Large-scale Boundary Layer Ingesting Propulsor Research

Dr. Mark. L. Celestina, Mary-Jo Long Davis
NASA Glenn Research Center
Cleveland, Ohio, United States of America

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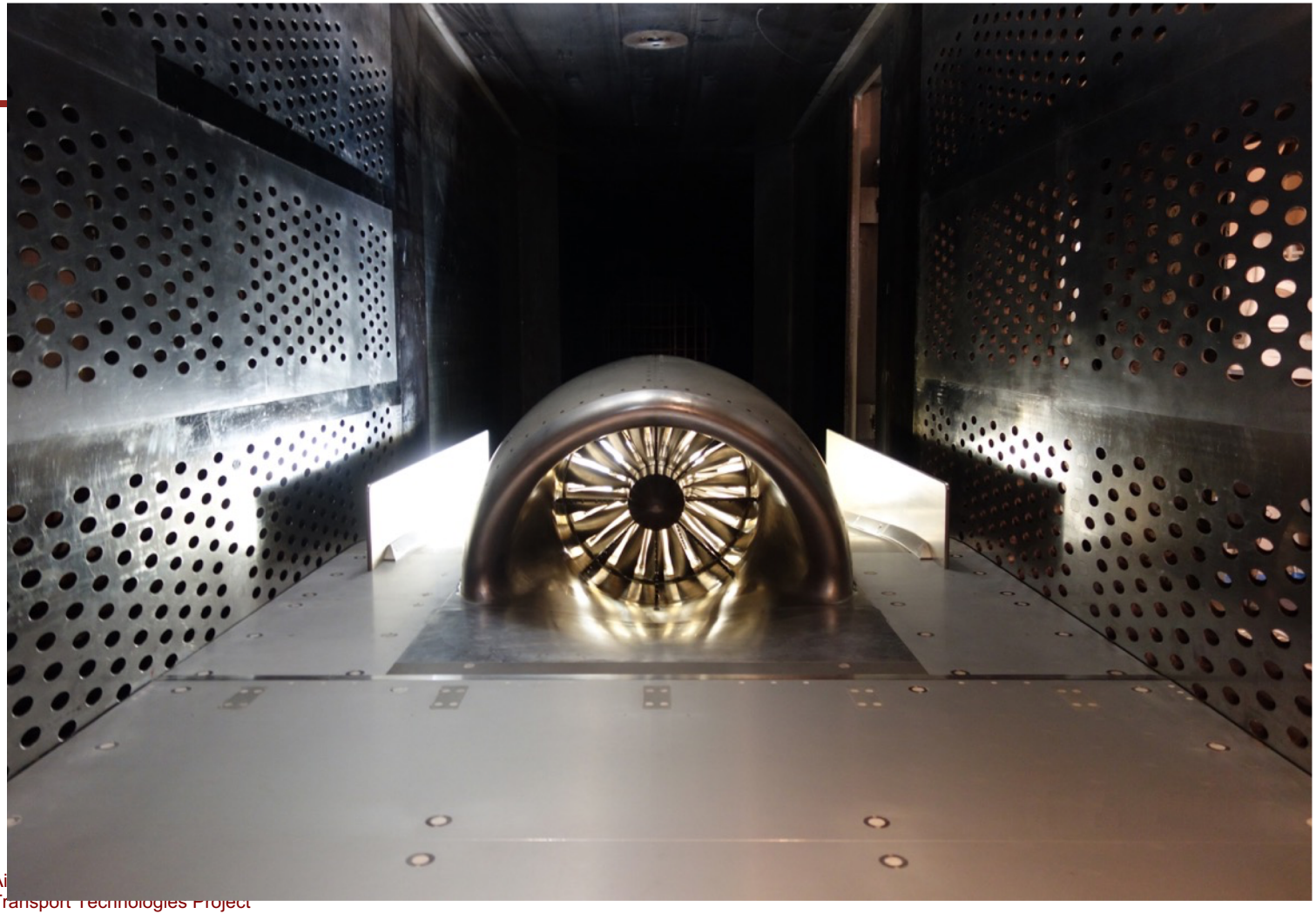
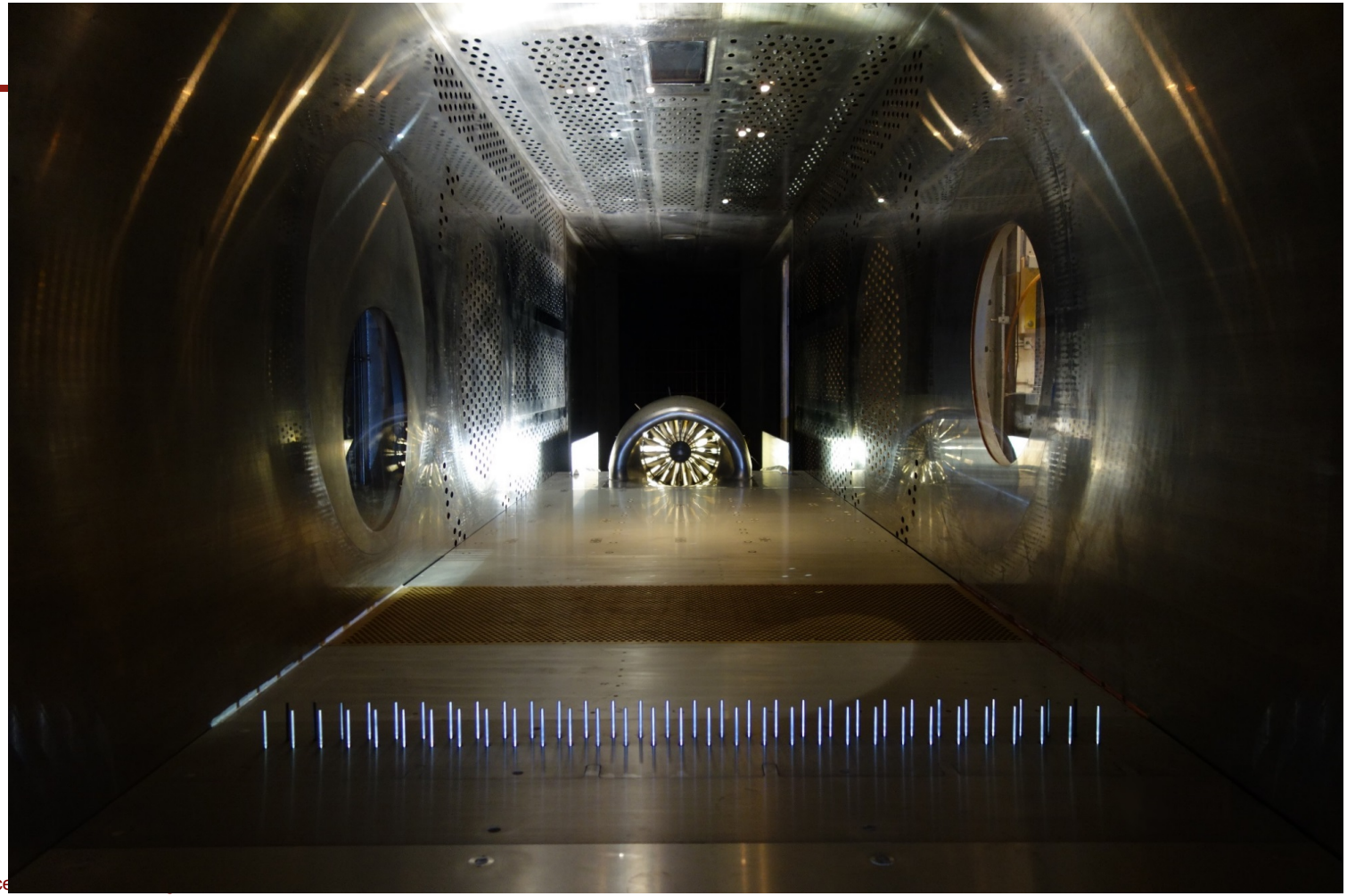




Overview

- NASA is broadly engaged in advanced subsonic commercial vehicle concepts to enable the reduction of fuel burn.
- This paper will discuss an embedded boundary layer ingestion (BLI) application which was tested in NASA GRC's 8x6 wind tunnel at high-speed.
- The benefits and challenges with the design and test of this particular BLI system are presented.
- A vehicle-level system study is presented using the results of this test on an advanced concept aircraft.

NASA Subsonic Transport System-Level Measures of Success

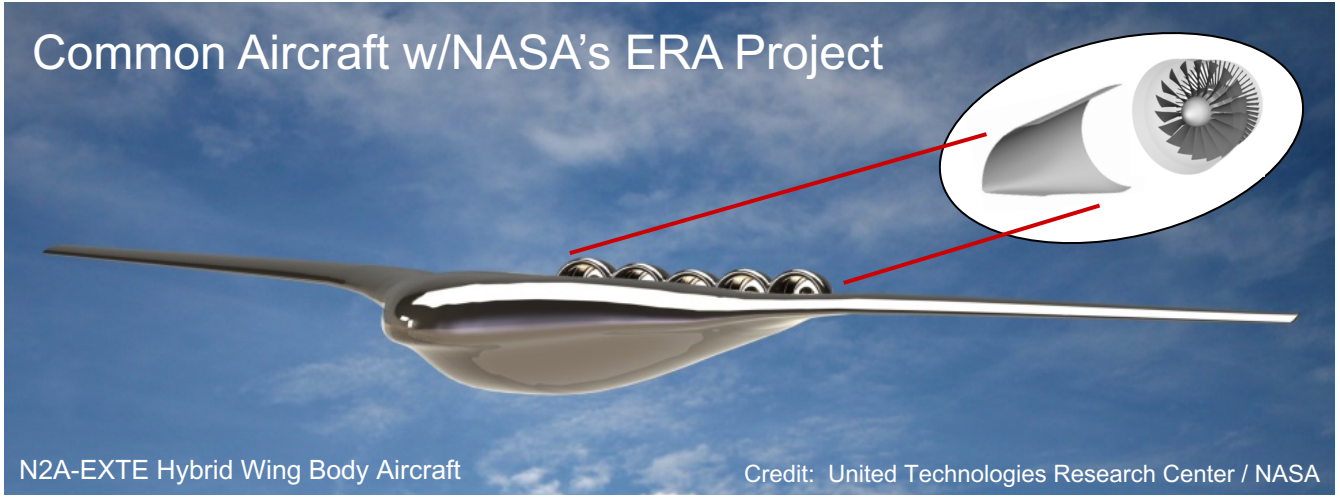
Use industry pull to mature technology that enables aircraft products that meet near-term metrics and push to mature technology that will support development of new aircraft products that meet or exceed mid-term and far-term metrics.

TECHNOLOGY BENEFITS*	TECHNOLOGY GENERATIONS (Technology Readiness Level = 5-6)		
	Near Term 2015-2025	**Mid Term** 2025-2035	**Far Term** beyond 2035
Noise Reduction (cum below Stage 4)	22 – 32 dB	32 – 42 dB	42 – 52 dB
LTO No_x Emissions Reduction (below CAEP 6)	70 – 75%	80%	> 80%
Cruise No_x Emissions Reduction (rel. to 2005 best in class)	65 – 70%	80%	> 80%
Fuel/Energy Consumption Reduction (rel. to 2005 best in class)	40 – 50%	50 – 60%	60 – 80%

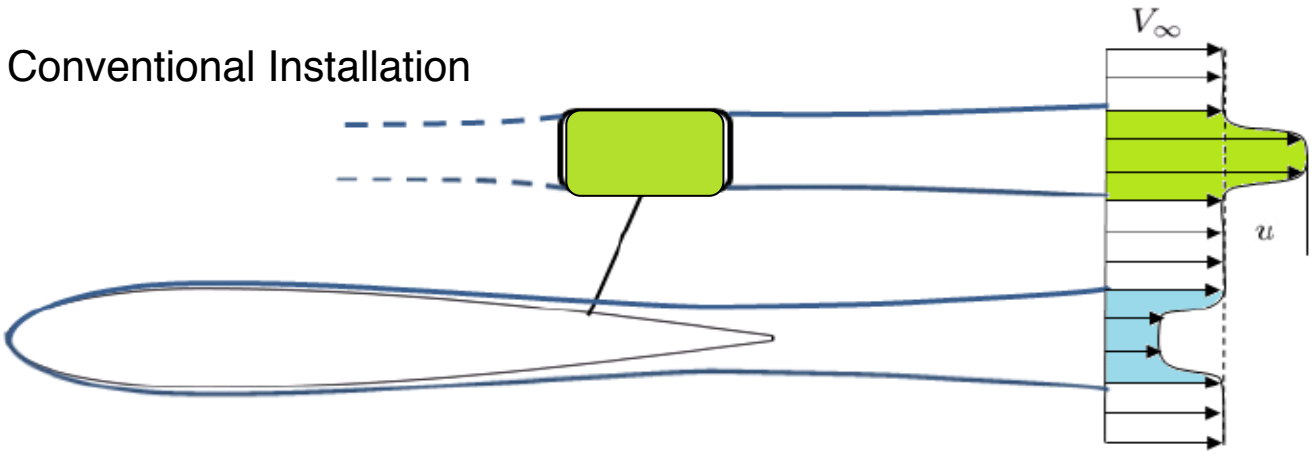
* **Note:** Reference is best commercially available or best in class in 2005.

Boundary Layer Ingestion

- The technology of a propulsion system with boundary layer ingestion (BLI) has been significantly advanced through a number of analytical, computational, and experimental studies.



Boundary Layer Ingestion



AIAA-2014-2573

Propulsion system is installed on the aircraft with pylons to avoid or minimize any interactions with the aircraft wake as much as possible

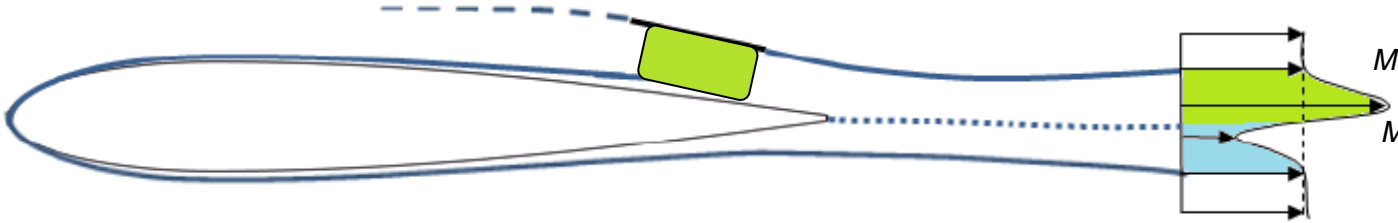
Boundary Layer Ingestion

Principle
Place engine downstream of the body in order to ingest its wake *ideally* to re-energize the wake back to freestream velocity

Propulsor ingests and reaccelerates the airframe boundary layer

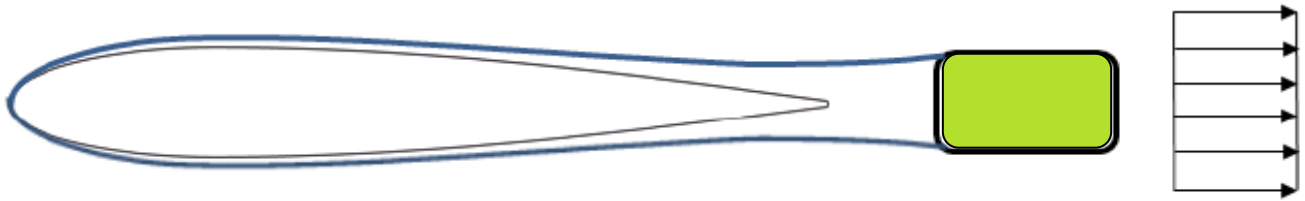
Less Wake & Lower Jet Kinetic Energy for the same net force
Means
Less Power needs to be added to the flow by the Propulsor
Means
Less Fuel Burn

Boundary Layer Ingestion (180 Degree Distortion)



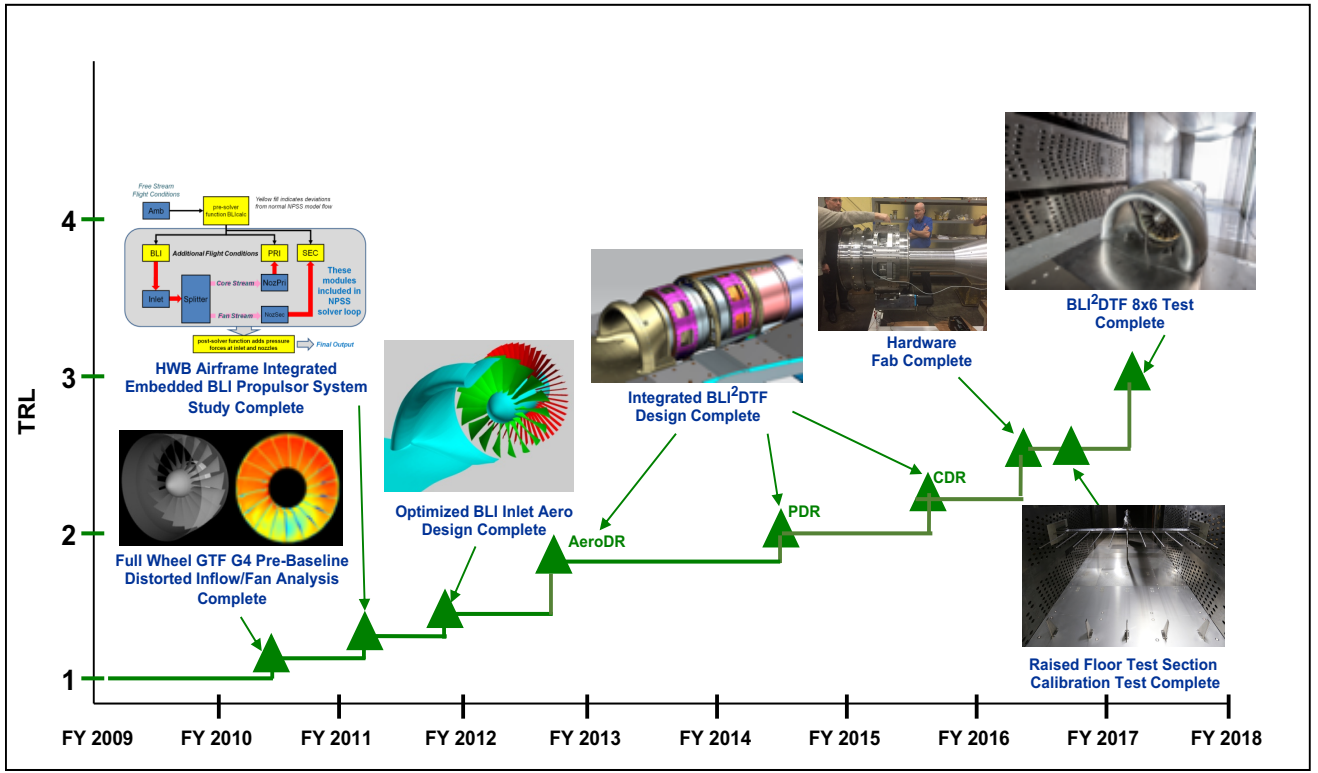
Momentum excess from jet exhaust
Partially Balanced
Momentum deficit due to a/c wake

Wake Ingestion (360 Degree Distortion)

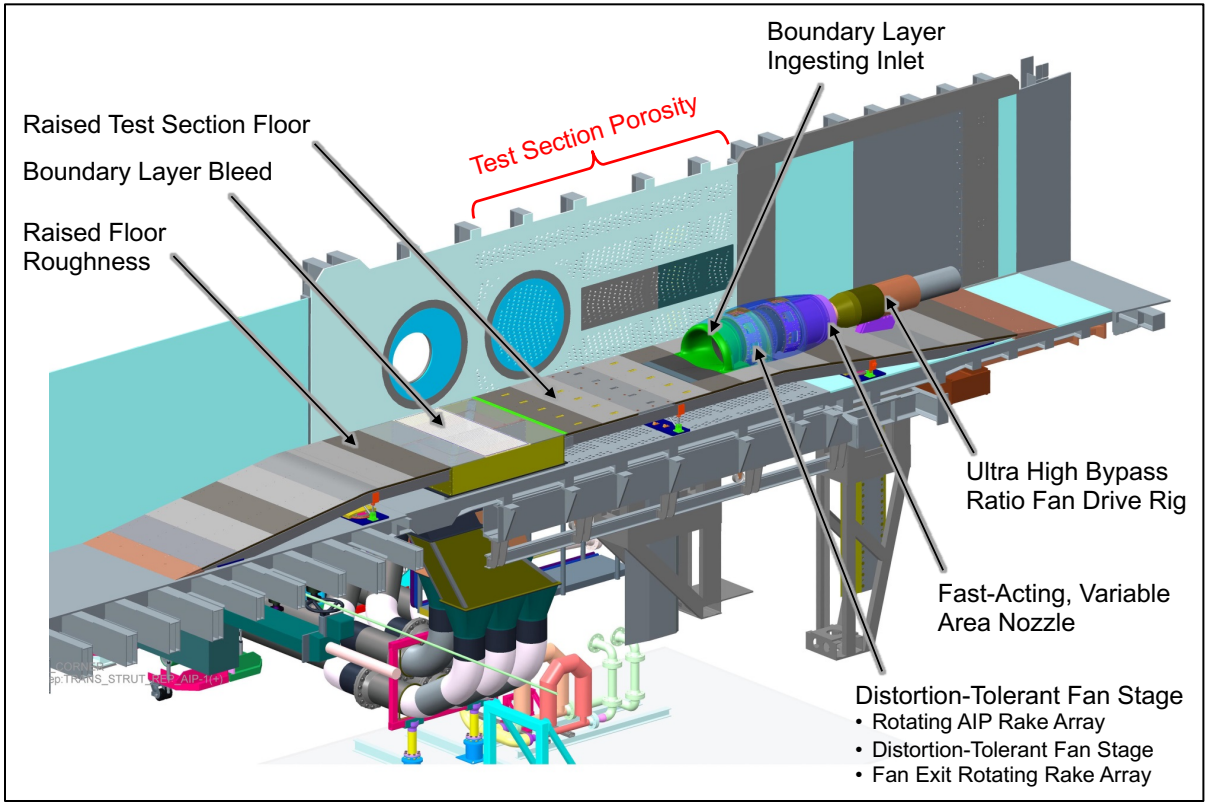


Balanced

TRL Timeline for BLI²DTF Propulsor

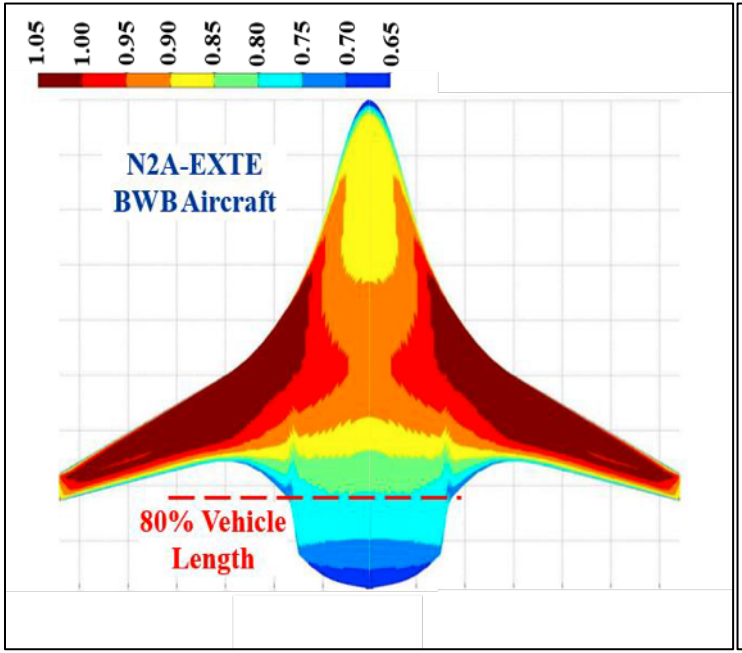


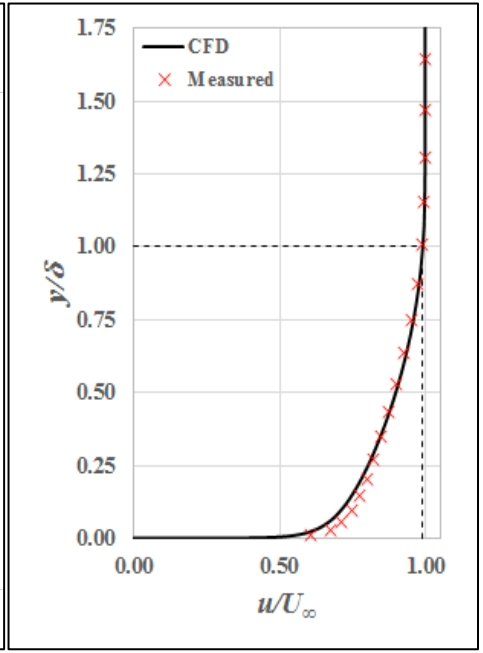
WT Setup with BLI²DTF Propulsor



Inlet Boundary Layer Profile

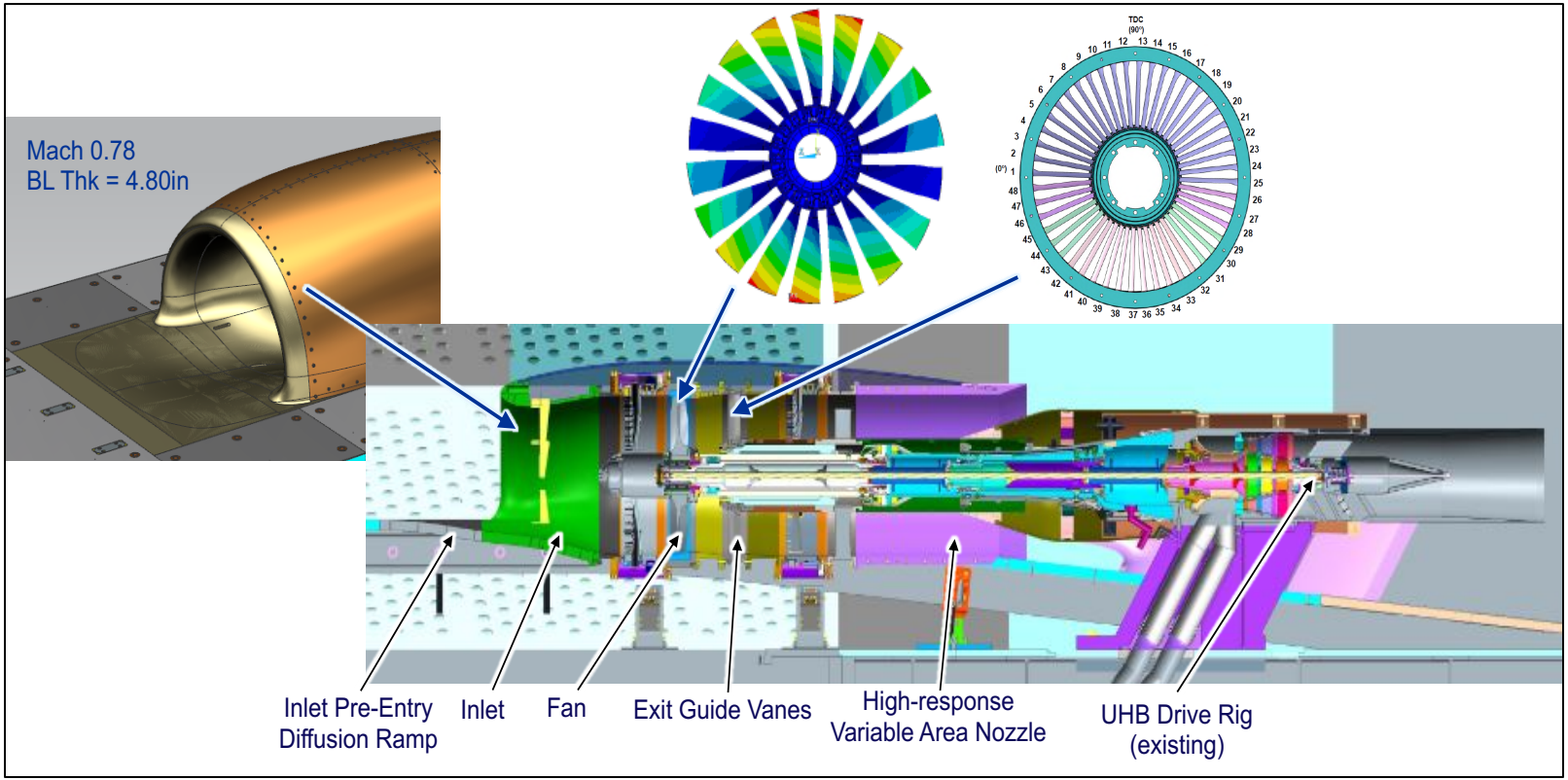
Target incoming BL determined by CFD



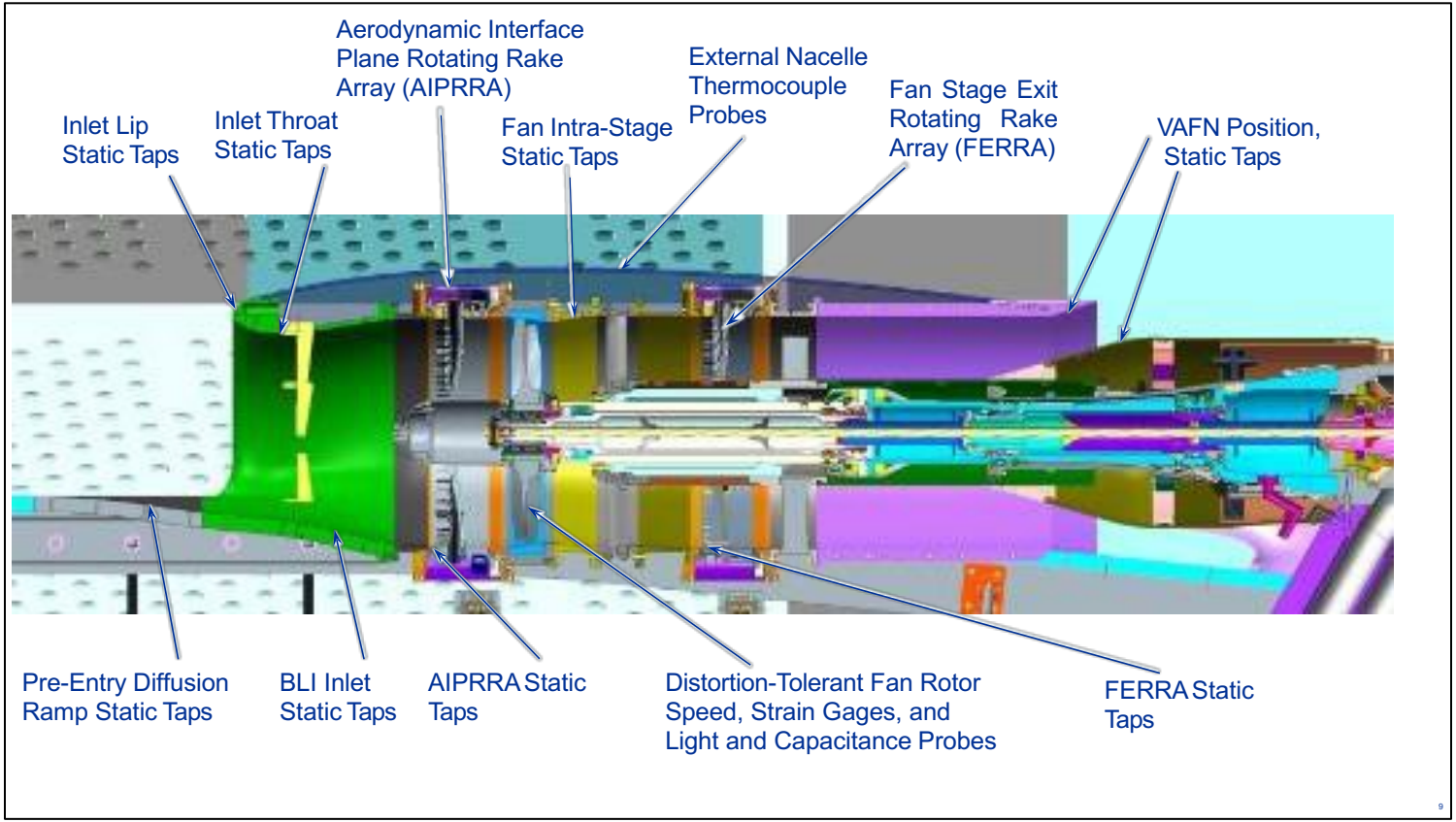


BLI²DTF Propulsor

BLI inlet with distortion-tolerant fan stage (18 Rotors / 48 Vanes).

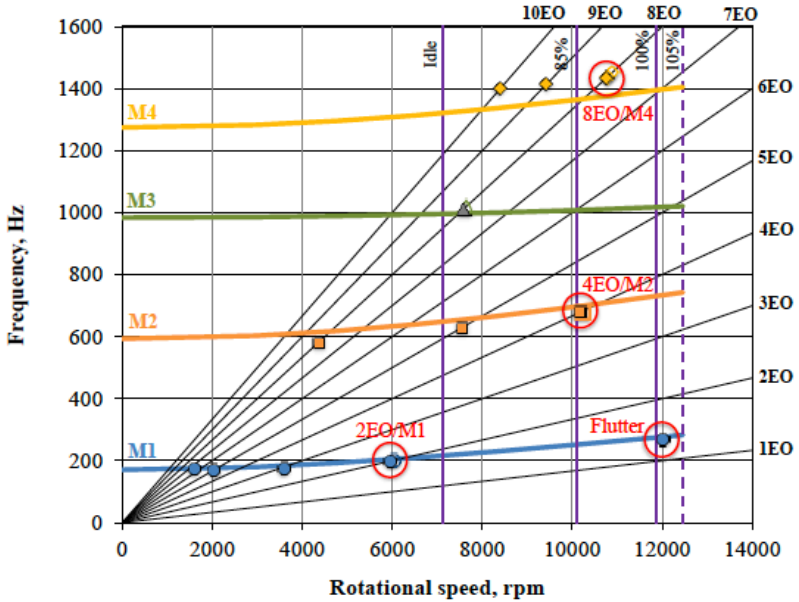


BLI²DTF Propulsor Instrumentation

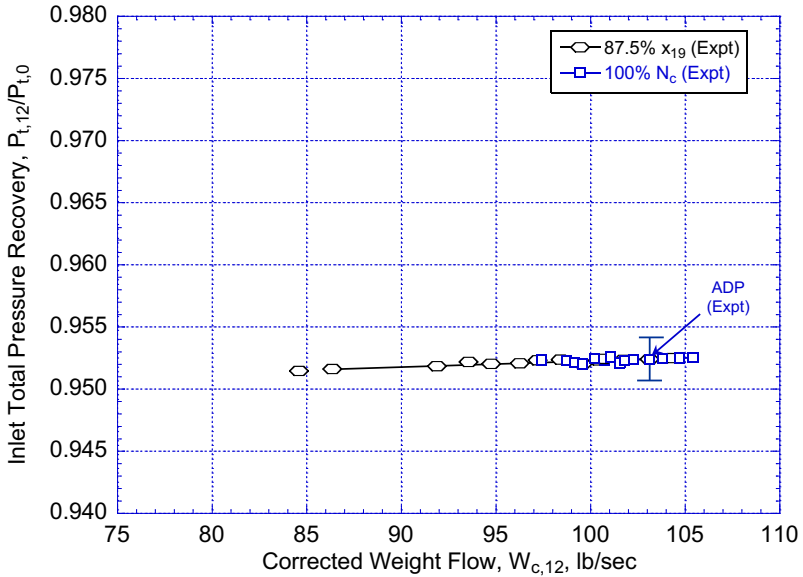


AEROMECHANIC RESPONSE & INLET PERFORMANCE

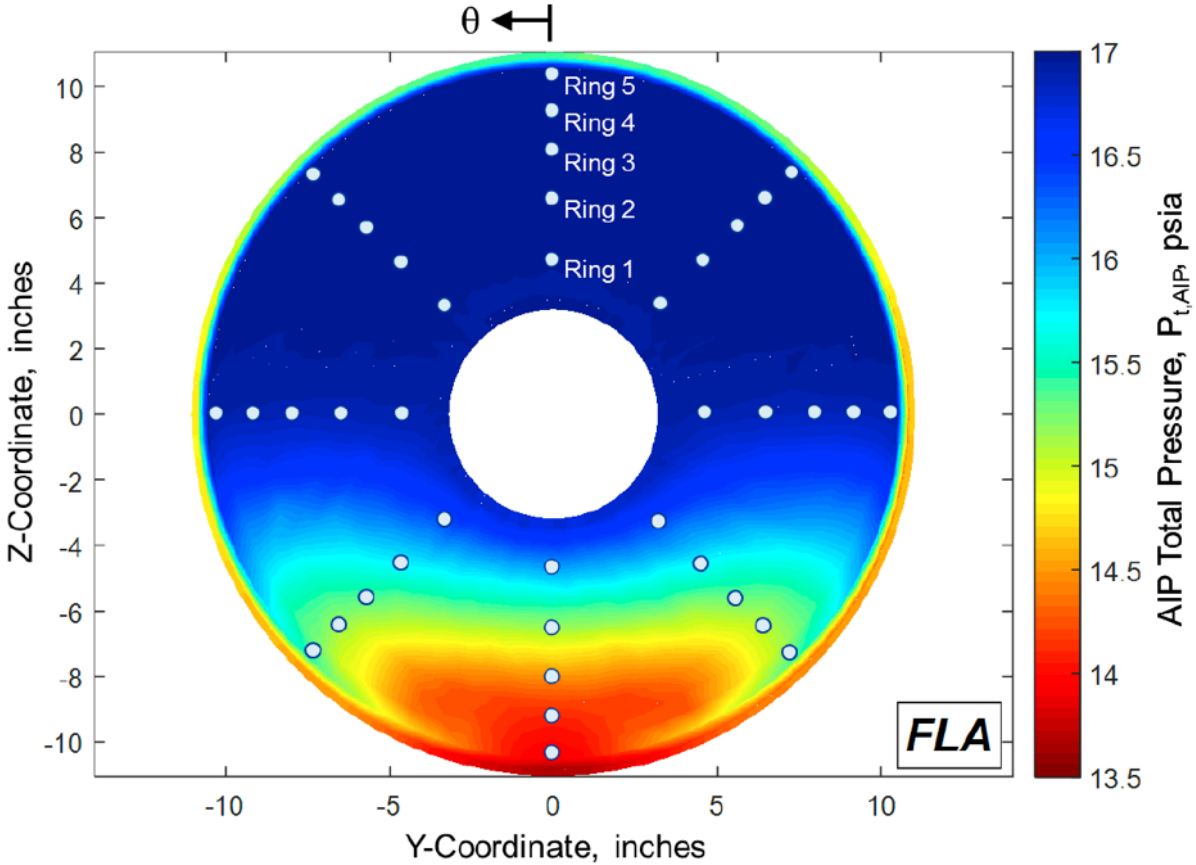
Campbell diagram



Inlet Performance Map

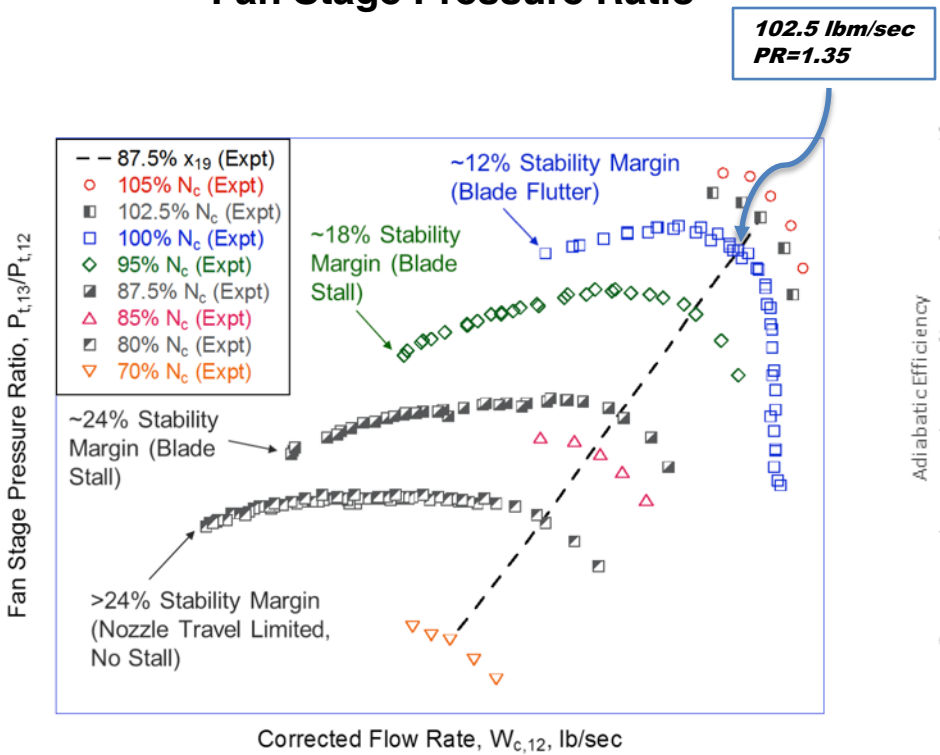


Inlet Distortion at the AIP

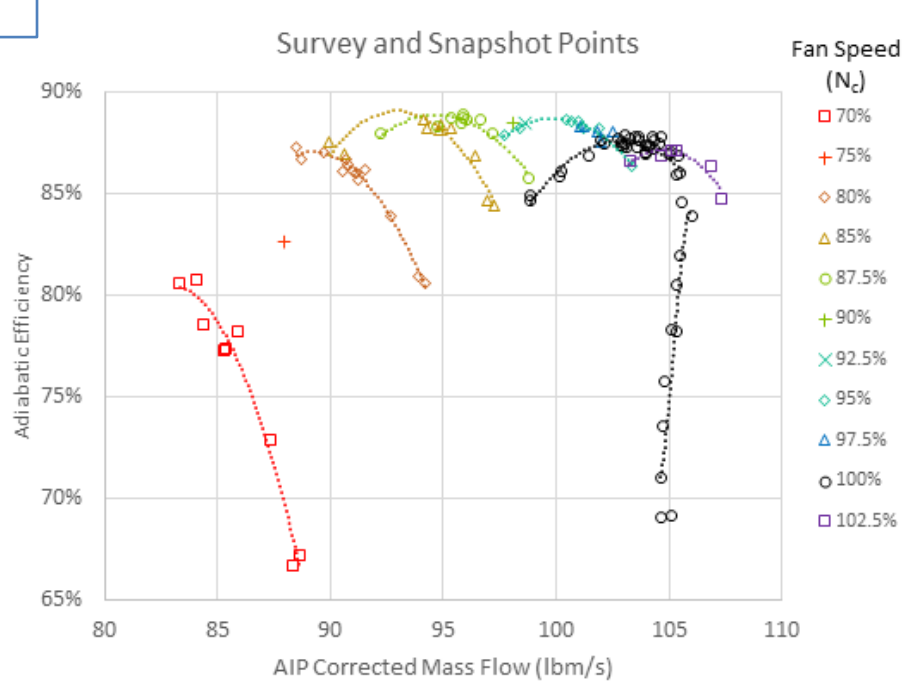


Performance & Operability Maps

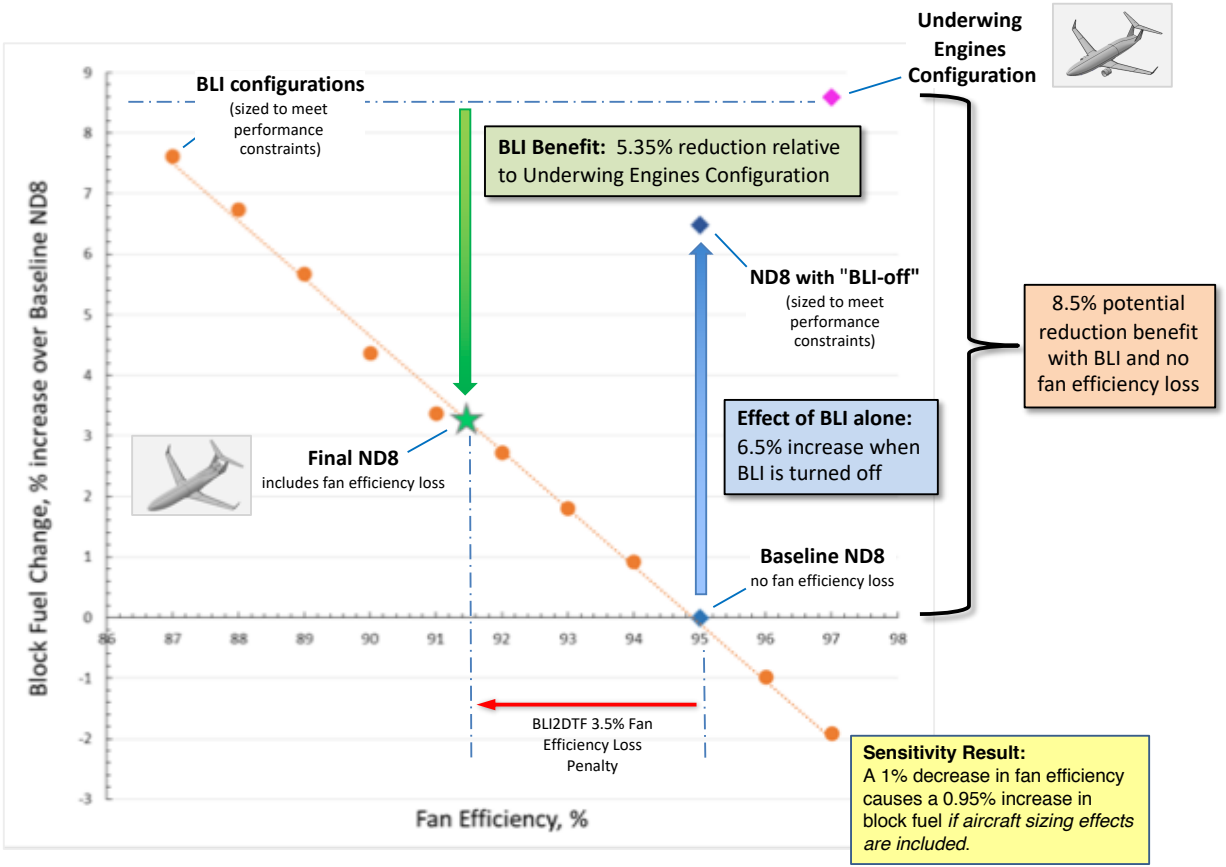
Fan Stage Pressure Ratio



Fan Stage Adiabatic Efficiency



System Study Assessment – NASA D8 Aircraft



CONCLUSION

- Type I BLI propulsor was developed & tested in the NASA GRC 8x6 wind tunnel
- New Tools/Techniques Developed for BLI:
  - Integrated Design of Inlet and Fan
  - Aeromechanics tools for Critical Modes Analysis
  - Raised floor to deliver the ‘right’ boundary layer
  - Rotating Rake Arrays to Capture Data
  - Unique Post-Processing Capabilities for non-clean inlet flow
- System study shows good fuel burn reduction potential for BLI

NASA Glenn Research Center, NASA Langley Research Center, United Technologies Research Center, Vantage Partners, Virginia Polytechnic University, Air Force Arnold Engineering Development Center

BLI²DTF Technology and Development Test Team

NASA GRC

*David Arend **
Milind Bakhle
Linda Bartos
Phil Bastian
Greg Blank
Brian Brandenburg
Tracy Cantley
Rula Coroneos
David Cotton
Thomas DeMichael
Timothy Dunlap
Shannon Eichorn
Terry Ferrier
Dan Graf
Thomas Gyekenyesi
Dave Hamilton
Tim Heineke
Charles Herrmann
Stefanie Hirt
Andy Kehrt
Joseph Kerka
Dean Kocan
Robert Kohler
Marty Krupar
Christopher Hughes
Roger Luptak
Mark Mader
Andy Marlow
Laura Maynard-Nelson
Ronald Mcclanahan
Christopher Metro
Steven Miller
James Min
Richard Minter
Tonya Mitchell
Adabelle Narvaez-legeza
Quynhgiao Nguyen
Edie Parrott
Jonathon Ponder
Joseph Powell
Andrew Provenza
David Reagan
Jeff Robinson
Raymond Robinson
Joe Rossoll
Jeff Rusick
Henry Scott
Tony Shook
Patrick Spanos
George Stefko
Amanda Stevenson
Tom Vannuyen
Gary Williamson
Barry Wilson
John Wolter
Kin Wong
Linda Yoon

NASA LaRC

Ricardo A. Arteaga
Troy A. Asher

U.S. Air Force

Jim Sirbaugh

Alcyon Technical Services

Robert Joyce

Alphaport

Katherine Harcula

HX5 Sierra

Drew Johnson

Jacobs Technology

Aaron Dozier
Joseph Dussling
John Eckert
Derrick Espenschied
Aaron Johnson
Michelle Lasic
Mark Lasky
Daniel Meter
Don Mohnickey
William Rozman
Steve Sedensky

Kent State University

Ali Adbul-Aziz

Science Applications International Corp (SAIC)

Hin Yee

Sierra

Matthew Conley
Cris Contreras
Larry Becks
Pete Brown
Bertram Floyd
Mike Garapic
Daniel Goodell
Christopher Griffiths
Chris Hampton
Paul Hleba
Arnie Kuchenmeister
Jesus Lopez
Ray Lotenero
Cori Lupton
Karl Manik
Jay Morales
Beth Osborn
Ray Parker
Dan Pitts
John Restifo
Tom Rini
Jim Simon
Russell Stucke
Dean Szabo
Tony Ventura
Kyle Webster
Ernest Williams
Chris Yager

University of Toledo

Kirsten Duffy
Tondapu S. Reddy

United Technologies Research Center

Lawrence Binek
William Cousins
Razvan Florea
Eric Gray
Larry Hardin
Matthew Kennedy
Om Sharma
Mark Stucky
Greg Tillman
Dmytro Voytovych

Vantage Partners, LLC

Neil Adams
Tim Beach
James Buckley
Eric Carlberg
Curisha Drafton
Gary Drlik
Lawrence Edwards
Arthur Erker
Paul Gebby
Vincent Graziano
Gerard Gronowski
David Gubics
John Heese
David Hervol
John Jones
Lawrence Kren
Scott Metzger
Gregory Nathan
Malcolm Robbie
Dale Robinson
David Root
John Shaker
Jeff Stone
Ronald Storozuk
Kathleen Sukel
Michael Young
Maciej Zborowski

Zin Technologies

Joe Assion
Max Aynik
Lawrence Cola
John Gazzaniga
Tina Grzincic
John Gyekenyesi
Michael Kussmaul
Gregory Metzler
Joseph Ursic Zin
Robert Werner

*Team Lead denoted with **