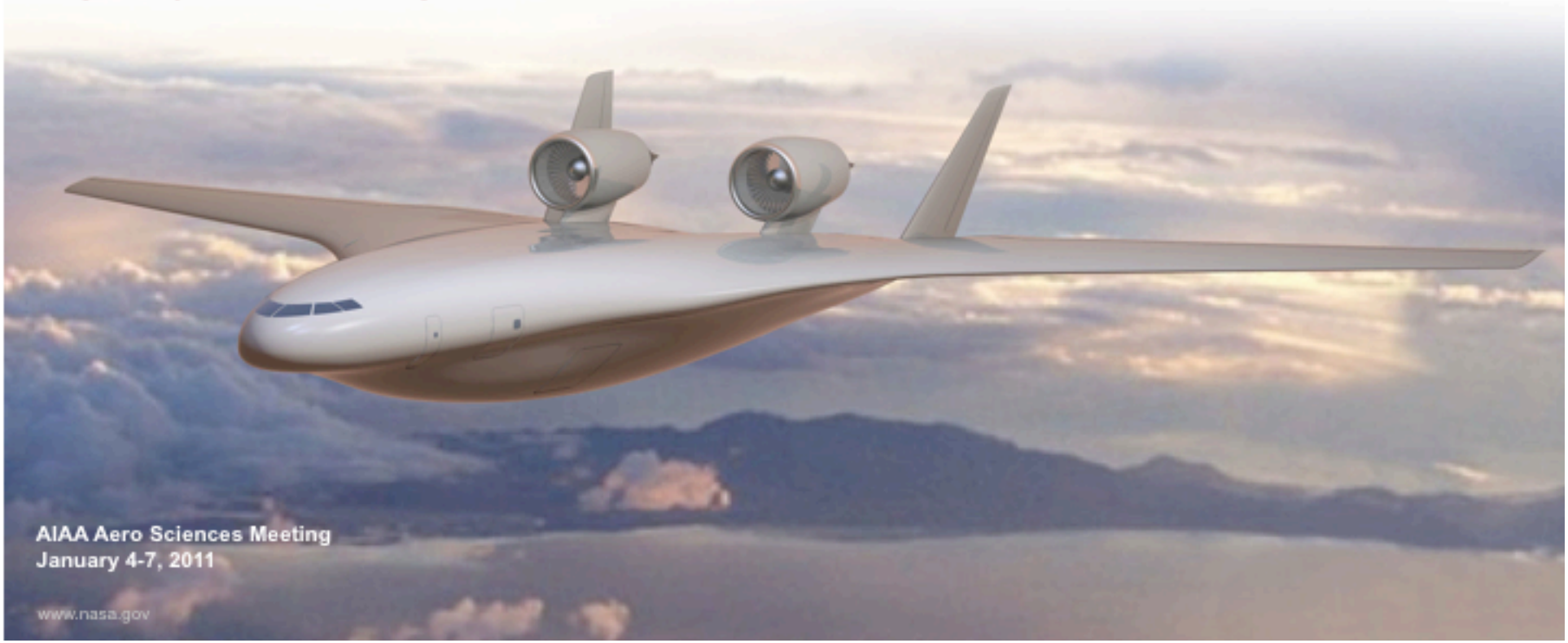
National Aeronautics and Space Administration

ERA-Propulsion-Airframe Integration

Integrated Shape Design of a UHB Single-Aisle Transport

Dr. Stephen Smith
VSI PAI Element Lead
Environmentally Responsible Aviation
Integrated Systems Research Program



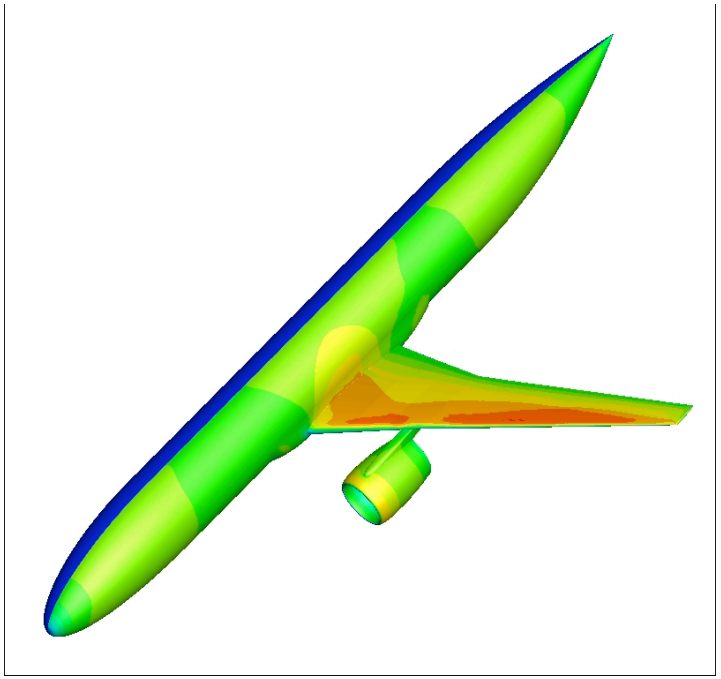
AIAA Aero Sciences Meeting
January 4-7, 2011

ERA – Propulsion-Airframe Integration

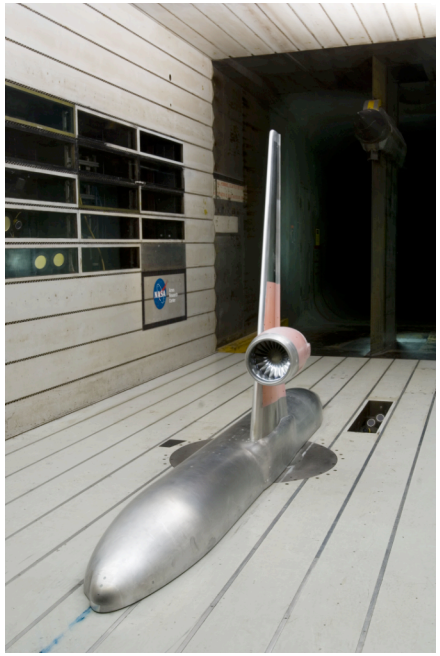
Integrated Shape Design of a UHB Single-Aisle Transport

- Simultaneous shape optimization of wing and nacelle using new Cart3D-Adjoint optimization framework

- Powered semi-span wind tunnel model validation of cruise performance

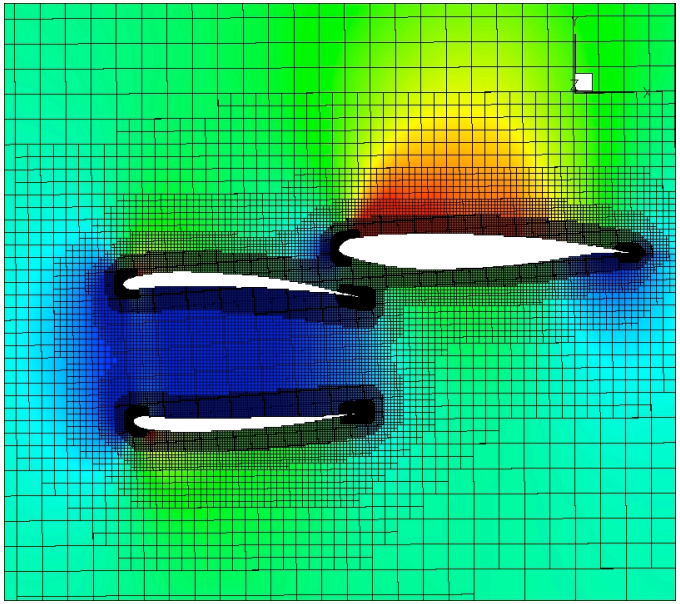


Acknowledgments:
Marian Nemec, Mathias Wintzer
Steve Krist
Chris Hughes and Jeff Flamm
Dan Tweedt -- AP Solutions, Inc



Simultaneous shape optimization of wing and nacelle using new Cart3D-Adjoint optimization framework

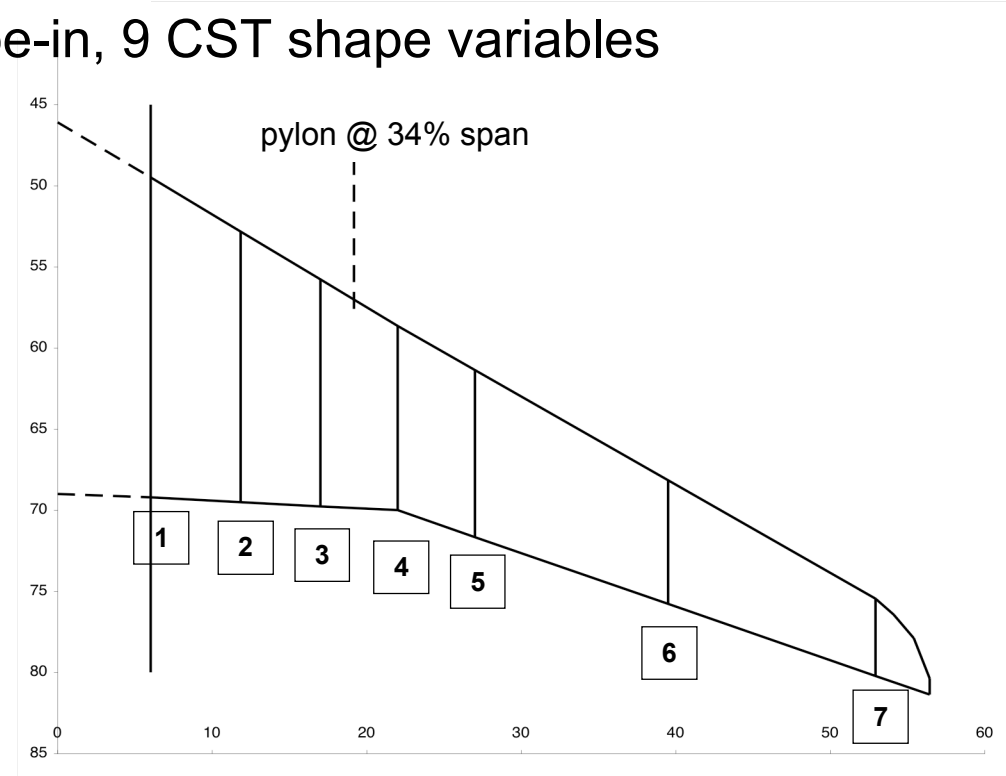
- Cart3D-Adjoint optimization framework developed w/support from FA SFW and SUP projects– see AIAA 2011-1249
- Cartesian-Grid Euler CFD provides ‘instant’ grid, fast solution on complex configurations
- Adjoint solution provides ‘free’ optimization gradients, enables large number of design variables
- Multiple geometry generators supported, including CAD-based and analytic parametric models
- Ongoing developments:
  - Adjoint-based error-adaptive grid refinement
  - 3D integral boundary layer



UHB Integration Wing

- Wing size similar to B-737-800, 88” fan
- Multiple design points M=0.78--0.79, CL=0.47-0.52
- Span-loading constrained by semi-span rolling moment
- 7 wing defining stations, enables complex twist for min. drag
- Wing sections defined by CST parameters, 10 upper + 10 lower + twist
- Nacelle camber, incidence, toe-in, 9 CST shape variables
- Pylon camber
- Total 161 design variables

Sref=1320 ft^2
B=112.86
AR=9.65

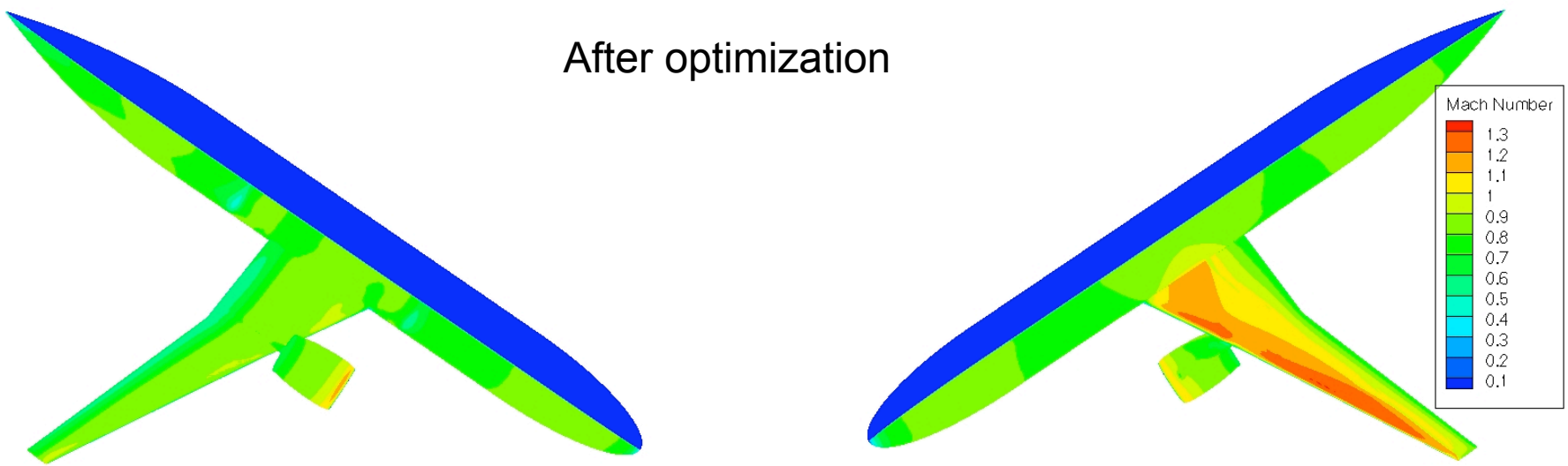


UHB Wing Optimization Results

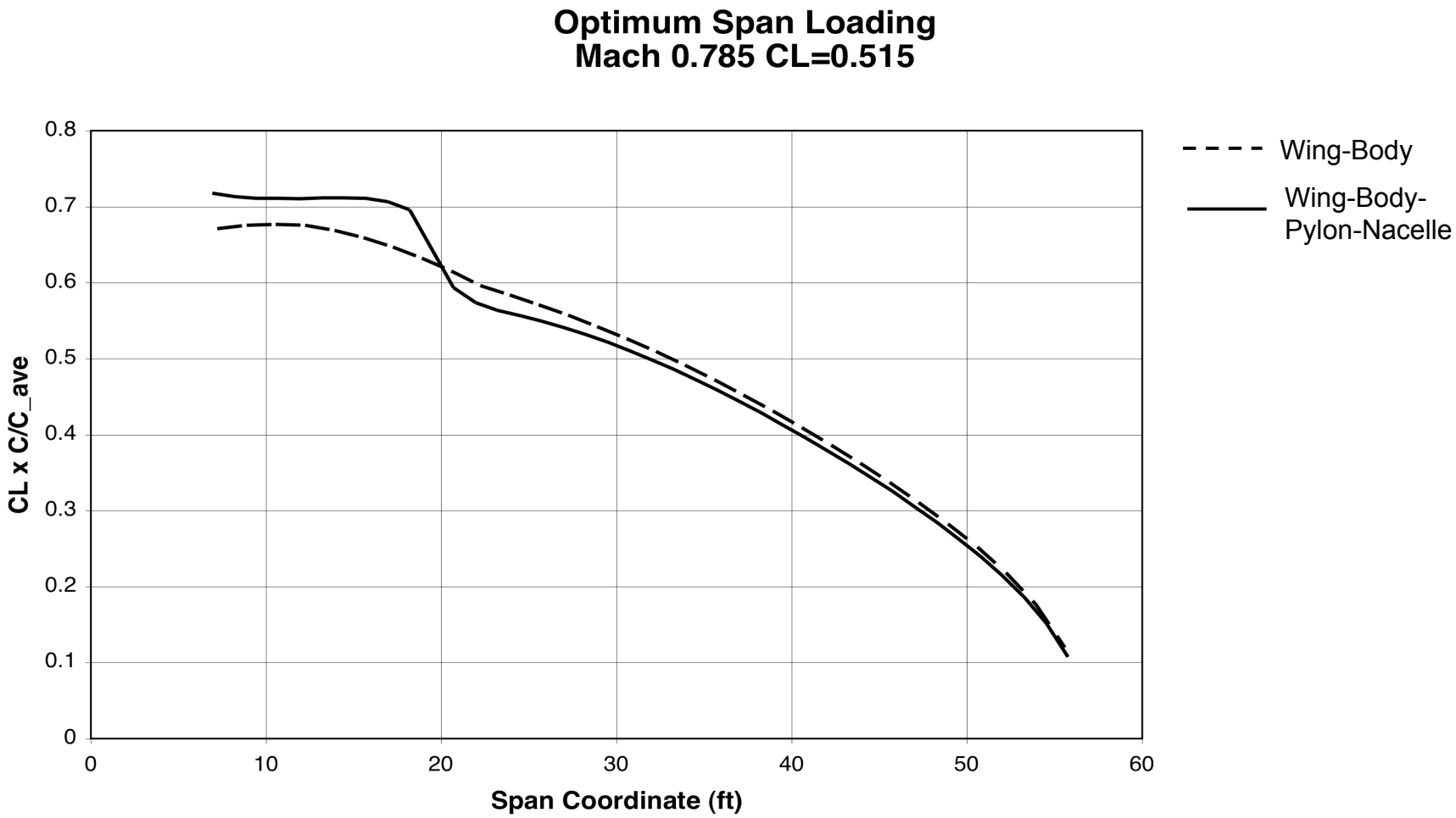
M=0.785 CL=0.515
Mach contours

Baseline

After optimization

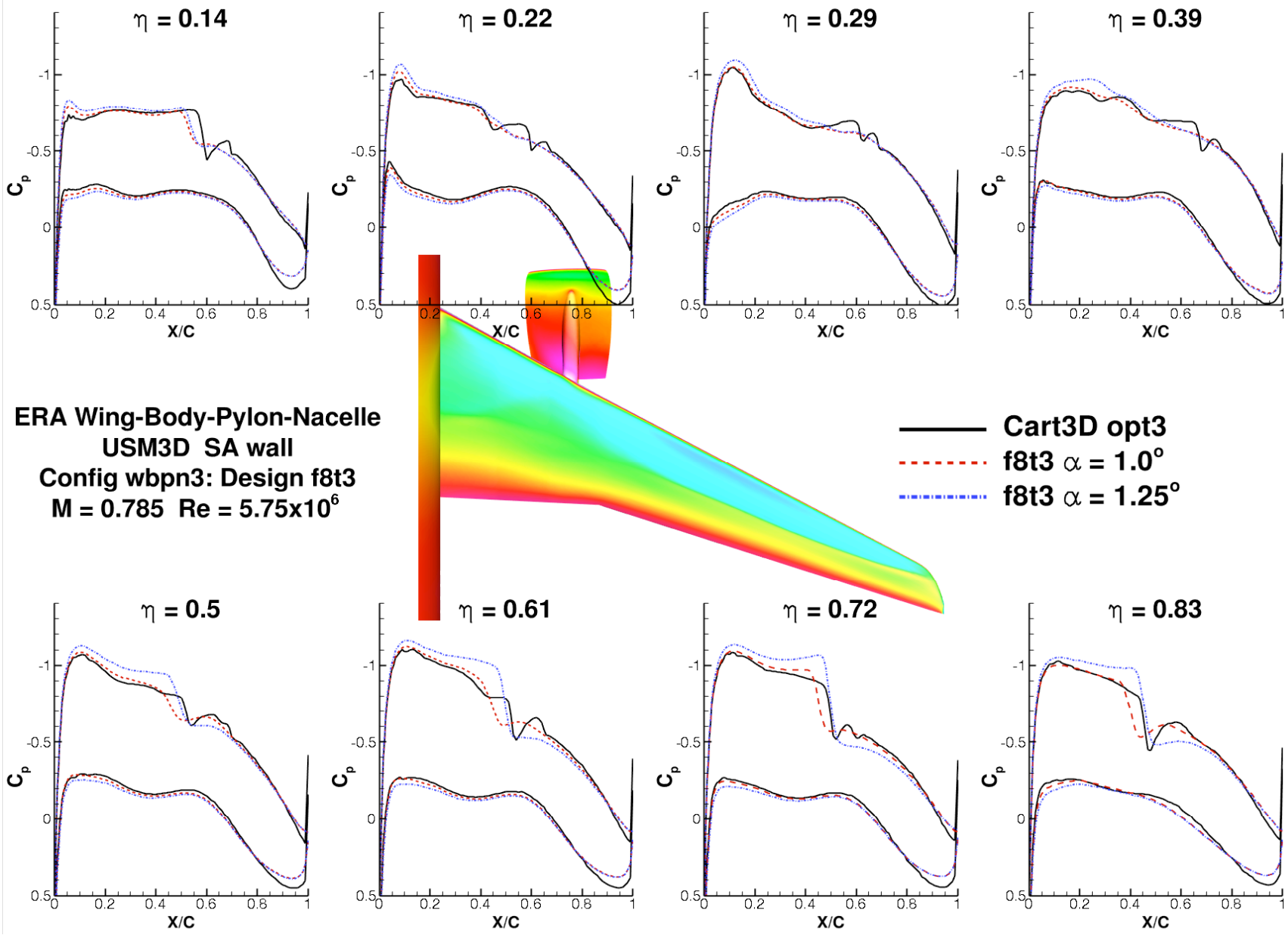


UHB Wing Optimization Results



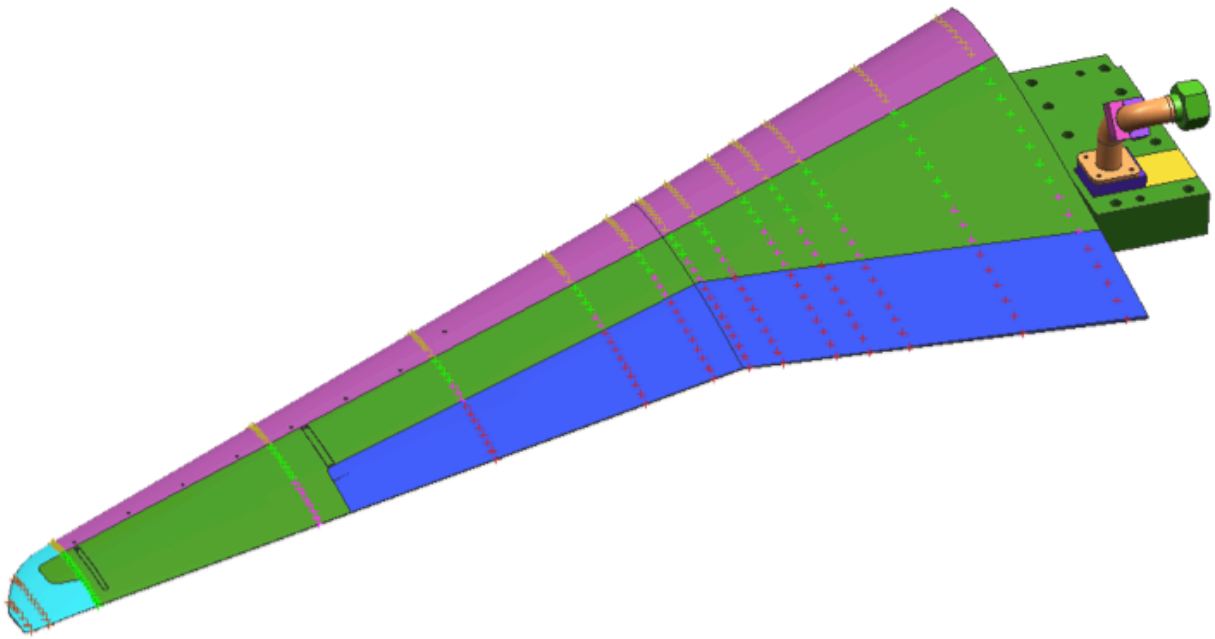
USM3D CDISC inverse design to match Cart3D

span loading and pressure distributions

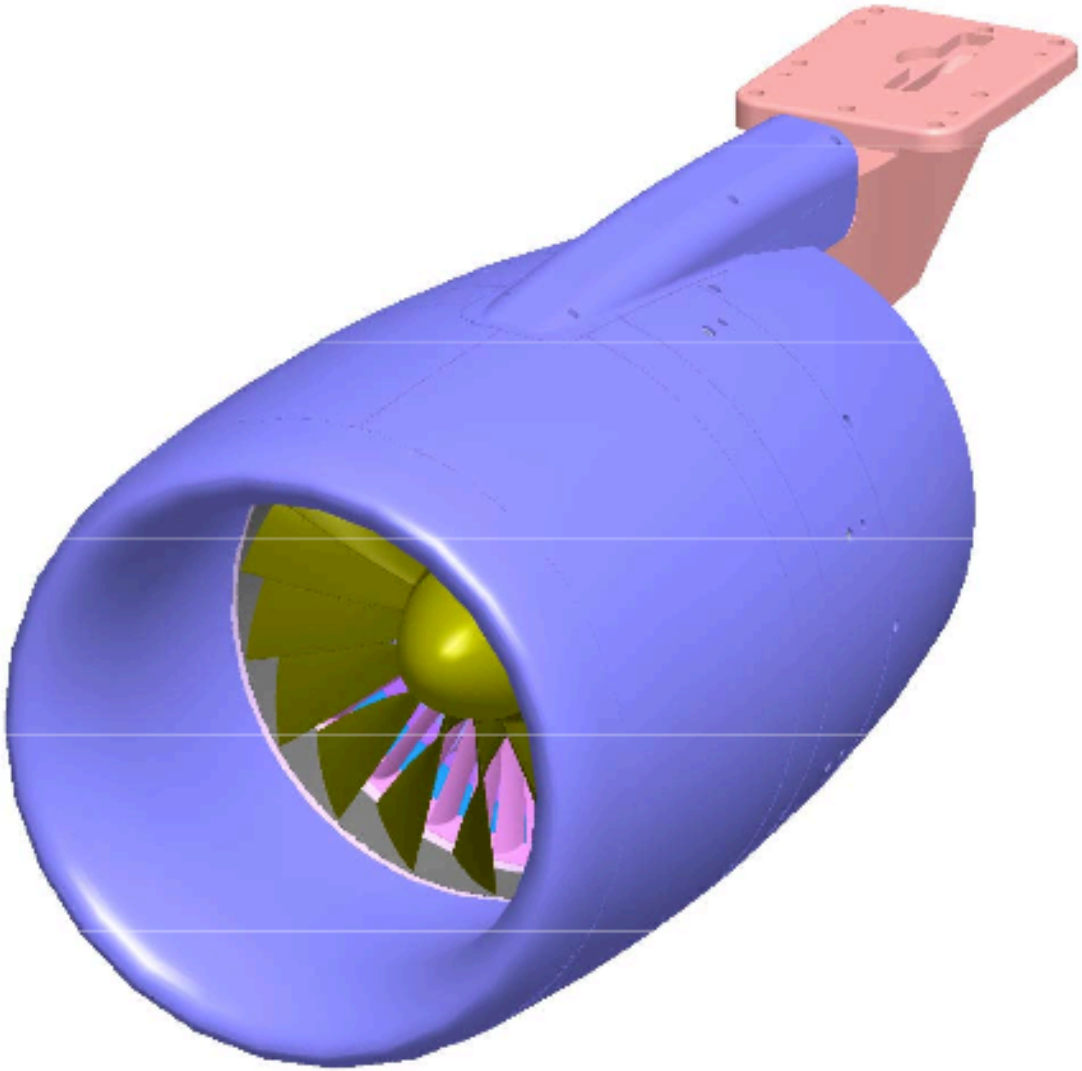


Powered semi-span wind tunnel model for validation of cruise performance

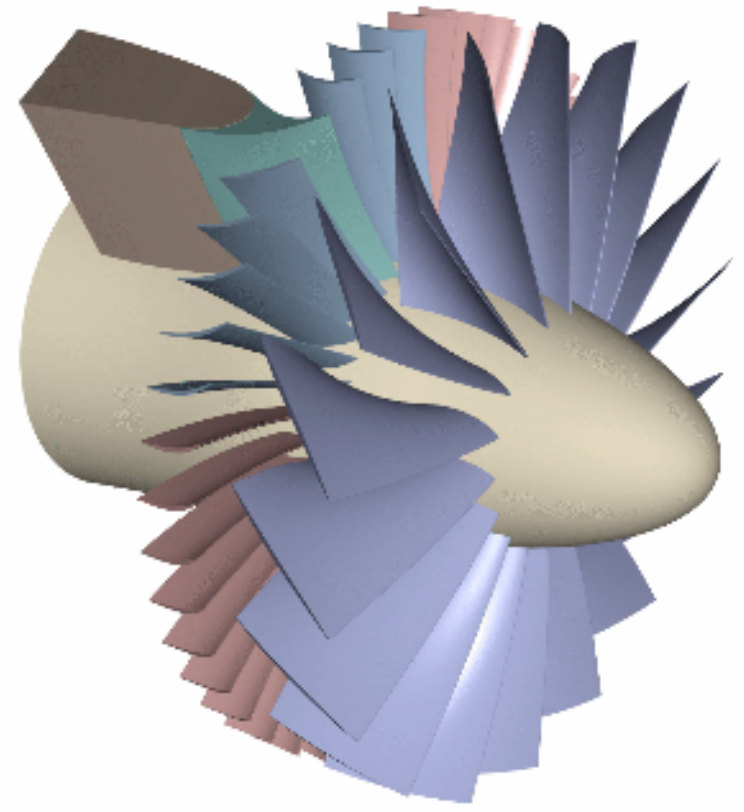
- Semispan model based on Cart3D optimum + CDISC USM3D
- Powered by new BPR~15--18 turbine-powered simulator
- Force & moments + 700 surface pressures + PSP
- Provision for future installation of high-lift system for low-speed integration studies



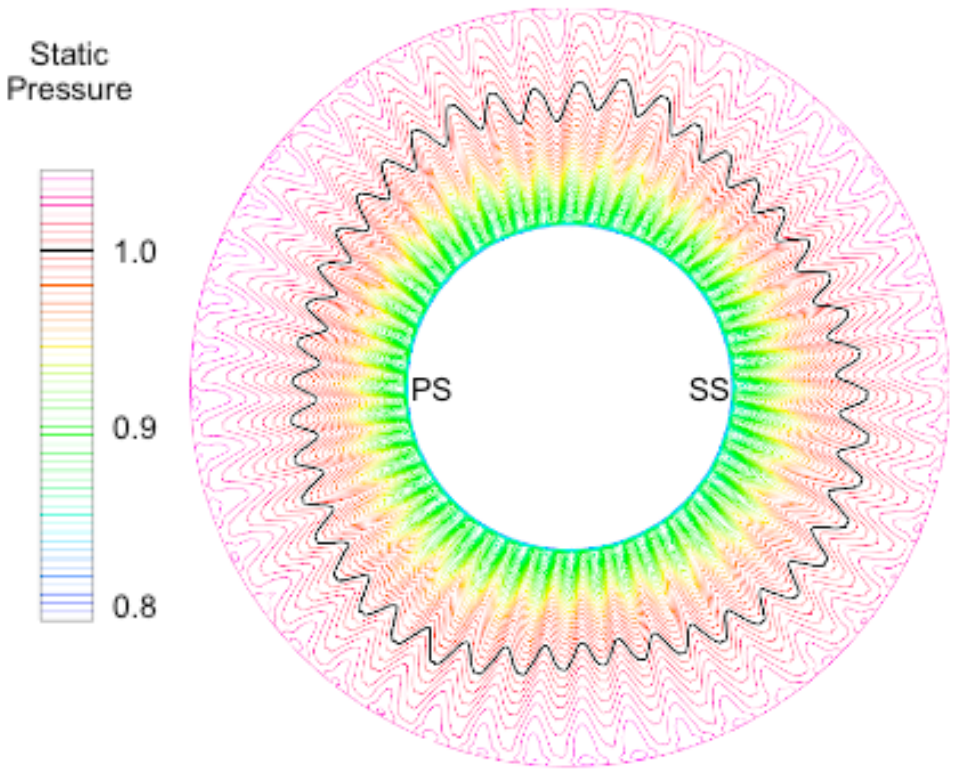
New BPR~15--18 turbine-powered propulsion simulator

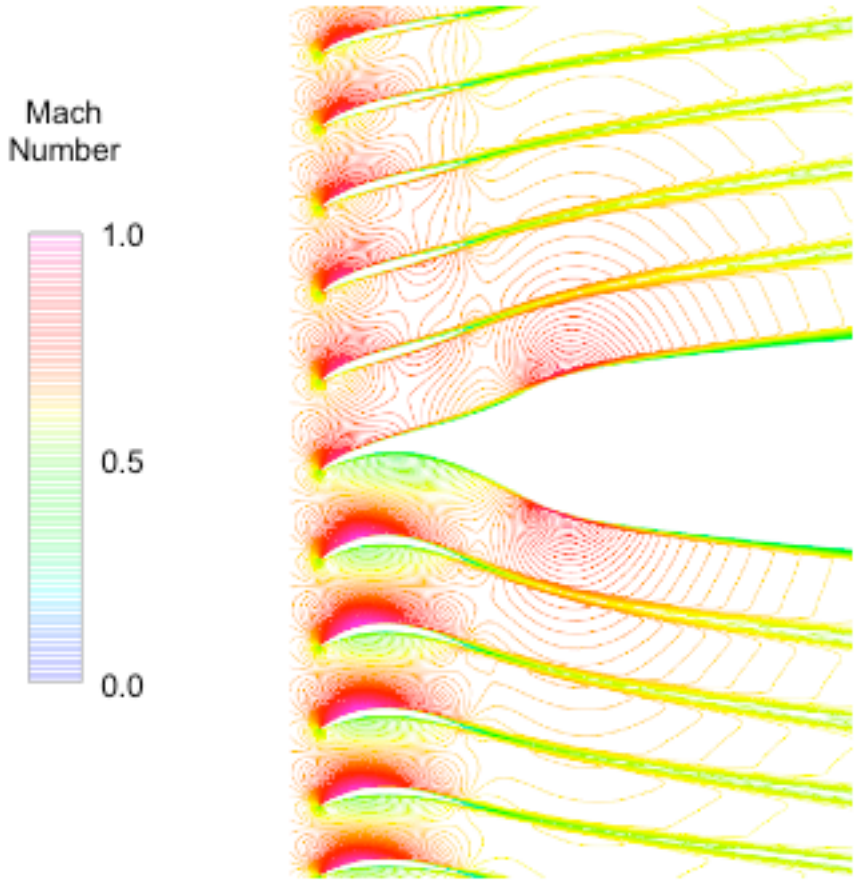


Fan-stator design for TPS with large service block



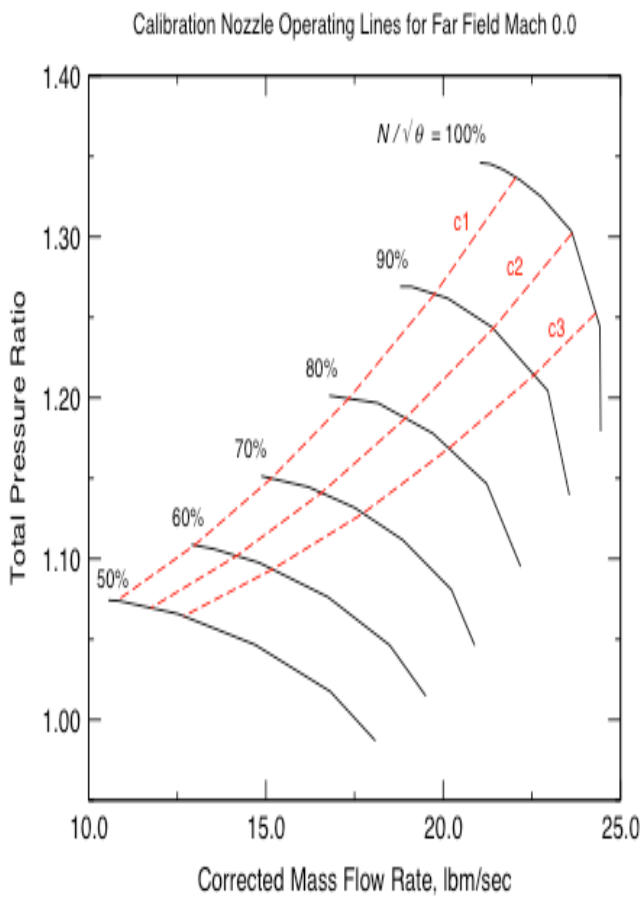
Fan-stator design for TPS with large service block

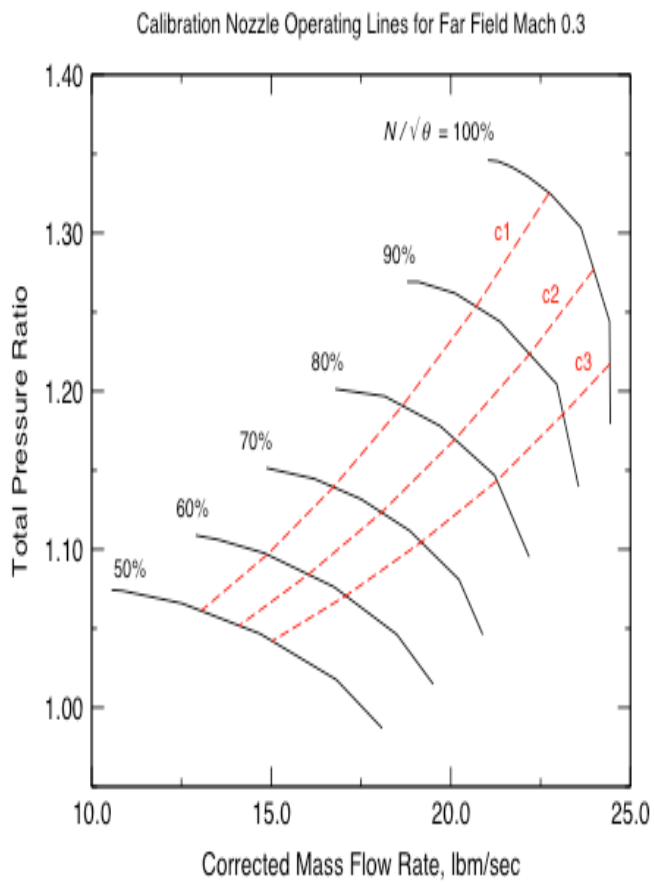


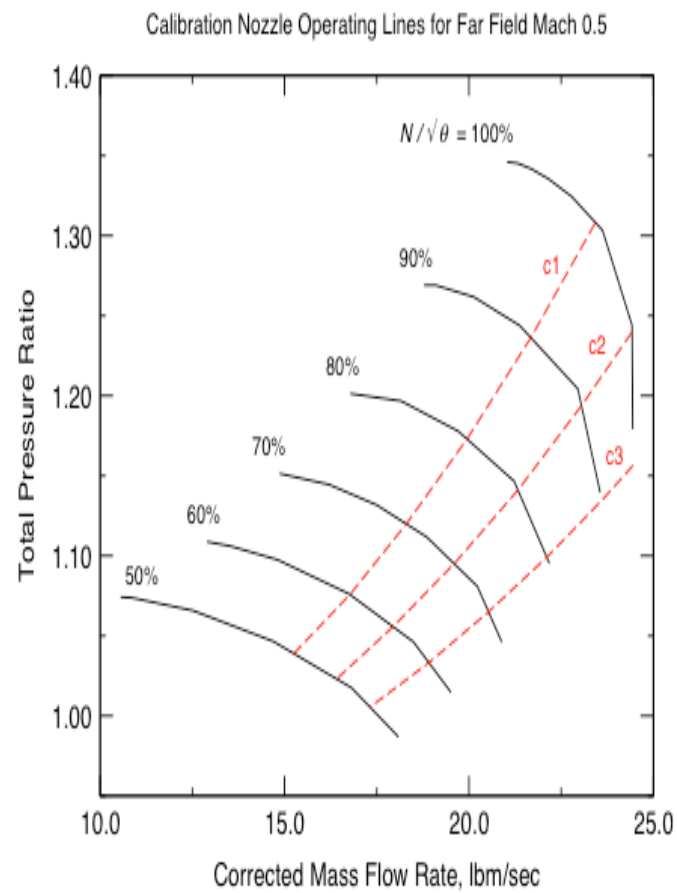


TPS Airflow Calibration Methodology

with calibrated large-capture inlet







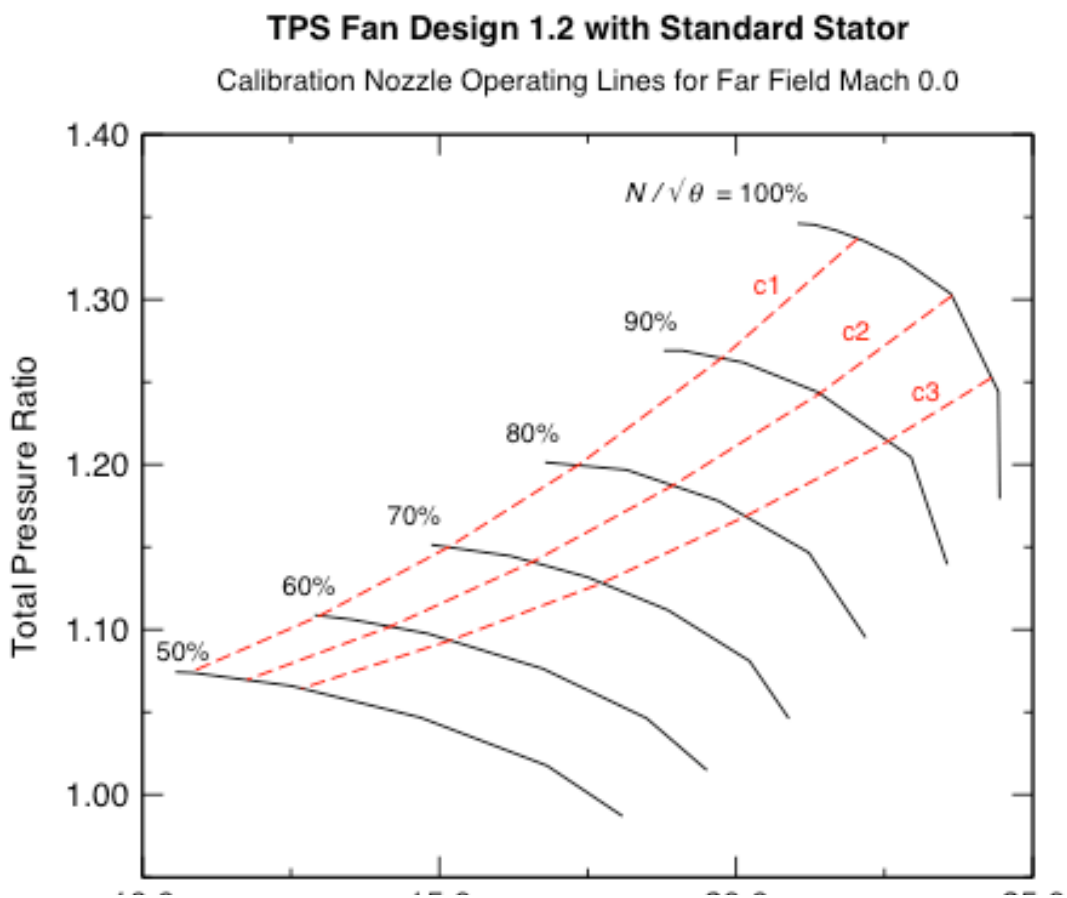
Summary

- Cart3D-Adjoint shape design with 161 variables
- Simultaneous design of wing, nacelle, pylon
- USM3D-CDISC viscous design correction

- New BPR~15--18 TPS to simulate UHB installation
- Powered semi-span test to validate cruise performance Nov-Dec 2011
- Provision for future low-speed performance and aeroacoustic testing

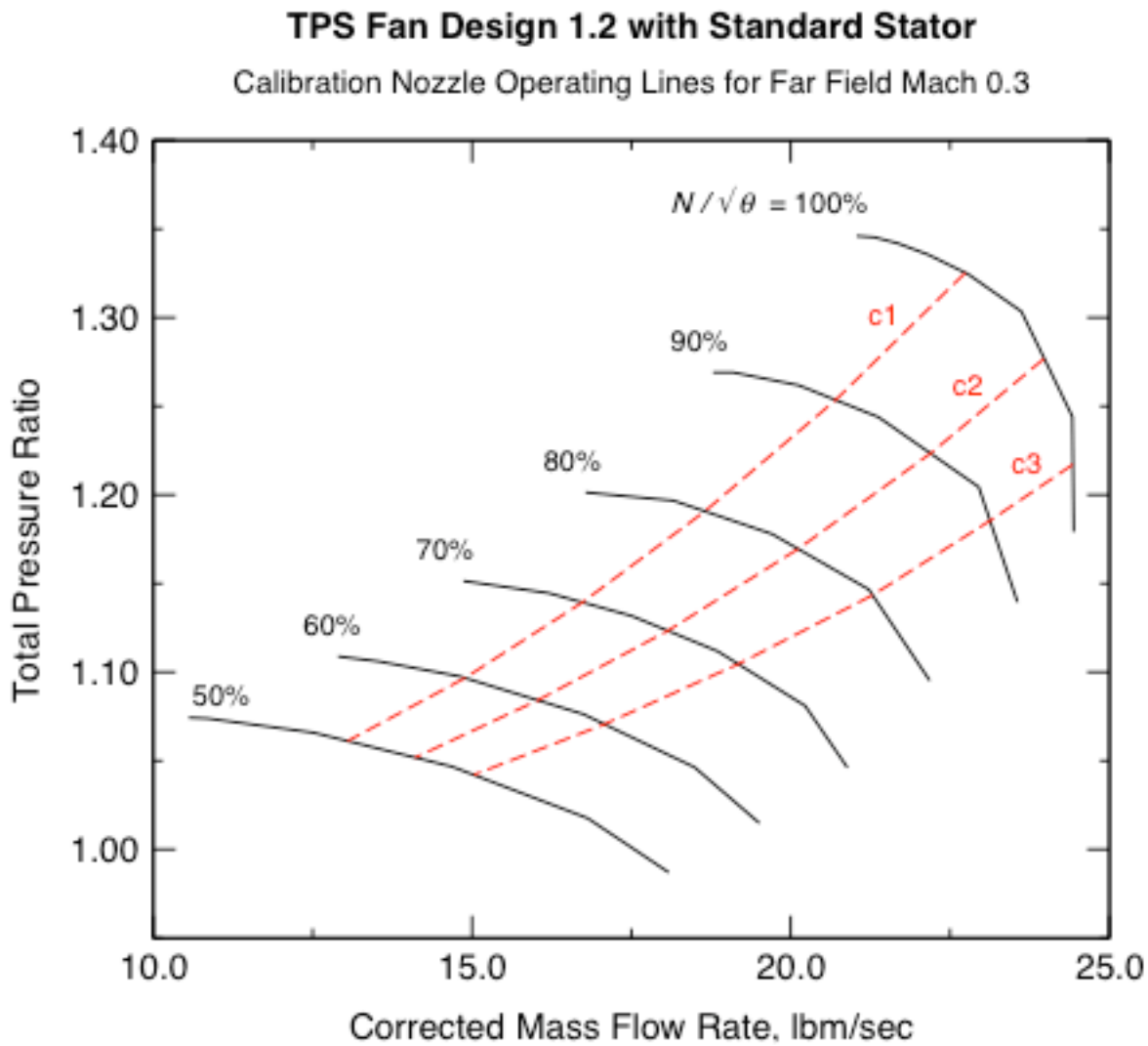
TPS Airflow Calibration Methodology

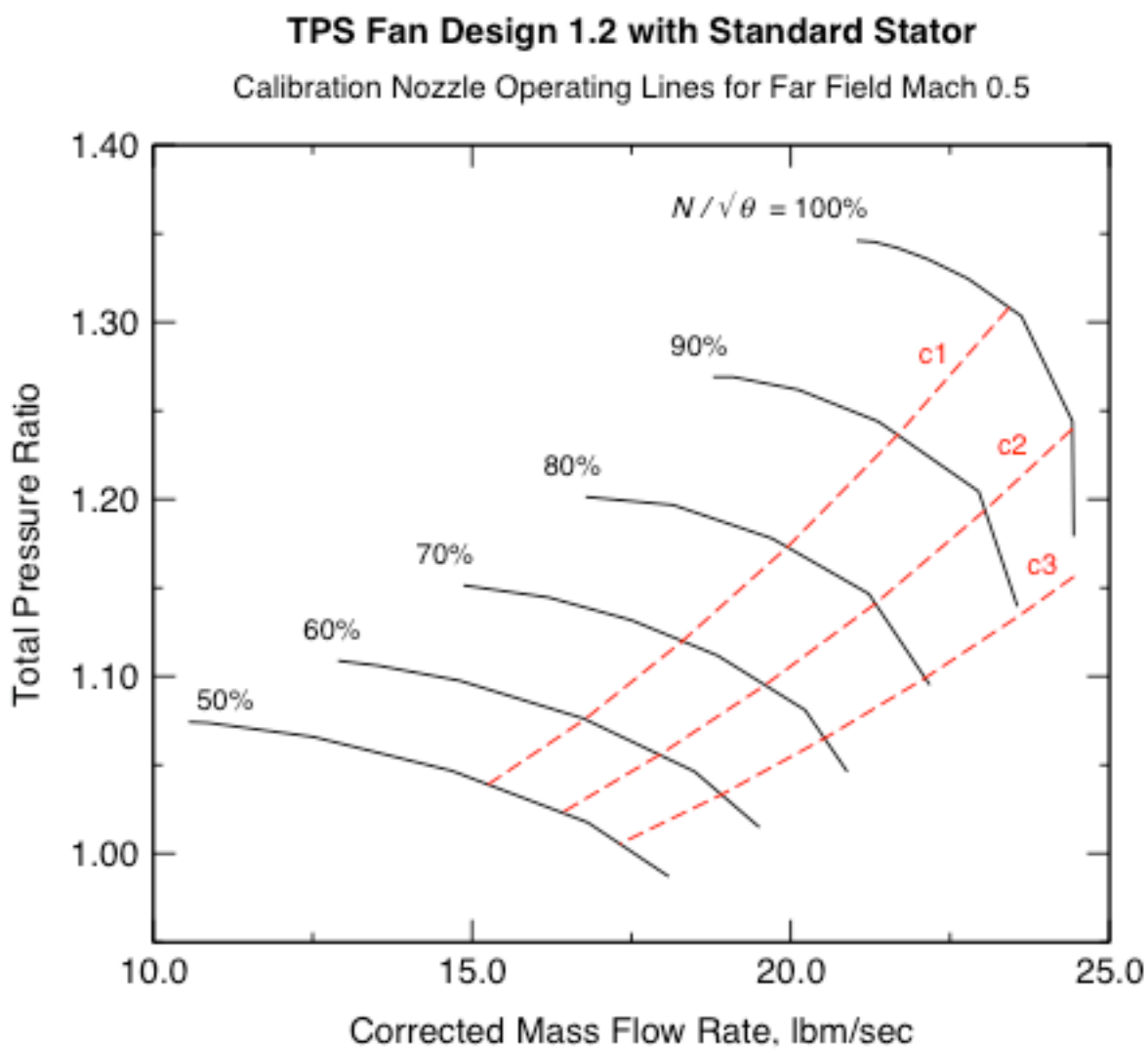
with calibrated large-capture inlet



TPS Airflow Calibration Methodology

with calibrated large-capture inlet



TPS Airflow Calibration Methodology

with calibrated large-capture inlet