Demonstrating FAA Certifiable Ultra-Efficient Commercial Aircraft Configurations

FAA CLEEN-II Public Session

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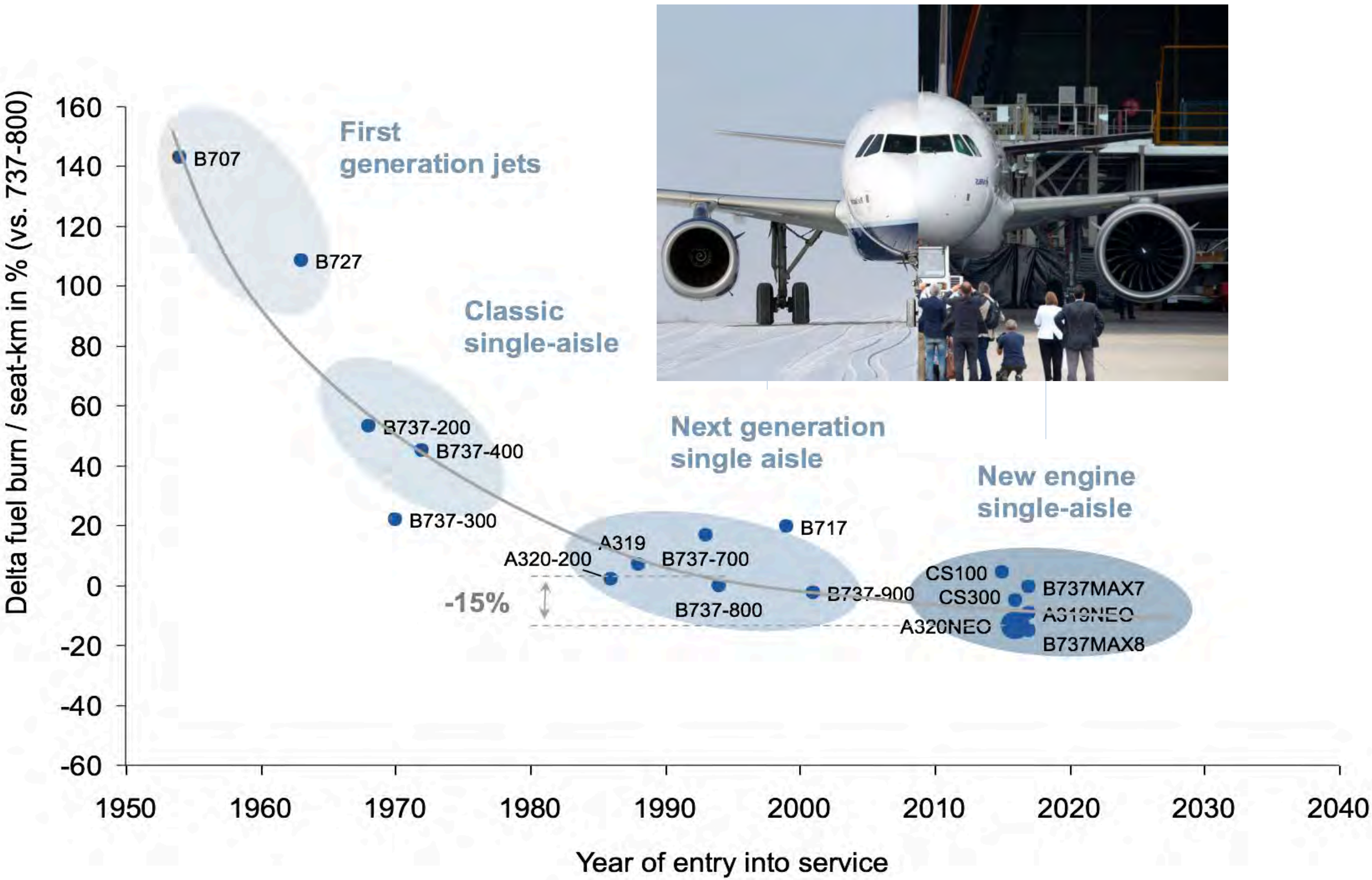
Program Synopsis

- Under the FAA CLEEN II program, Aurora is developing composite airframe technologies that will enable unconventional aircraft configurations and reduce fuel burn, emissions, and noise.
- A common theme amongst future ultra-efficient aircraft concepts is the non-traditional, complex shape of the aircraft structure. One of these aircraft concepts, the D8 (developed by NASA, MIT, Aurora, and P&W), is particularly interesting from an advanced composite aerostructures standpoint because the configuration alone is responsible for most of the projected benefits. The step change in performance due to the shape of the aircraft – rather than for any of the individual technologies integrated into the aircraft – implies that a significant efficiency benefit can be realized on a much shorter time scale than would be required for the maturation of many separate, incremental technologies.
- The D8 configuration, enabled by its uniquely shaped fuselage, results in up to 49% fuel burn reduction, 40EPNdB cumulative noise reduction, and 52% LTO NOx reduction with integrated boundary layer ingesting (BLI) engines. The D8 fuselage further enables 16% fuel burn reduction, 16EPNdB cumulative noise reduction, and 21% LTO NOx reduction with wing mounted engines. Advanced composite airframe design and manufacturing methods will enable the D8 and shapes like it to be built with reliable, repeatable, and certifiable processes.
- The program was initiated in November 2015 and is currently funded through FY2017

Historical progression of fuel efficiency

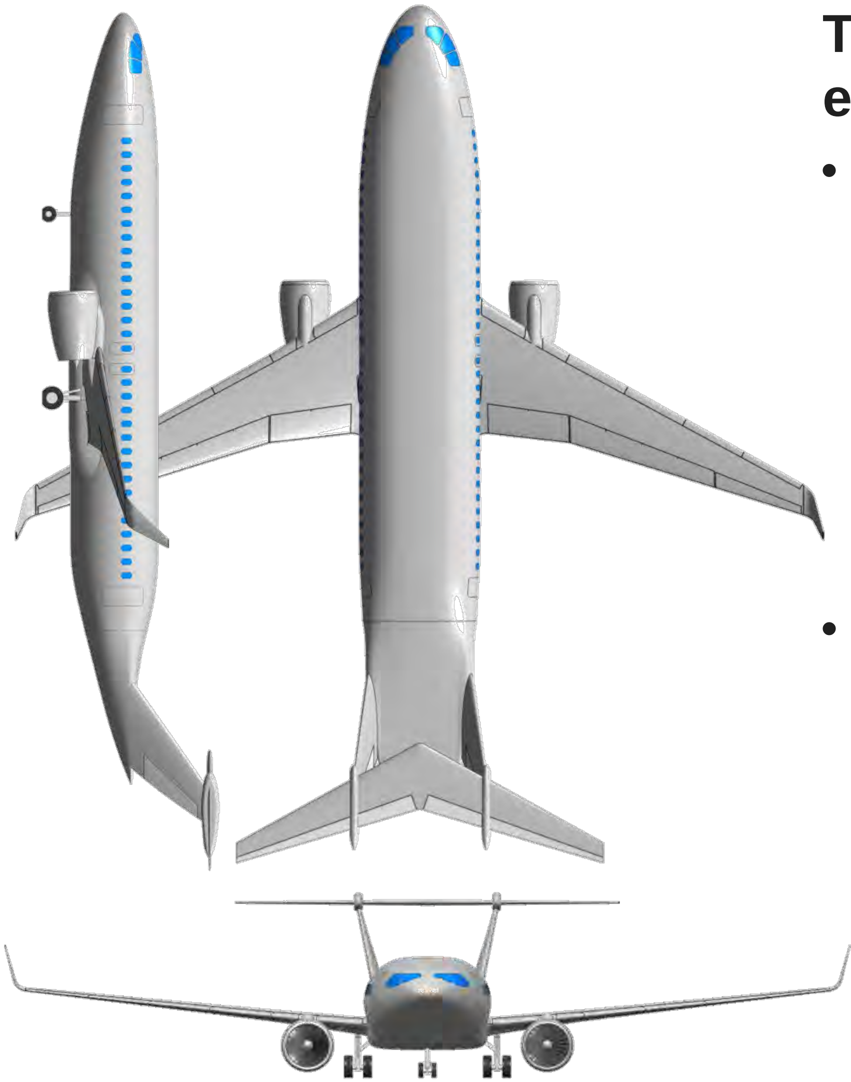


Note: Fuel burn / seat-km is based on the design mission of each aircraft. Estimated fuel burn from published payload-range diagrams, aircraft fuel volume and publicly available marketing material Source: Airbus, Boeing, Bombardier

Program Purpose

- Aircraft fuel efficiency generally improves at 1.5% per year
- NASA and others have been funding low-TRL studies of aircraft with disruptive improvements in all domains of environmental efficiency (noise, fuel, emissions) in order to accelerate the rate of efficiency improvements
  - These concepts are now moving up the TRL scale with wind tunnel tests and flight demonstrators
- A common theme amongst the advanced concepts is the non-traditional, complex shape of the aircraft structure
  - Advanced composites enables reliable production of new shapes that were otherwise difficult or inefficient to build

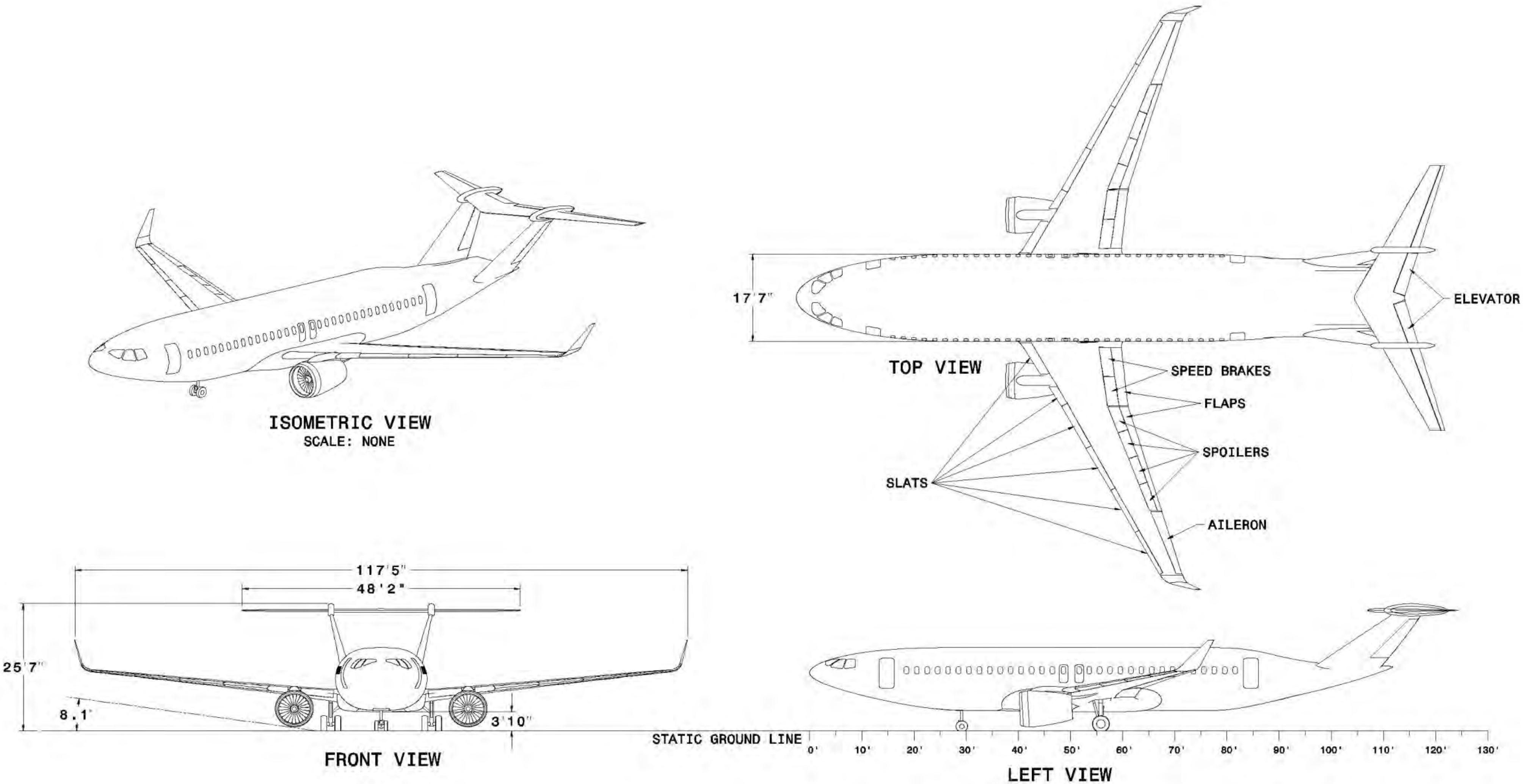
Project's Expected Benefits



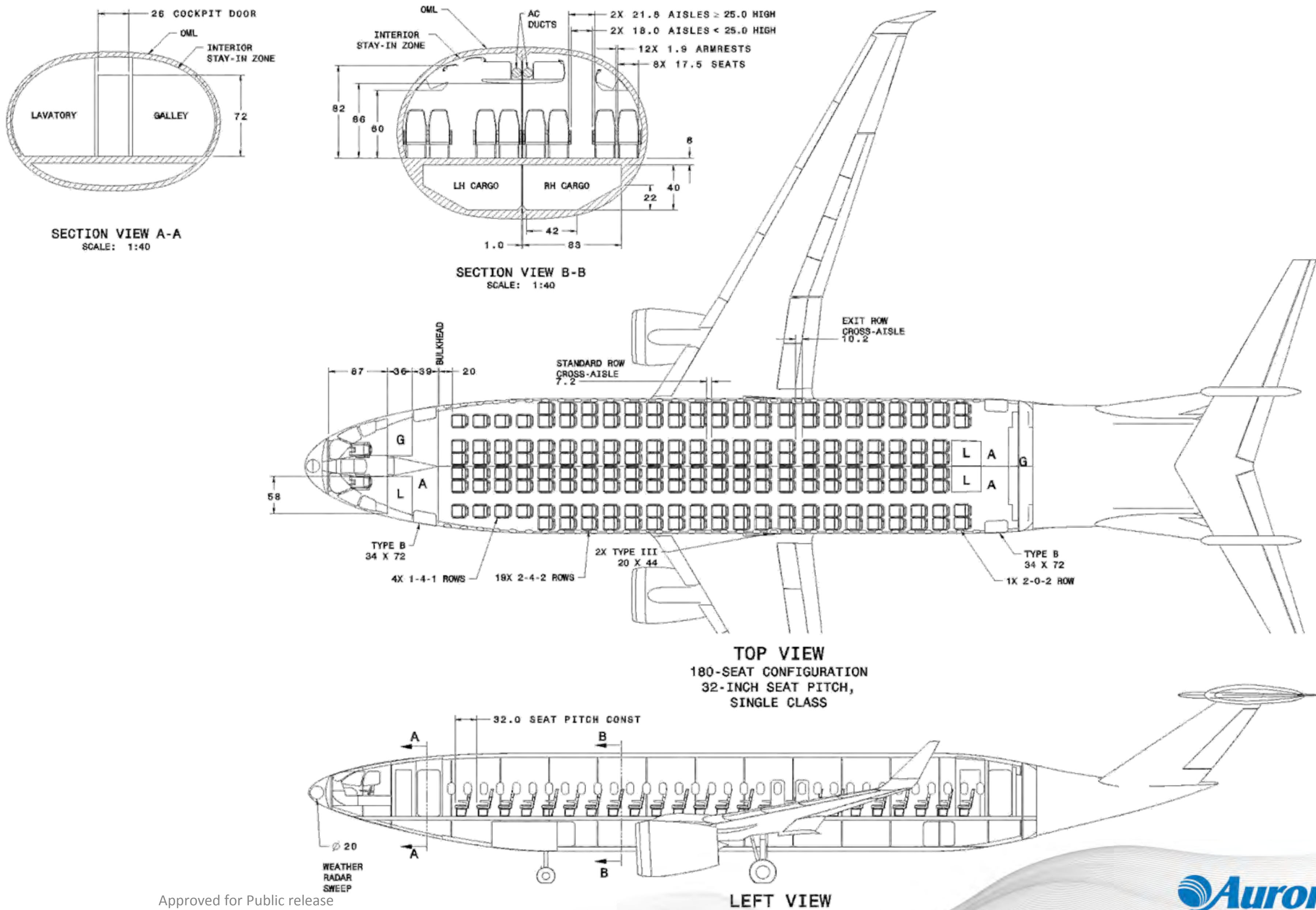
Technology developed in CLEEN-II enables advanced configurations :

- B737-800/A320 class
  - 180pax, 3000 nmi range
  - 49% fuel, 40EPNdB cumulative noise, and 52% LTO NOx benefits with current technology and integrated BLI engines
  - 16% fuel, 16 EPNdB cumulative noise, and 21% LTO NOx benefits for 2025 with wing mounted engines
- Assessing family variants

Wing Mounted Engines with D8 Fuselage



D8 Passenger Layout



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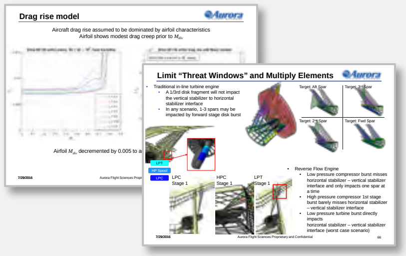
Initial Market Assessment Informs Technical Development

So far, focused mainly on technology development

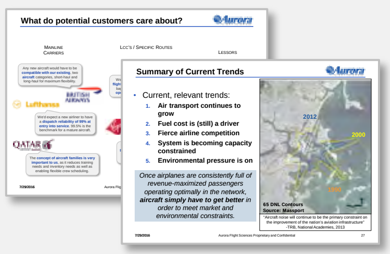


Tech development

Feasible performance / features

Customer expectations / priorities

Commercial assessment

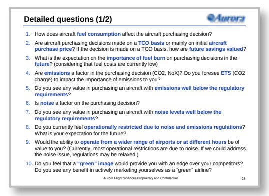


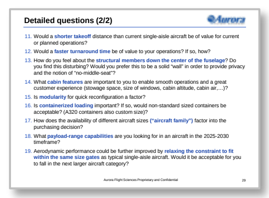
Conducted interviews with airline professionals in order to understand:

1) Is there a market for the D8? **Would airlines consider buying the D8**?

2) What **performance characteristics / features of the D8 are valuable** to airlines, which ones less so?

Prepared list of questions to gather feedback:





- What **size** should the aircraft be?
- How do **fuel economy, emissions, noise and takeoff performance** factor into the aircraft **purchasing decision**?
- How do they feel about the **D8 cabin**? Are the **tension rods** acceptable?
- …

Primarily Three Family Members Discussed with Airlines

		Range	# Seats @ 32 in pitch
D8-L		**4,500 nm**	**250**
D8-M		**3,000 nm**	**180**
D8-S		**3,000 nm**	**150**

Comparable to 737-800 and A320. Used to illustrate performance

Airlines select aircraft using three main criteria

Order of aircraft selection process

Mission compatibility

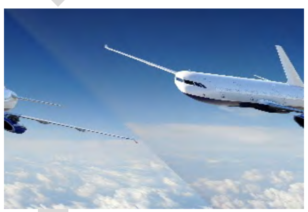
Does it fit the network? Can it **perform the planned missions** (range, payload capacity, takeoff performance, infrastructure compatibility)?

Expected load factor

Financials

How **costly** is it to operate the aircraft? What is the aircraft's **revenue** potential? What **profits** can the aircraft generate after taking into account aircraft price?

Total achievable profits



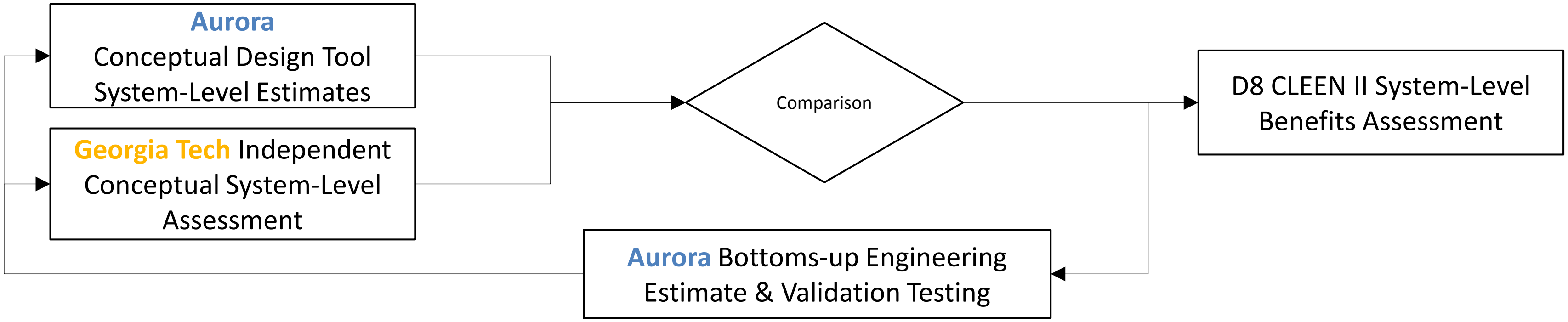
Soft factors

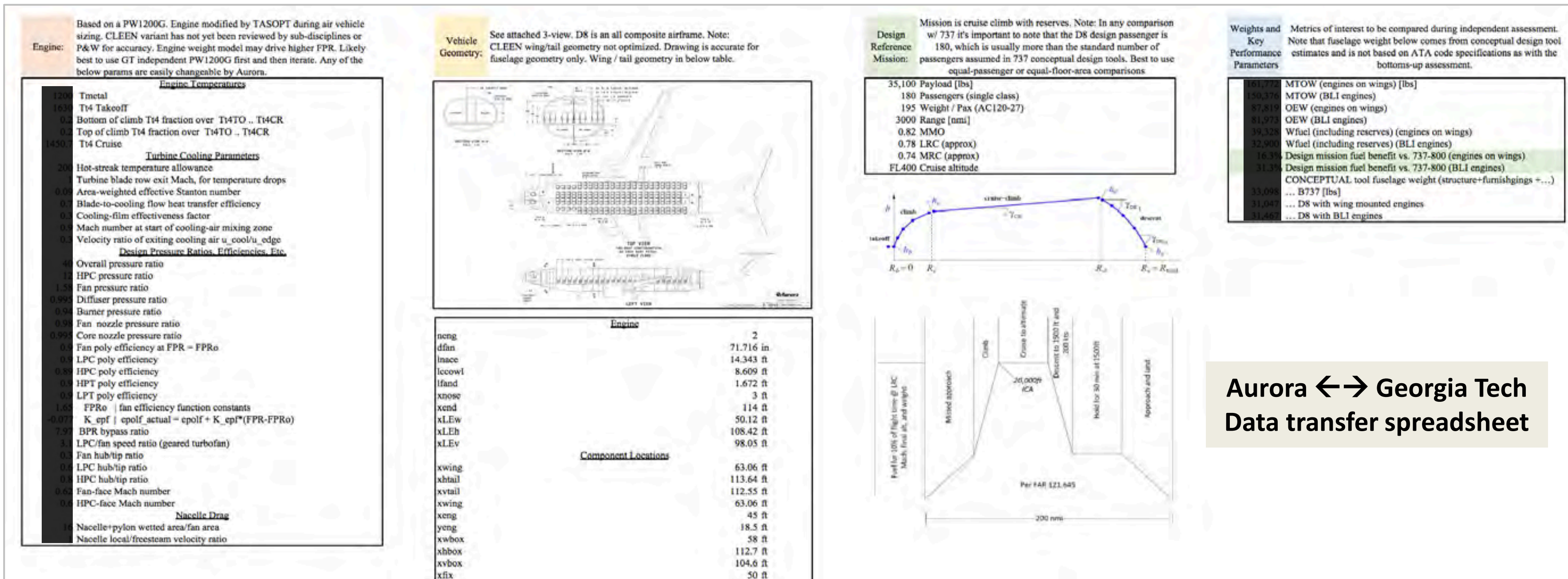
What **image** does the aircraft convey? Does it **support the brand**?

Delta demand

Georgia Tech Performance Assessment

Aurora has started working with Georgia Tech in order to support an independent assessment of the system-level benefits of the dual-lobe fuselage





Aurora ←→ Georgia Tech Data transfer spreadsheet

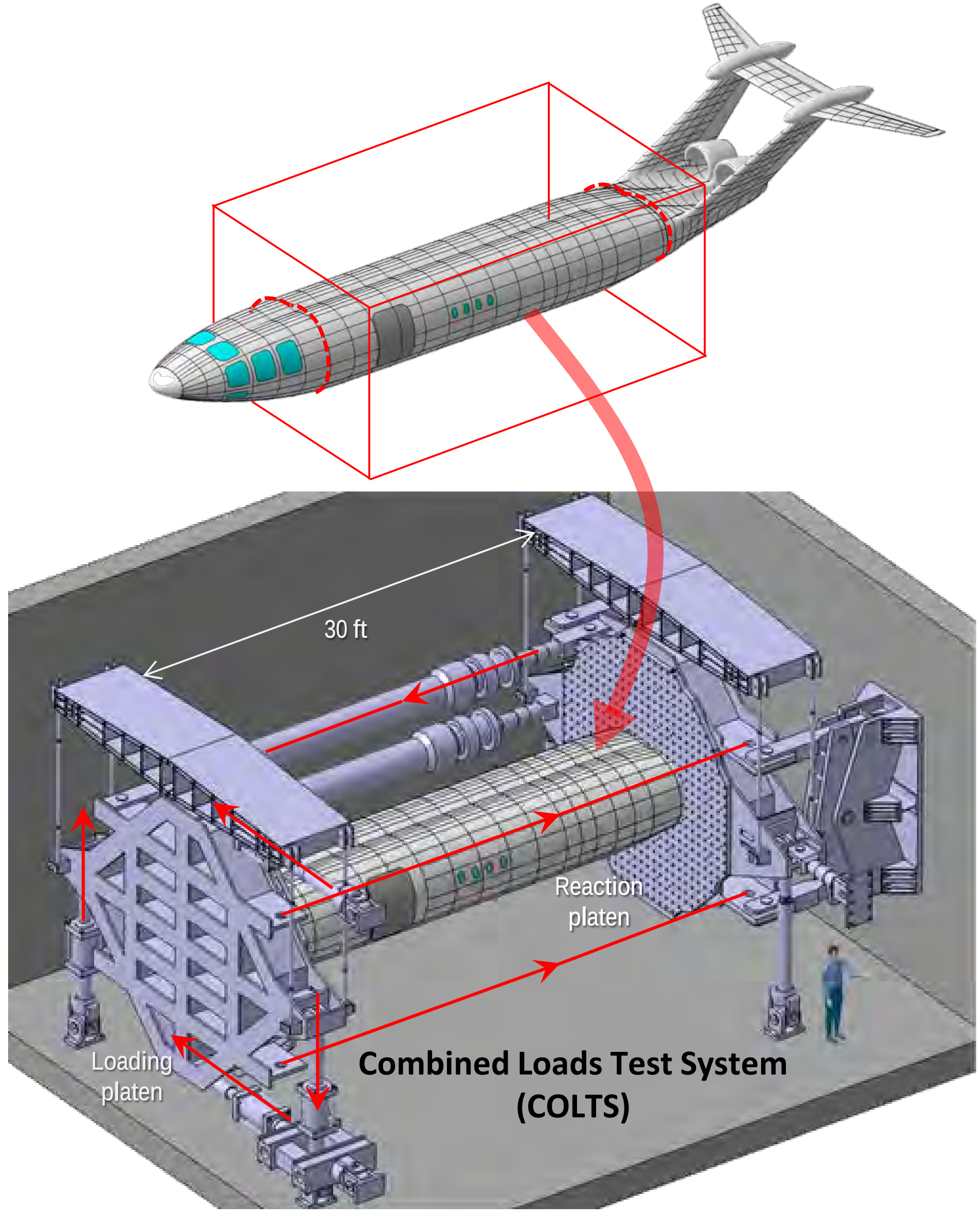
CLEEN II Technology

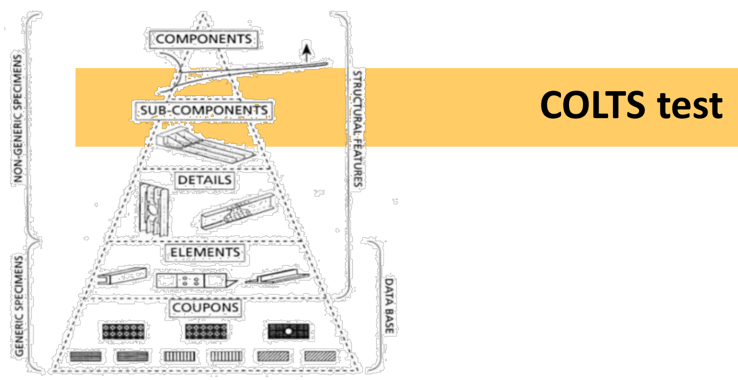
CLEEN Technology	Goal Impact	Benefits and Application
Advanced composite, unconventional airframe design-build	primary: Fuel burn secondary: NOx and noise reduction	49% fuel, 40EPNdB cumulative noise, and 52% LTO NOx benefits with current technology and integrated engines 16% fuel, 16 EPNdB cumulative noise, and 21% LTO NOx benefits for 2025 with wing mounted engines

Program Description

Design and manufacture an all-composite, half-scale fuselage section of the D8 using materials and manufacturing processes that demonstrate configuration feasibility, weight benefits, and the ability to be FAA-certified. The build approach for the fuselage includes Automated Fiber Placement (AFP) manufacturing of the fuselage barrel.

The development culminates in testing a 30ft section of the fuselage under combined shear, bending, and pressure loads in the NASA Langley COLTS facility.





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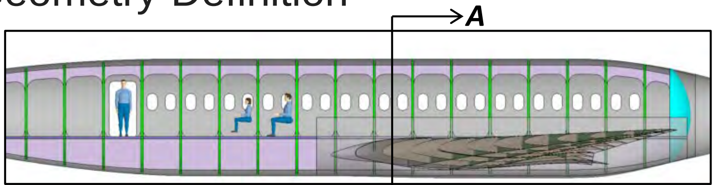
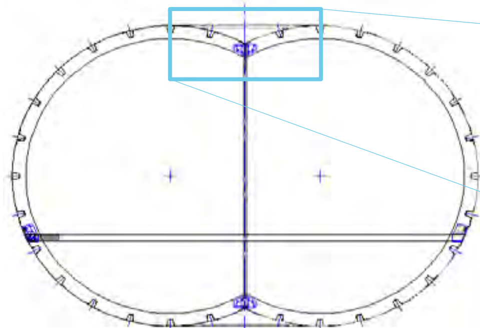
Program Description – Current Scope

CLEEN II effort develops one of key structural enablers of the D8 configuration, the "Y"-joint formed at the inflection of the skin

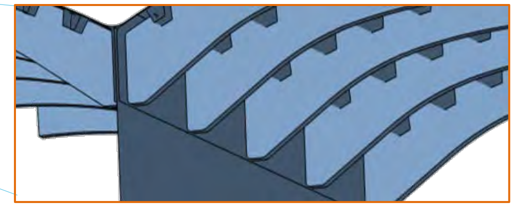
- Geometry Definition



Section A-A corresponds to maximum moment

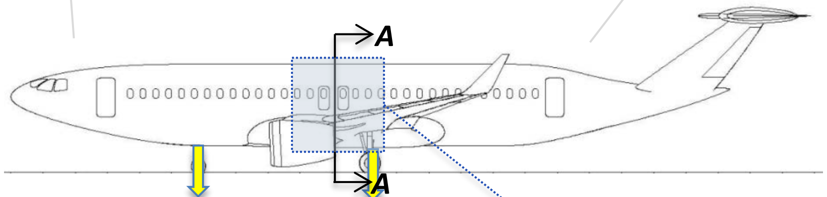


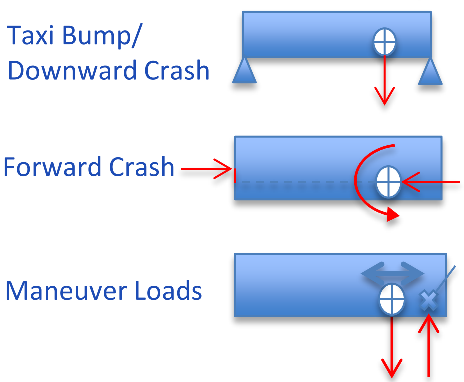
Fuselage Section A-A



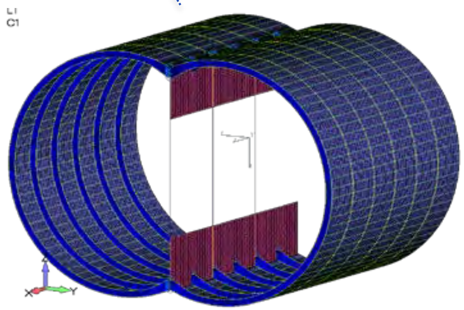
Representative fuselage skin, frame, stringer, and "Y-joint"

- Component Sizing Definition

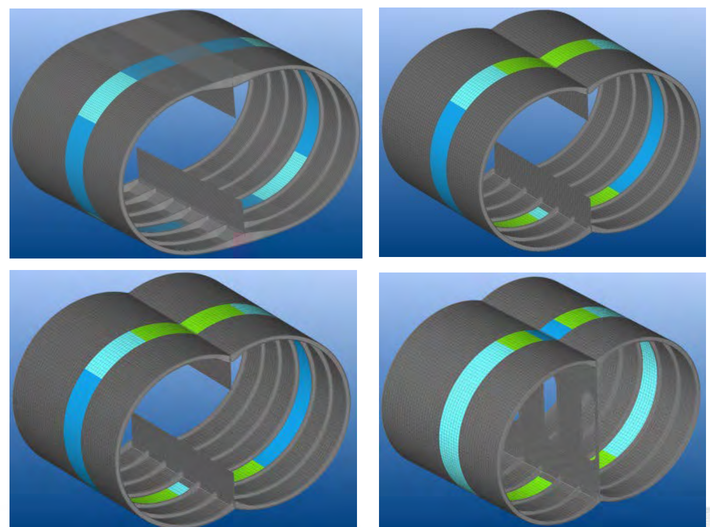




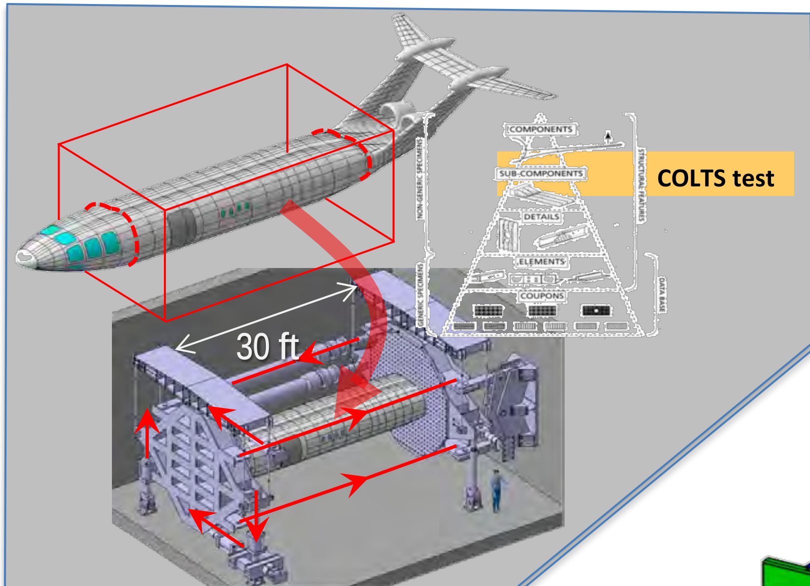
Fuselage section FEM



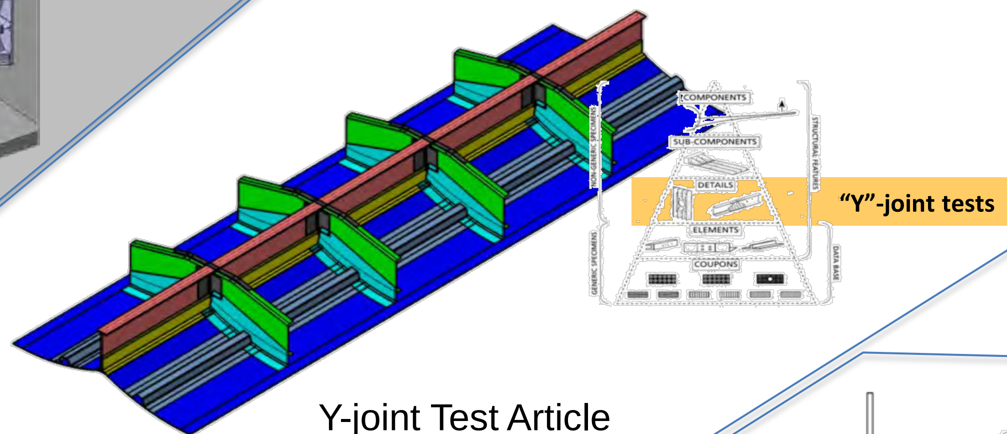
Trade studies conducted to optimize joint load path and size components for testing



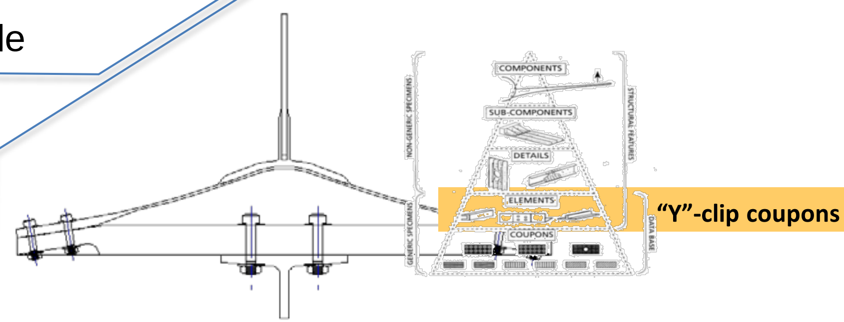
Building Block Test Development



Full Barrel (future)



Y-joint Test Article



Y-Clip Coupon

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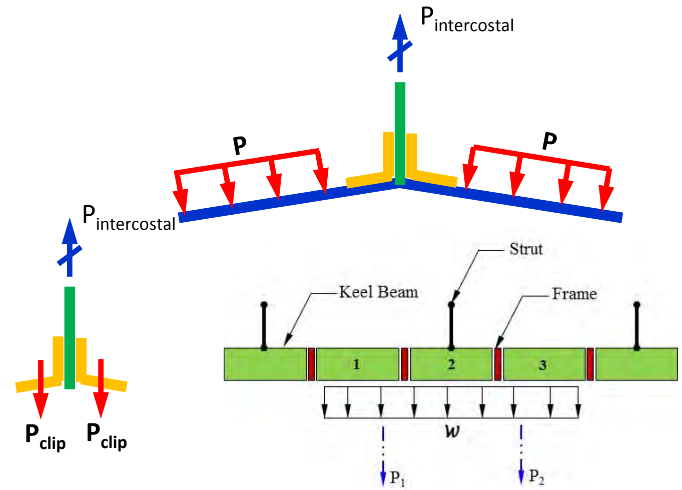
Program Description – Current Scope

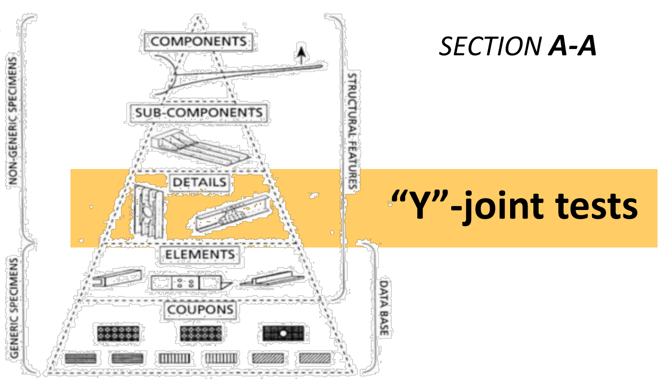
Detailed test articles will be manufactured in order to investigate the unique "Y" joint of the double-bubble fuselage, validate finite element models, and inform design decisions prior to the fuselage barrel (sub-component) section being tested at the NASA COLTS facility.

- Experimental testing at detail level of the building-block approach to define "allowables" of the "Y" joint
- "Knockdown" factors will be determined for the "Y" joint when the testing at the sub-component level

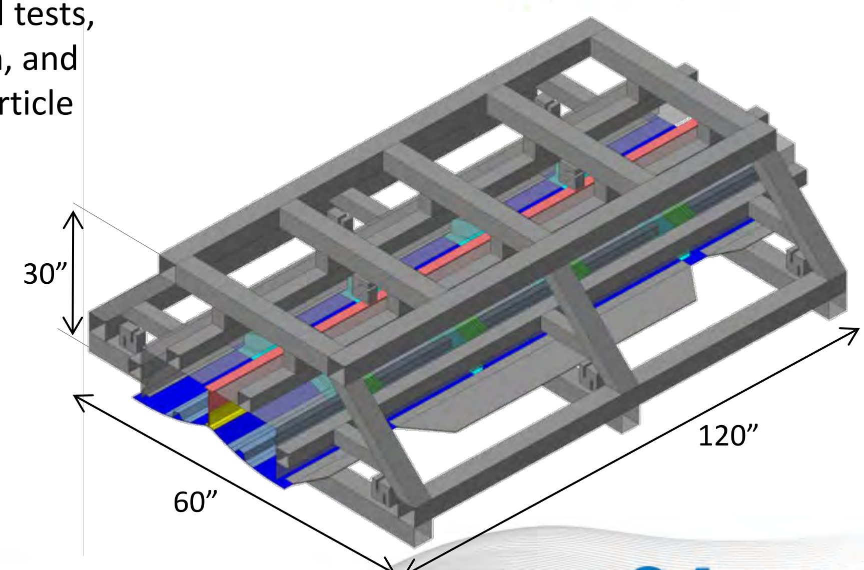


Benefit: Design validation of joint concept prior to full COLTS test article.

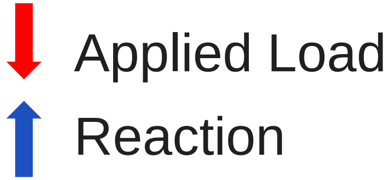
One self-reacting fixture is used for incremental tests, first with a plain skin, and then a second test article with frame sections.

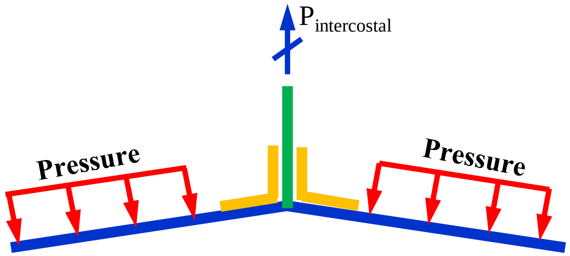


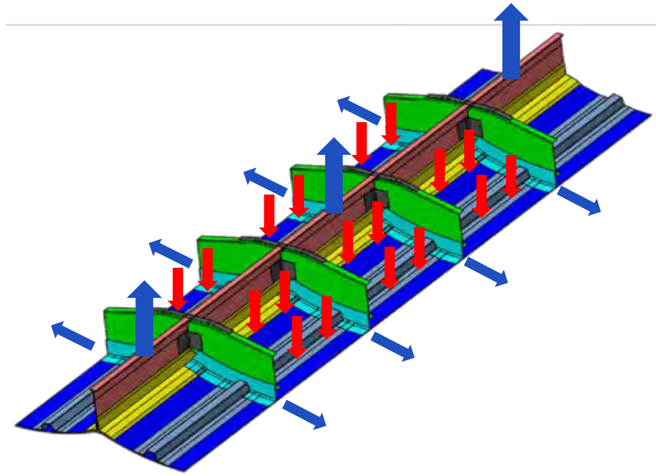
*SECTION **A-A***

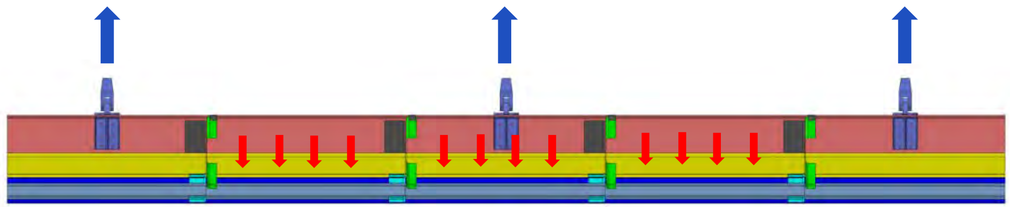


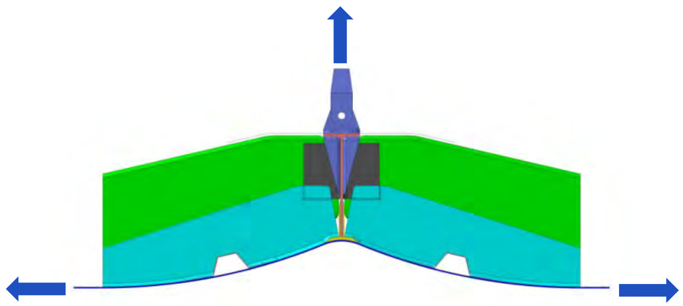
Load Approach







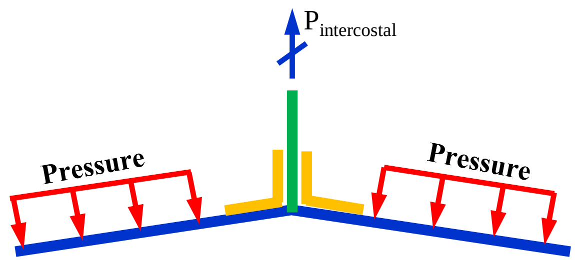


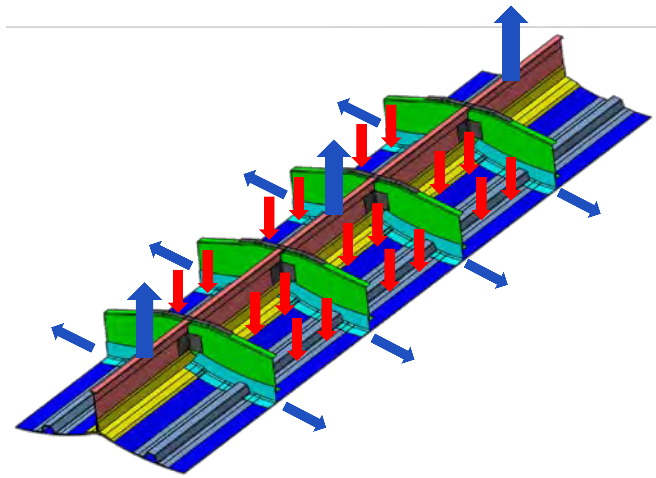


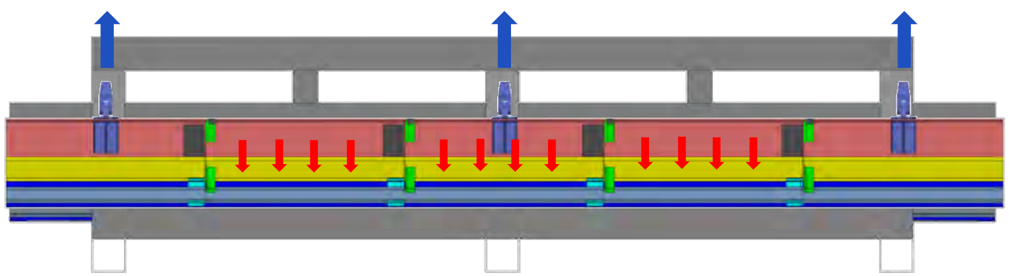
Load Approach

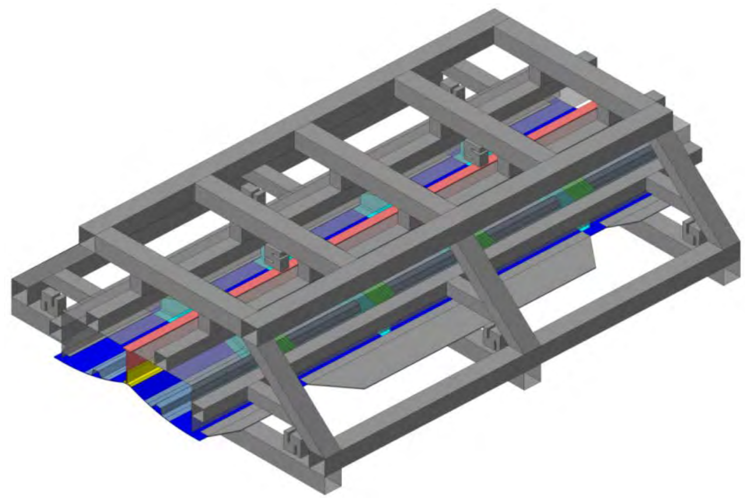
Applied Load

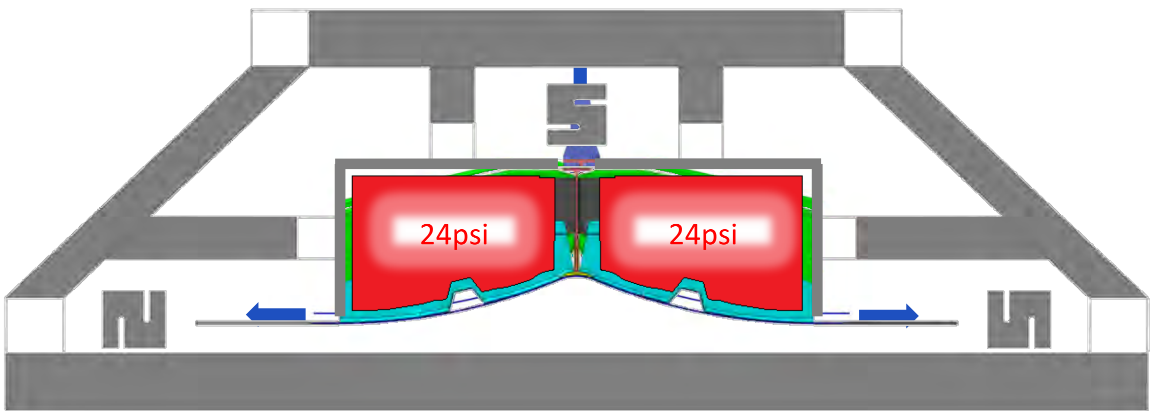
Reaction



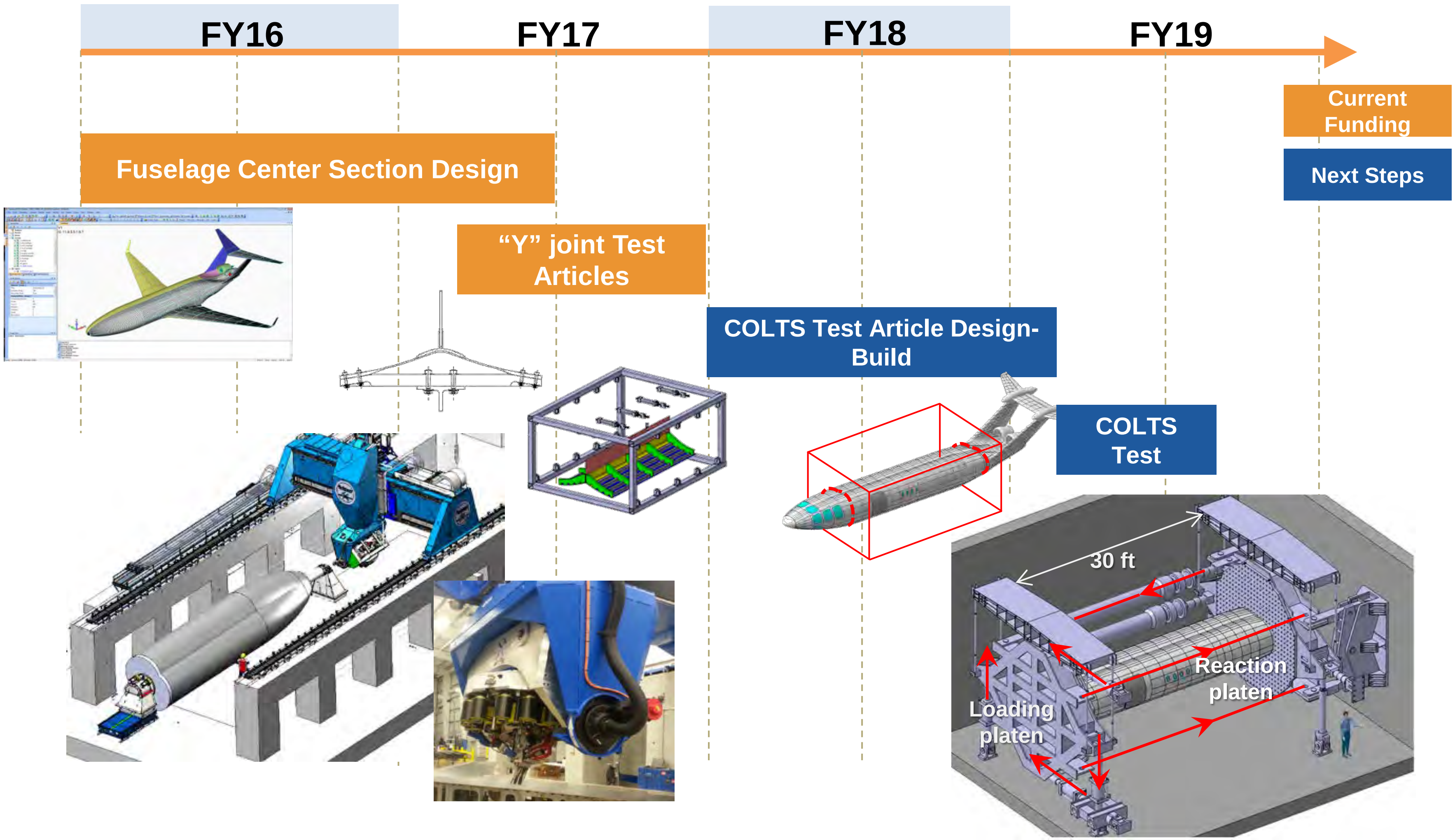






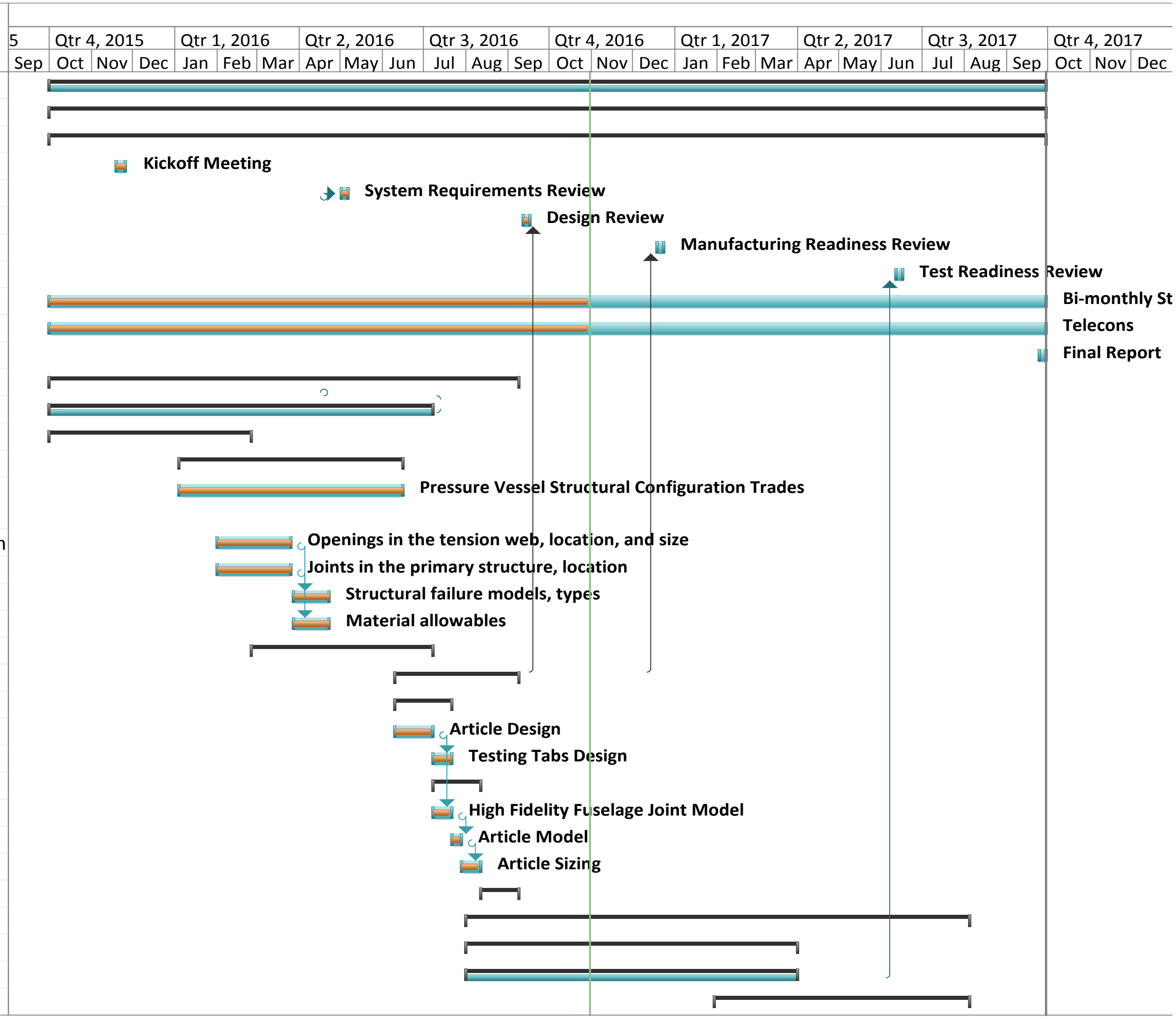


Project Schedule



Detail Schedule

WBS	% Comple	Task Name
1	**55%**	**CLEEN II**
1.1	**54%**	**Project Management**
1.1.1	**54%**	**Program Management Office**
1.1.2	100%	Kickoff Meeting
1.1.3	100%	System Requirements Review
1.1.4	75%	Design Review
1.1.5	0%	Manufacturing Readiness Review
1.1.6	0%	Test Readiness Review
1.1.7	54%	Bi-monthly Status Reports
1.1.8	54%	Telecons
1.1.9	0%	Final Report
1.2	**93%**	**Design**
1.2.1	**94%**	**Design Trade Studies**
1.2.1.1	**100%**	**Fuselage Layout Trades**
1.2.1.2	**100%**	**Structural Trades**
1.2.1.2.1	100%	Pressure Vessel Structural Configuration Trades
1.2.1.2.2	100%	Openings in the tension web, location, an
1.2.1.2.3	100%	Joints in the primary structure, location
1.2.1.2.4	100%	Structural failure models, types
1.2.1.2.5	100%	Material allowables
1.2.1.3	**72%**	**XD8 Fuselage Design and Analysis**
1.2.2	**83%**	**Test Article Design and Analysis**
1.2.2.1	**90%**	**CAD Model**
1.2.2.1.1	90%	Article Design
1.2.2.1.2	90%	Testing Tabs Design
1.2.2.2	**75%**	**Finite Element Models**
1.2.2.2.1	75%	High Fidelity Fuselage Joint Model
1.2.2.2.2	75%	Article Model
1.2.2.2.3	75%	Article Sizing
1.2.2.3	**81%**	**Test Planning**
1.3	**10%**	**Fabrication, Procurement, and Assembly**
1.3.1	**14%**	**Tooling Design and Fabrication**
1.3.1.1	**14%**	**Article and Apparatus Manufacturing**
1.3.2	**0%**	**Small / Trial Part Testing**



Approved for Public release

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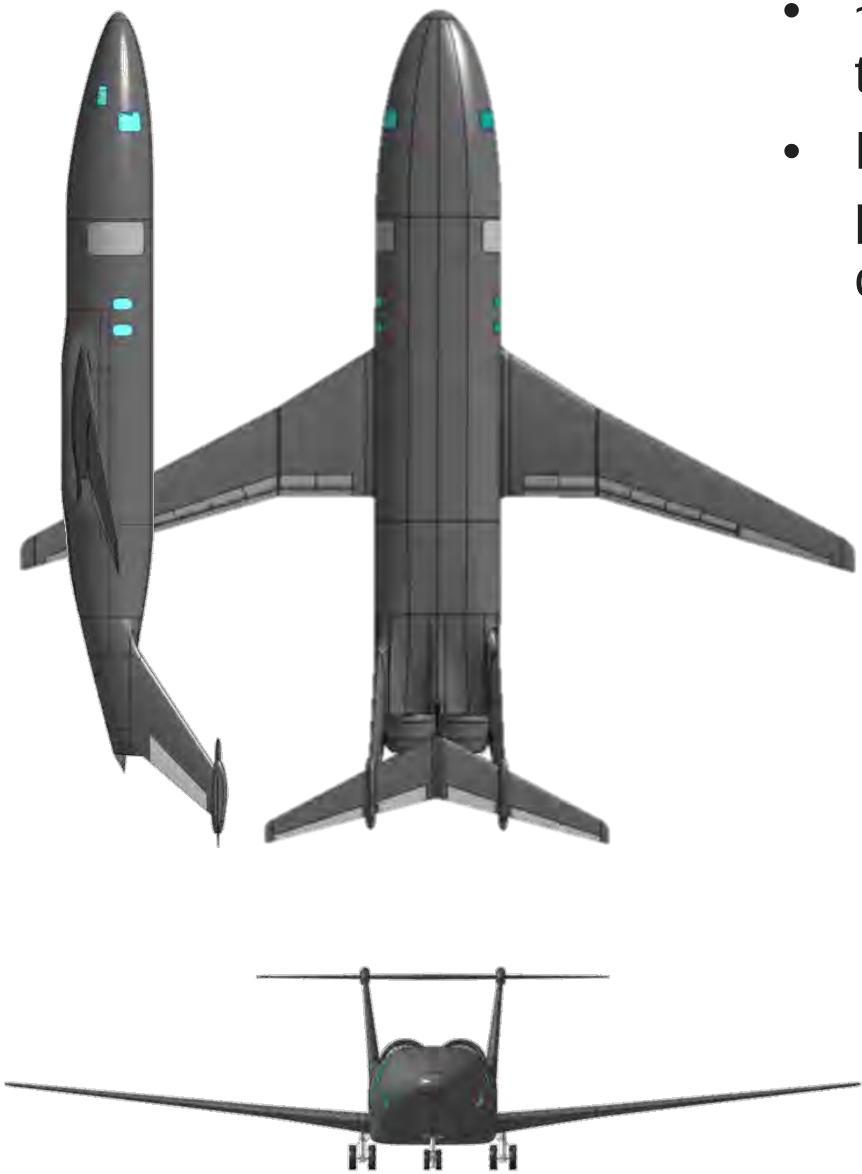
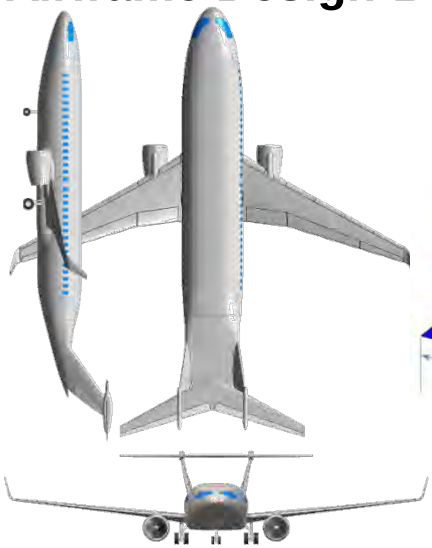
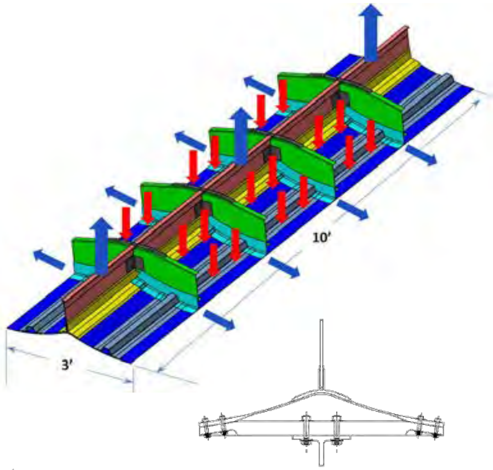
X-Plane D8 (XD8) Concept



- ~50% scale objective flight demonstrator of the D8 Objective aircraft.
- Designed to demonstrate the operability, performance, and feasibility of key configuration technologies:
  - Boundary Layer Ingestion (BLI)
  - Composite structures

Advanced Composite Unconventional Airframe Design-Build





Anticipated Benefits:

- *49% fuel, 40EPNdB cumulative noise, and 52% LTO NOx benefits with current technology and integrated engines*
- *16% fuel, 16 EPNdB cumulative noise, and 21% LTO NOx benefits for 2025 with wing mounted engines*

Risks/Mitigation Plans:

- *Building block approach to design validation*
- *"Y"-clip element tests*
- *Combined load test at NASA Langley COLTS facility*

Objectives:

- *Satisfy load and geometry constraints with weight efficient design*
- *Demonstrate airframe fabrication using production methods capable of type certification*

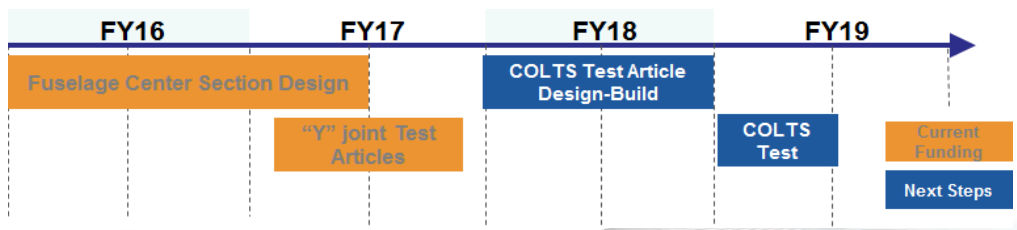
Work Statement:

- *Design center fuselage of scale demonstrator*
- *Test article design and fabrication*
- *AFP tool design and fabrication*
- *Test and evaluation*

Accomplishments/ Milestones since you initiated this technology/project:

- *Performed design trade studies*
- *Test matrix planning*
- *Test article design and optimization*
- *Tool design and procurement*

Schedule:



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Summary

- Under CLEEN II, Aurora is developing composite airframe technologies enabling unconventional configurations that will reduce fuel burn, emissions, and noise.
- The D8 configuration developed by NASA / MIT/ Aurora / P&W results in up to 49% fuel burn reduction with integrated boundary layer ingesting (BLI) engines and 16% with wing mounted engines
- Advanced composite airframe design and manufacturing methods can enable efficient aircraft configurations to be built with reliable, repeatable, and certifiable processes.