

Overview of Propulsion-Airframe Integration Research at NASA
ICAS PAPER 2026_1059

Dr. Julia Stephens
NASA Glenn Research Center
Subsonic Vehicle Technologies and Tools



National Aeronautics and Space Administration



Overview of Propulsion-Airframe Integration Research at NASA

Dr. Julia Stephens
NASA Glenn Research Center
Subsonic Vehicle Technologies and Tools (SVTT)
ICAS 2026

Propulsion-Airframe Integration in Next Generation Concepts

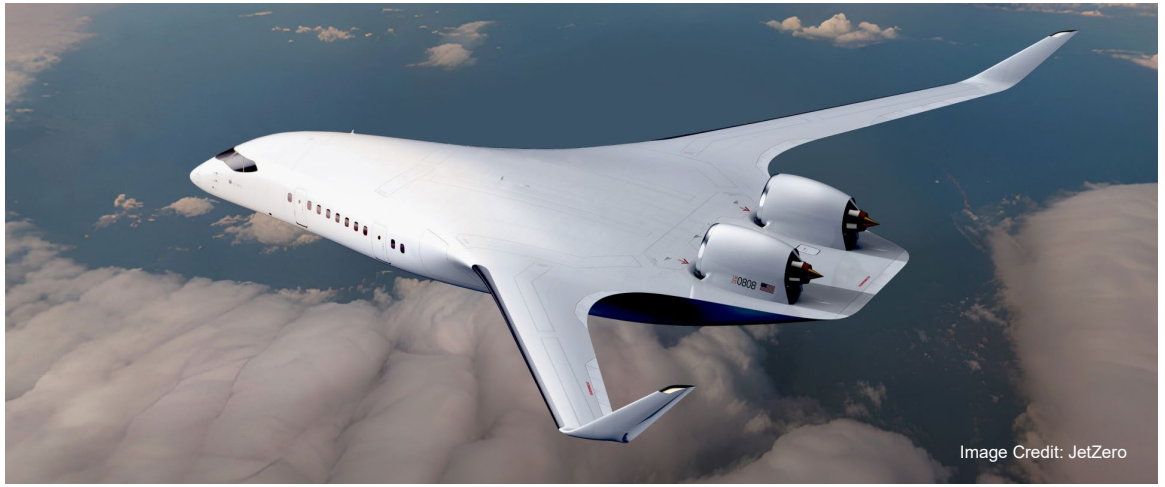
NASA AACES (Advanced Aircraft Concepts for Environmental Sustainability) 2050



Georgia Tech

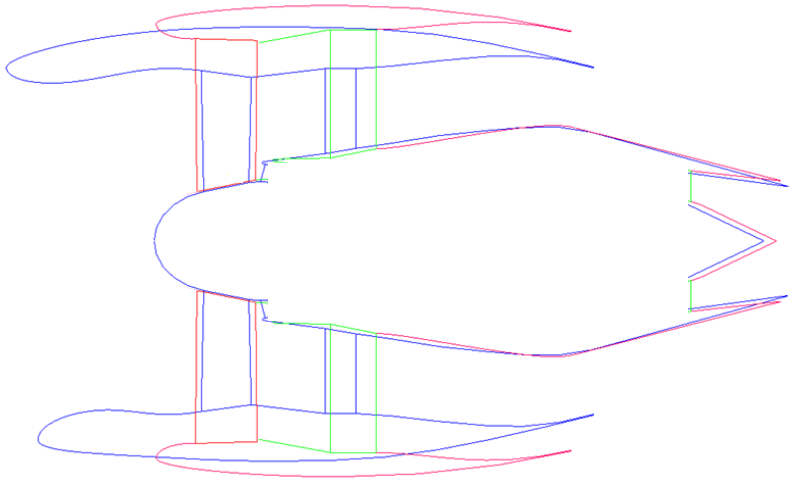


Electra Aero

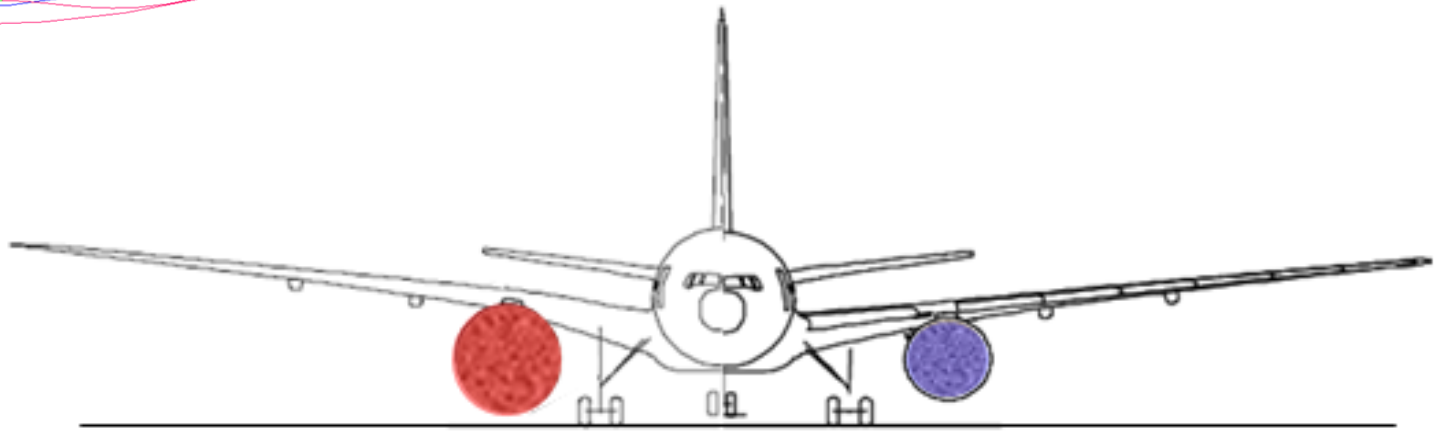


JetZero

Propulsion-Airframe Integration Now



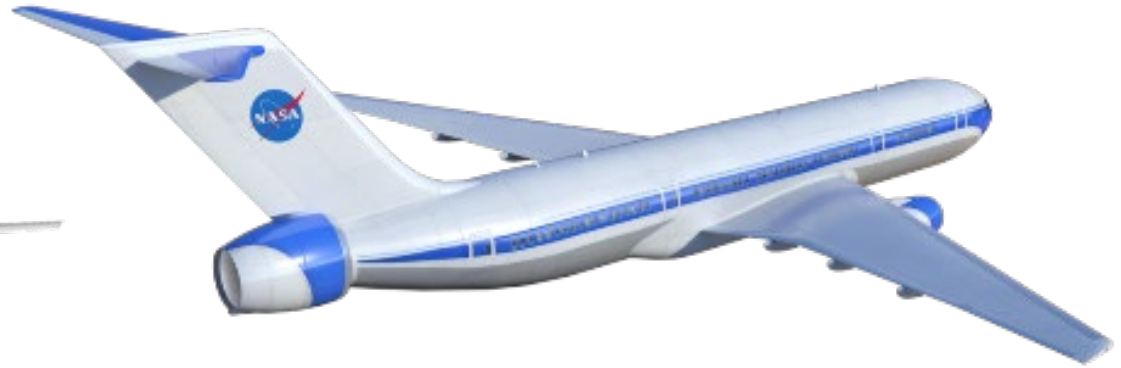




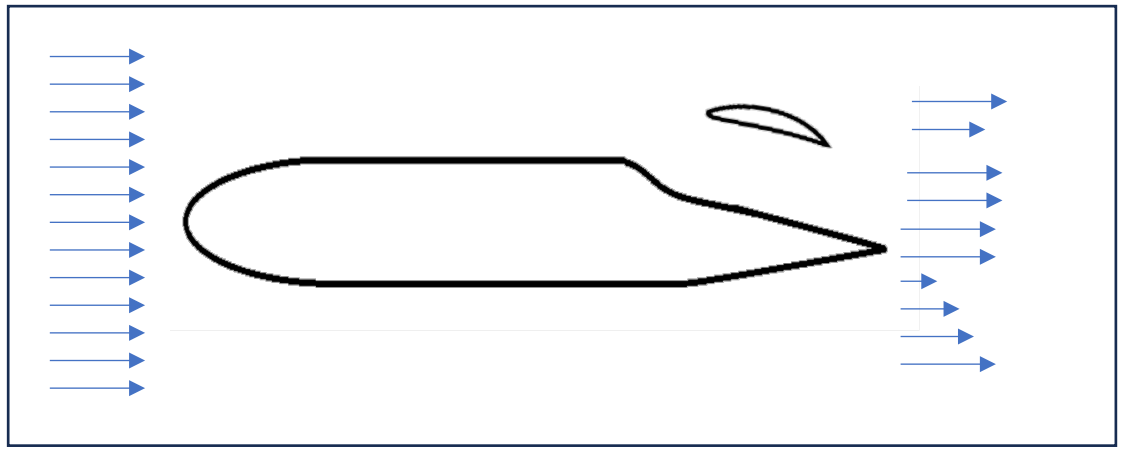
Hughes, C., “The Promise and Challenges of Ultra High Bypass Ratio Engine Technology and Integration”, AIAA Aero Sciences Meeting, 2011

Boundary Layer Ingestion (BLI) and Propulsion-Airframe Integration

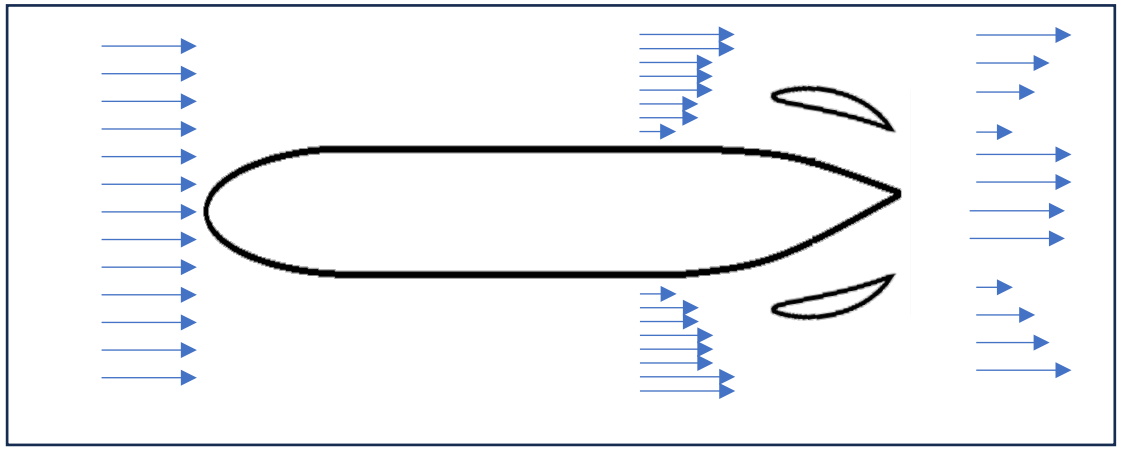




Type 1



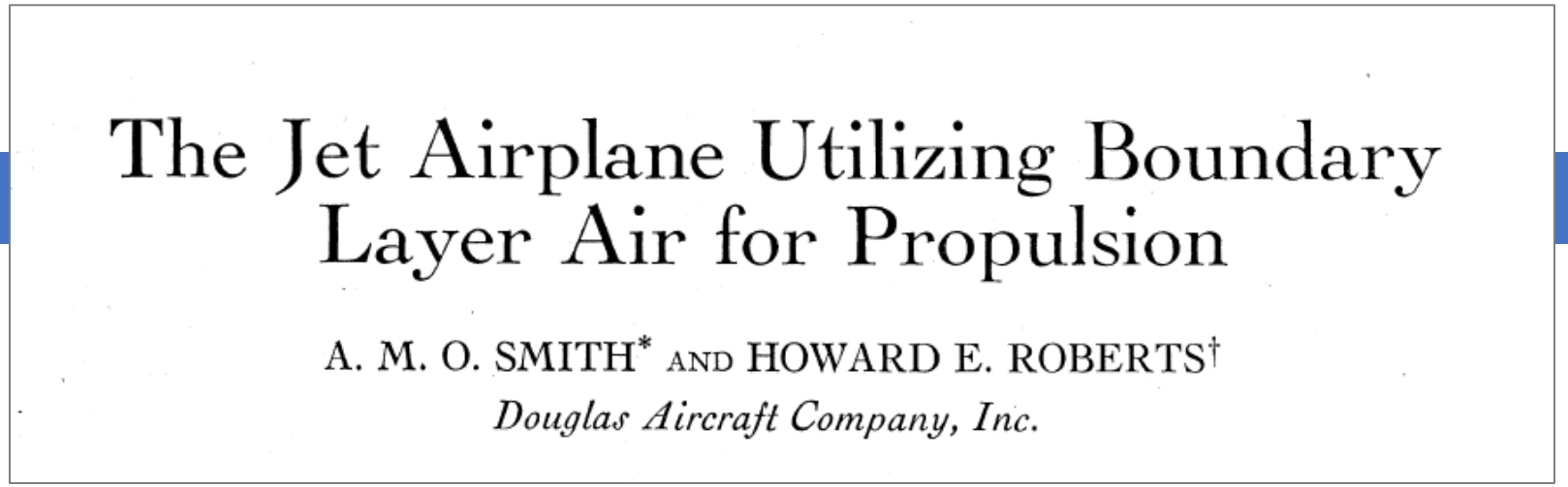
Type 2



Classical BLI Concept Research

Smith and Roberts

1947



The Jet Airplane Utilizing Boundary Layer Air for Propulsion

A. M. O. SMITH* AND HOWARD E. ROBERTS†

Douglas Aircraft Company, Inc.

Smith, A. M. O., and Roberts, H. E., "The Jet Airplane Utilizing Boundary Layer Air for Propulsion," *Journal of the Aeronautical Sciences*, Vol. 14, No. 2, Feb. 1947, pp. 97–109.

Classical BLI Concept Research



Lynch, F. T., “A Theoretical Investigation of the Effect of Ingesting Boundary Layer Air on Turbofan Engine Fuel Consumption,” Douglas Aircraft Co., Rept. SM 23981, Long Beach, CA, May 1960.

Douglass, W. M., “Propulsive Efficiency with Boundary Layer Ingestion,” McDonnell Douglas Corp., Rept. MDC J0860, Long Beach, CA, Aug. 1970.

Classical BLI Concept Research

Smith and Roberts 1947

Lynch 1960

Douglas 1970

Smith 1993

Proposed an alternate performance metric due to the lack of typical thrust/drag accounting that accounts for the propulsor influence on the airframe, and the airframe influence on the propulsor.

- Power-Saving Coefficient
- Propulsive efficiency

Smith, L. H., “Wake Ingestion Propulsion Benefit,” *Journal of Propulsion and Power*, Vol. 9, No. 1, 1993, pp. 74–82.

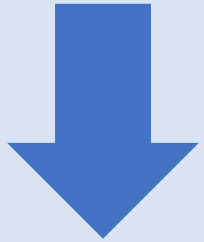
Classical BLI Concept Research

Smith and Roberts	Lynch	Douglas	Smith
1947	1960	1970	1993

Smith, L. H., “Wake Ingestion Propulsion Benefit,” *Journal of Propulsion and Power*, Vol. 9, No. 1, 1993, pp. 74–82.

Proposed an alternate performance metric due to the lack of typical thrust/drag accounting that accounts for the propulsor influence on the airframe, and the airframe influence on the propulsor.

- Power-Saving Coefficient
- Propulsive efficiency



Motivated Ed Grietzer (MIT) and Mark Drela to investigate BLI, eventually resulting in the D8 concept.

Genesis at NASA

Kawai, Ronald T., Friedman, Douglas M., and Serrano, Leonel, “Blended Wing Body (BWB) Boundary Layer Ingestion (BLI) Inlet Configuration and System Studies,” NASA/CR-2006-214534.

Kawai
et al.

2006

Completion of Boeing Phantom Works BWB Study in the NASA Ultra-Efficient Engine Technology Program Propulsion Airframe Integration Project

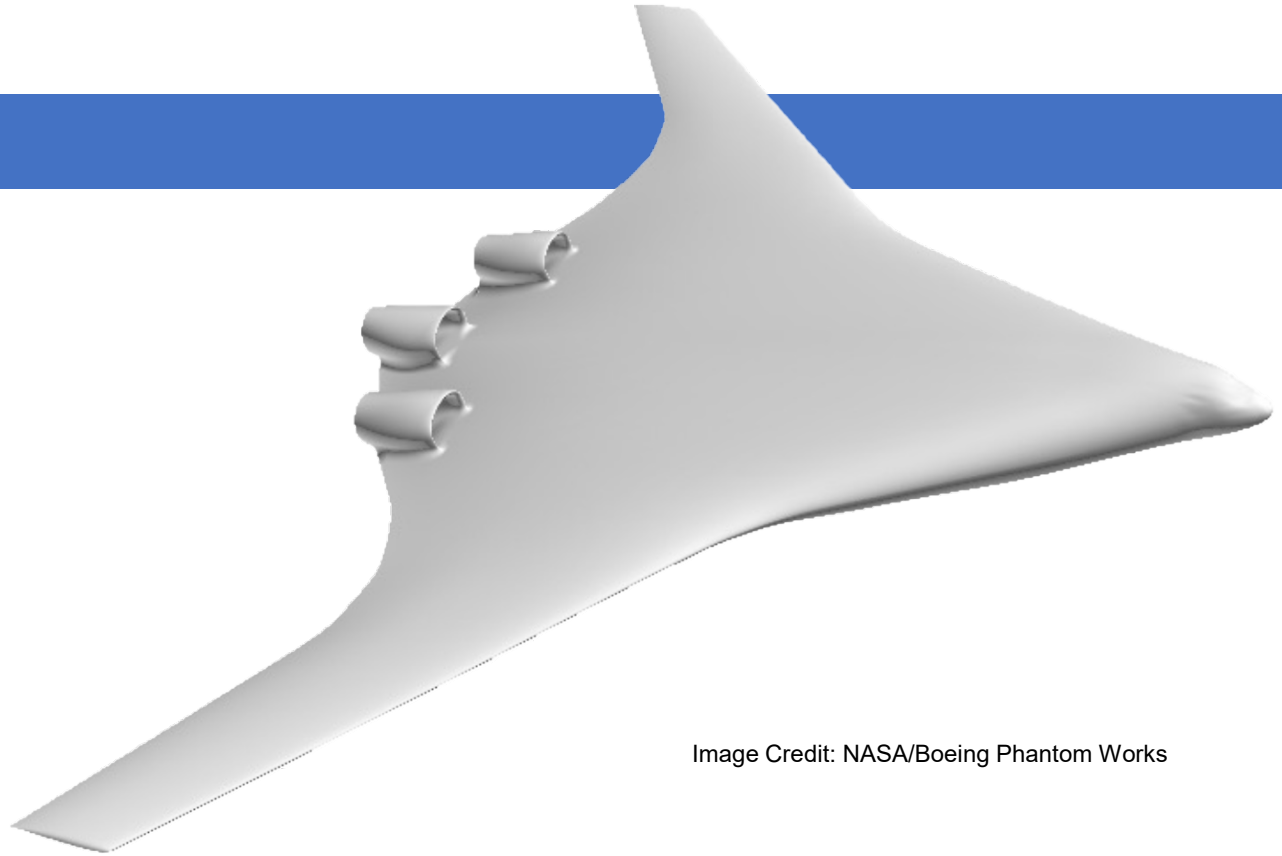


Image Credit: NASA/Boeing Phantom Works

Genesis at NASA

NASA N+2
Solicitation

2006

Amendment No. 4 to the NASA Research Announcement (NRA) Entitled “Research Opportunities in Aeronautics – 2006 (ROA-2006),” NNH06ZEA001N, Release May 23, 2006.



Florea, R. V., Reba, R., Vanslooten, P. R., Sharma, O., Stucky, M., O’Brien, W., Arend, D., “Preliminary Design for Embedded Engine Systems,” AIAA-2009-1131.

The D8 Program: Phase 1

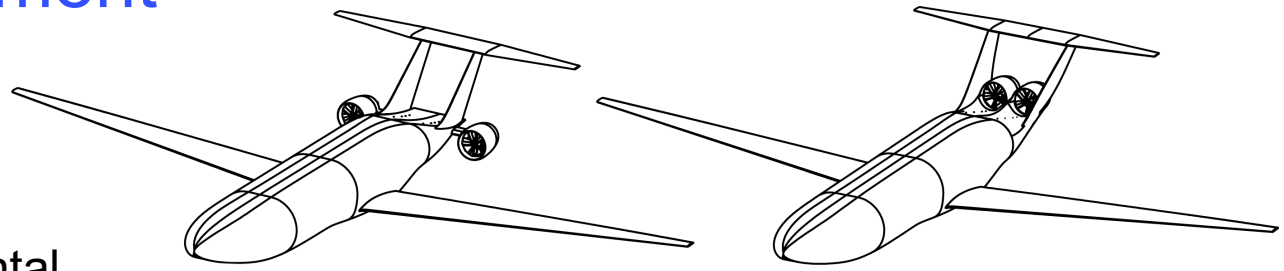
NASA N+3 Solicitation	Concept study
2008	**2010**

Greitzer, E. M., et al., “Aircraft and technology concepts for an N+3 subsonic transport,” NASA CR-2010-216794, 2010.



Image Credit: NASA/Aurora Flight Sciences

The D8 Program: Phase 2 Experiment

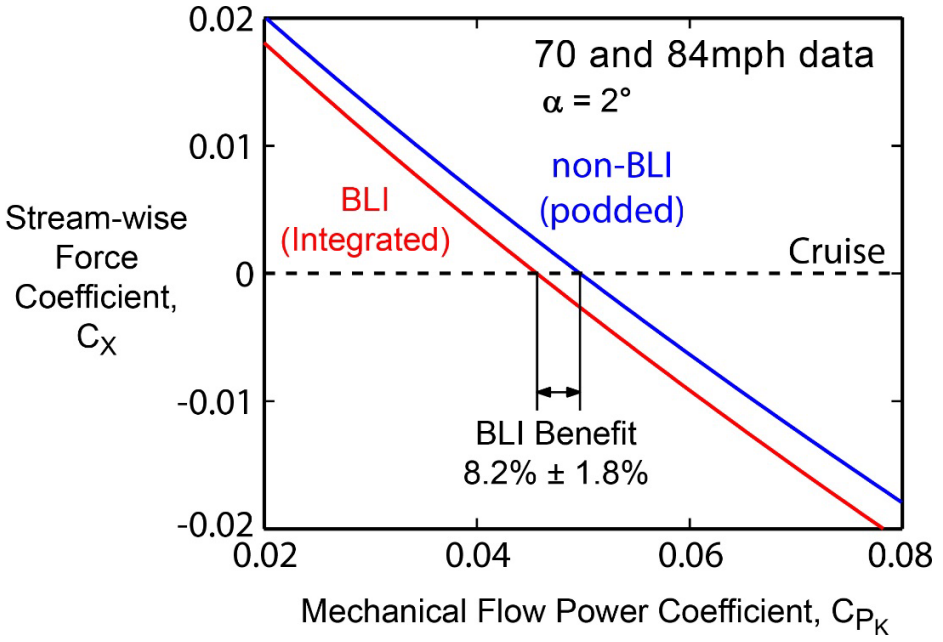


NASA N+3 Solicitation — Concept study — Experimental results

2008 — 2010 — 2014

Uranga, A., et al., "Boundary Layer Ingestion Benefit of the D8 Transport Aircraft," *AIAA Journal*, Vol. 55, No 11, November 2017.



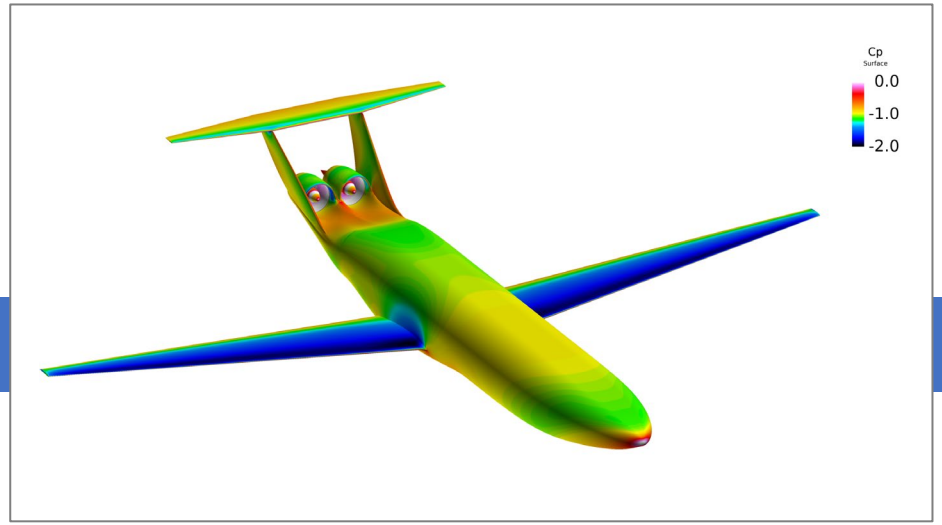


The D8 Program: Phase 2 Computational Assessment

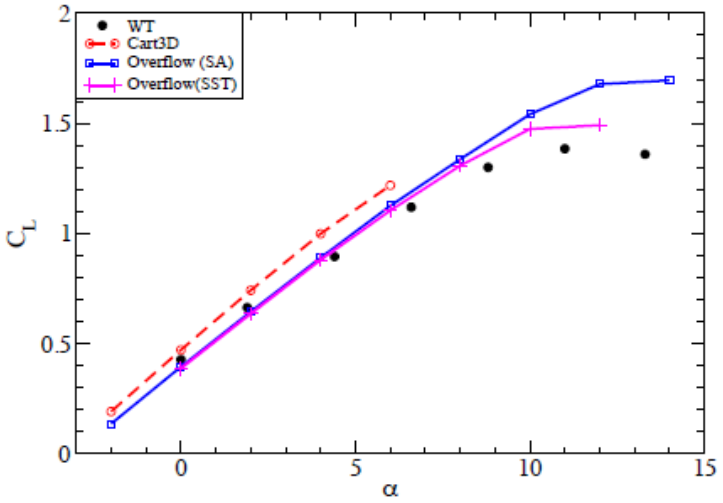
NASA N+3 Solicitation — 2008

Concept study — 2010

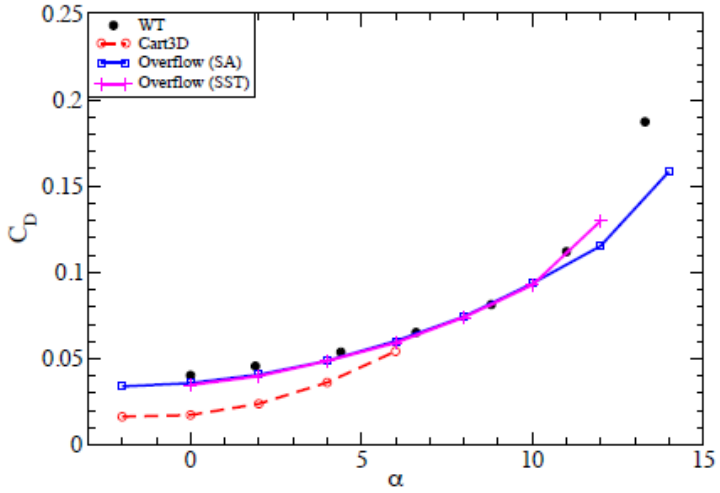
Computational results — 2014



Pandya, S. A., Uranga, A., "Computational Assessment of the Benefits of Boundary Layer Ingestion for the D8 Aircraft," 31st AIAA Applied Aerodynamics Conference, San Diego, CA, June, 2013.



(a) C_L



(b) C_D



Aviation Week Feature

September 30, 2013

The D8 Program: Phase 3

NASA N+3 Solicitation	Concept study	Computational results	Phase 3 Cooperative Agreement
2008	**2010**	**2014**	**2015–2017**

Technology Maturation and **Design** for a scaled Demo Vehicle.

The N3-X Program: Phase 1

NASA N+3 Solicitation

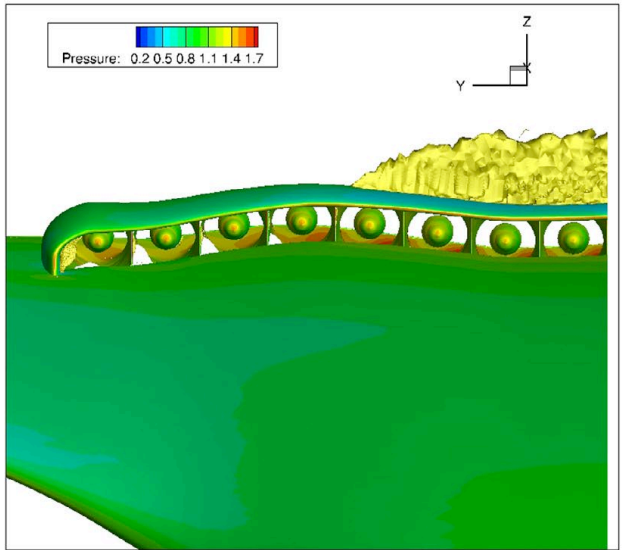
2008

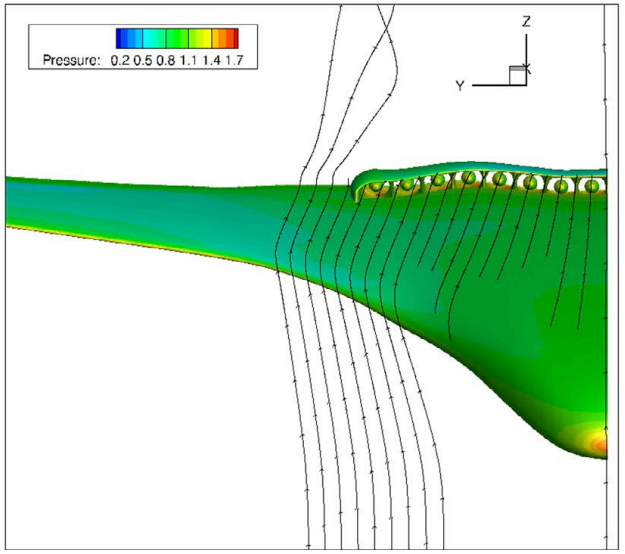
Concept study

2011



Felder et al., “An Examination of the Effect of Boundary Layer Ingestion on Turboelectric Distributed Propulsion Systems,” AIAA-2011-300, 2011.





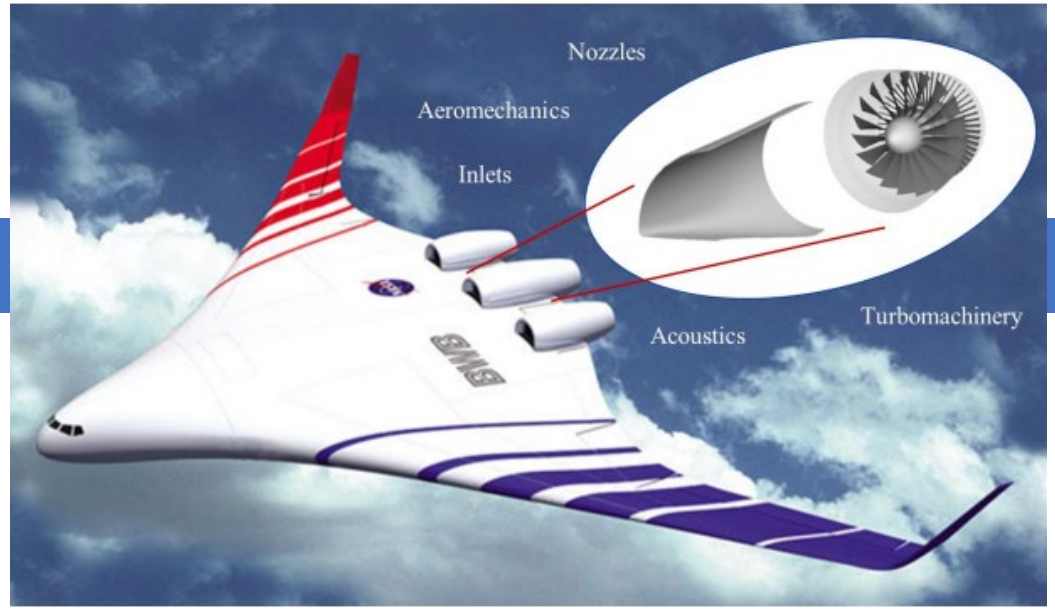
The BLI^{2}DTF

NASA N+2 Solicitation

Robust Design for Embedded Engine Systems NASA, United Technology Research Center, Virginia Tech

2006

Amendment No. 4 to the NASA Research Announcement (NRA) Entitled “Research Opportunities in Aeronautics– 2006 (ROA-2006),” NNH06ZEA001N, Release May 23, 2006.



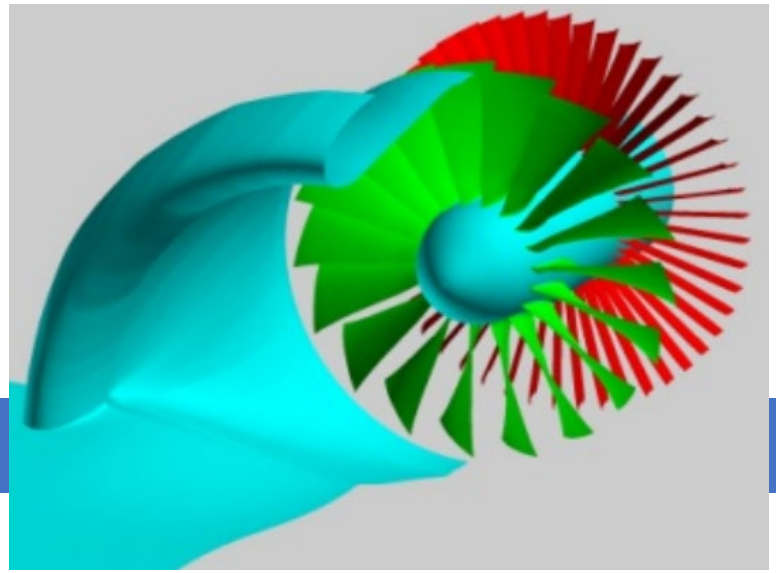
Arend, D., et al., “Generation After Next Propulsor Research: Robust Design for Embedded Engine Systems,” AIAA-2012-4041, AIAA/ASME/SAE/ASEE Joint Propulsion Conference and Exhibit, 2012.

The BLI^{2}DTF: Design

NASA N+2 Solicitation

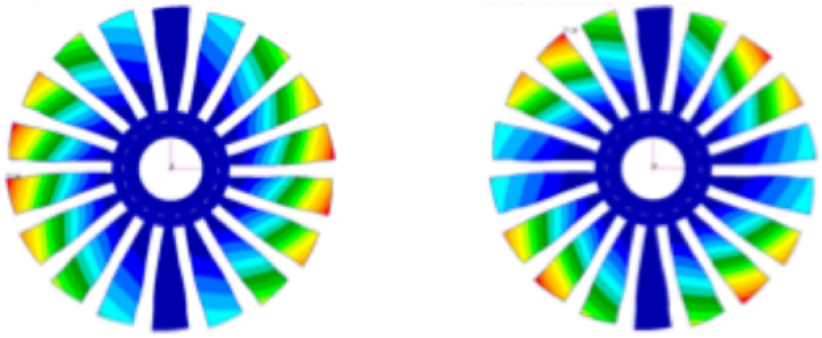
UTRC Propulsor Design

2006 **2014**



Bakhle, M., et al., "Aeromechanics Analysis of a Distortion-Tolerant Fan with Boundary Layer Ingestion," AIAA-2018-1891, AIAA Aerospace Sciences Meeting, 2018.

Cousins, W., et al., "Design of a Distortion-Tolerant Fan for a Boundary-Layer Ingesting Embedded Engine Application," AIAA-2017-5042, 53rd AIAA/SAE/ASEE Joint Propulsion Conference, 2017.

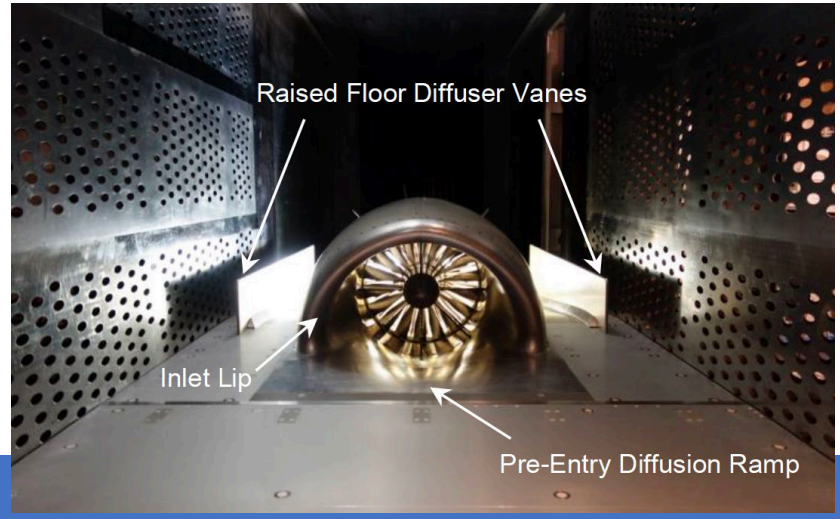


a) 1 nodal diameter (1 ND) pattern b) 2 nodal diameter (2 ND) pattern

Figure 9. Fan blade cyclic symmetry modal displacements (mode shapes) for mode 1.

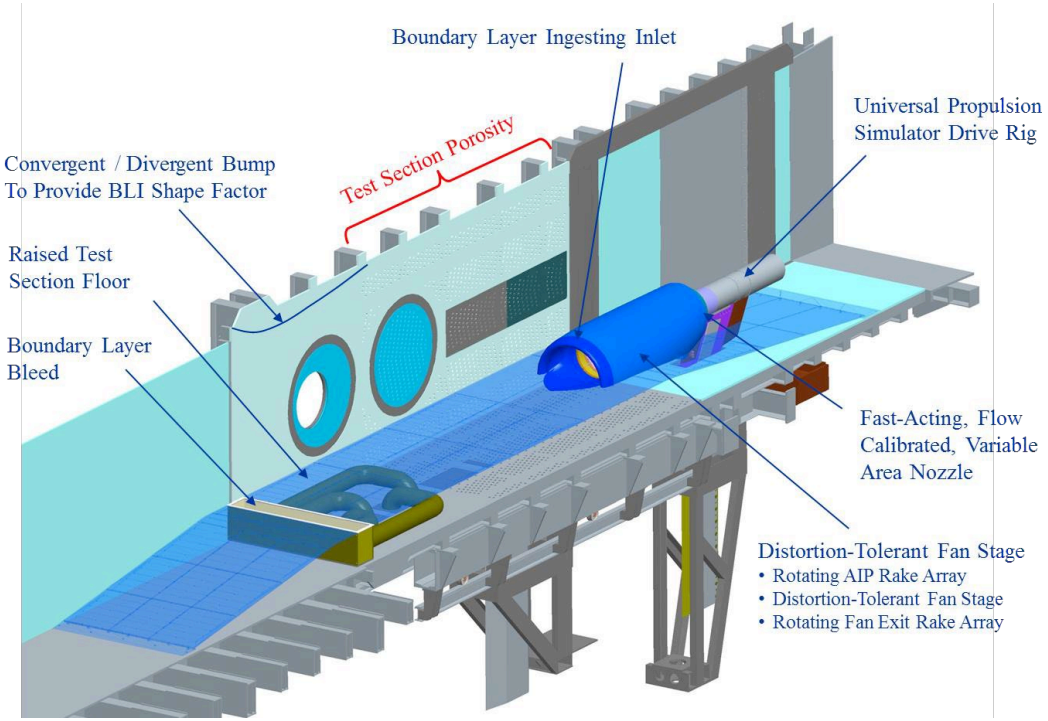
The BLI²DTF: Experiment Design

NASA N+2 Solicitation	UTRC Propulsor Design	NASA Glenn test
2006	2014	2017



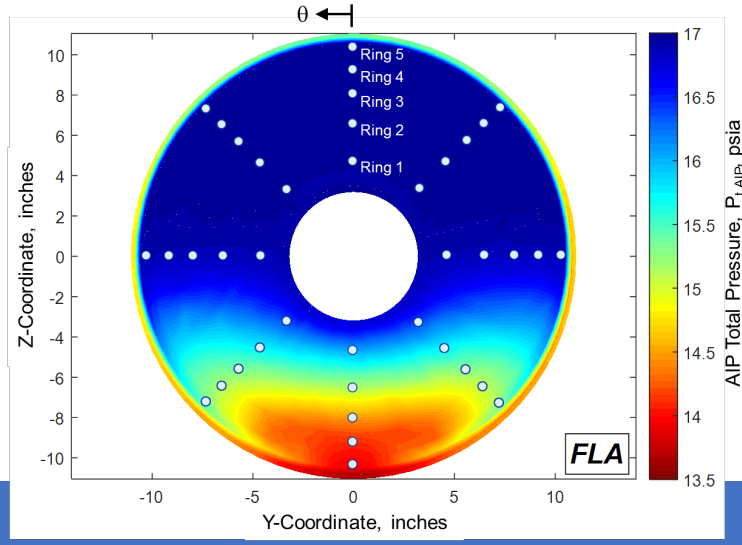
Hardin, L., et al., "Data Analysis Techniques for Fan Performance in Highly-Distorted Flows from Boundary Layer Ingesting Inlets," AIAA-2018-1888, AIAA Aerospace Sciences Meeting, 2018.

Hirt, S., et al., "Development of a Flow Field for Testing a Boundary-Layer-Ingesting Propulsor," AIAA-2017-5043, 53rd AIAA/SAE/ASEE Joint Propulsion Conference, 2017.

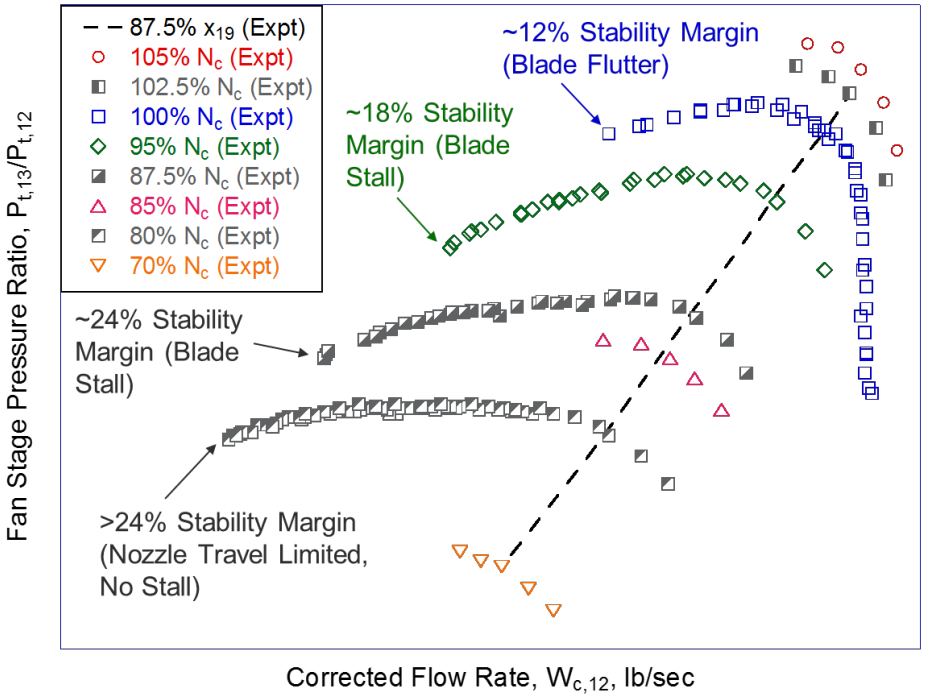


The BLI²DTF: Experimental Results

NASA N+2 Solicitation	UTRC Propulsor Design	NASA Glenn test
2006	2014	2017

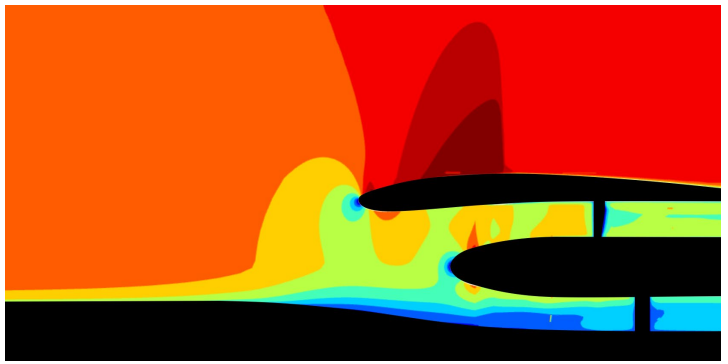


Arend, D., et al., "Experimental Investigation of an Ultra-High Bypass Ratio Embedded Boundary Layer Ingesting Propulsor for Subsonic Cruise Aircraft," ASME Turbo Expo, GT2020-15695, 2020.

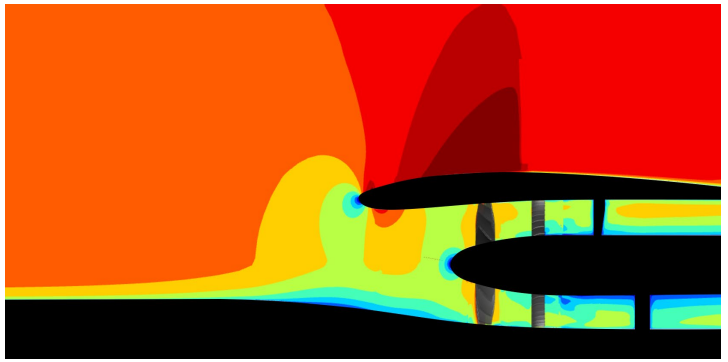


The BLI²DTF: Simulation

NASA N+2 Solicitation	UTRC Propulsor Design	NASA Glenn test	NASA Glenn modeling
2006	2014	2017	2024

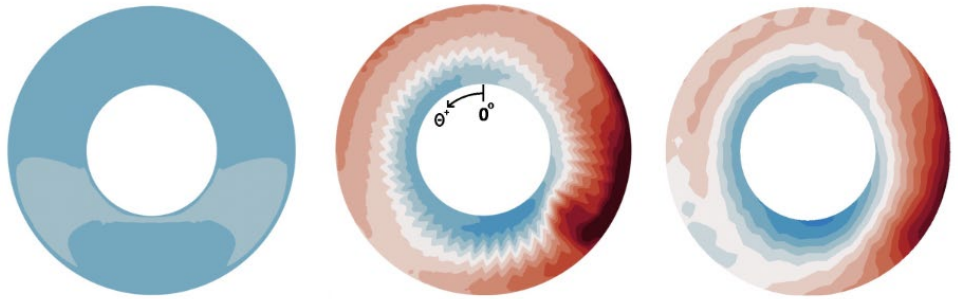


Actuator Zone



Coupled Simulation

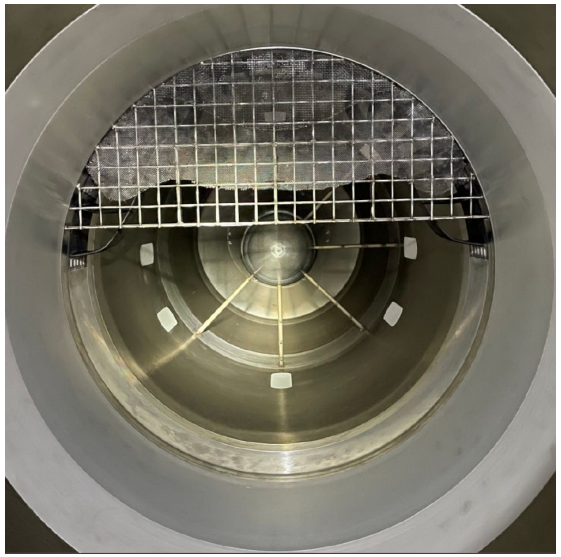
Heinlein, et al., "Performance Characteristics of a Boundary Layer Ingesting Inlet-Distortion Tolerant Fan Through CFD Code Coupling," AIAA SCITECH 2024, AIAA-2024-1195, 2024.

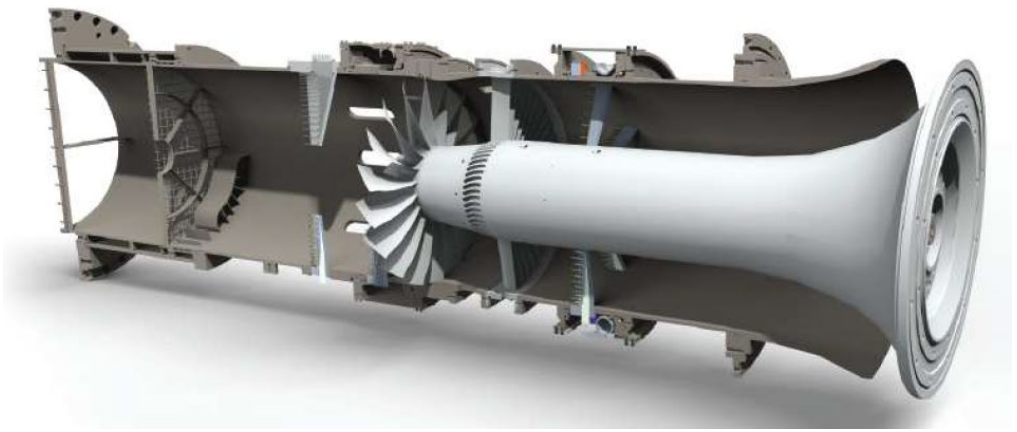


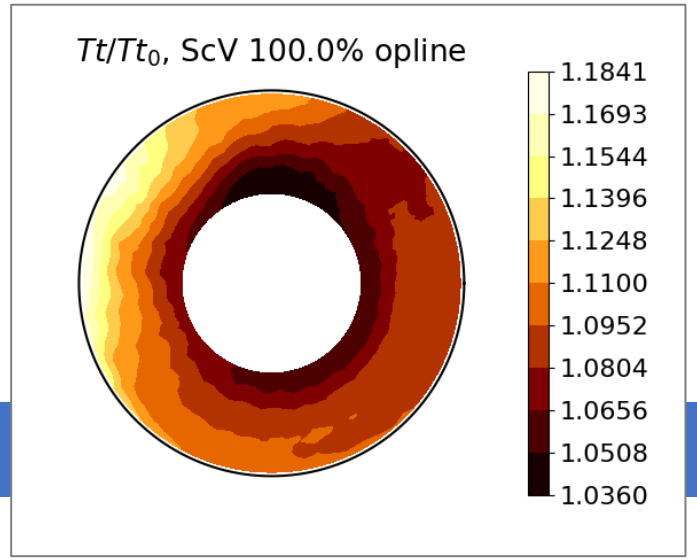
Actuator Zone | Coupled Simulation | Experiment

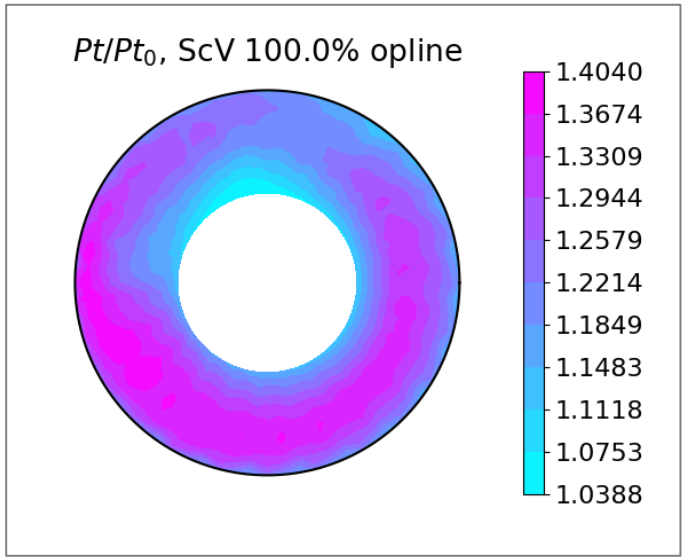
The BLI²DTF: ScreenVane Experiment

NASA N+2 Solicitation	UTRC Propulsor Design	NASA Glenn test	NASA Glenn modeling	NASA Glenn test
2006	2014	2017	2024	2025



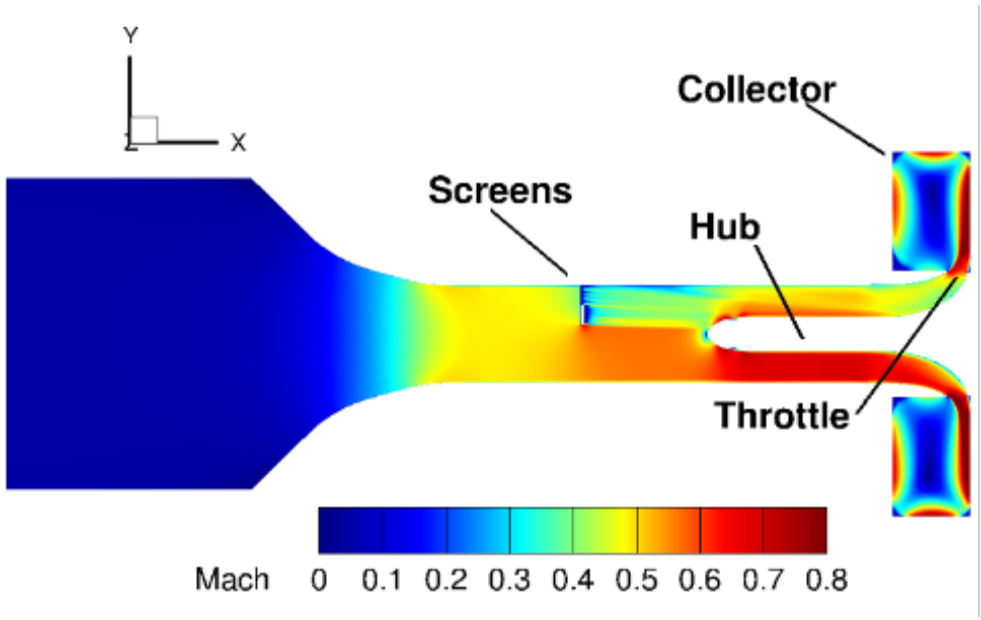


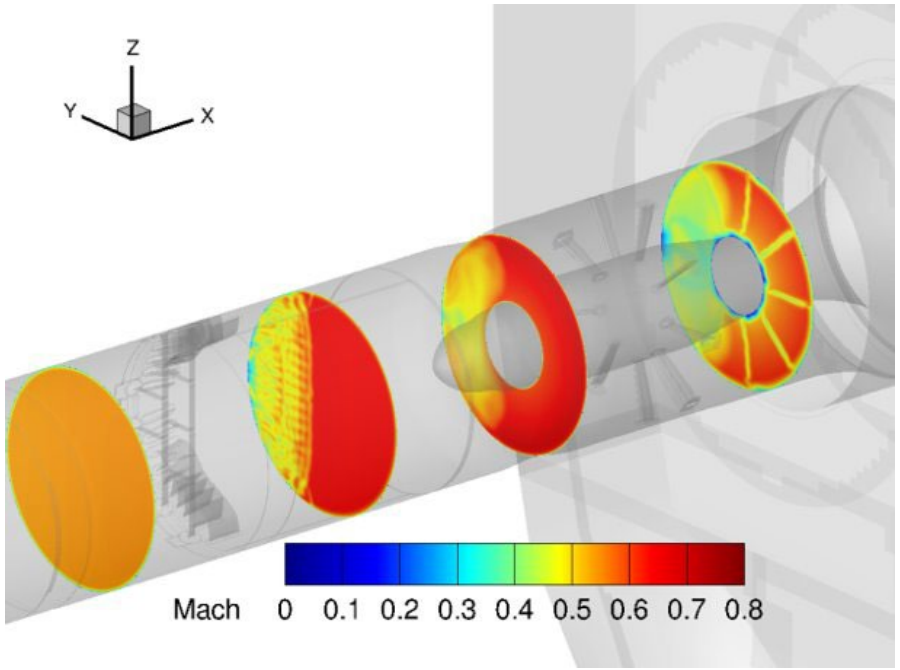




The BLI²DTF: ScreenVane Modeling

NASA N+2 Solicitation	UTRC Propulsor Design	NASA Glenn test	NASA Glenn modeling	NASA Glenn test	NASA Glenn modeling
2006	2014	2017	2024	2025	2026





Aft Thruster Research: Concept

NASA
STARC-ABL
Concept study

2016



Welstead & Felder, “Conceptual Design of a Single-Aisle Turboelectric Commercial Transport with Fuselage Boundary Layer Ingestion,” AIAA-2016-1027, 2016.

Aft Thruster Research: BLITS Experiment

NASA
STARC-ABL
Concept study

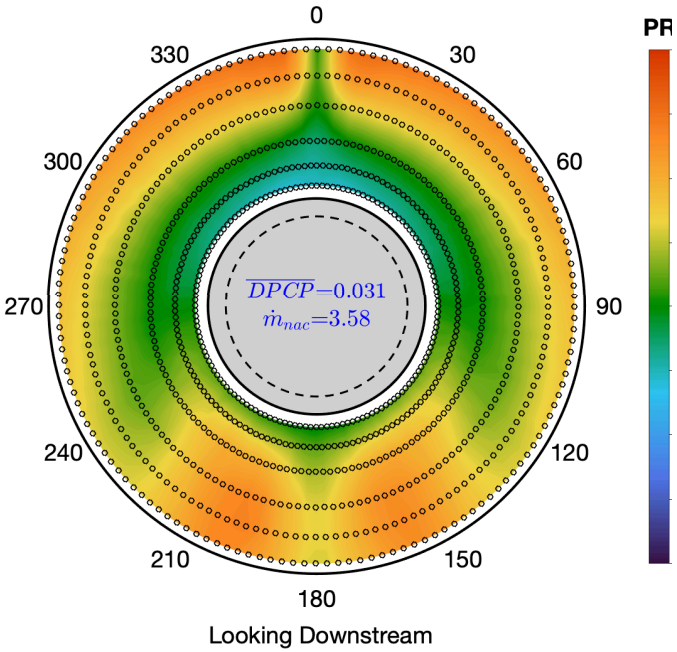
NASA
Langley
NTF test

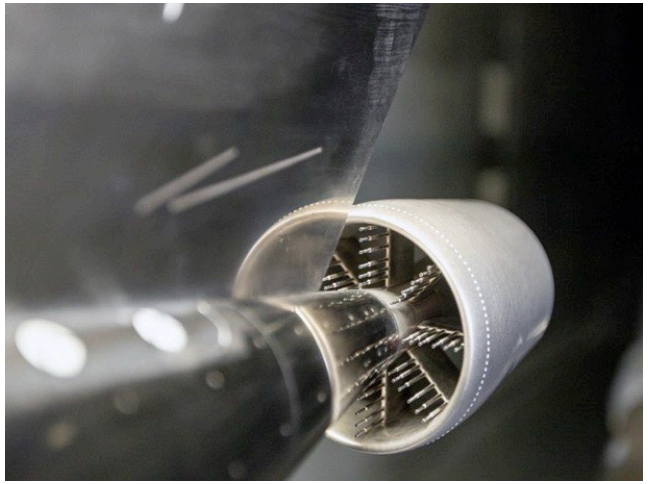
2016

2023



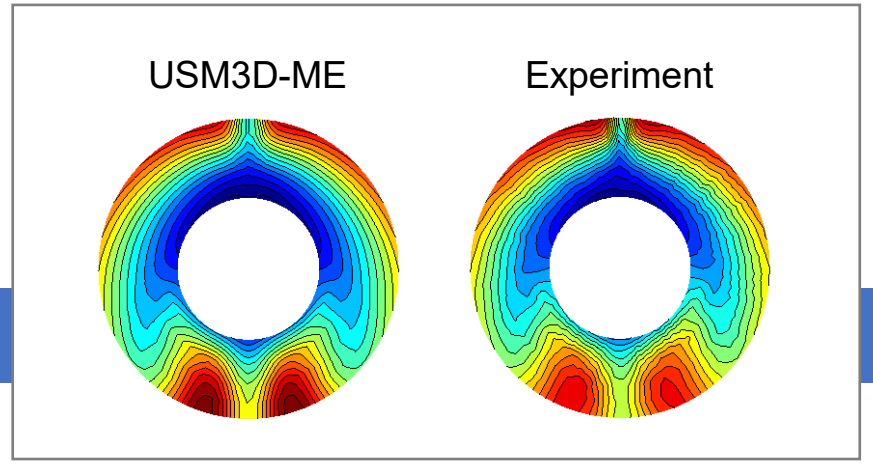
Chan, et al., “Experimental Investigation of a Boundary Layer Ingesting Tailcone Thruster Configuration at the National Transonic Facility,” AIAA Aviation 2024, AIAA-2024-3515, 2024.





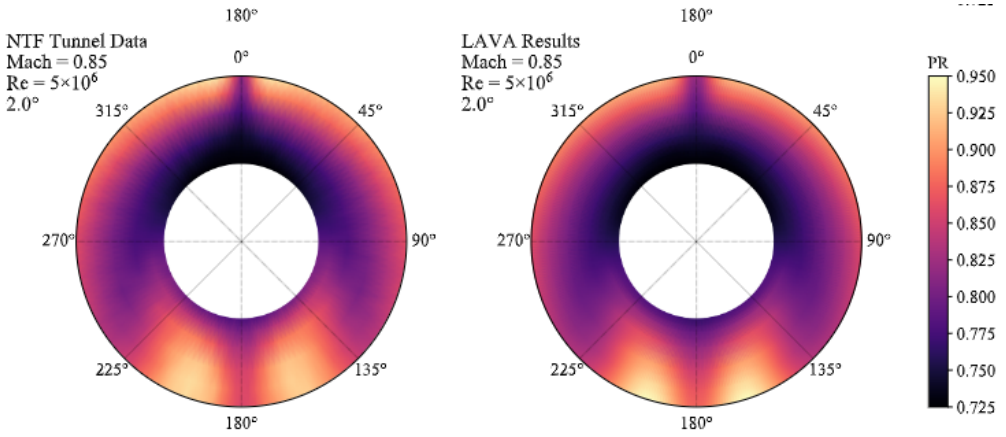
Aft Thruster Research: BLITS Modeling

NASA STARC-ABL Concept study	NASA Langley NTF test	NASA Langley NTF modeling
2016	2023	2024



Santos, et al., “Computational Analysis of a Boundary Layer Ingesting Tailcone Thruster Configuration Within the National Transonic Facility Using the LAVA Solver,” AIAA Aviation 2024, AIAA-2024-3766, 2024.

Bozeman, M., “USM3D-ME Analyses Performed in Support of a Wind Tunnel Test of a Boundary-Layer Ingestion Configuration,” AIAA Aviation 2024, AIAA-2024-4022, 2024.



Aft Thruster Research: BLITS Propulsor Design

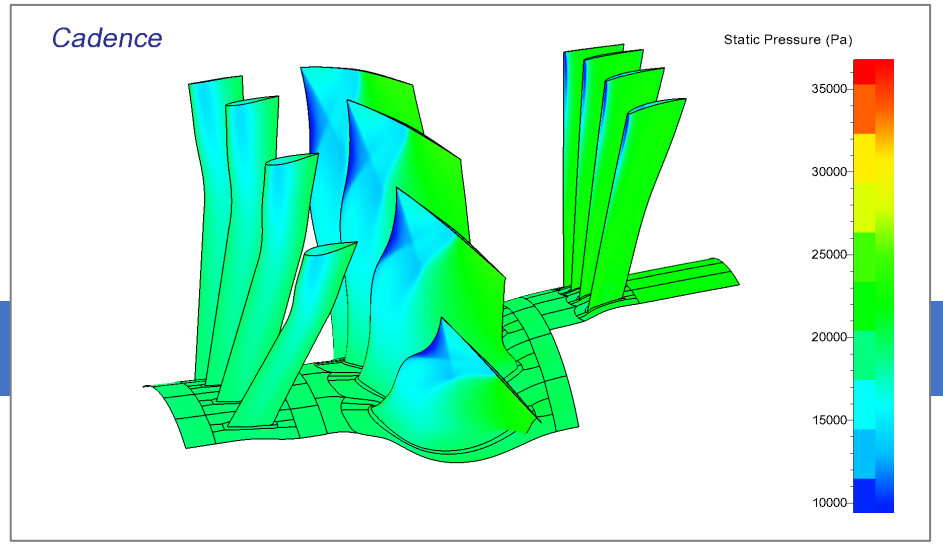
NASA STARC-ABL Concept study

NASA Langley NTF test

NASA Langley NTF modeling

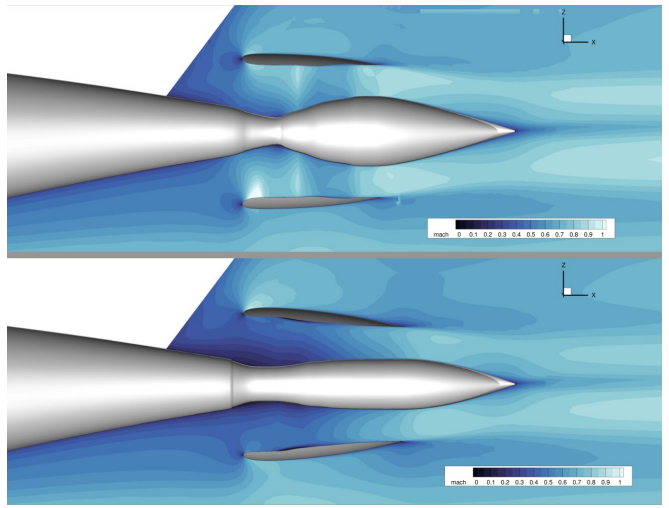
2016 2023 **2024**

Propulsor Design and System Studies





(c) CRM-TCT (d) TTBW-TCT

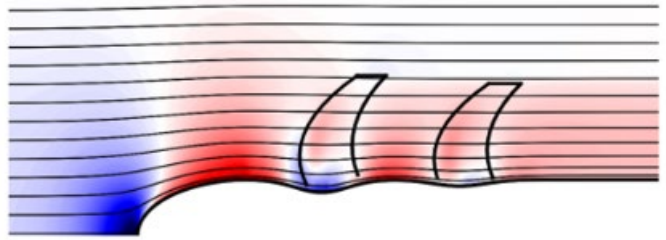


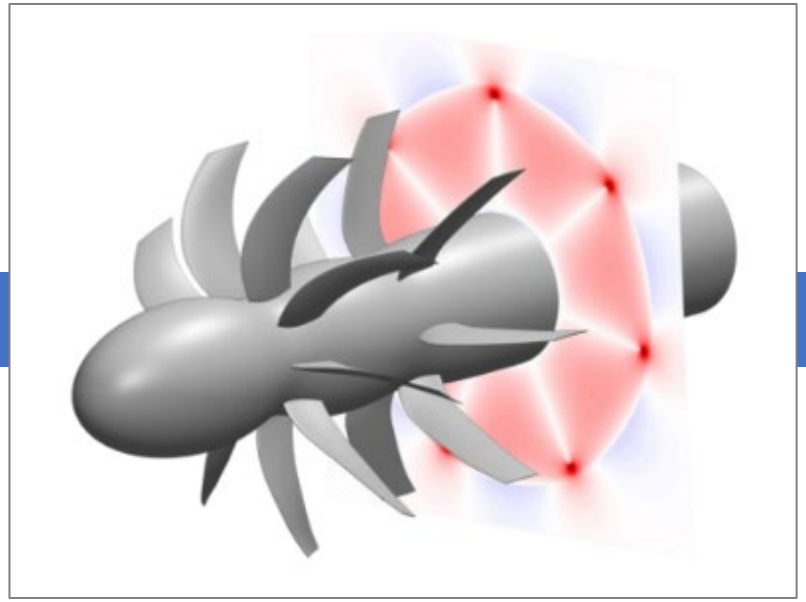
Machado, L., et al., "Aeropropulsive Assessment of a BLI Tail-Cone Thruster Propulsion System for the NASA Common Research Model and a Transonic Truss-Braced Wing Configuration," AIAA Aviation 2024, AIAA-2024-3767, 2024.

POC: Matthew Ha (GRC), PM: Dale van Zante, TL: Shishir Pandya

Open Fan Design: NOPEN

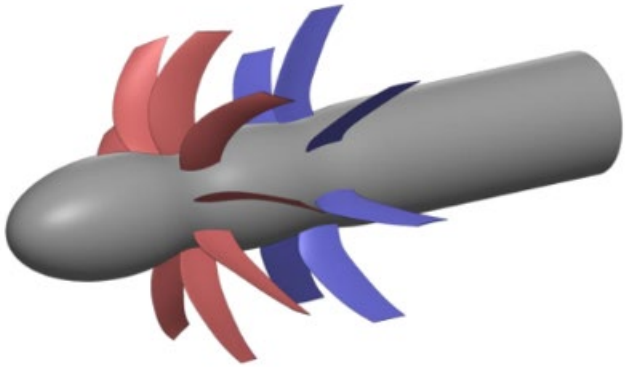
NASA
Open Fan
Design

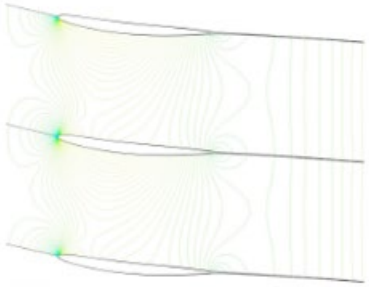




2026

Gillespie, et al., “Design and Optimization of an Open Rotor Stage,” GT2026-178157, ASME Turbo Expo, 2026, Milan, Italy.

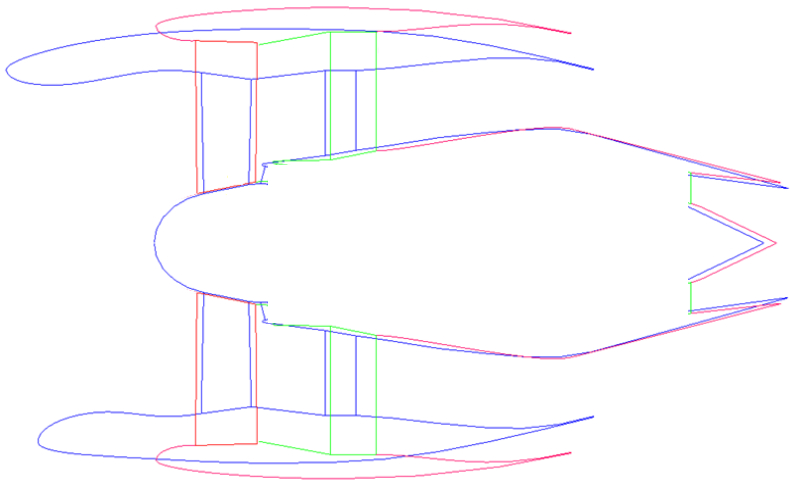




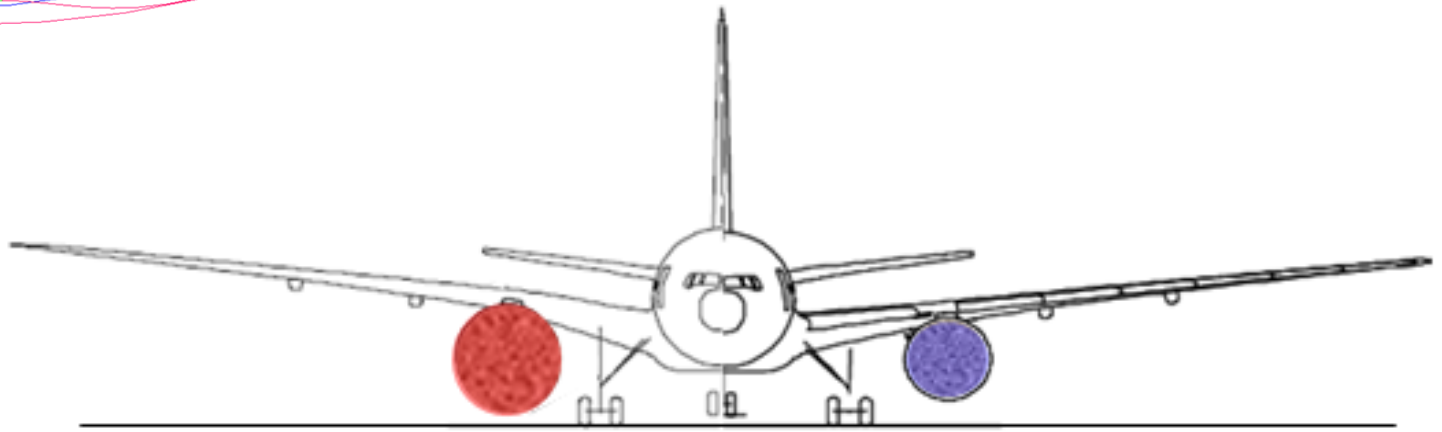




Propulsion-Airframe Integration Now







Hughes, C., “The Promise and Challenges of Ultra High Bypass Ratio Engine Technology and Integration”, AIAA Aero Sciences Meeting, 2011

Propulsion-Airframe Integration in Next Generation Concepts

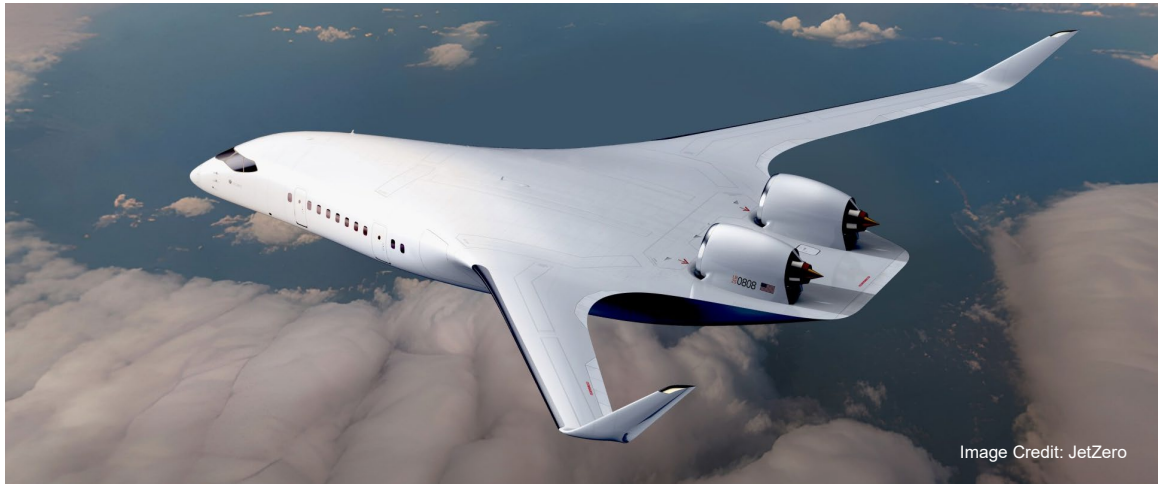
NASA AACES (Advanced Aircraft Concepts for Environmental Sustainability) 2050



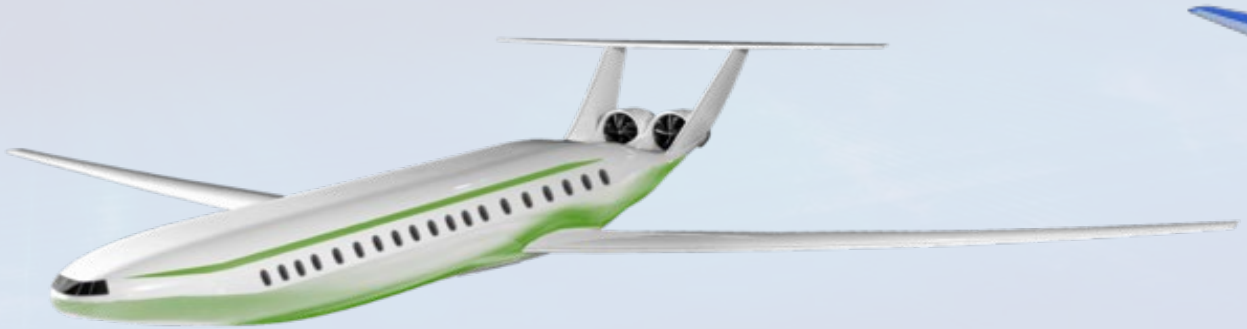
Georgia Tech

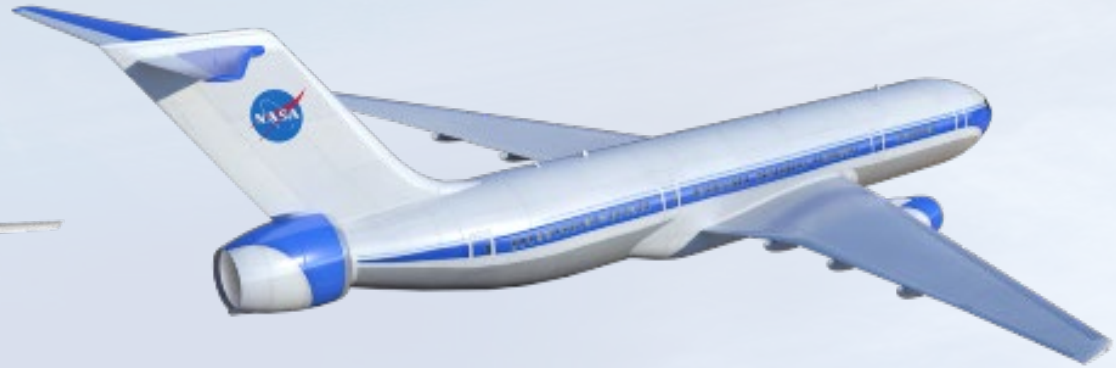


Electra Aero

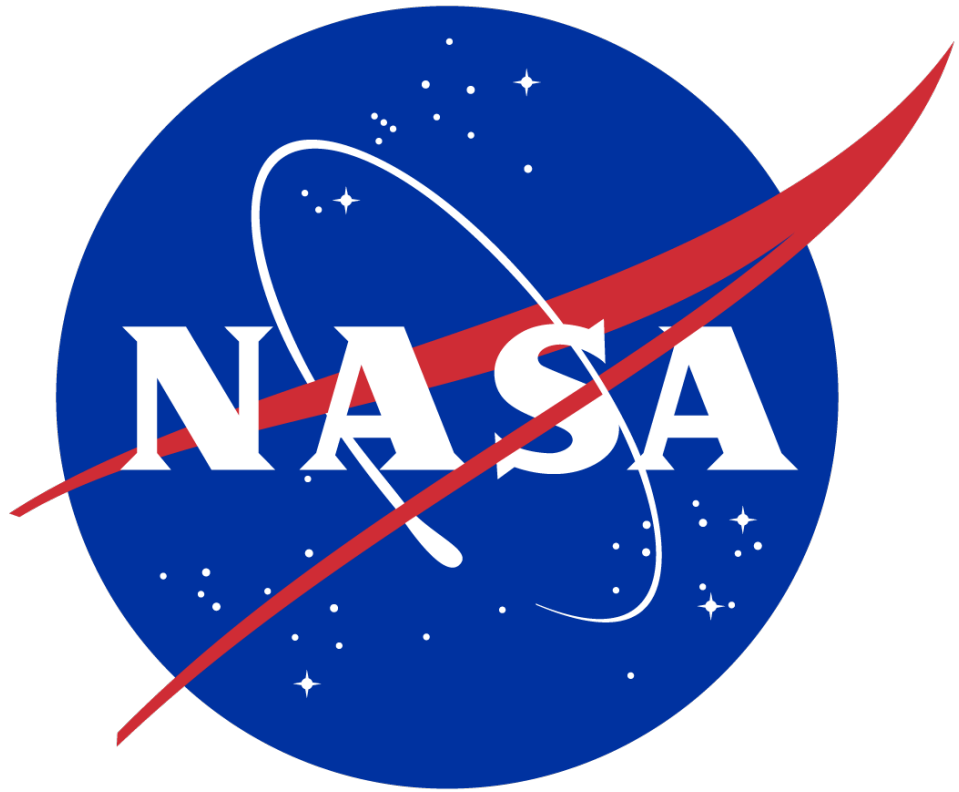


JetZero





Questions?


NASA