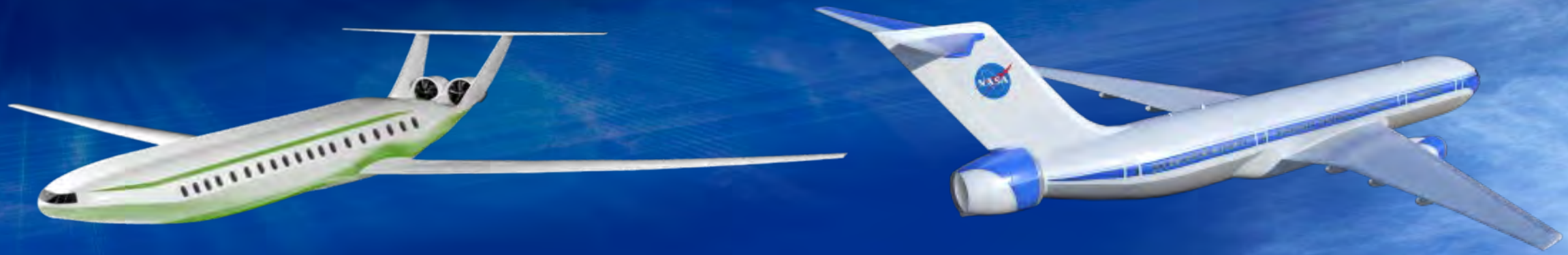


# Overview of Propulsion-Airframe Integration Research at NASA
# ICAS PAPER 2026_1059

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

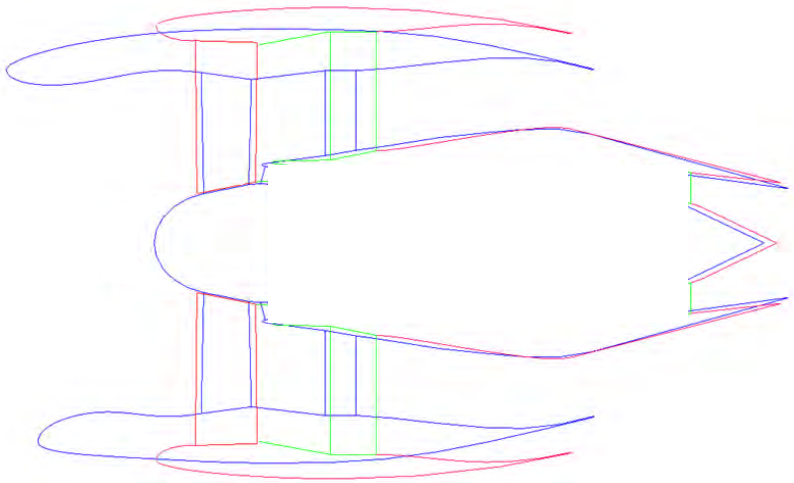



Electra Aero

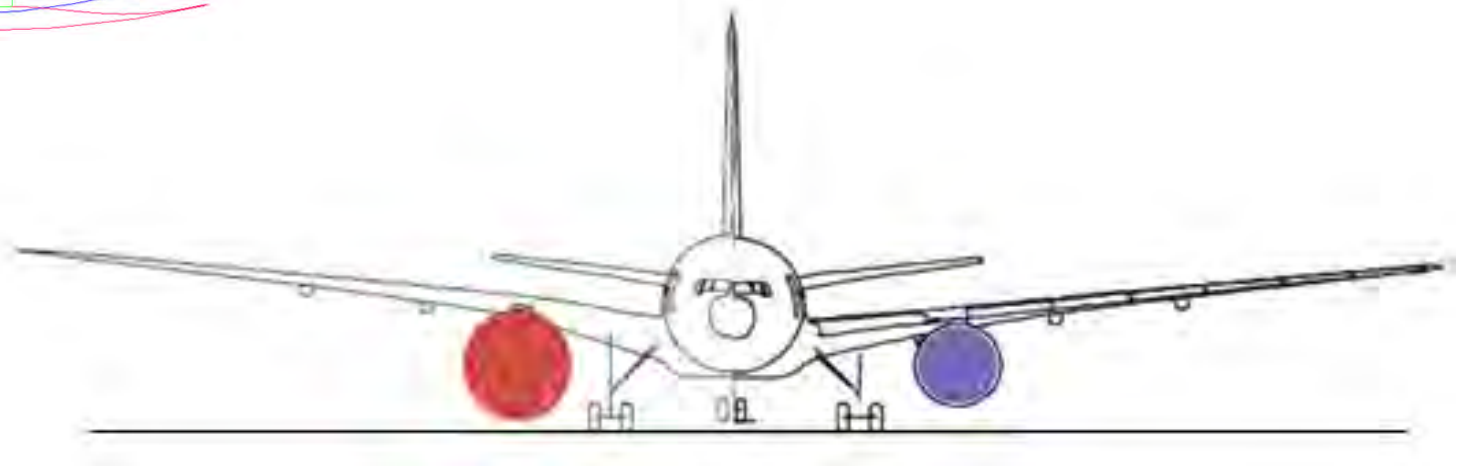



JetZero

# Propulsion-Airframe Integration Now



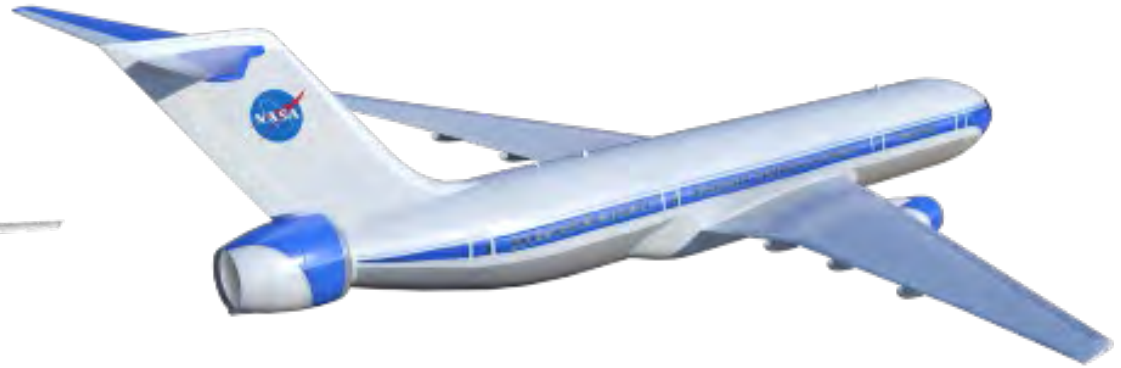




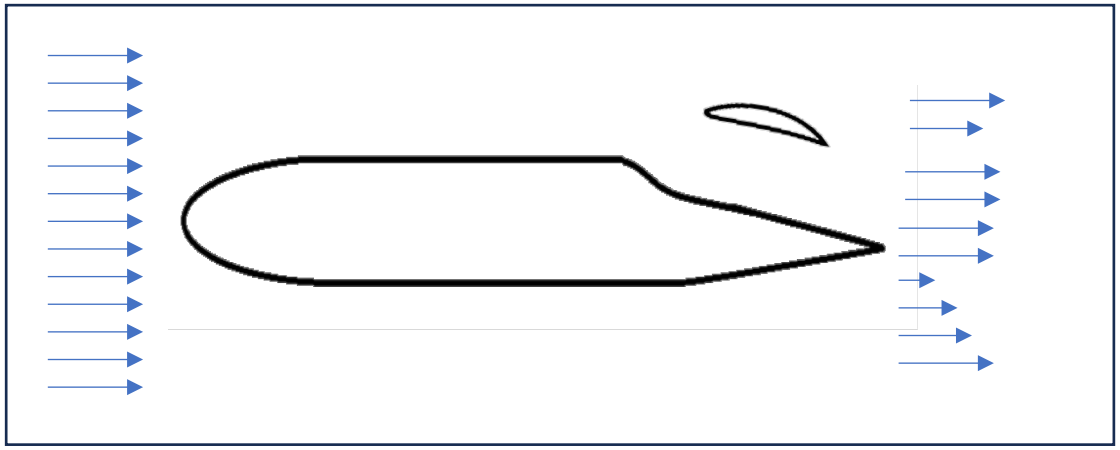
Hughes, C., “The Promise and Challenges of Ultra High Bypass Ratio Engine Technology and Integration”, AIAA Aero Sciences Meeting, 2011

# Boundary Layer Ingestion (BLI) and Propulsion-Airframe Integration

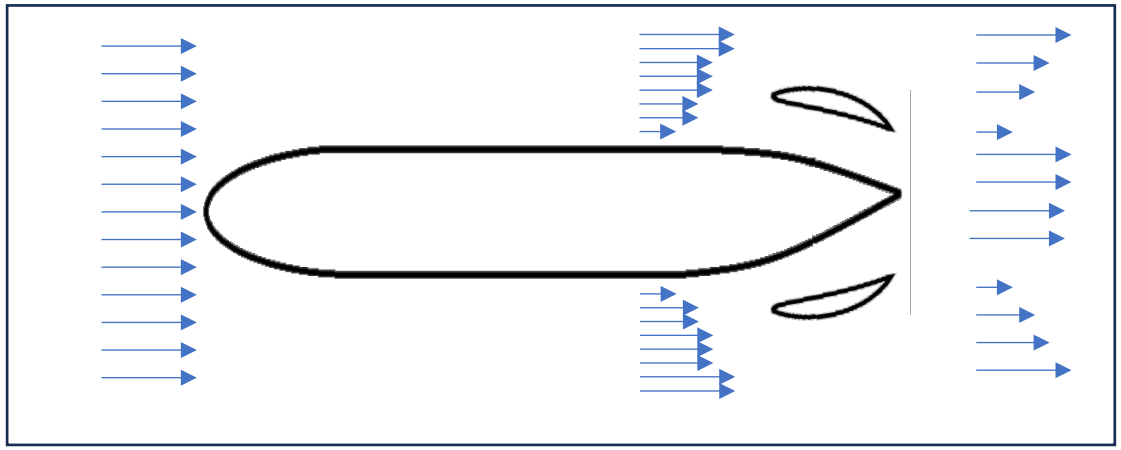




## Type 1



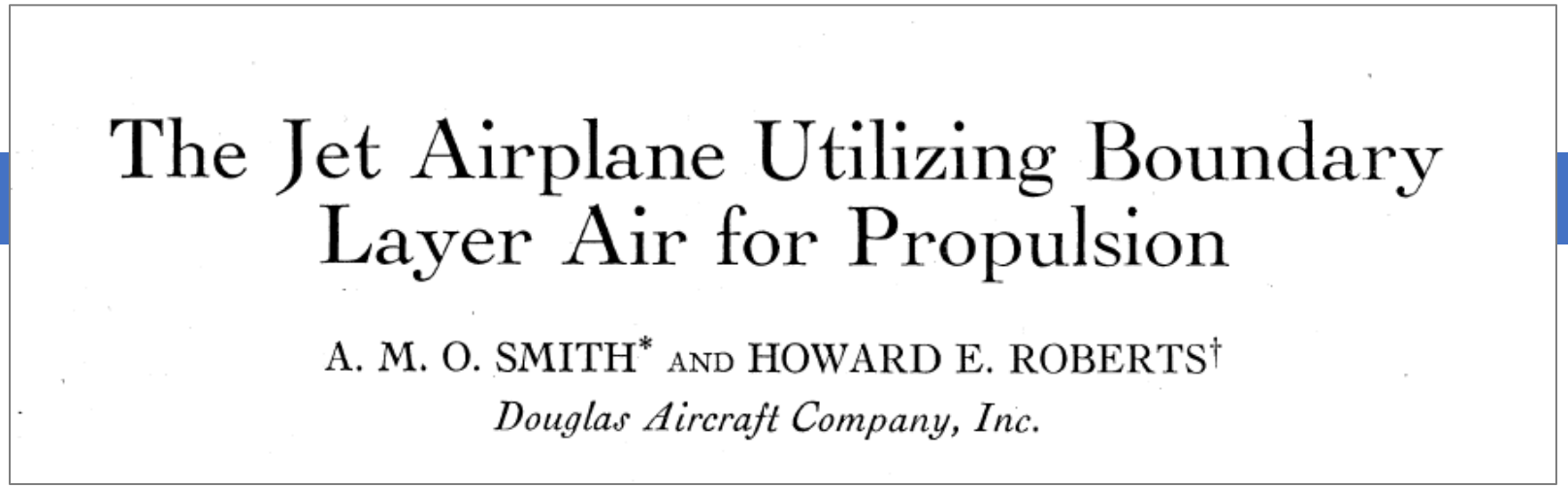
## Type 2



# 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




Internal investigations at Douglas. Little other interest.

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 | Lynch | Douglass | Smith |
|---|---|---|---|
| **1947** | **1960** | **1970** | **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.

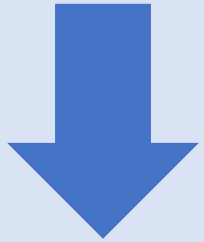
# Classical BLI Concept Research

| 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

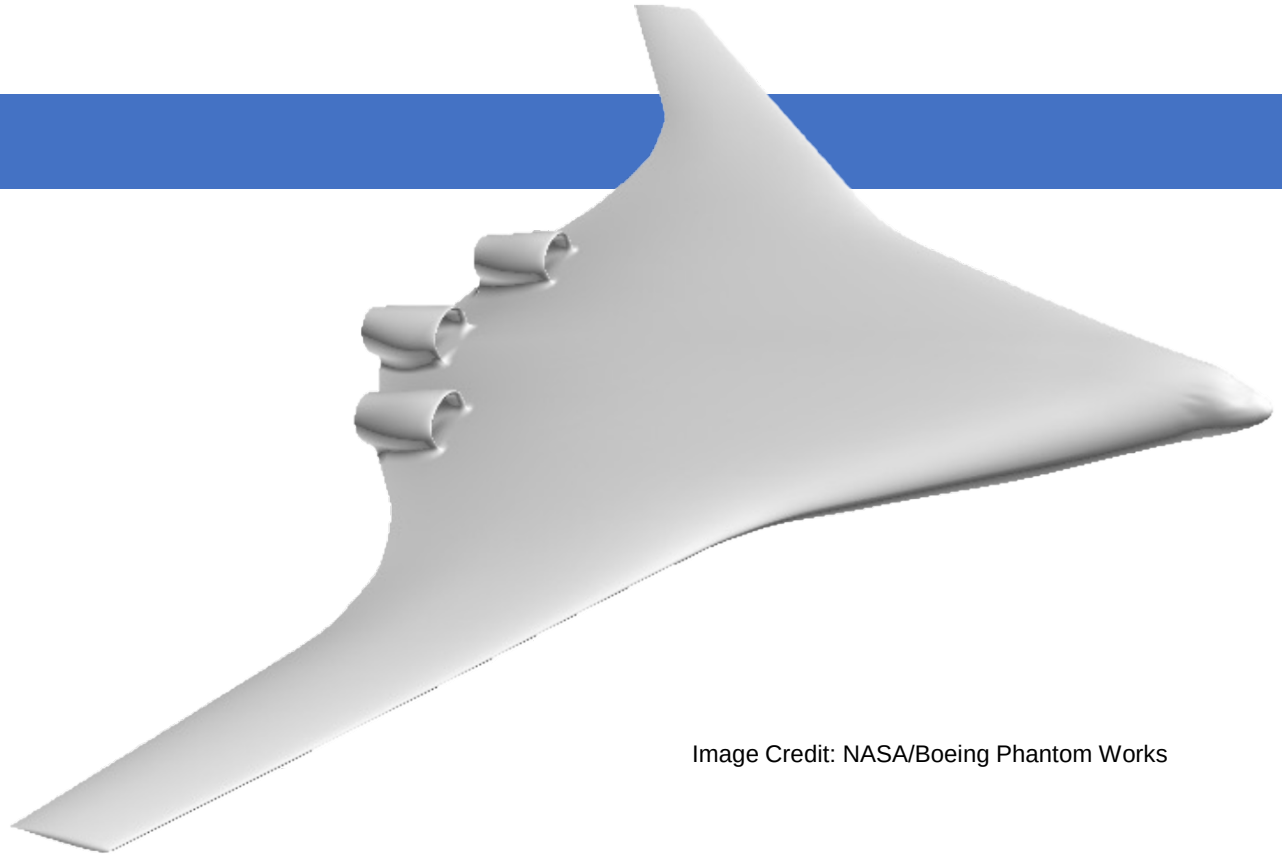


Image Credit: NASA/Boeing Phantom Works

# 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

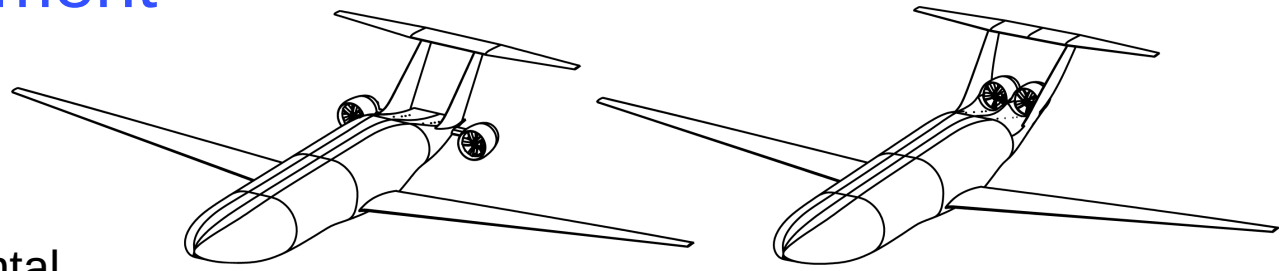
| NASA N+3 Solicitation | Concept study |
| --- | --- |
| **2008** | **2010** |

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



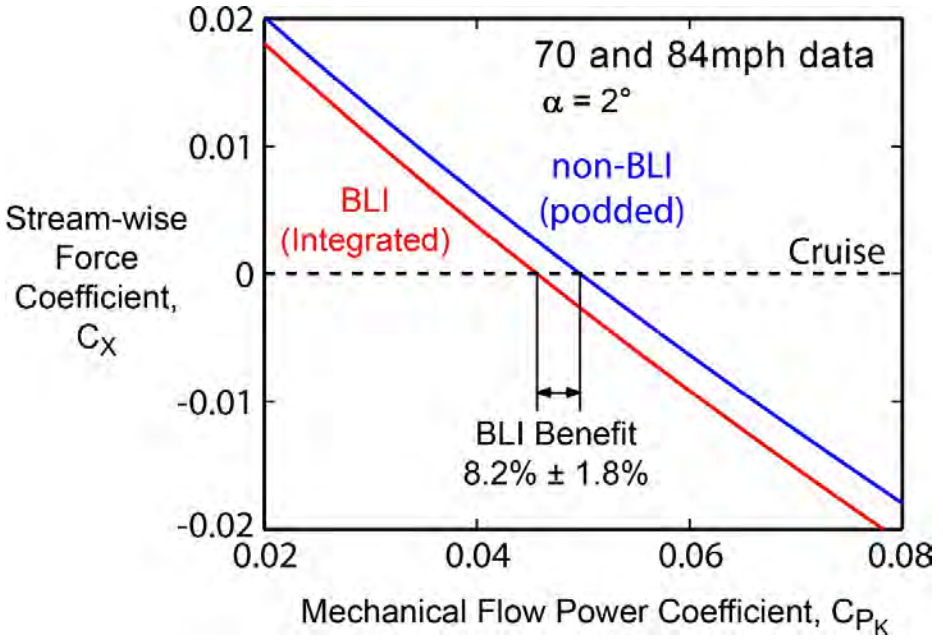
NASA N+3 Solicitation — 2008

Concept study — 2010

Experimental results — 2014

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



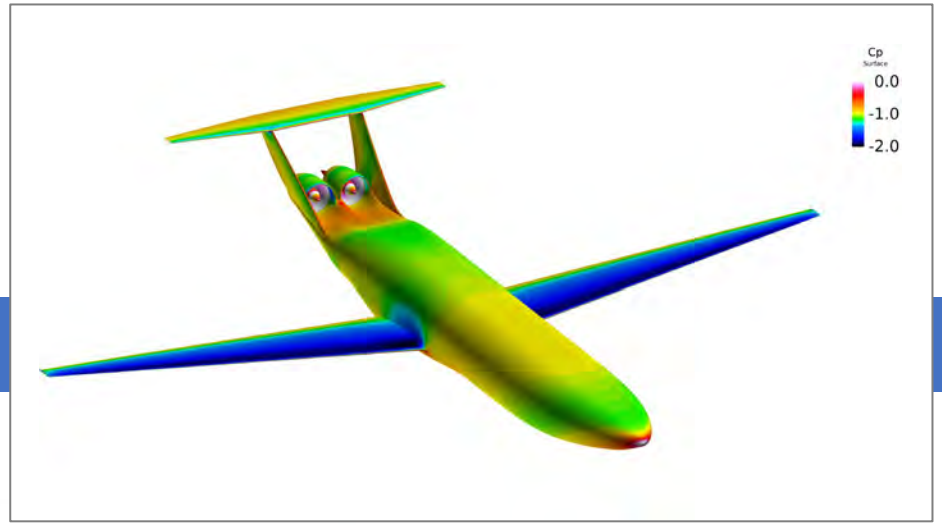


# The D8 Program: Phase 2 Computational Assessment

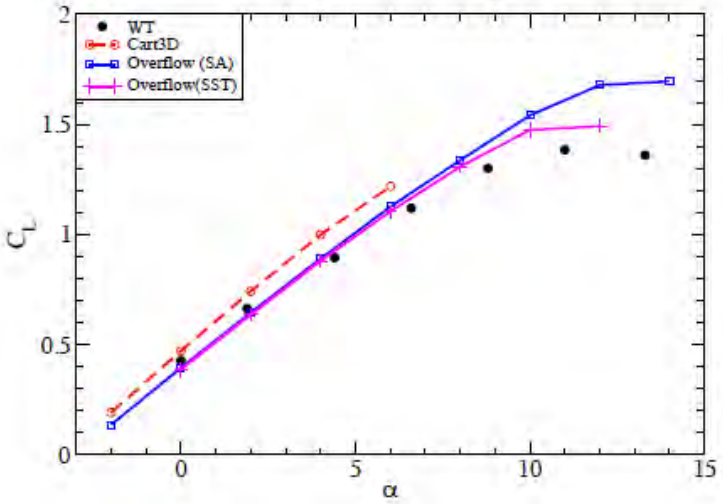
NASA N+3 Solicitation — 2008

Concept study — 2010

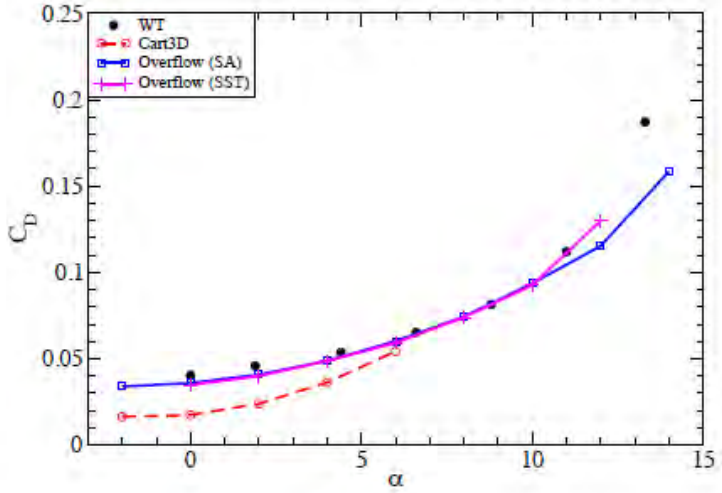
Computational results — 2014




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

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# The D8 Program: Phase 3

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

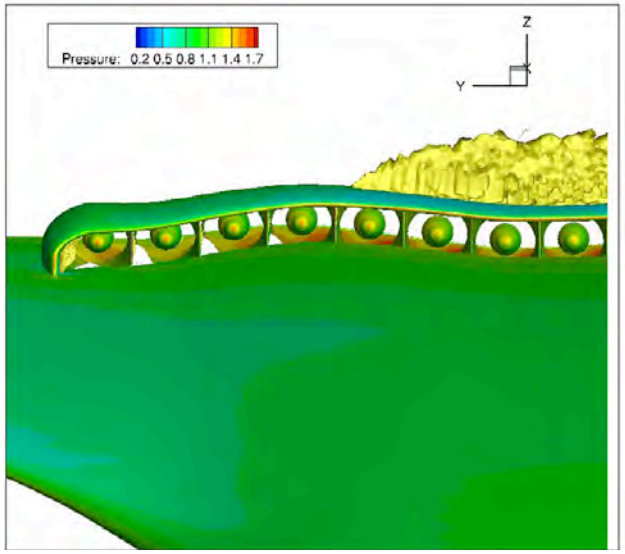
Technology Maturation and **Design** for a scaled Demo Vehicle.

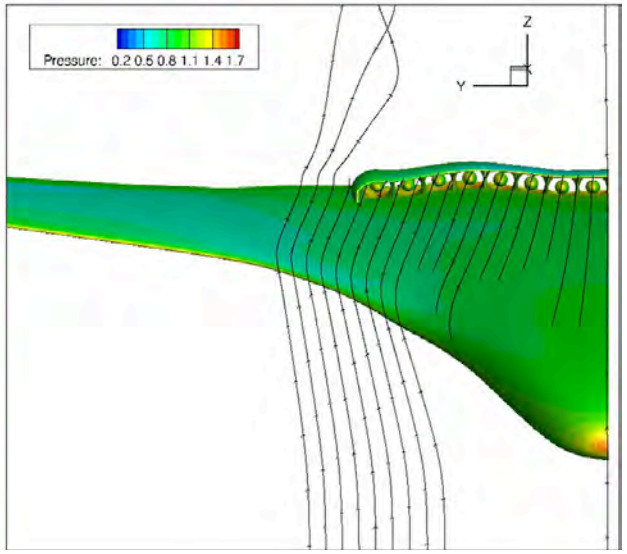
# The N3-X Program: Phase 1

| NASA N+3 Solicitation | Concept study |
| --- | --- |
| **2008** | **2011** |



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



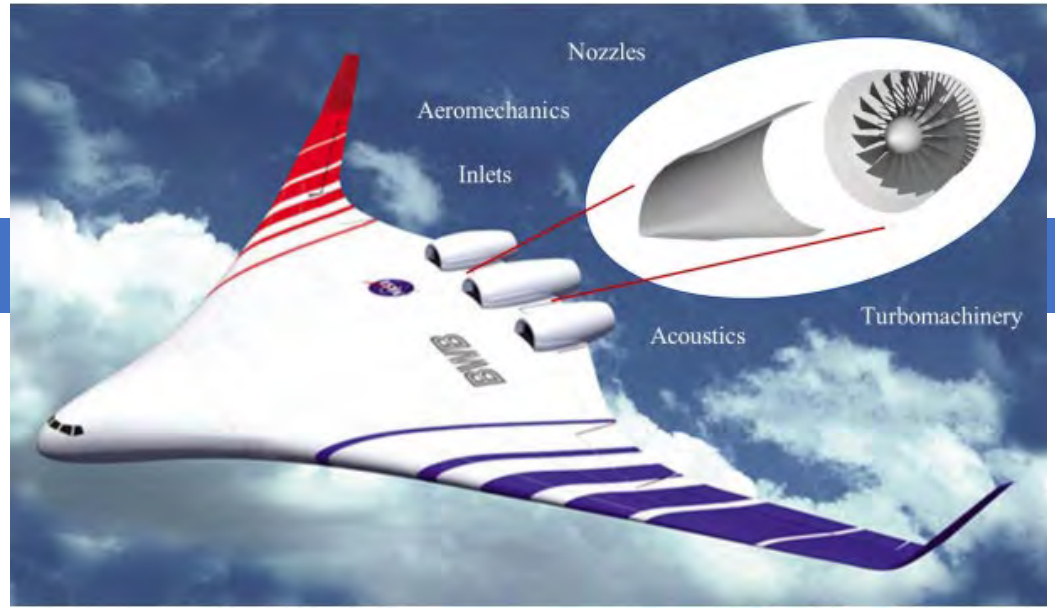
# The BLI$^2$DTF

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.



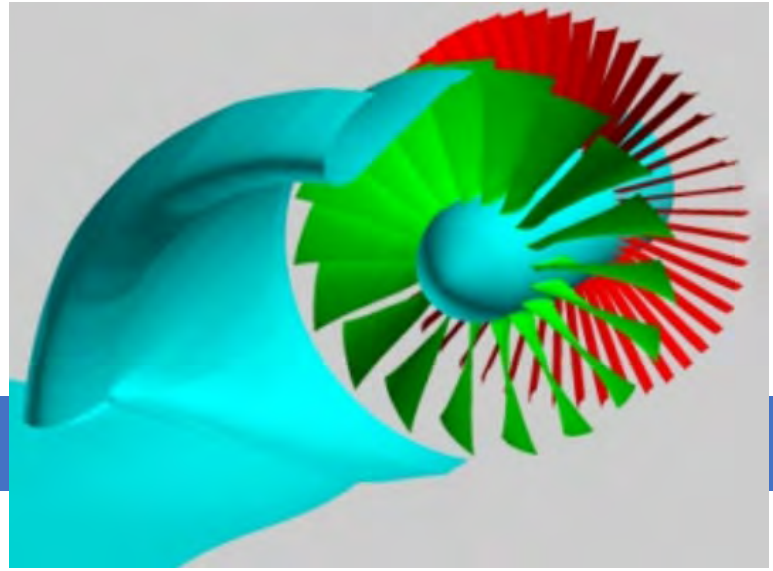

Arend, D., et al., “Generation After Next Propulsor Research: Robust Design for Embedded Engine Systems,” AIAA-2012-4041, AIAA/ASME/SAE/ASEE Joint Propulsion Conference and Exhibit, 2012.

# 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.

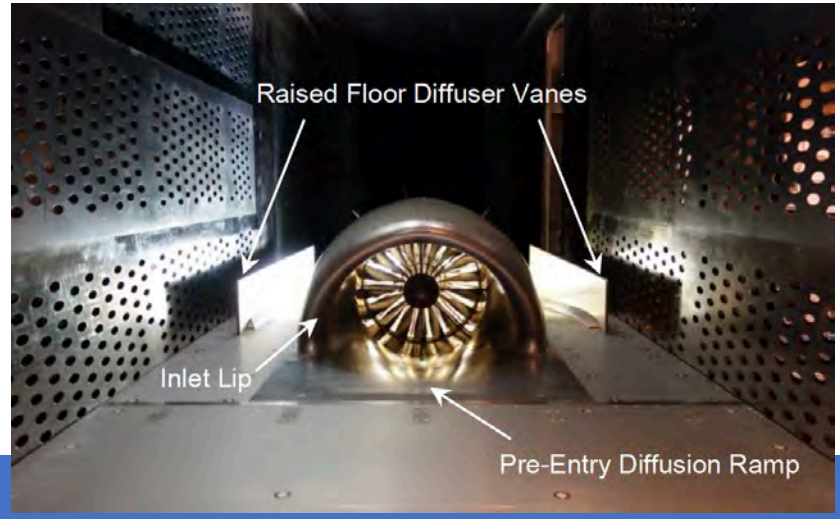


a) 1 nodal diameter (1 ND) pattern b) 2 nodal diameter (2 ND) pattern

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

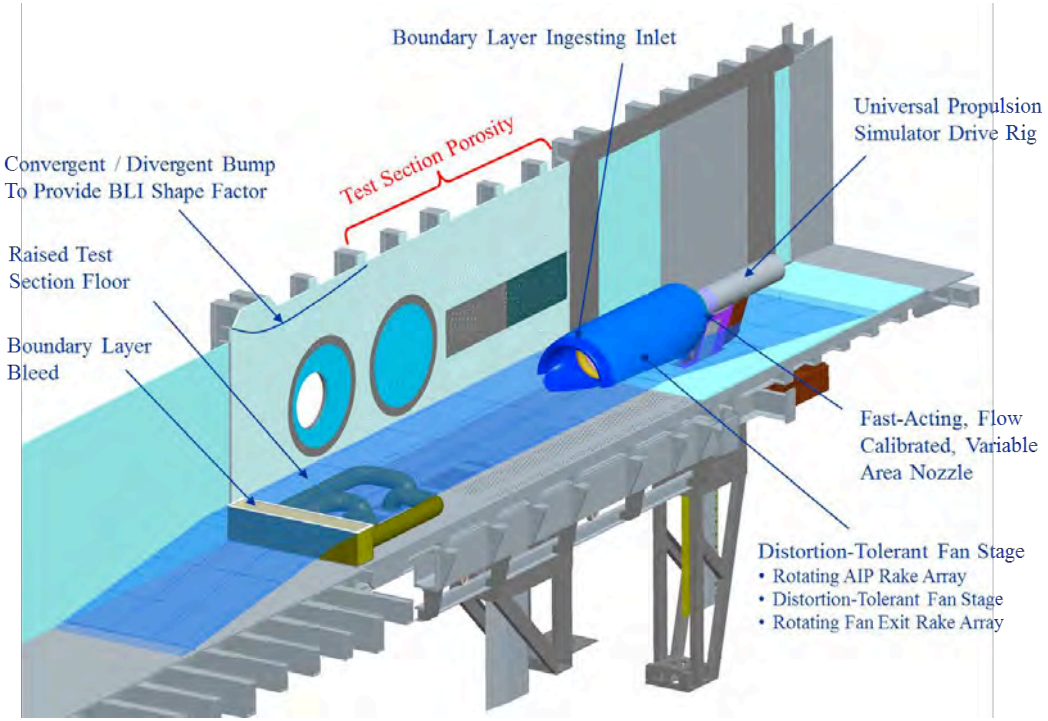
# The BLI²DTF: Experiment Design

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



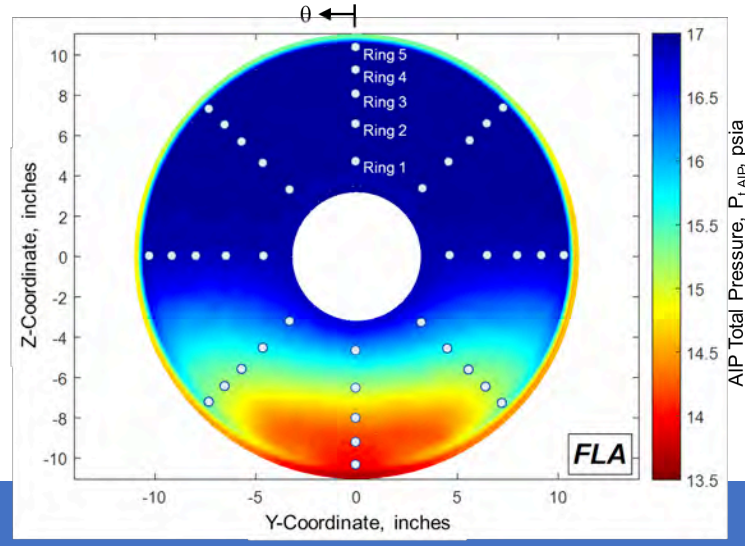

Hardin, L., et al., "Data Analysis Techniques for Fan Performance in Highly-Distorted Flows from Boundary Layer Ingesting Inlets," AIAA-2018-1888, AIAA Aerospace Sciences Meeting, 2018.

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.

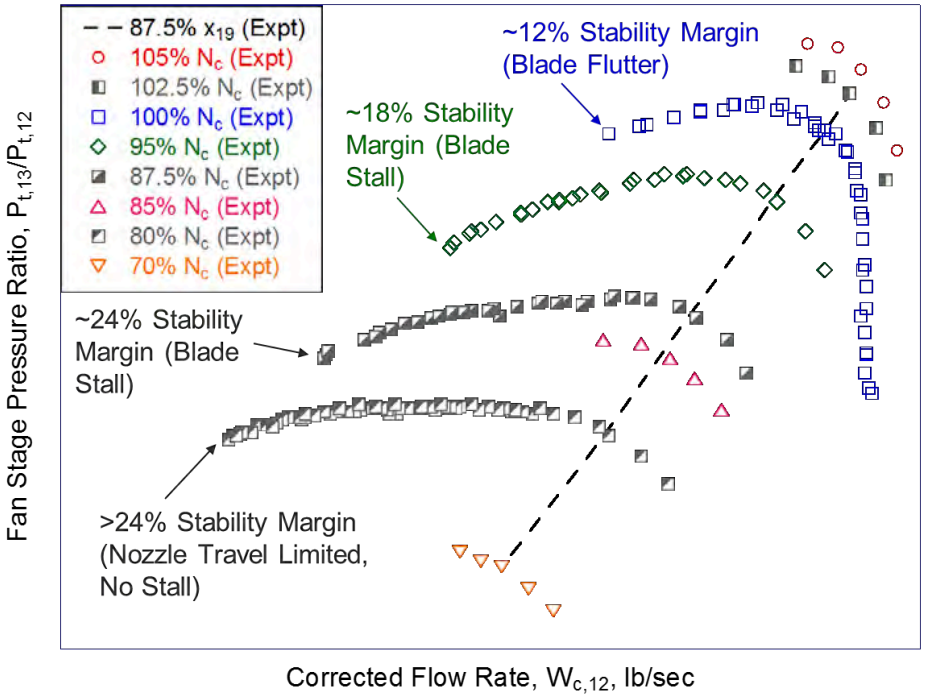


# The BLI²DTF: Experimental Results

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

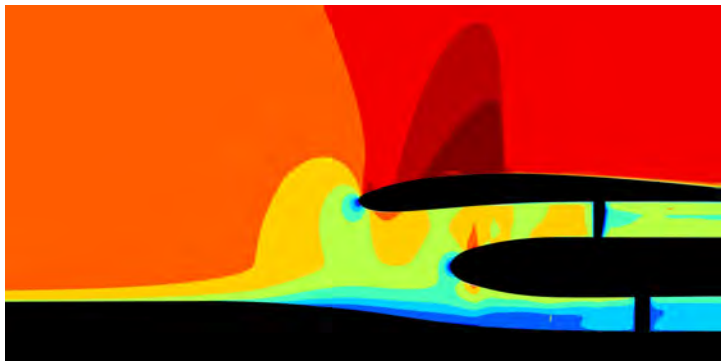



Arend, D., et al., "Experimental Investigation of an Ultra-High Bypass Ratio Embedded Boundary Layer Ingesting Propulsor for Subsonic Cruise Aircraft," ASME Turbo Expo, GT2020-15695, 2020.

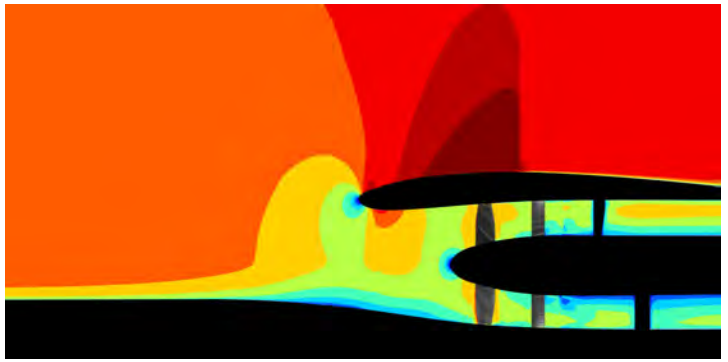


# The BLI²DTF: Simulation

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

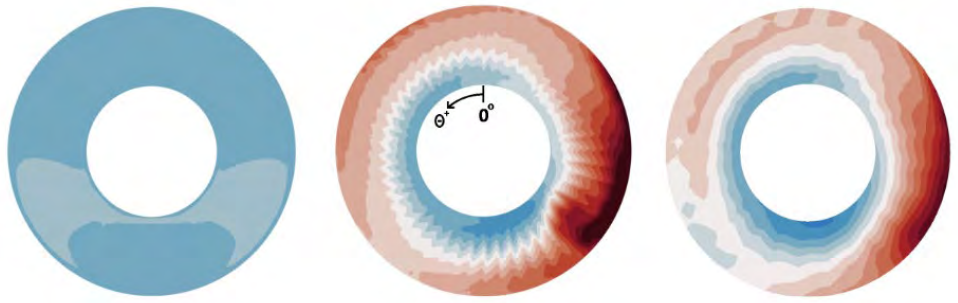


Actuator Zone



Coupled Simulation

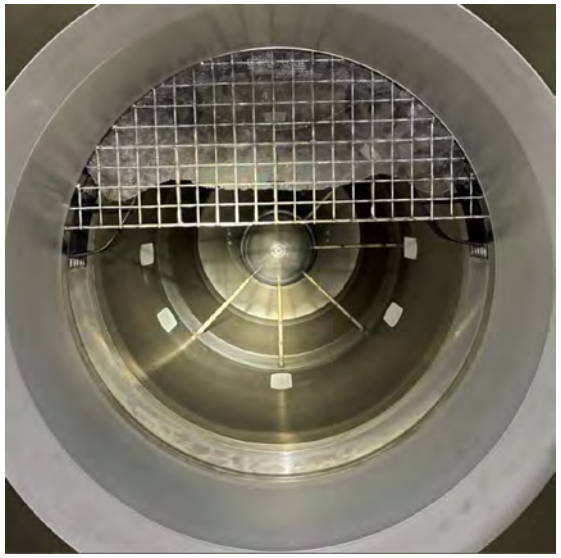
Heinlein, et al., “Performance Characteristics of a Boundary Layer Ingesting Inlet-Distortion Tolerant Fan Through CFD Code Coupling,” AIAA SCITECH 2024, AIAA-2024-1195, 2024.

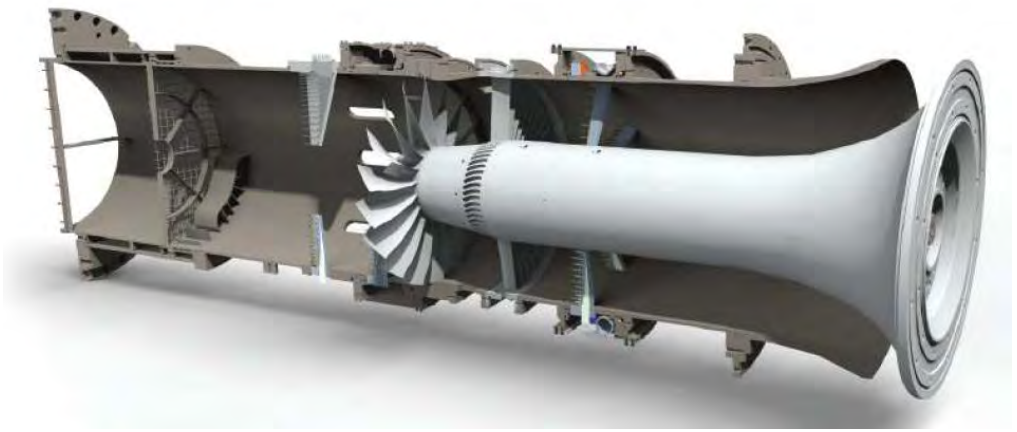


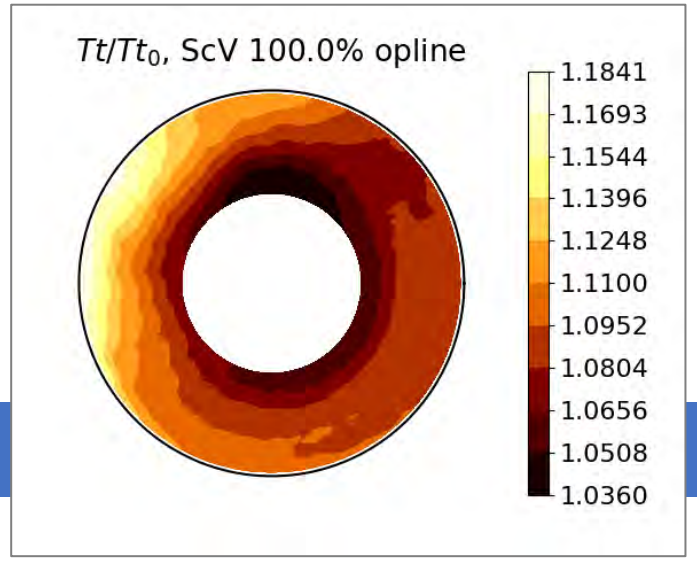

Actuator Zone  Coupled Simulation  Experiment

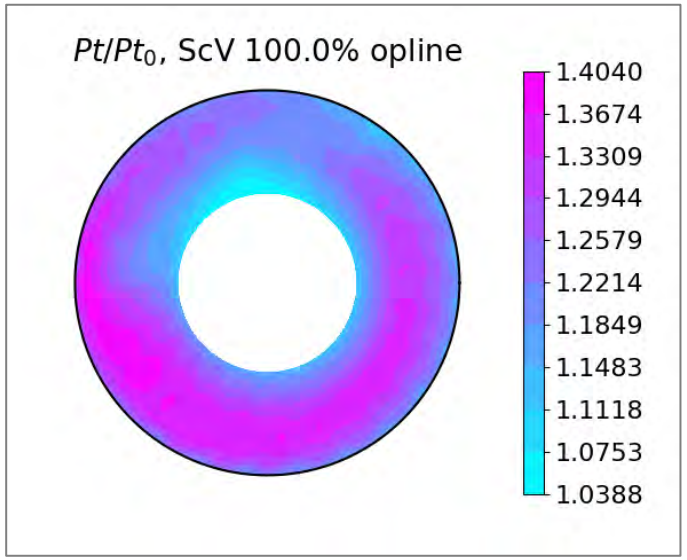
# The BLI$^2$DTF: ScreenVane Experiment

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



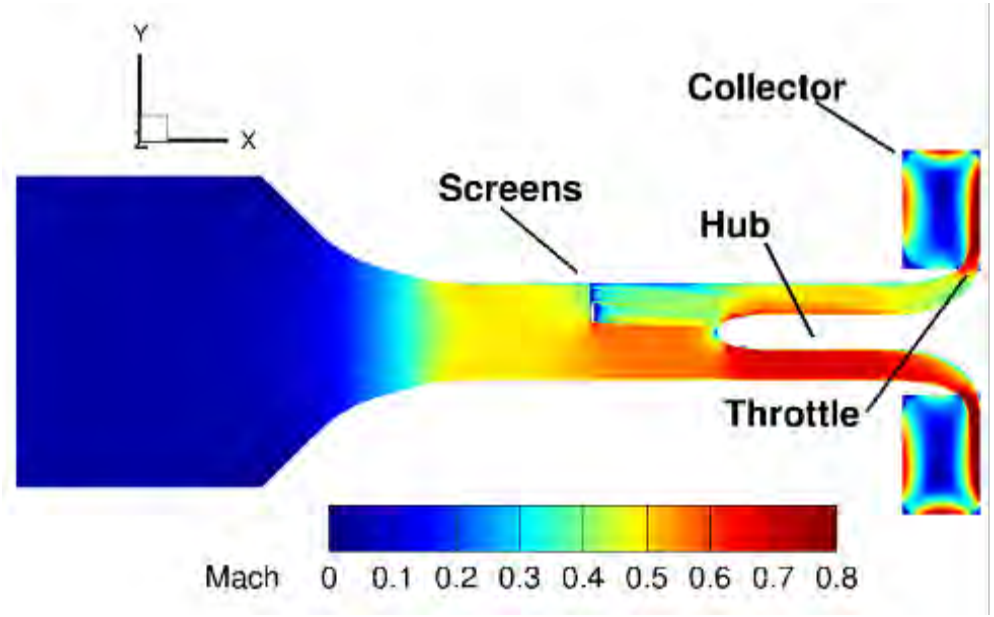


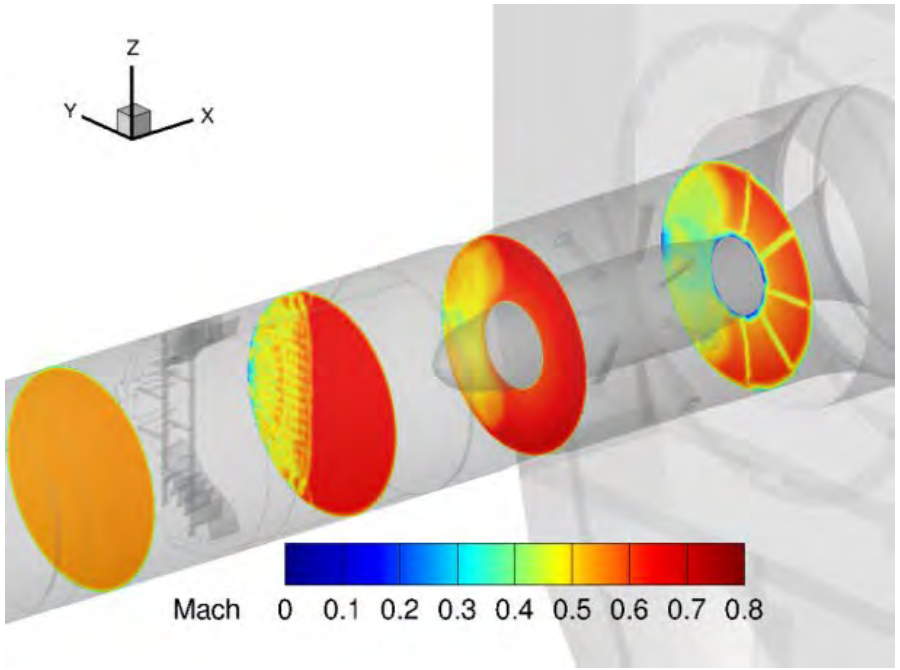


# The BLI²DTF: ScreenVane Modeling

| 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**



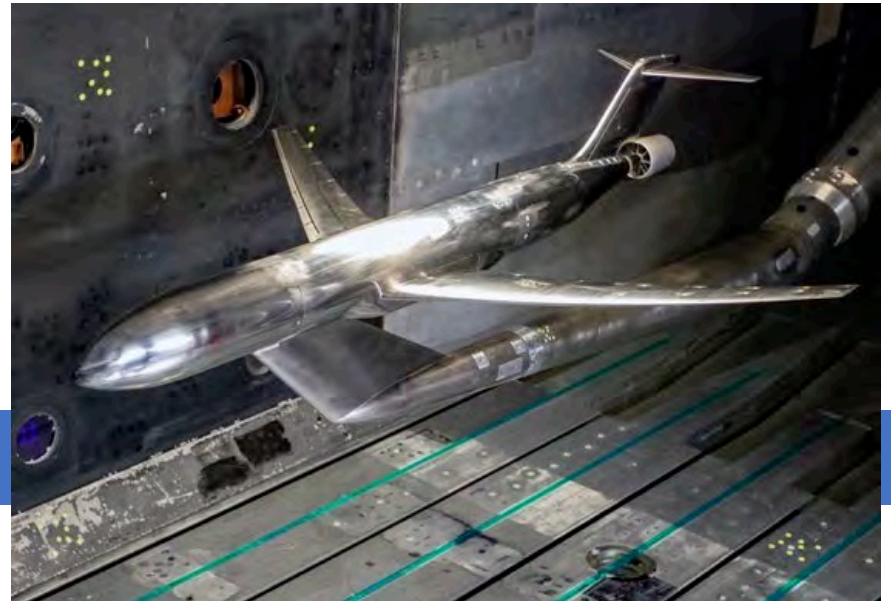

Welstead & Felder, “Conceptual Design of a Single-Aisle Turboelectric Commercial Transport with Fuselage Boundary Layer Ingestion,” AIAA-2016-1027, 2016.

# Aft Thruster Research: BLITS Experiment

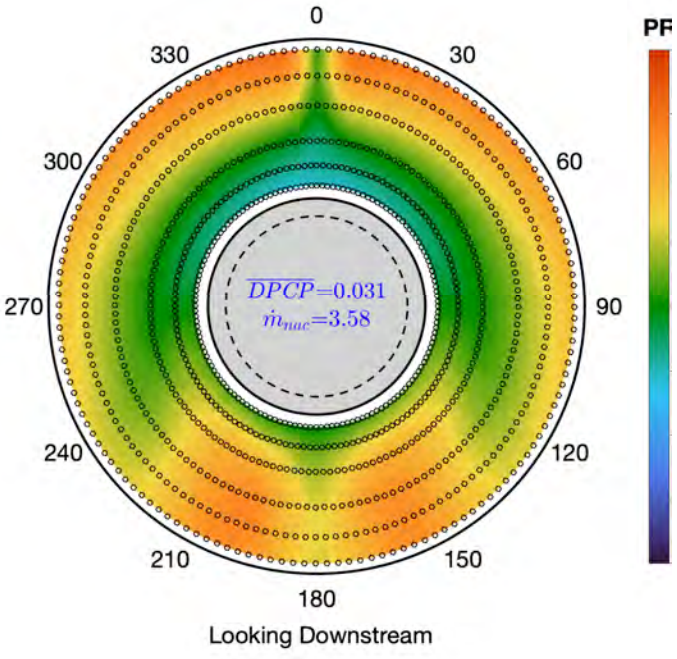
NASA
STARC-ABL
Concept study

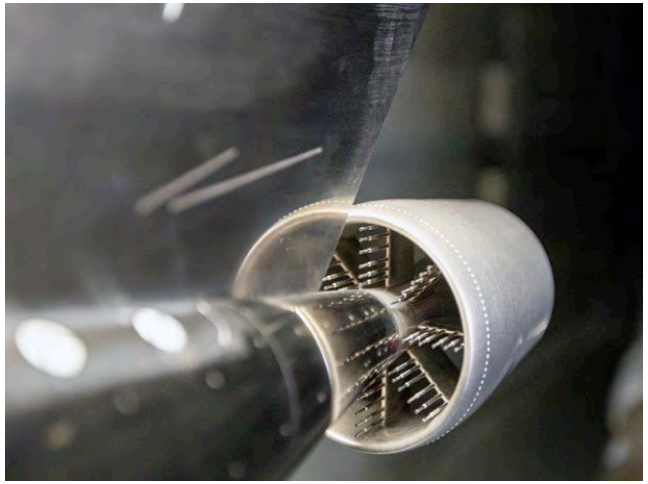
NASA
Langley
NTF test

**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.



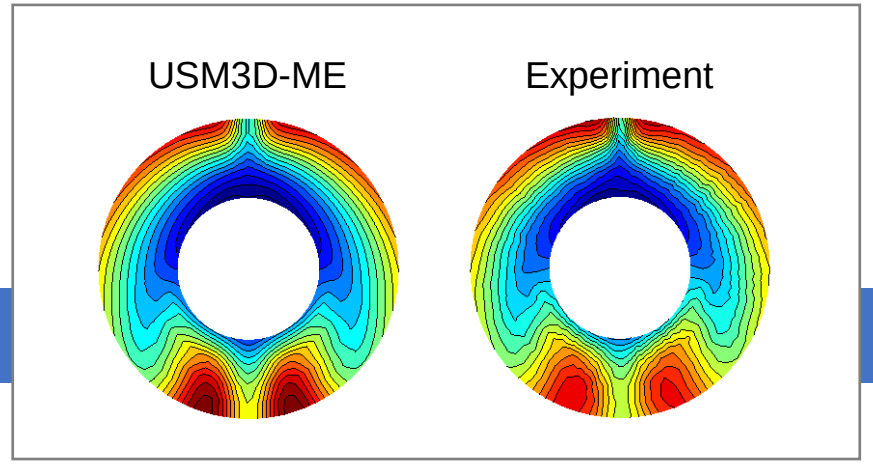
# Aft Thruster Research: BLITS Modeling

NASA STARC-ABL Concept study

NASA Langley NTF test

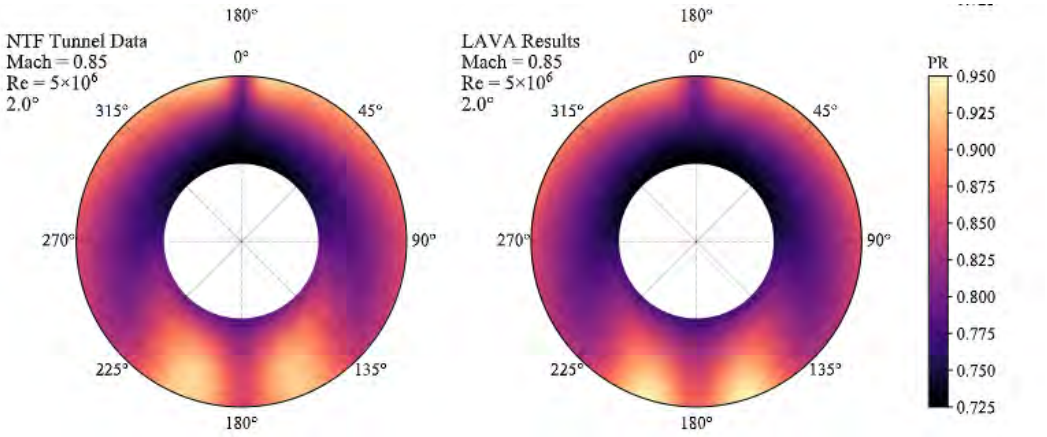
NASA Langley NTF modeling

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.



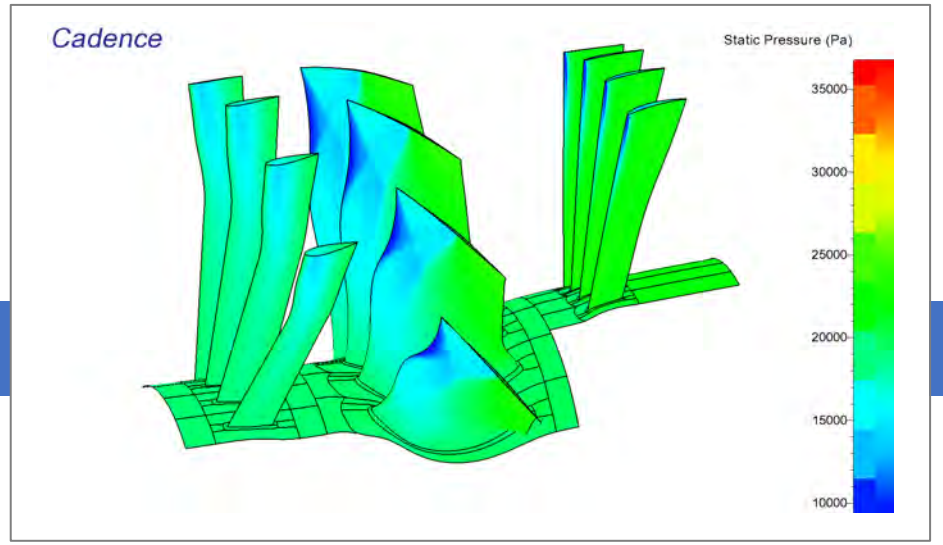
# Aft Thruster Research: BLITS Propulsor Design

NASA STARC-ABL Concept study

NASA Langley NTF test

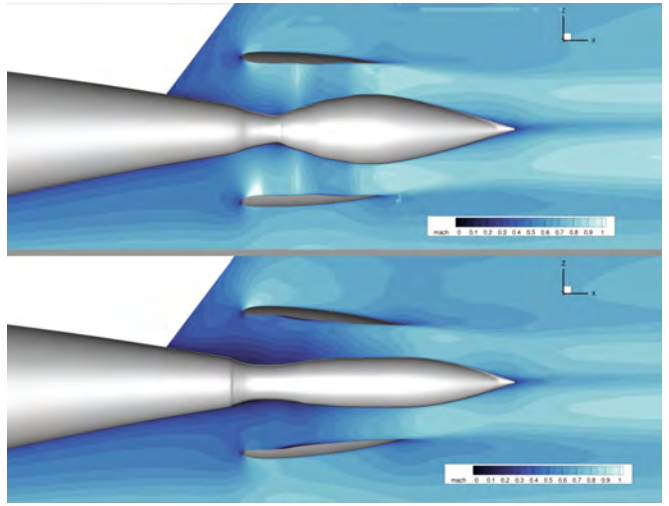
NASA Langley NTF modeling

2016 2023 **2024**




Propulsor Design and System Studies



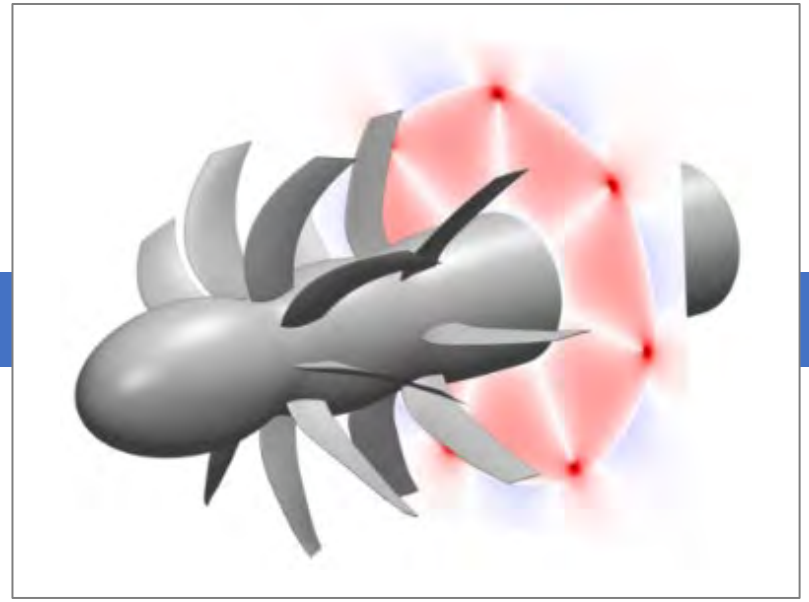
Machado, L., et al., “Aeropropulsive Assessment of a BLI Tail-Cone Thruster Propulsion System for the NASA Common Research Model and a Transonic Truss-Braced Wing Configuration,” AIAA Aviation 2024, AIAA-2024-3767, 2024.

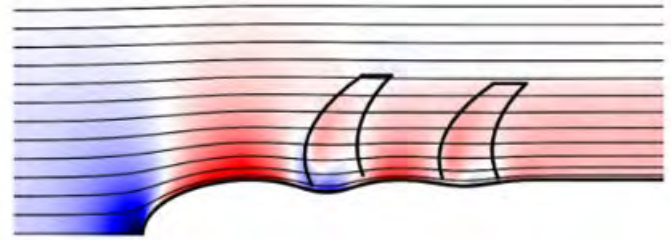


POC: Matthew Ha (GRC), PM: Dale van Zante, TL: Shishir Pandya

# Open Fan Design: NOPEN

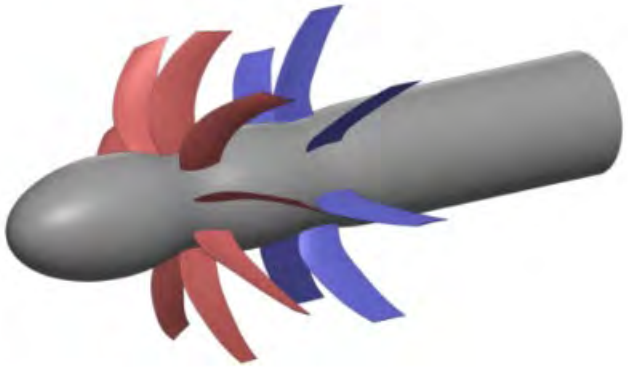
NASA Open Fan Design

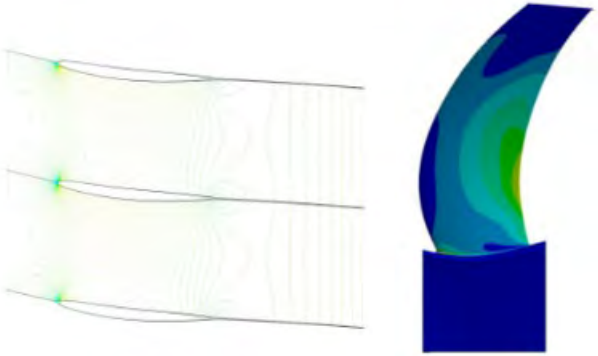




**2026**

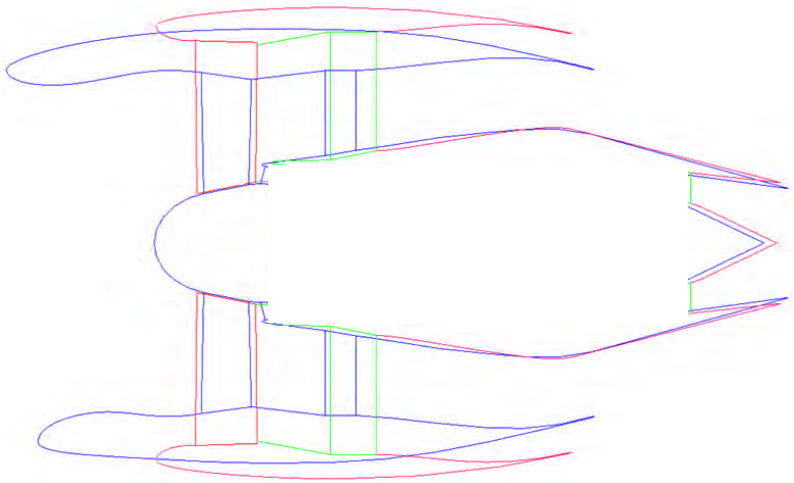
Gillespie, et al., “Design and Optimization of an Open Rotor Stage,” GT2026-178157, ASME Turbo Expo, 2026, Milan, Italy.



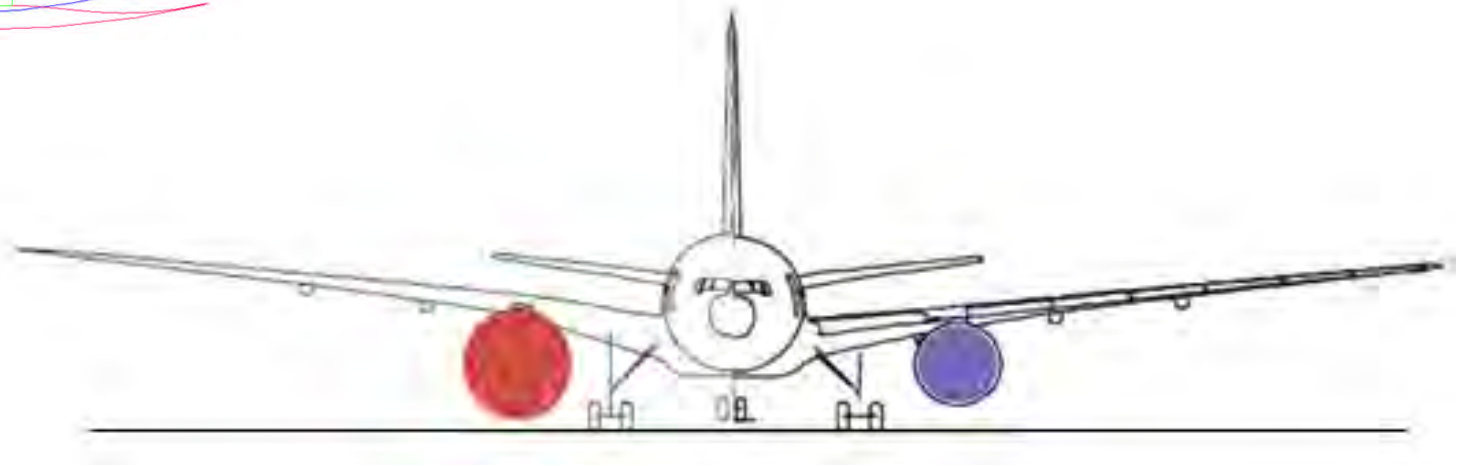




# Propulsion-Airframe Integration Now







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

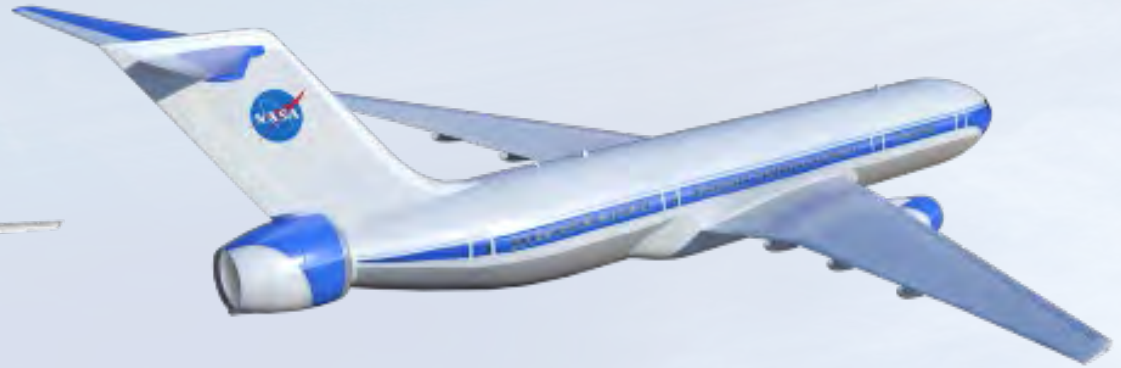



Electra Aero

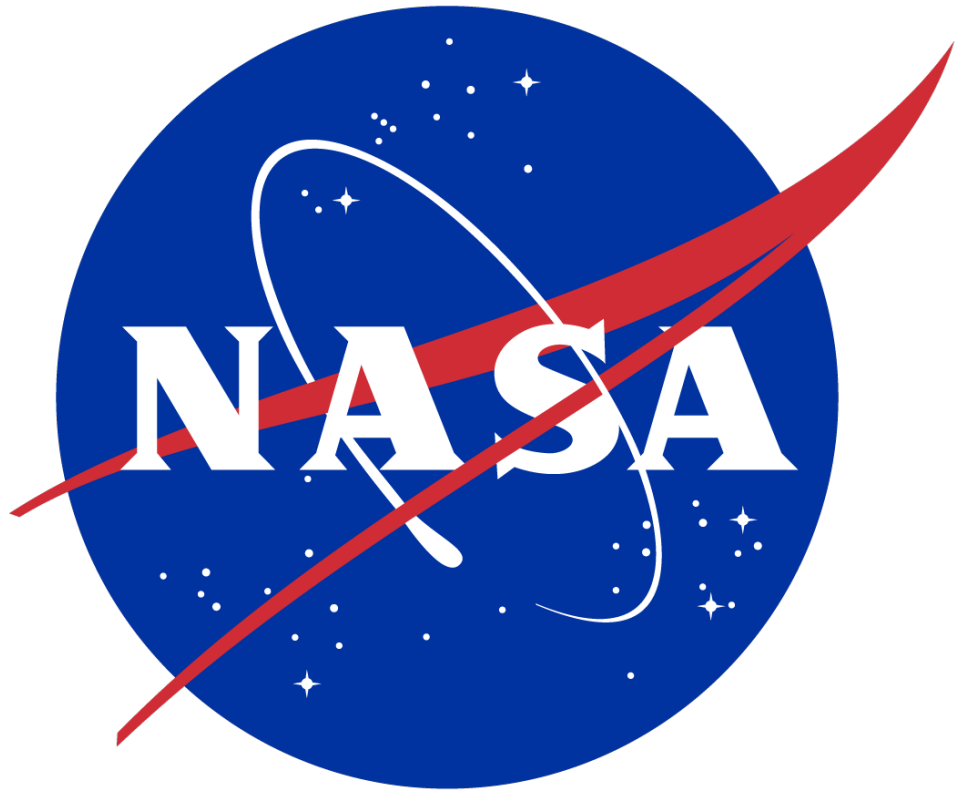



JetZero





# Questions?


NASA