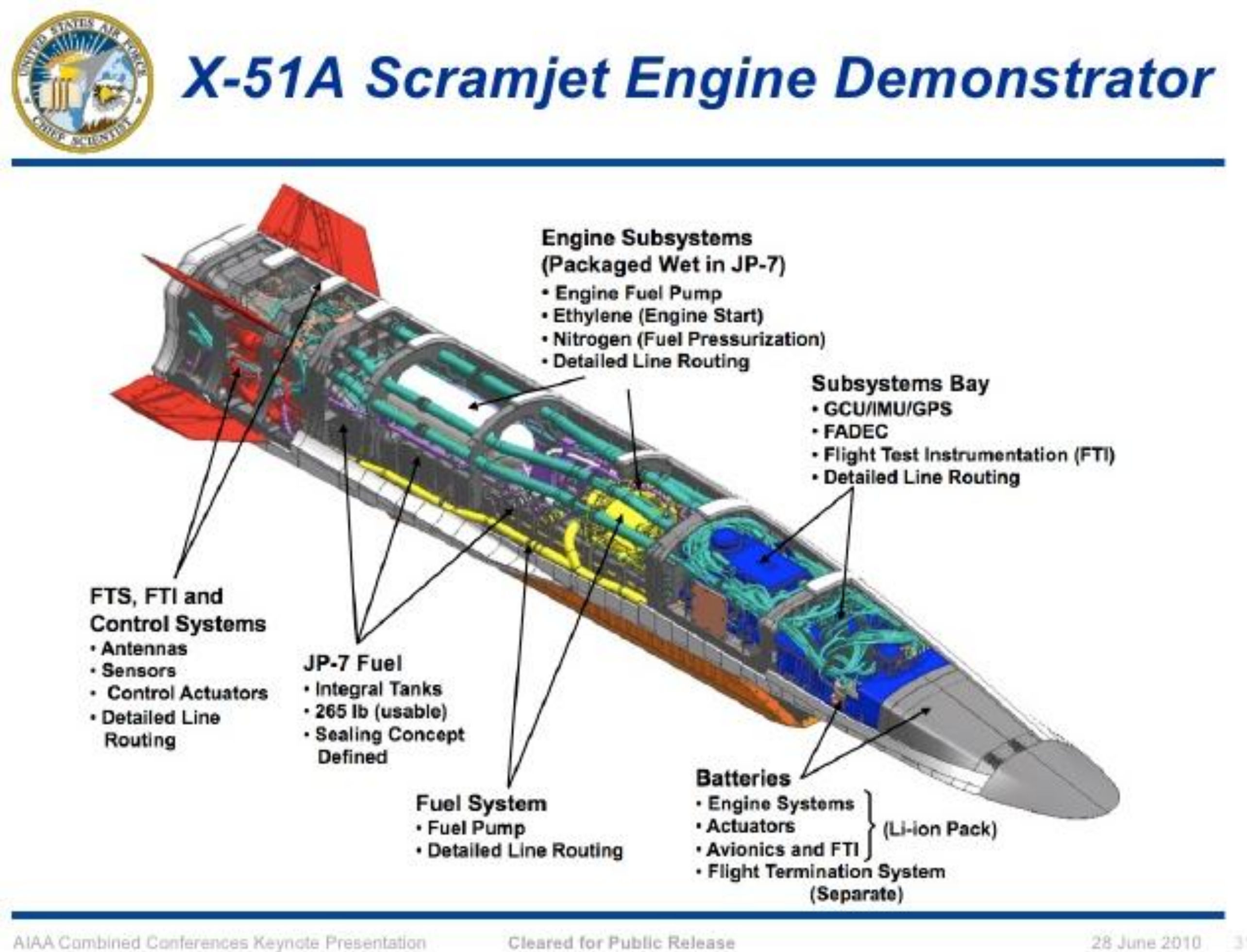
Long term developments
Supersonic & Hypersonic concepts

- Several concepts are under study:
  - Supersonic
  - Hypersonic
  - Atmospheric flight
  - Space flight
  - Combination of atmospheric and space flight

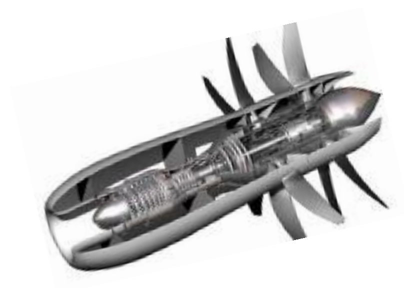
Long term developments
Supersonic & Hypersonic concepts



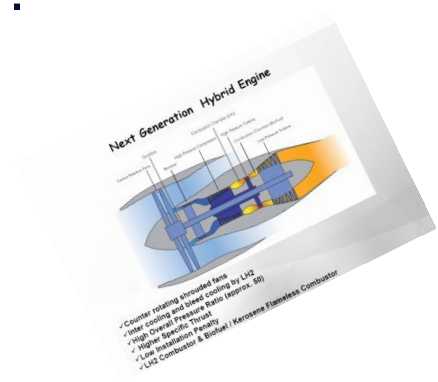
Summary

In which direction are we moving?

Yr 2020



Yr 2030



Yr 2050

End