Aircraft Concepts and Technologies for Sustainable Aviation

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Outline

• Perspectives on Transportation
  – Aircraft fuel efficiency
  – Aviation and the global environment

• Future Aircraft Concepts
  – Near-term opportunities
  – Longer-term options

• Reflections on this Meeting
Modern Aircraft Fuel Efficiency

For a flight from Seattle to Washington D.C., each passenger needs about 29 gallons of fuel.

\[
\frac{3,709 \text{ gal}}{130 \text{ pax}} = 29 \text{ gal/pax (81 PMPG)}
\]

Typical car in SF bay area:
\[
25 \text{ mpg} \times 1.3 \text{ pax} = 32 \text{ PMPG (Similar to Amtrak)}
\]

2,325 mi, 3,709 gal, 162 pax, 80% load factor
Aviation Contribution to GHG

• Transport responsible for about 13%-20% of all GHG emissions.
• Aviation contributes about 13% of transportation CO2 emissions.
• That seems like 2%-3% of CO2, but net effect is perhaps 2-4 times this (4%-12%), and is increasing.

Global CO₂ Emissions per Transport Sector (%)

- Aviation: 13%
- Others: 13%
- Road: 74%

Total aviation accounts for about 13% of CO₂ emissions from transport sources compared to 74% of total transport CO₂ emissions from road transport.
Sustainable Aviation – The Problem

With the expected increase in global air travel over the next 20-30 years, the reliability and environmental impact of aviation are becoming critical issues for the future of flight.

Issues:
Safety
Efficiency
Noise
NO$_x$
CO$_2$
H$_2$O
Sustainable Aviation

Goal: Develop technologies that will allow increased capacity with a reduction in environmental impact.
Approaches to Sustainable Aviation

- Aerospace system design for the environment
- Safely increase the capacity of the airspace system
- Active monitoring and managing air transportation's environmental footprint
Increasing Aircraft Efficiency

• Engine efficiency, $\eta$, is about 40% (twice that of automobiles), and further gains are increasingly difficult.

• Transportation is basically 0% efficient. Why do we need energy?

• Energy / distance = Drag / $\eta$ = Weight / $\eta$ L/D
Aircraft L/D

Evolution of M L/D for Long-Haul Commercial Transports
Range >4500 nmi

M (L/D)max

Year Entered in Service

Lift-to-Drag Ratio of Other Transport Modes

Passenger car:
L/D = 100 at V≈0
L/D = 40 at V = 60 mph
L/D = 16 at V = 120 mph

Rail car: L/D = 1000+ at V≈0

Ships: 550 ft destroyer at 35 kts: L/D ≈ 18
L/D is not fundamentally limited to ~20

Current transport fuel consumption is partly due to turbulent tube + wing configuration, but also due to optimization metrics (cost).

Eta Sailplane: L/D = 70
Span: 31 m
Optimization for Cost, Fuel, NOx, Climate
Trading Cost and Climate Impact

![Graph showing the relationship between trading cost and climate impact for narrowbody aircraft. The graph plots 100-year global warming against cost, with data points indicating initial and final cruise altitudes and cruise Mach numbers.](image-url)
Contrails and Aviation-Induced Cloudiness

Persistent contrails formed in supersaturated and cold air.
Contrails and Aviation-Induced Cloudiness

Effect on climate has high uncertainty and might be mitigated with active rerouting.
Climate Cost Trade with Contrail Avoidance
“New” Technologies

New technologies and configuration concepts shift the trade-space
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Near-Term Natural Laminar Flow Transport

- 150 pax
- 3000 n mi turbulent range
- Mach 0.75
- TOFL 7500 ft
- -6% to -8% fuel burn compared with turbulent wing design
Boeing High L/D Electric Transport Concept

- N+3 Design Study
- Electric propulsion with batteries/fuel cells/hybrid considered
- 70% fuel burn reduction for 900 mi range, 750 wh/kg batteries
- Mach 0.7 to 0.78
Specific Energy of Power Systems

Electric power systems intriguing but very challenging.

Near term possibilities for smaller aircraft.

Most electric storage tech development focused on cost, volume.
Reflections

NASA focus on green aviation:

– Provides a framework for integrating research across ARMD and with related organizations
– Encourages more direct interaction with industry
– Defines a clearly relevant field of study for students and university researchers
– Addresses the most important problem in aeronautics
Back-up Slides