AIRCRAFT AND TECHNOLOGY CONCEPTS FOR AN N+3 SUBSONIC TRANSPORT

MIT, Aurora Flights Science, and Pratt & Whitney

Elena de la Rosa Blanco

May 27, 2010

Message

- Defined documented scenario and aircraft requirements
- Created two conceptual aircraft: D (double-bubble) Series and H (Hybrid Wing Body) Series
  - D Series for domestic size meets fuel burn, LTO NOx, and balanced field length N+3 goals, provides significant step change in noise
  - H Series for international size meets LTO NOx and balanced field length N+3 goals
  - D Series aircraft configuration with current levels of technology can provide major benefits
- Developed first-principles methodology to simultaneously optimize airframe, engine, and operations
- Generated risk assessment and technology roadmaps for configurations and enabling technologies

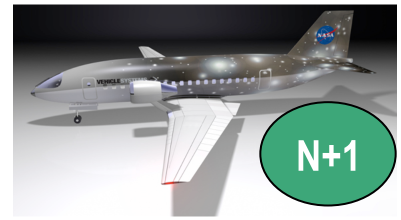
Project Enabled by University-Industry Collaboration

- MIT
  - (GTL) Propulsion, noise, (ACDL) aircraft configurations, systems, (ICAT) air transportation, and (PARTNER) aircraft-environment interaction
  - Student engagement (education)
- Aurora Flight Sciences
  - Aircraft components and subsystem technology; Aerostructures and manufacturing; System integration
- Pratt & Whitney
  - Propulsion; System integration assessment
- Collaboration and teaming
  - Assessment of fundamental limits on aircraft and engine performance
  - Seamless teaming within organizations AND between organizations

NASA System Level Metrics

…. technology for dramatically improving noise, emissions, performance

CORNERS OF THE TRADE SPACE	N+1 (2015)*** Generation Conventional Tube and Wing (relative to B737/CFM56)	N+2 (2020)*** Generation Unconventional Hybrid Wing Body (relative to B777/GE90)	N+3 (2025)*** Generation Advanced Aircraft Concepts (relative to user defined reference)
Noise	- 32 dB (cum below Stage 4)	- 42 dB (cum below Stage 4)	-71 dB (cum below Stage 4)
LTO NOx Emissions (below CAEP 6)	-60%	-75%	better than -75%
Performance: Aircraft Fuel Burn	-33%**	-40%**	better than -70%
Performance: Field Length	-33%	-50%	exploit metro-plex* concepts



- Energy intensity metric for comparison of fuel burn
- Add **a climate impact** metric for evaluation of the aircraft performance
  - Global temperature change as a result of the emissions

Three Major Results from N+3 Program

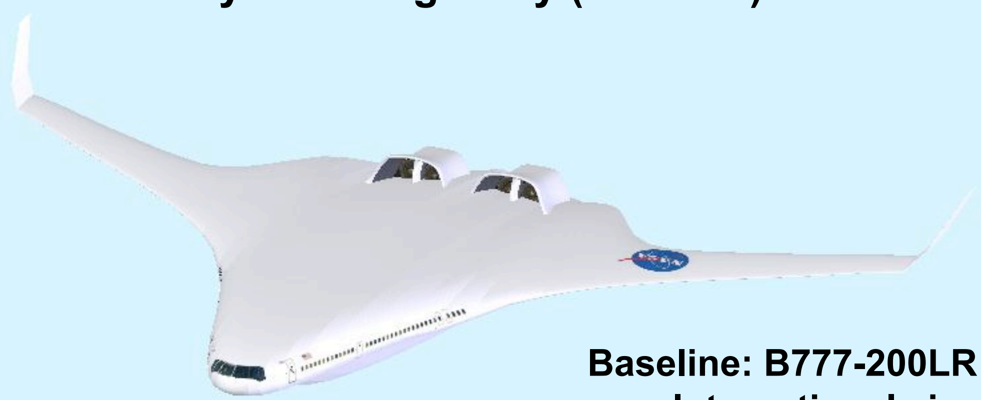
- Development and assessment of two aircraft configurations:
  - D Series for domestic size meets fuel burn, LTO NOx, and balanced field length N+3 goals, provides significant step change in noise
  - H Series for international size meets LTO NOx and balanced field length N+3 goals
- Comparison of D Series and H Series for different missions (domestic and international)
- Trade study identification of D Series benefits from configuration vs. advanced technologies

Two Scenario-Driven Configurations

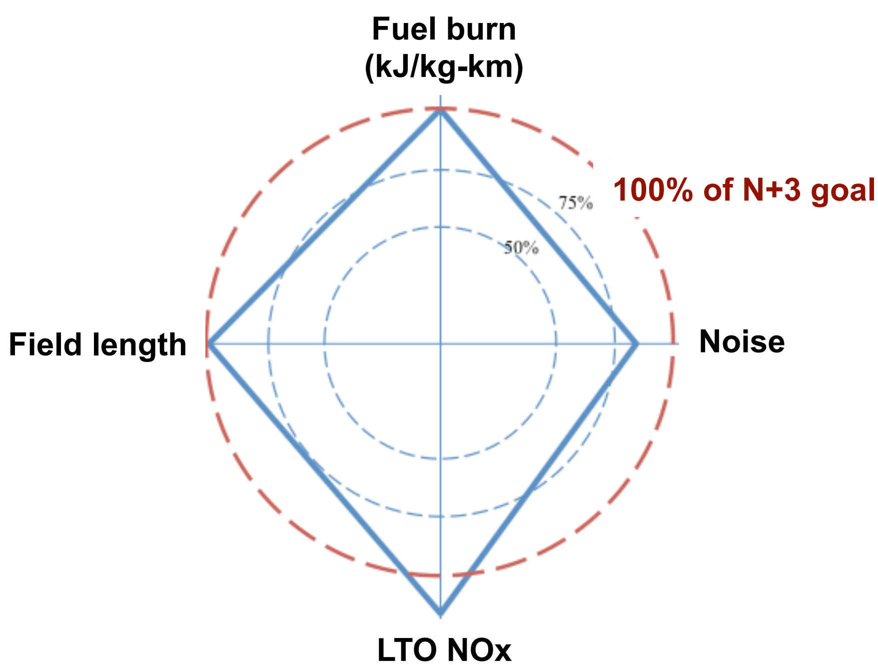
Double-Bubble (D series):
modified tube and wing with lifting body

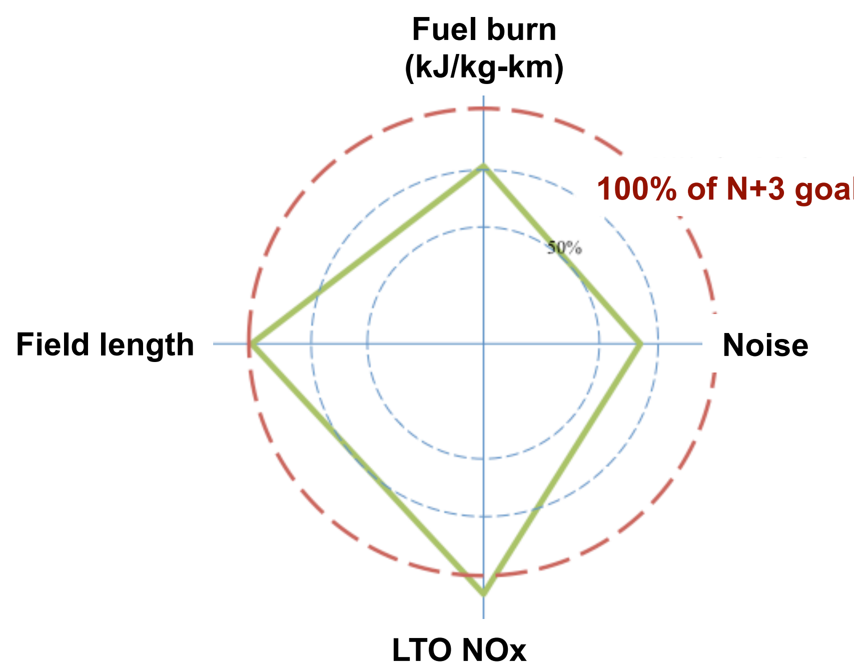
Baseline: B737-800
Domestic size

Hybrid Wing Body (H series)

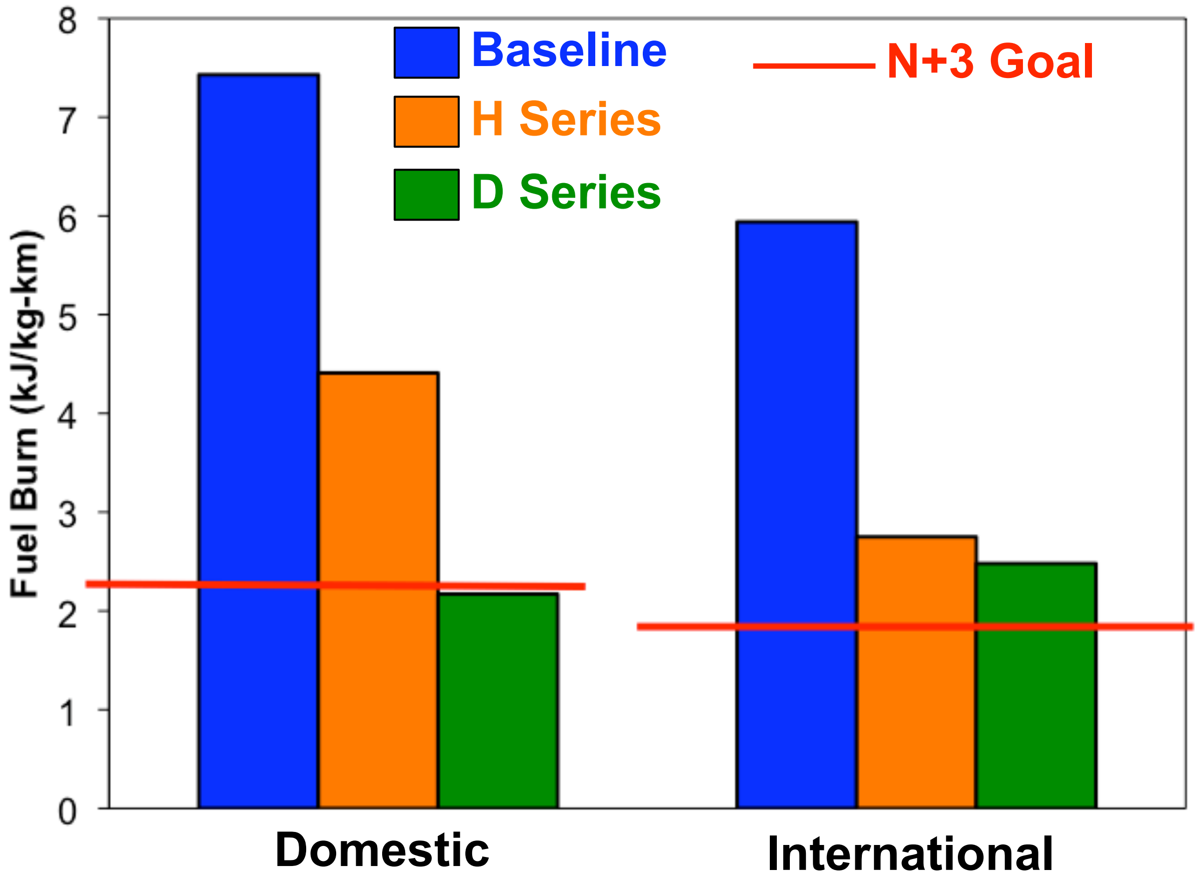


Baseline: B777-200LR
International size



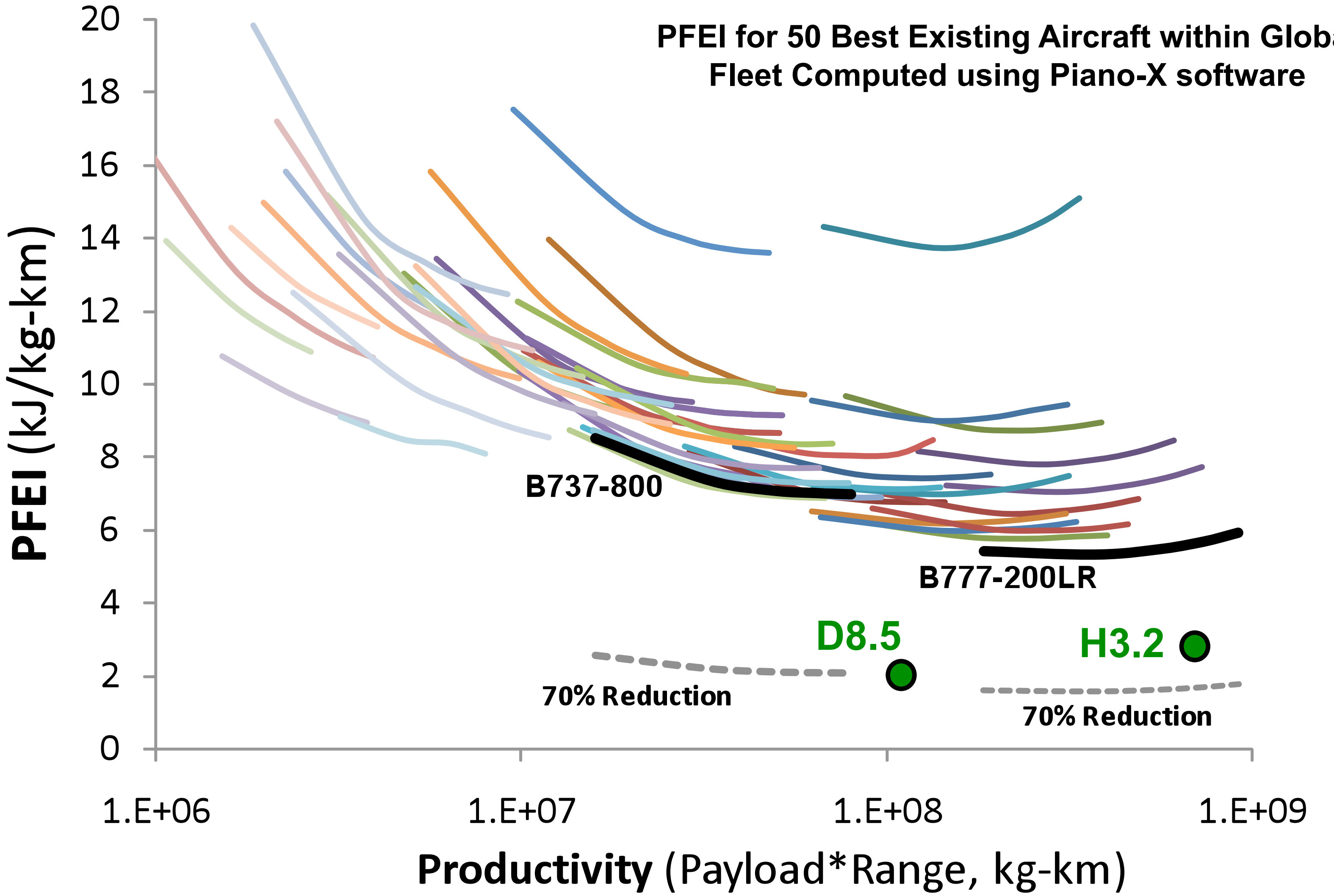


D and H Series Fuel Burn for Different Missions

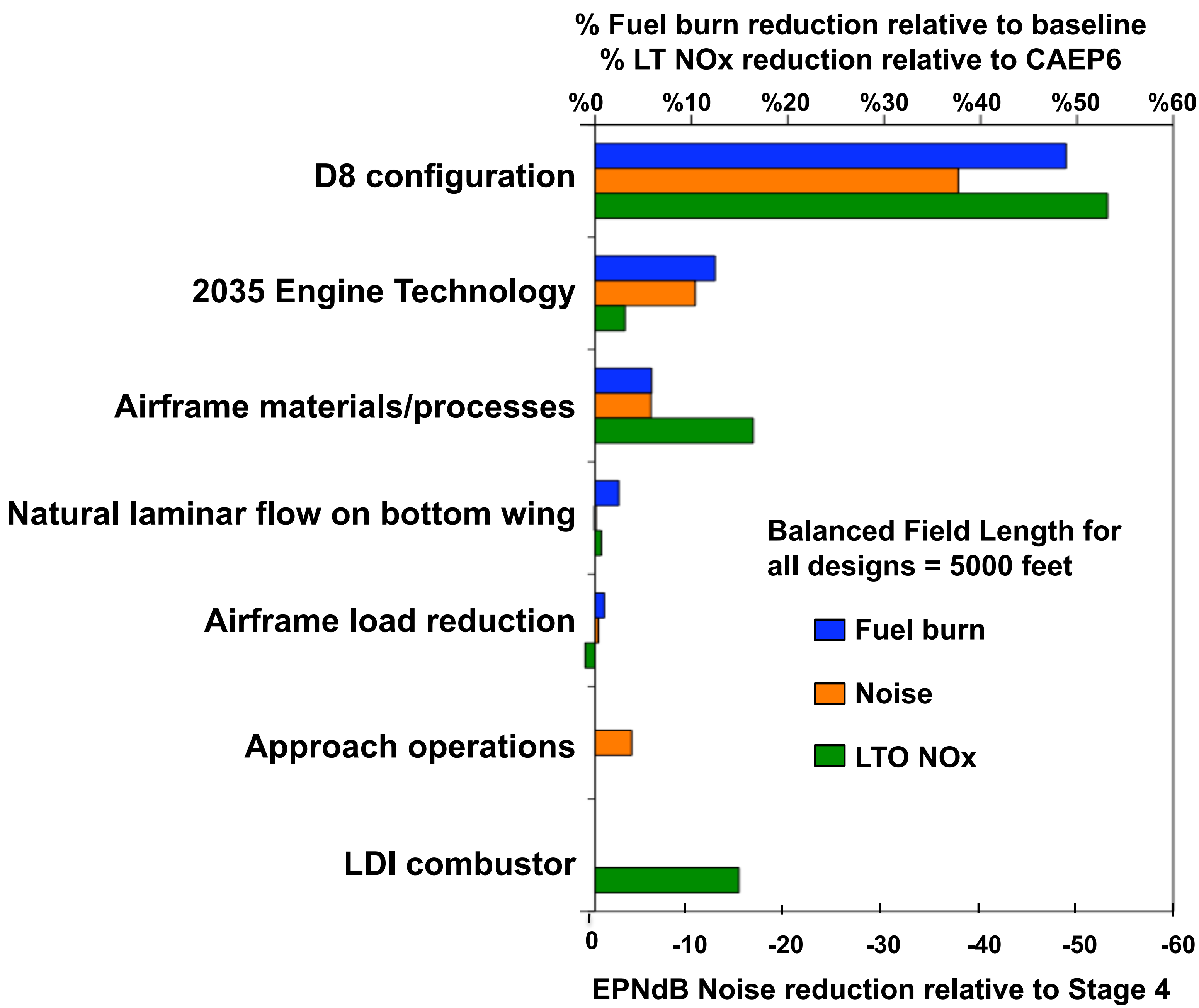


- D Series has better performance than H Series for missions examined
- H Series performance improves at international size

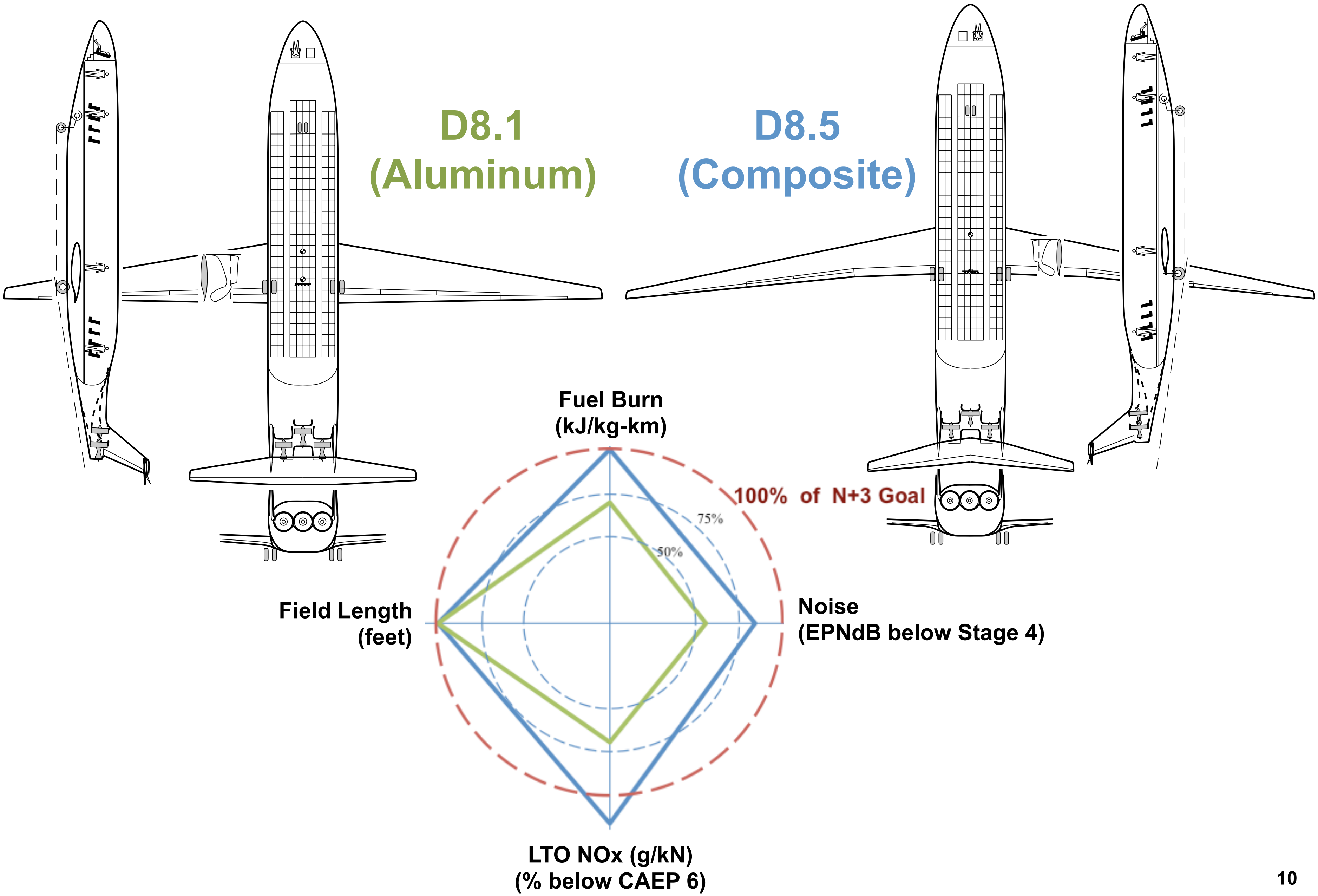
Fuel Burn Baselines and Results



D Series Configuration is a Key Innovation

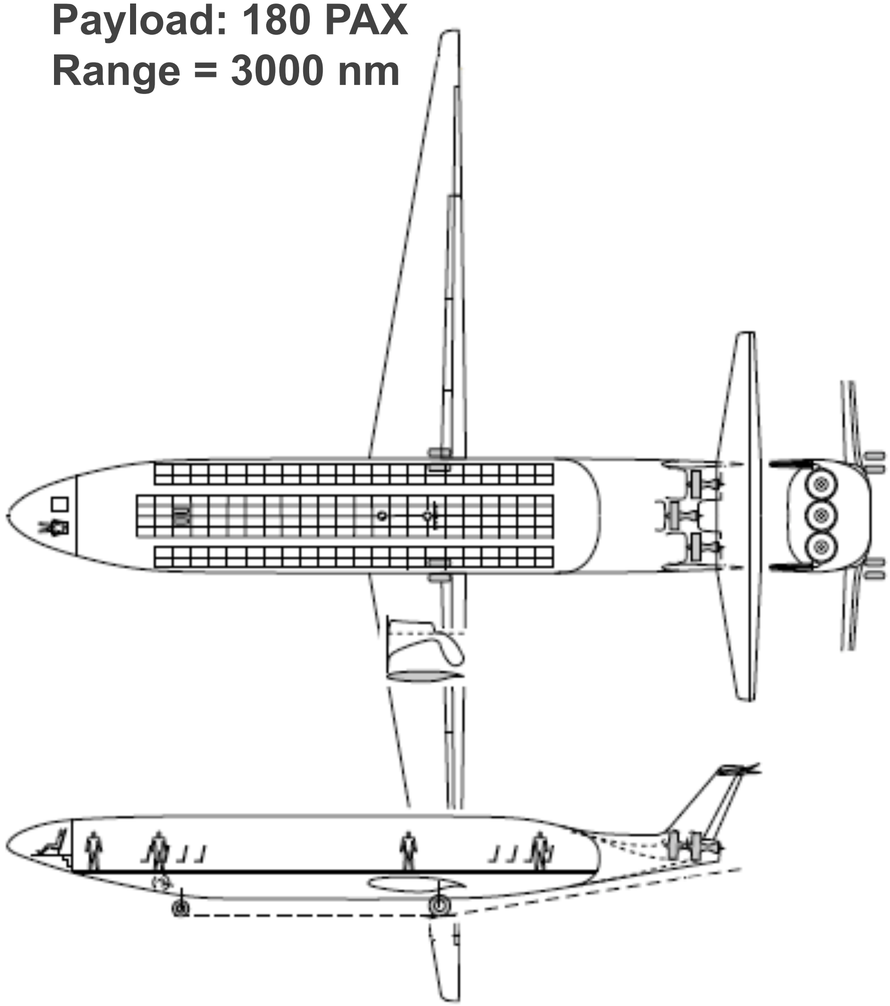


D8 Configurations: Design and Performance



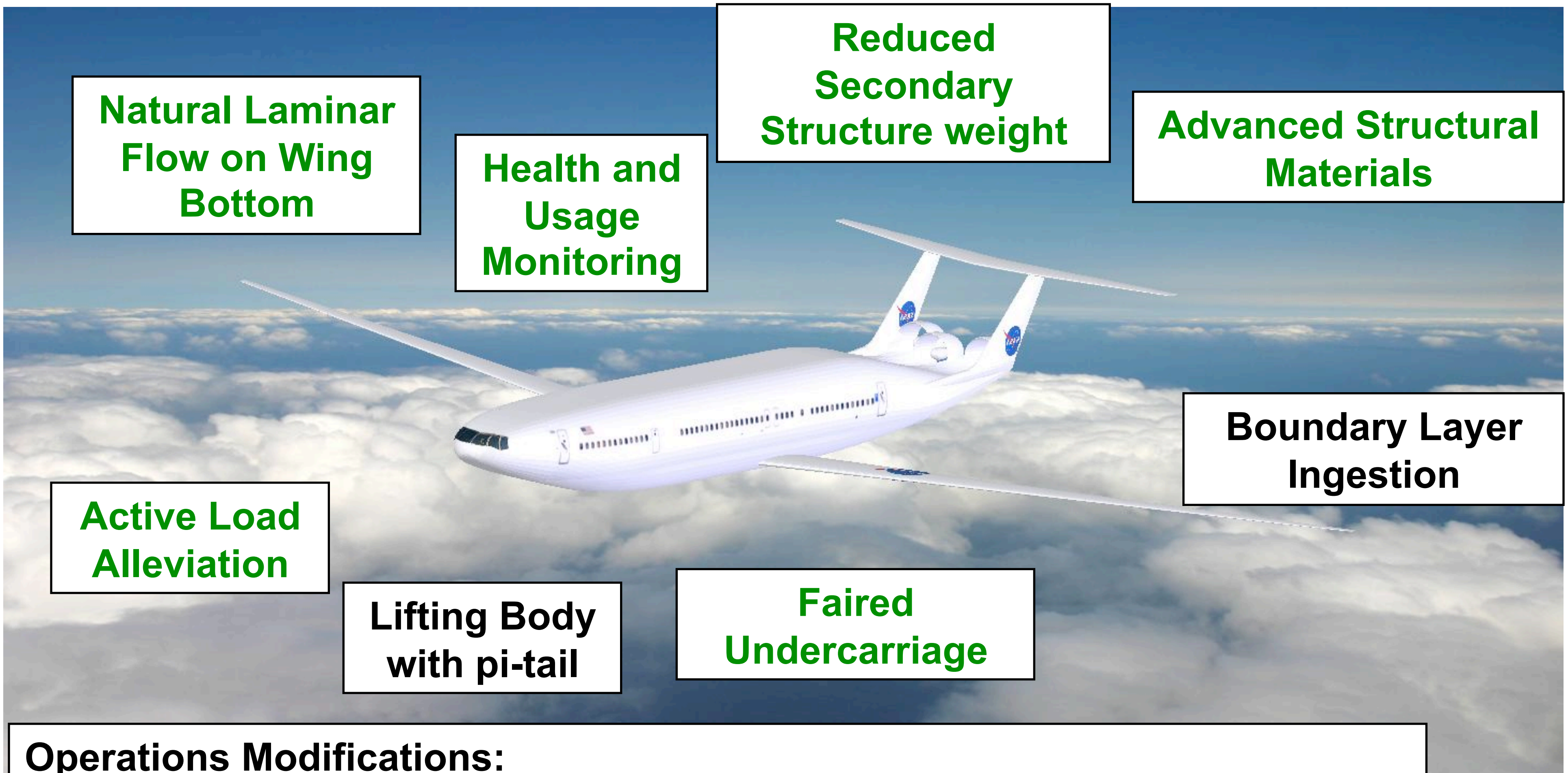
D8 – Double Bubble Configuration with current technologies

Payload: 180 PAX
Range = 3000 nm



- Double bubble lifting fuselage with pi-tail
- Engines flush-mounted at aft fuselage with boundary layer ingestion; engine noise shielding and extended rearward liners
- Reduced cruise Mach number with unswept wings and optimized cruise altitude
- Eliminates slats
- BFL = 5000 feet

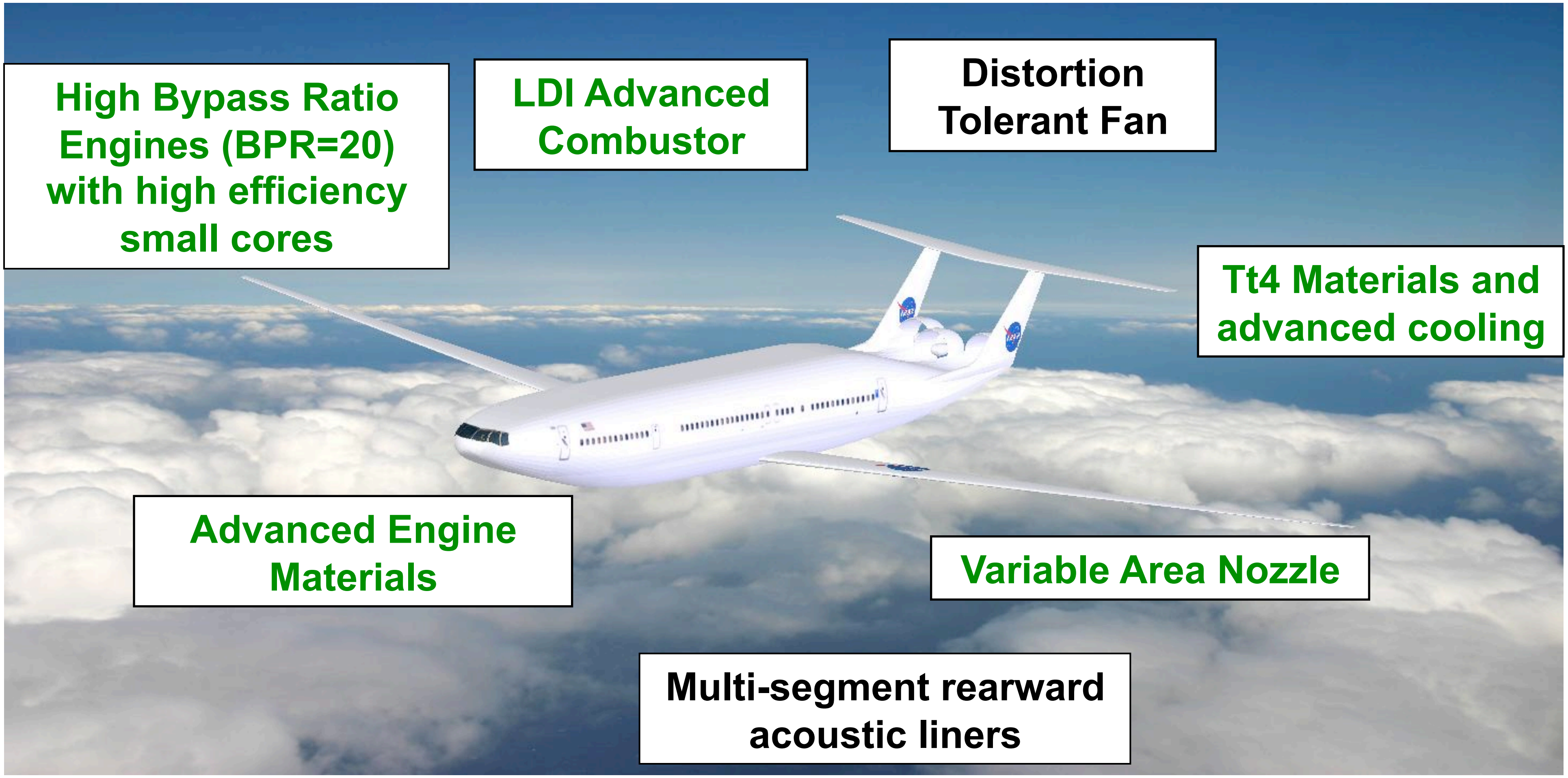
D8.5 Airframe Technology Overview



Operations Modifications:

- Reduced Cruise Mach:0.72 for D8.1 and 0.74 for D8.5
- Optimized Cruise Altitude: 40,000 ft. for D8.1 and 45,000 ft. for D8.5
- Descent angle of 4º
- Approach Runway Displacement Threshold

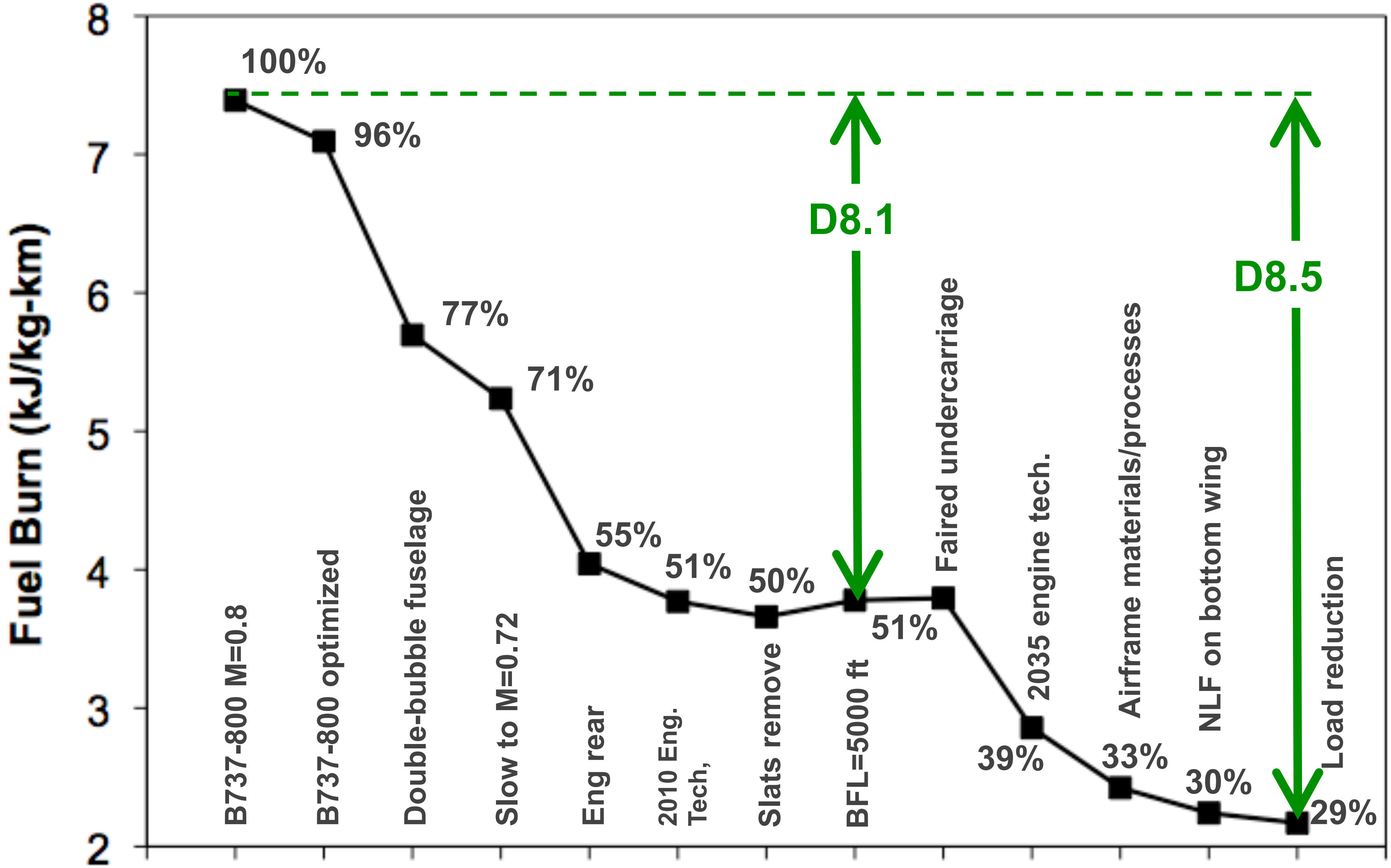
D8.5 Engine Technology Overview



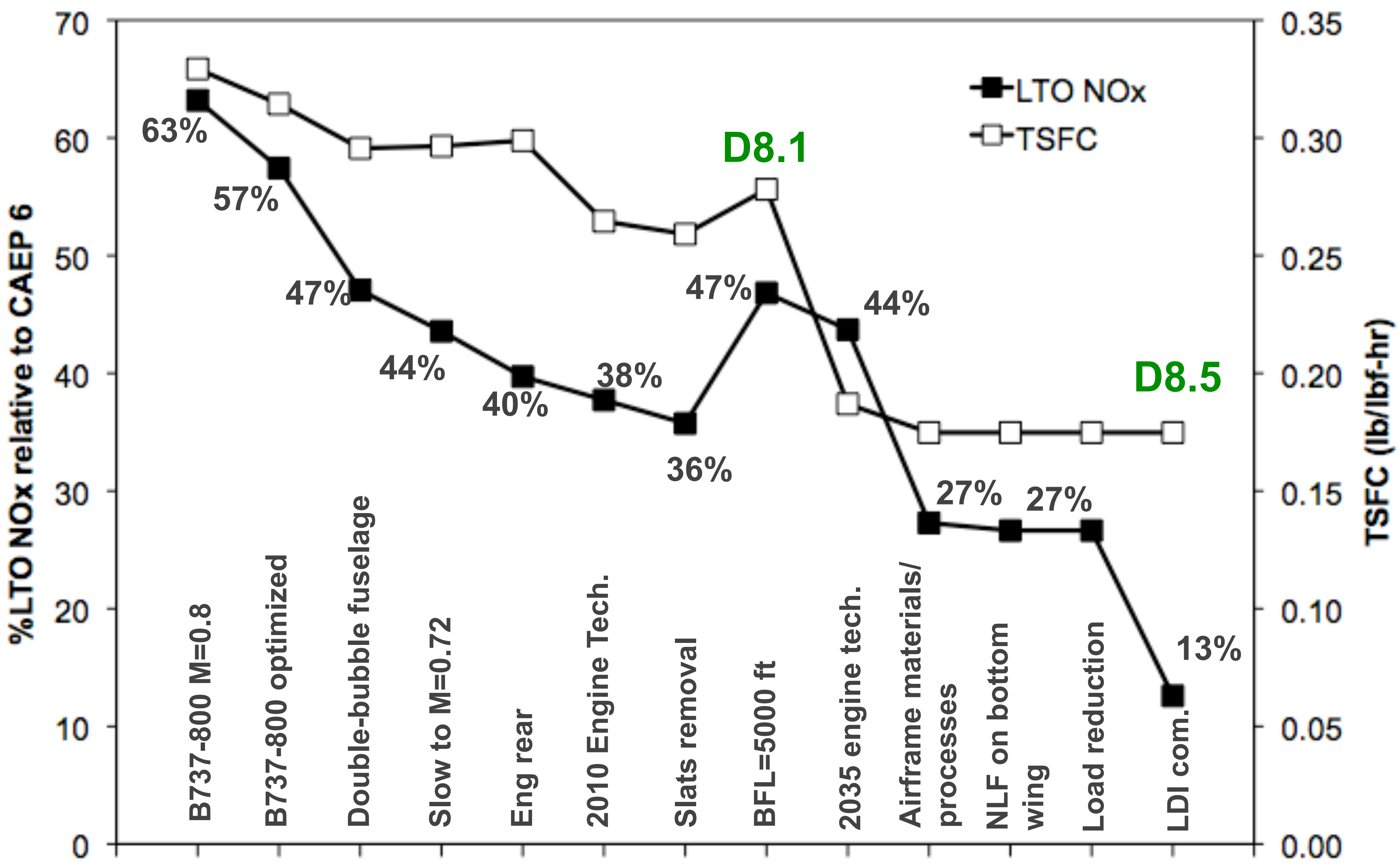
Design Modification Sequence from B737-800 to D8.1 and D8.5

- Case 0: B737-800
- Case 1: Optimized B737-800
- Case 2: Fuselage replacement from tube+wing to double bubble
- Case 3: Reduced cruise Mach number from 0.8 to 0.72
- Case 4: Engines flush-mounted on top, rear fuselage
- Case 5: 2010 Engine technology
- Case 6: Slats elimination
- Case 7 **(D8.1)**: Balanced Field Length reduced from 8000 ft. to 5000 ft.
- Case 8: Faired Undercarriage
- Case 9: 2035 Engine technology
- Case 10: Advanced Airframe materials and processes
- Case 11: Natural laminar flow on bottom wing
- Case 12: Airframe loads reduction
- Case 13: Approach operations
- Case 14 **(D8.5)**: LDI combustor

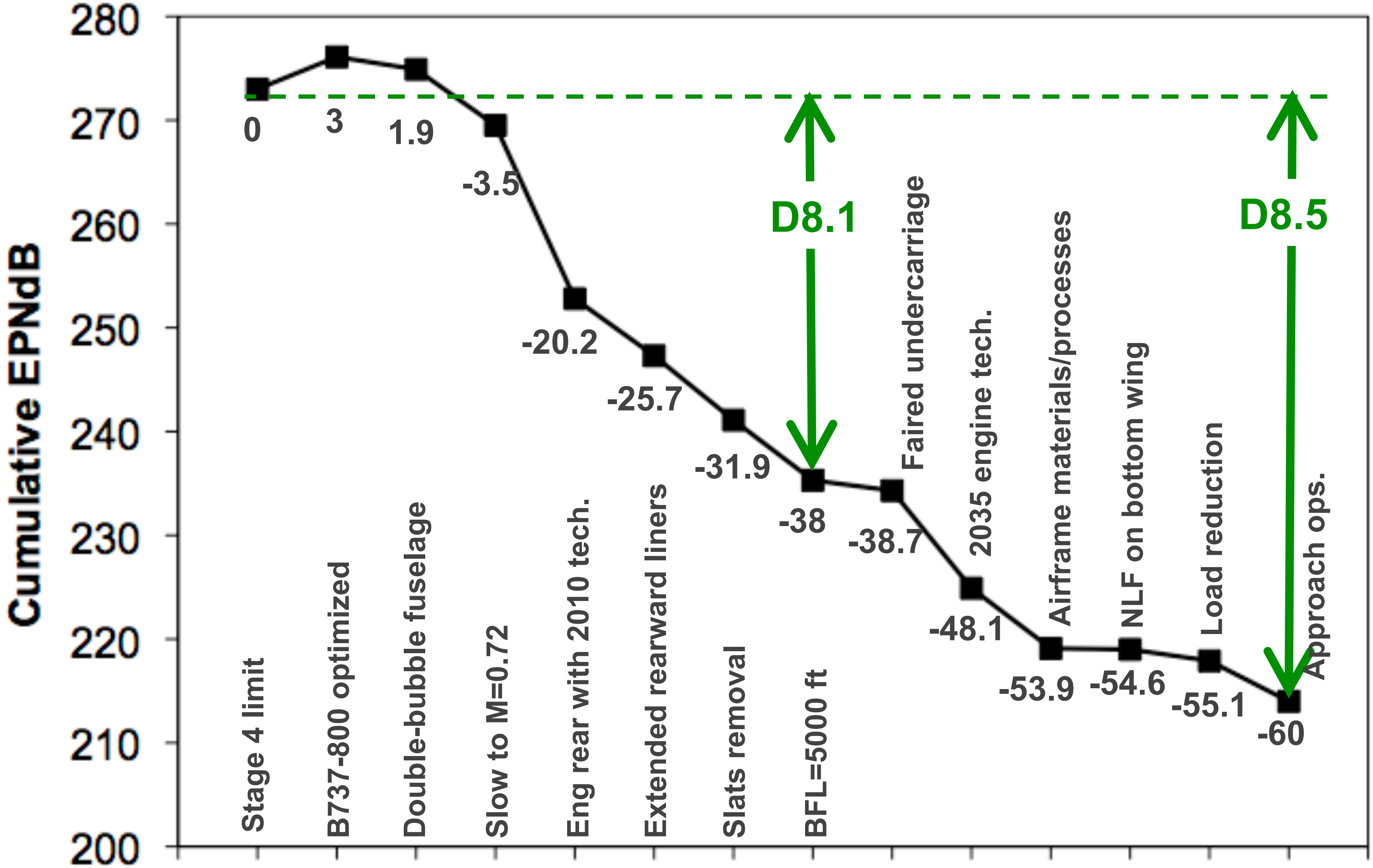
Fuel burn evolution from B737-800 to D8.1 and D8.5



LTO NOx evolution from B737-800 to D8.1 and D8.5



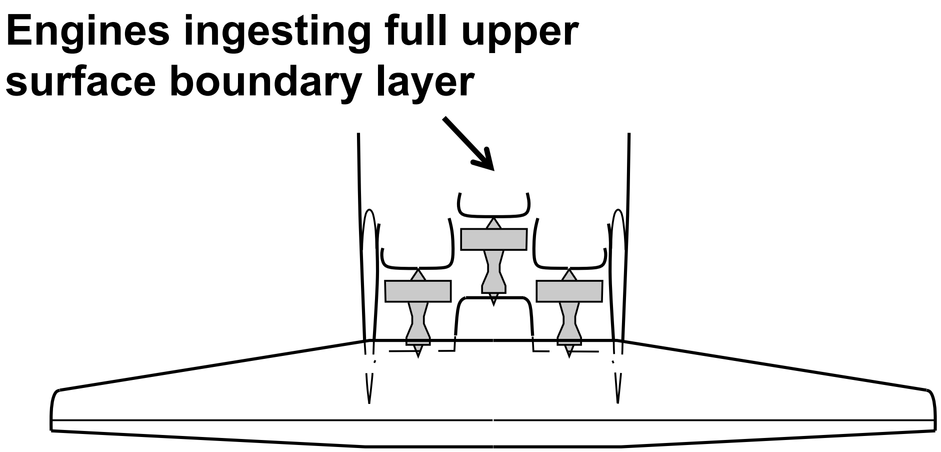
Noise evolution from B737-800 to D8.1 and D8.5

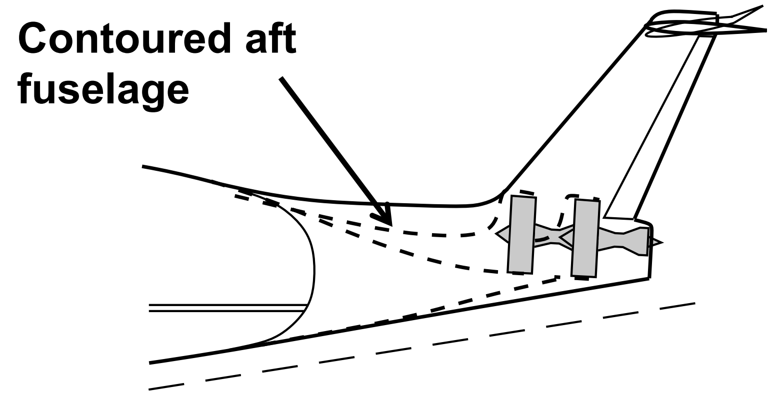


B737 ➡ D8 Study–Main Observations

- Improvement arises from integration and exploitation of indirect benefits – there is no one “magic bullet”
- Design methodology allows exploration of interactions
- D8 fuselage alone is slightly draggier than B737's, but enables…
  - lighter wing
  - smaller lighter tails
  - enables fuselage BLI
  - smaller, lighter engines
  - shorter, lighter landing gear
  - … etc

D8 BLI Approach





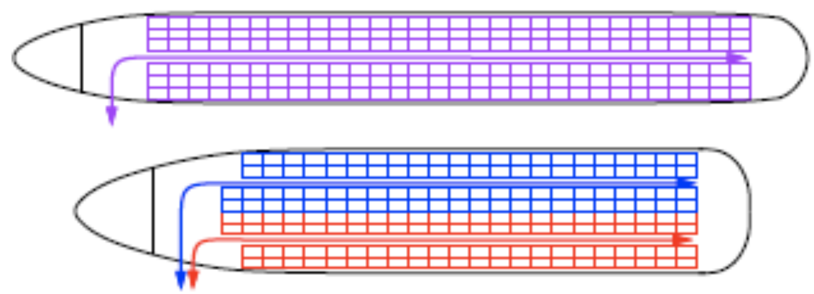
- Entire upper fuselage BL ingested
- Exploits natural aft fuselage static pressure field
  - Fuselage's potential flow has local M = 0.6 at fan face
  - No additional required diffusion into fan
  - No generation of streamwise vorticity
  - Distortion is a smoothly stratified total pressure

Improved Load/Unload Time and Airport Capacity

- **Climate change impact**. D8 results on over 80% climate improvement from B737-800
- **Improved Load/Unload Time**. D8.5 provides reduction in block time during load and unload and approach operations

B737-800
30 x 6 per aisle
(35 min. load, unload)

D8.5
23 x 4 per aisle
(20 min. load, unload)



	Flight time (hr)		Trip time (hr)		
	B737	**D8.5**	**B737**	**D8.5**	
NYC-LAX	4.81	5.29	5.98	5.96	**(D8.5 is 1 minute faster than B737)**
NYC-ORD	1.55	1.73	2.71	2.40	**(D8.5 is 19 minutes faster than B737)**
BOS-DCA	0.93	1.06	2.09	1.73	**(D8.5 is 22 minutes faster than B737)**

- **Airport capacity**. D8 could allow for increased airport capacity due to wake vortex strength reduction

First principle innovative aircraft design optimization tool (M. Drela)

TASOPT (Transport Aircraft System OPTimization)

- Modelled on a first-principles basis, NOT from correlations
- Simultaneously optimizes airframe, engine, and operations parameters for given mission
- Developed in modules so easily integrated with other tools
- Generate required output files for detailed aeroelastic and aerodynamic analysis
- Allows aircraft optimization with constraints on noise, balanced field length, and other environmental parameters

Summary

- Established documented scenario and aircraft requirements
- Created two conceptual aircraft: D (double-bubble) Series and H (Hybrid Wing Body) Series
  - D Series for domestic size meets fuel burn, LTO NOx, and balanced field length N+3 goals, provides significant step change in noise
  - H Series for international size meets LTO NOx and balanced field length goals
  - D Series aircraft configuration with current levels of technology can provide major benefits
- First-principles methodology developed to simultaneously optimize airframe, engine, and operations
- Generated risk assessment and technology roadmaps for configurations and enabling technologies

Elena de la Rosa Blanco (edlrosab@mit.edu)

Link to presentation: http://www.nasa.gov/topics/aeronautics/features/future_airplanes.html