Making an Extraordinary Machine Better
An Extraordinary Machine: The Passenger Jet

Compared to an automobile, a modern jet is . . .

• $10 \times$ faster (560 mph)
• $100 \times$ safer per passenger-mile
• comparable in fuel burn per passenger-mile
Typical Passenger-Miles Per Gallon

200 P
× 0.6 mpg
120 P-mpg

4 P
× 25 mpg
100 P-mpg

2 P
× 50 mpg
100 P-mpg

1 P
× 50 mpg
50 P-mpg
Subsonic vs. Supersonic

- Boeing 787 (Subsonic): 200 P × 0.6 mpg = 120 P-mpg
- Concorde (Supersonic): 120 P × 0.17 mpg = 20 P-mpg
- Hummer (Subsonic): 1 P × 15 mpg = 15 P-mpg

... some things are just fundamentally more energy-intensive
Progress

Wright Flyer  Boeing 707  Boeing 787

1903  ...  55 years  ...  1958  ...  55 years  ...  2013

45 P-mpg  120 P-mpg

\[ P\text{-mpg} \sim \frac{\text{Payload weight}}{\text{Total weight}} \times \frac{\text{Lift/Drag}}{} \times \text{Engine efficiency} \]
What Else Can We Do? — Unducted Fan

McDonnell-Douglas MD-UHB Demo (1987)

10-15% better in P-mpg, but noisy
What Else Can We Do? — Engine/Airframe Integration

**Conventional Propulsion**

- Zero Net Momentum
- Wasted Kinetic Energy
- Wake, or "draft"
- Propulsion jet

**Boundary Layer–Ingesting (BLI) Propulsion**

- Zero Net Momentum
- Wasted Kinetic Energy
- Combined wake and jet

BLI is 5-10% better in P-mpg, and quiet
What Else Can We Do? — Unconventional Configurations

Blended Wing-Body

Truss-Braced Wing

Likely better, but risky (many uncertainties)
A Recent Concept: The D8 “Double-Bubble” Aircraft

Estimated 140–165 P-mpg,
via synergy between configuration and integrated engines
Configuration Comparison

B737-800
- 0.80 Mach
- 180 Passengers
- 2600 mi
- 170000 lb
- 95 P-mpg

D8.2
- 0.72 Mach
- 180 Passengers
- 3000 mi
- 135000 lb
- 145 P-mpg
D8 Fuselage – Primary Benefits

- More fuselage lift → shrinks exposed wing
- Localized nose lift → shrinks tail, tail download, wing

D8 Fuselage–lift fraction 19%

B737–800 Fuselage–lift fraction 13%

Lighter wing

Smaller required tail download

Smaller required wing lift

Nose lift
Load/Unload Time Comparison

B737–800
30 x 6 per aisle
(30 minutes load, unload)

D8
23 x 4 per aisle
(15 minutes load, unload)

NYC-LAX gate-to-gate time is similar, despite D8’s slower cruise
Technology Development

Current and future wind tunnel tests

MIT 10x7 Tunnel

20:1 Model

11:1 Model

NASA Langley 22 x 14 Tunnel

4:1 Model
Technology Development

BLI Propulsor Testing
Technology Development

20:1 D8 wind tunnel model
The D8 aircraft . . .

. . . changing the look of commercial aviation