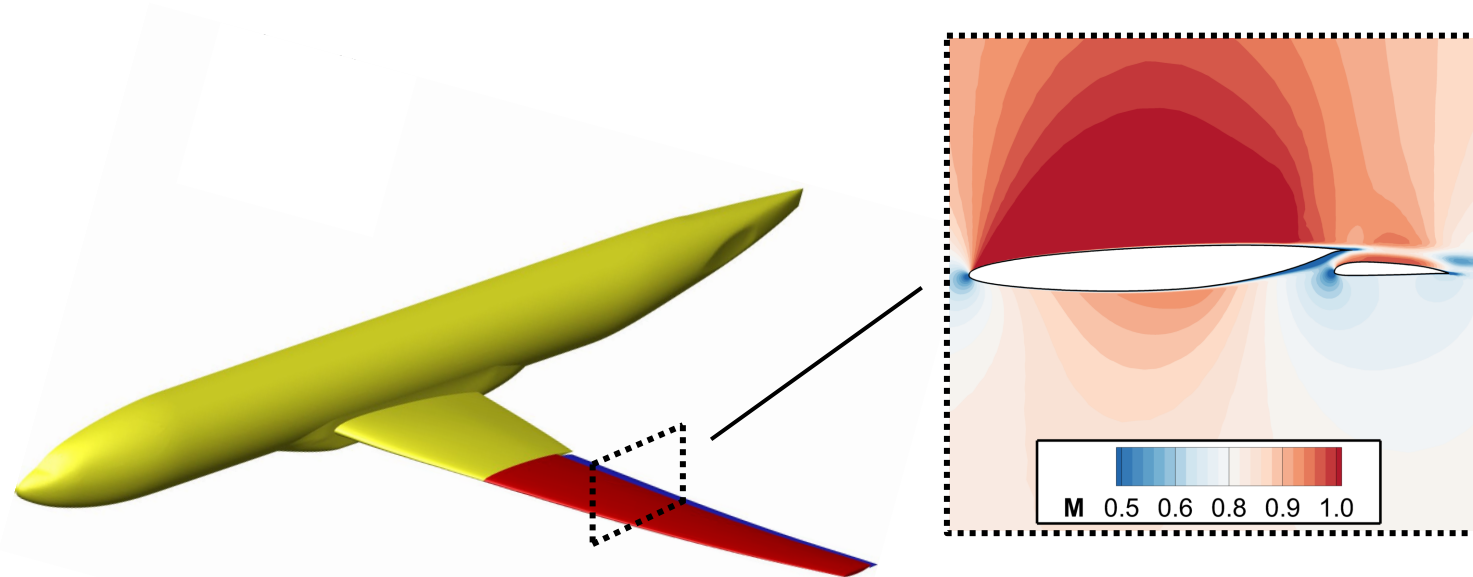
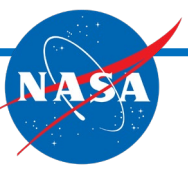


Cruise Slotted Wing Design with Natural Laminar Flow for Transonic Commercial Transport Aircraft



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NASA Langley Research Center

AIAA SciTech Forum, January 2025



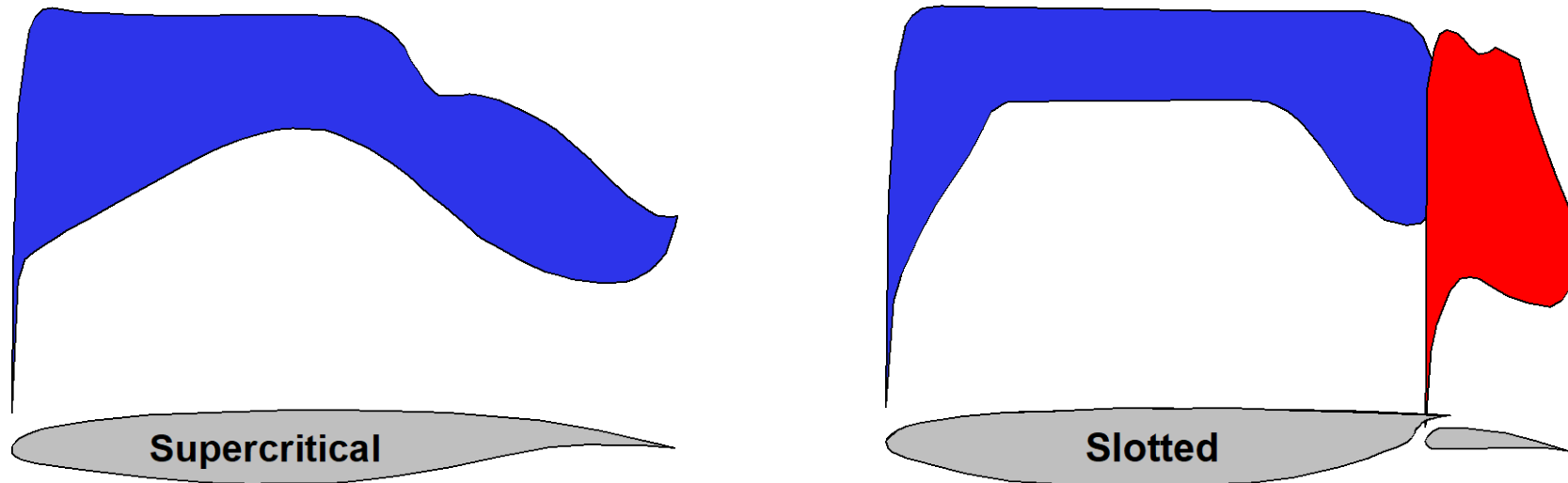
Outline

- **Introduction**
- **Geometry and Design Conditions**
- **Computational Tools and Design Constraints**
- **Design Results**
- **Concluding Remarks**

Cruise Slotted Wing Technology

Concept

The Cruise Slotted Wing (CSW) is a transonic multielement wing concept with a forward main element and an aft flap element, separated to form an intermediate slot.



Design Advantage

Flow-through slot permits stronger pressure recovery without separation, enables greater aft loading to help reduce shock strength and pressure drag

Research History

Objective

Quantify the potential vehicle performance benefits of CSW technology in application to next-generation, single-aisle transonic commercial transports with cruise speeds near Mach 0.8

2D Airfoil Design

Aft Laminar Multielement Airfoil (ALMA)
2.7% profile drag reduction relative to supercritical airfoil

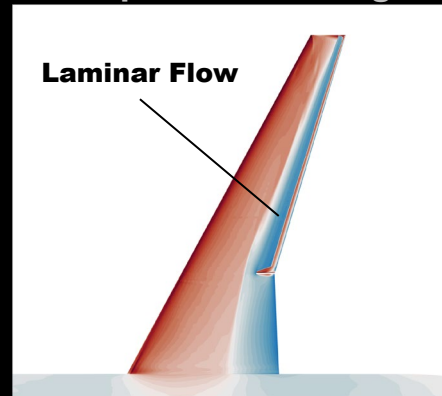


AIAA Paper 2021-2525



3D ALMA Wing Design

Slotted Wing with Natural Laminar Flow (NLF) flap
comparable drag as conventional supercritical wing

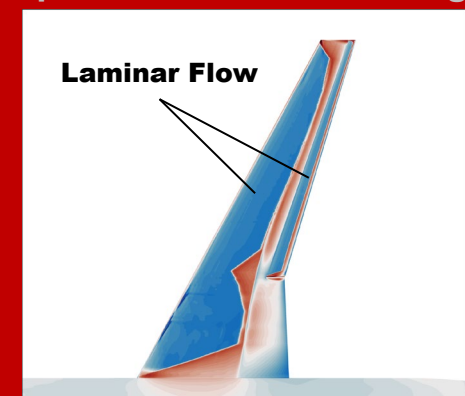


AIAA Paper 2024-0677



3D NLF Wing Design

Slotted Wing with NLF flap and wing upper surface
comparing to conventional supercritical and NLF wing



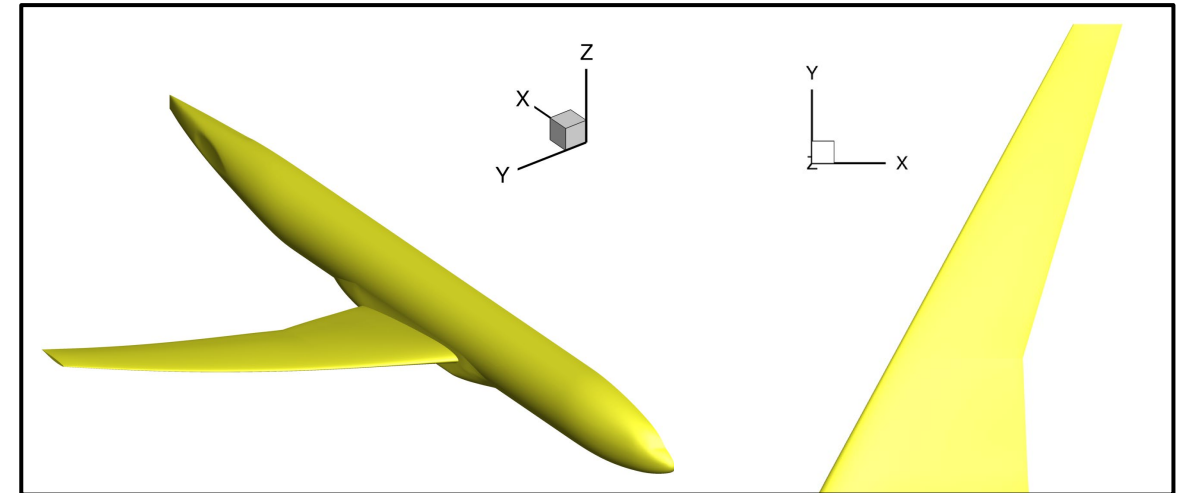
Current Paper

Geometry and Design Conditions

Baseline Conventional Wing

Mach-0.8 variant of the Common Research Model (CRM-M8) created for a representative single-aisle, transonic transport aircraft model

Configuration	λ	M_∞	Re_{cref}	C_L
CRM	35°	0.85	43.2×10^6	0.500
CRM-M8	25°	0.80	21.1×10^6	0.543

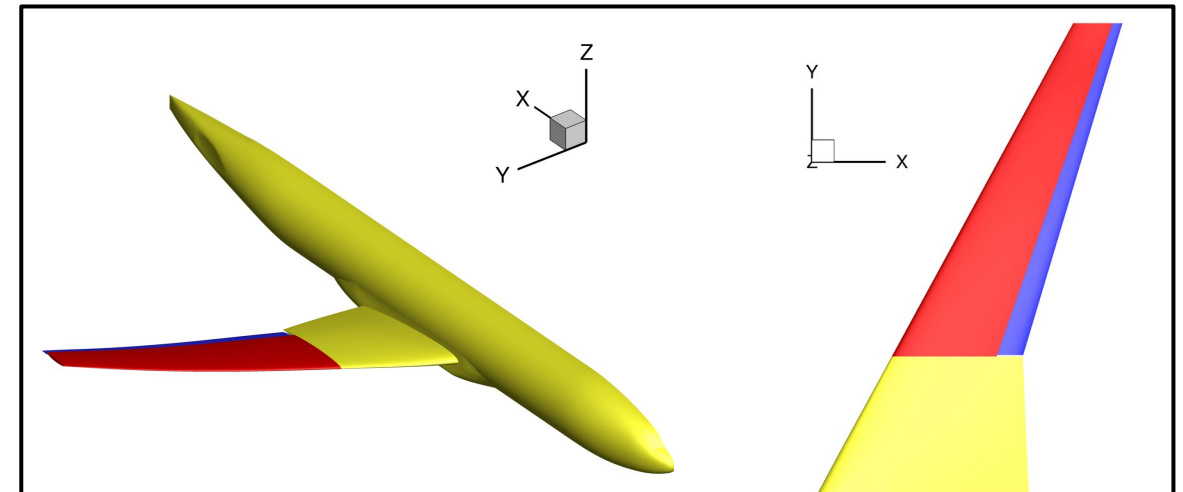


CRM-M8 Conventional Wing

Baseline Cruise Slotted Wing

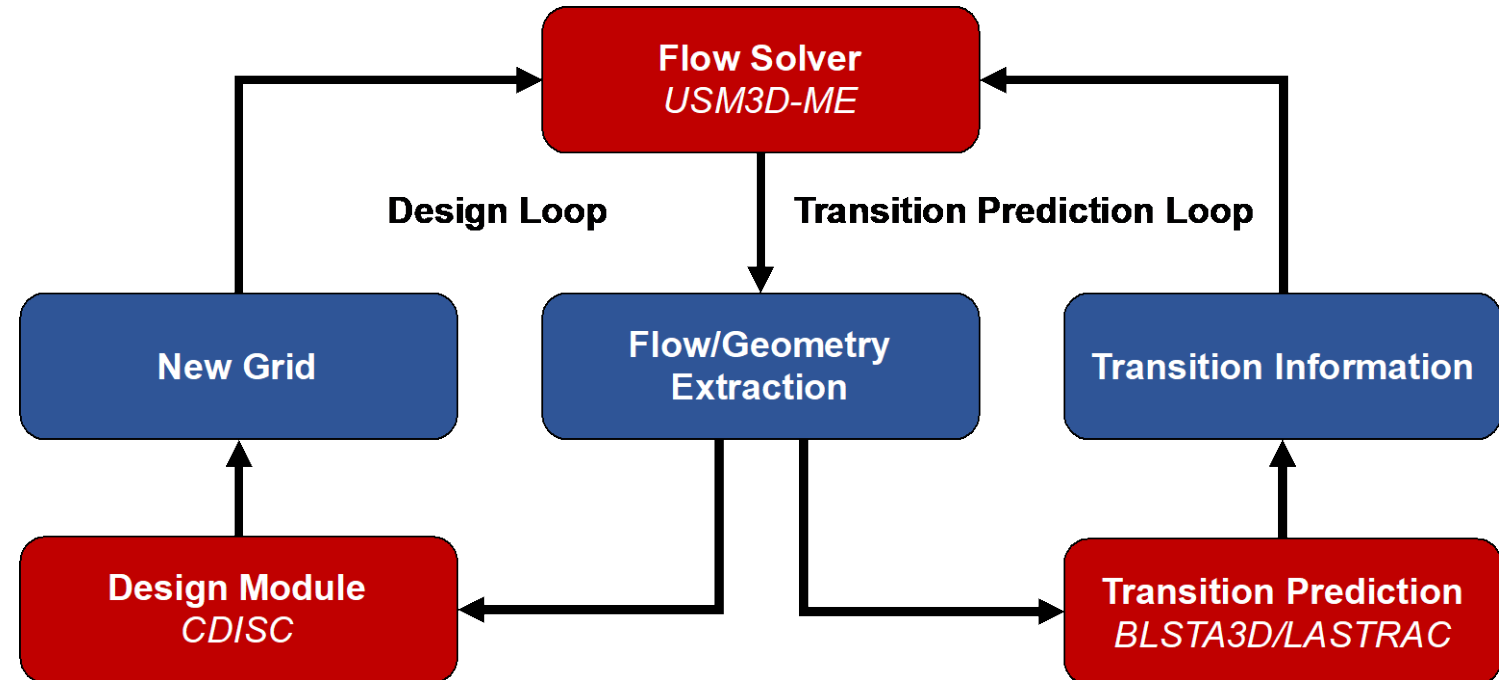
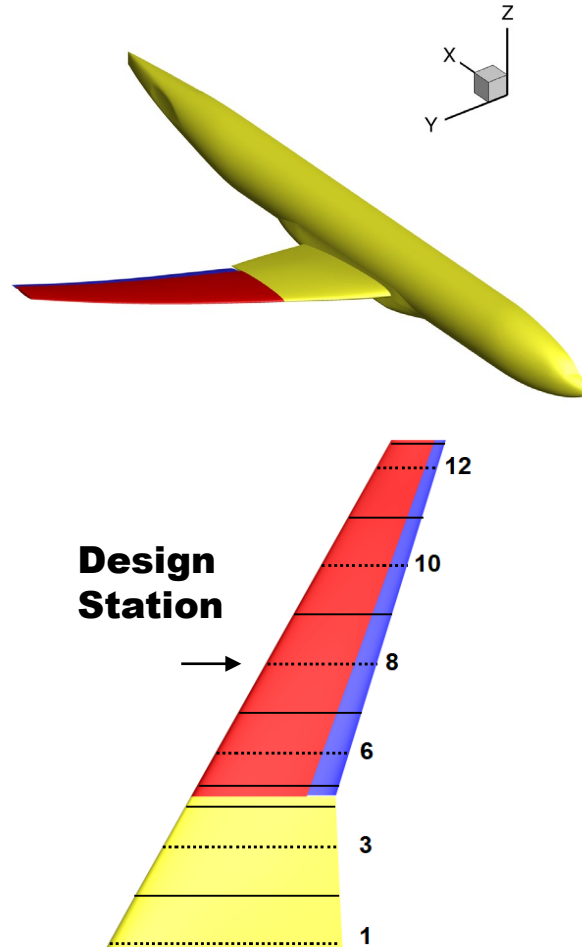
MAKESLOT code creates partial-span, slotted wing geometry from conventional wing

Features common fuselage and inboard wing, outboard slotted wing with **main element** and **flap**

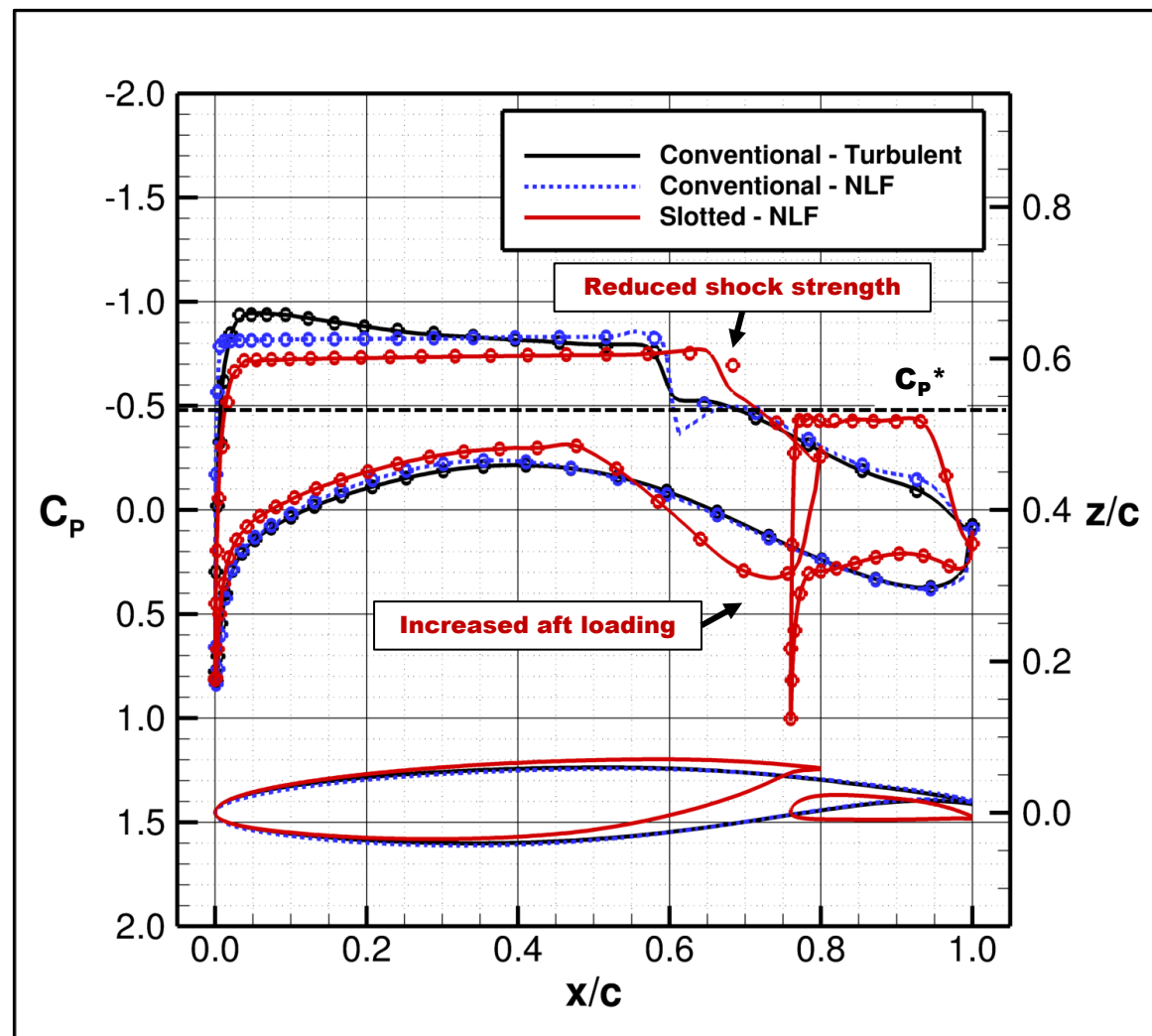
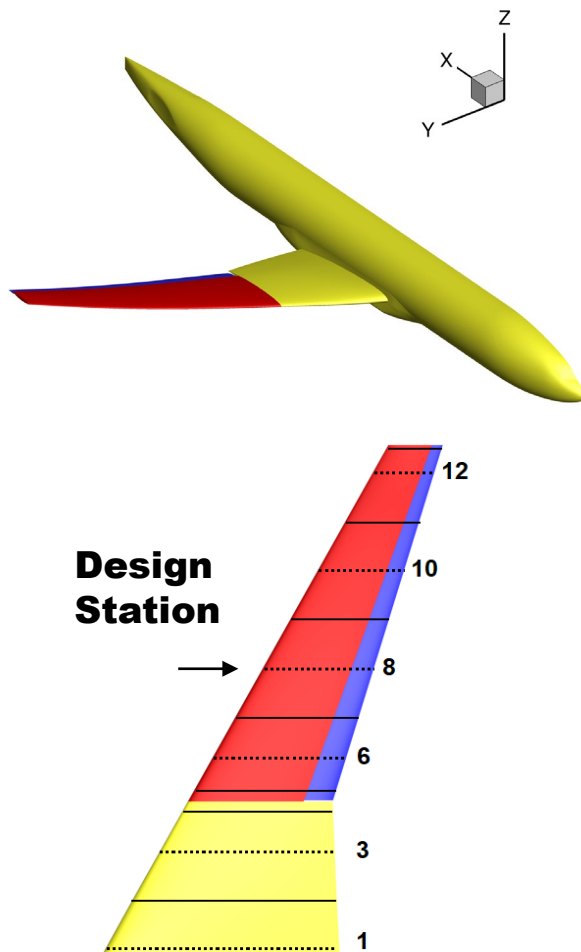


CRM-M8 Cruise Slotted Wing

Computational Tools

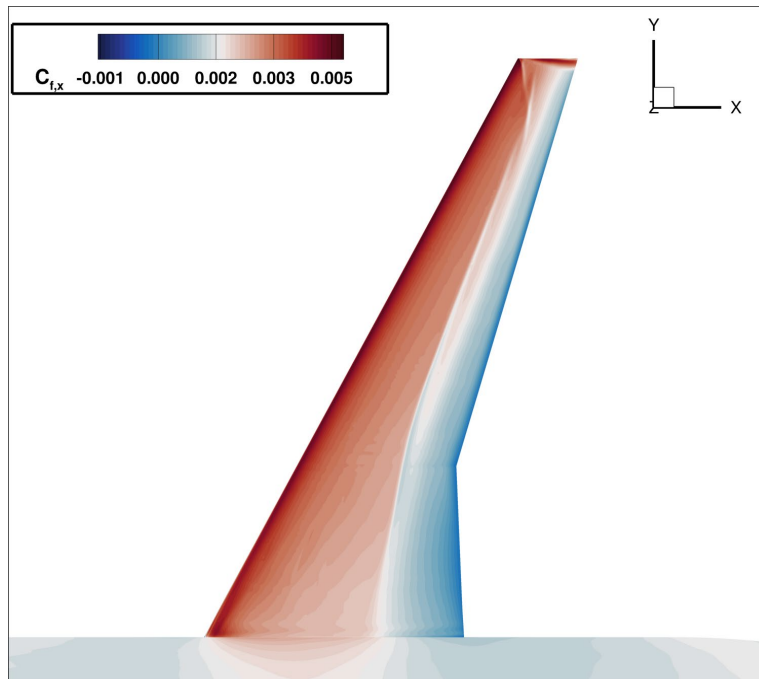


CDISC Target Pressures

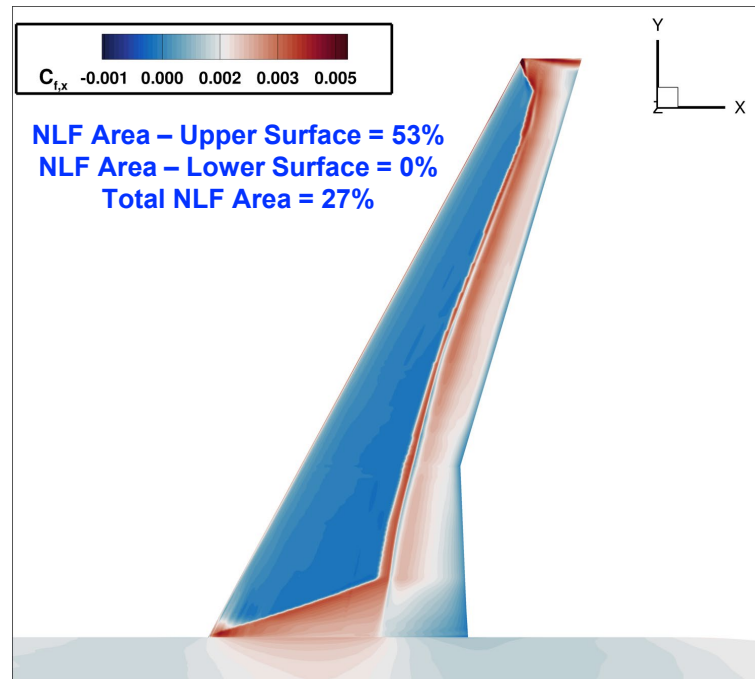


Cruise Performance: Laminar Flow Extents

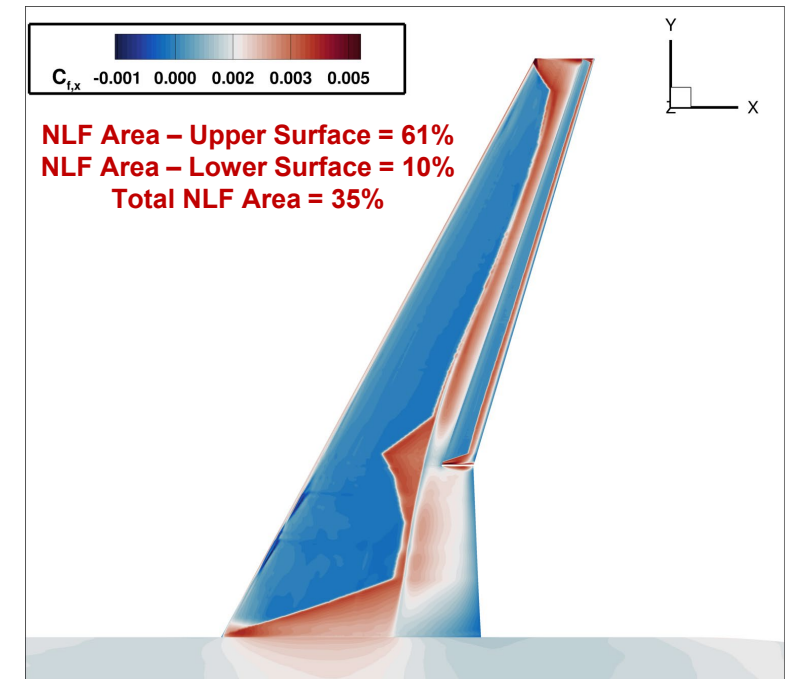
$M = 0.8$, $Re_{\text{cref}} = 21.1$ million, $C_L = 0.543$



Turbulent Conventional Wing

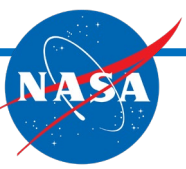


NLF Conventional Wing



NLF Cruise Slotted Wing

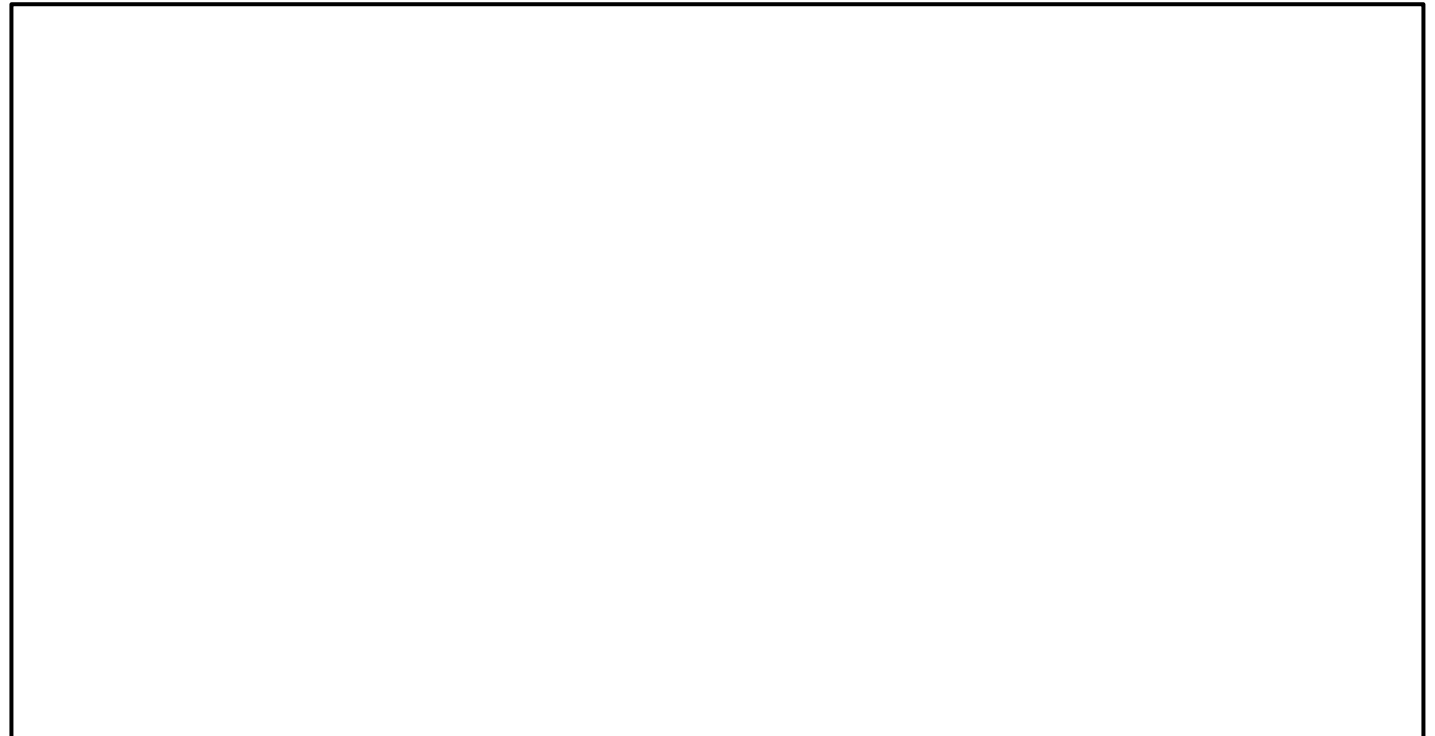
Slotted wing architecture enables increased extents (+8%) of NLF surface area due to laminarization of aft flap element



Cruise Performance: Drag Decomposition

$M = 0.8$, $Re_{\text{cref}} = 21.1$ million, $C_L = 0.543$

- Relative to **turbulent conventional wing**, the **NLF conventional wing** reduces the total drag by 18.4 ct
- The **NLF slotted wing** achieves additional 1.4-ct drag reduction relative to the **NLF conventional wing**
 - ~0.8 ct viscous drag reduction
 - ~0.6 ct pressure drag reduction

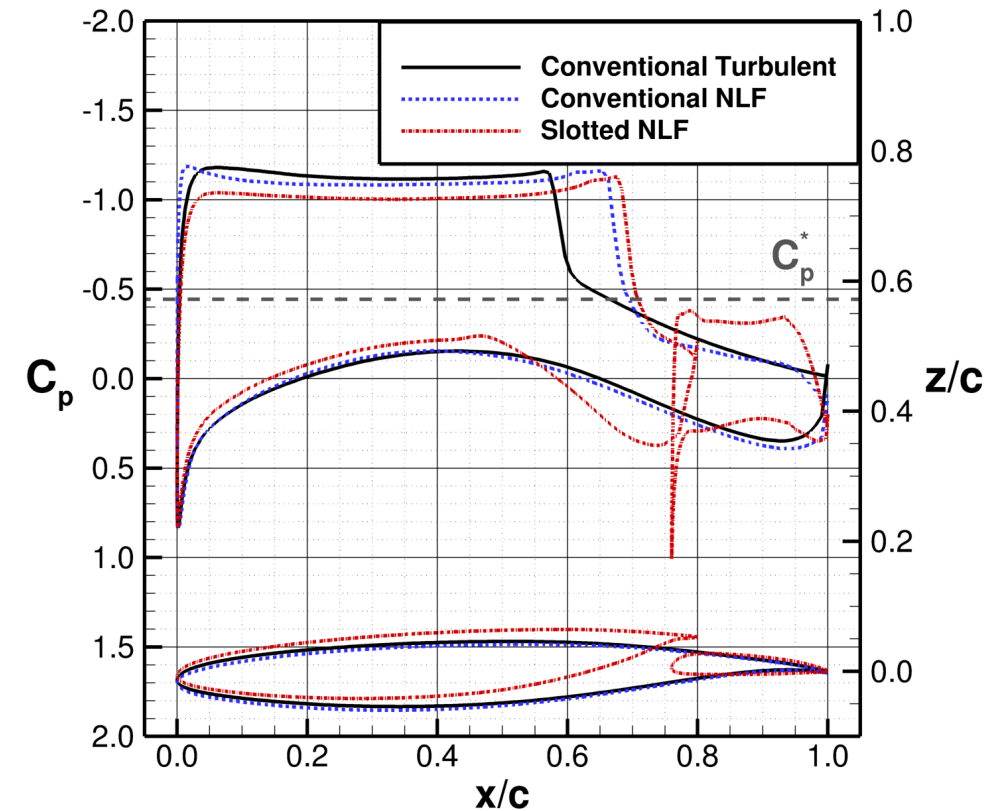


Off-design Performance: Drag Polar

$M = 0.8$, $Re_{cref} = 21.1$ million



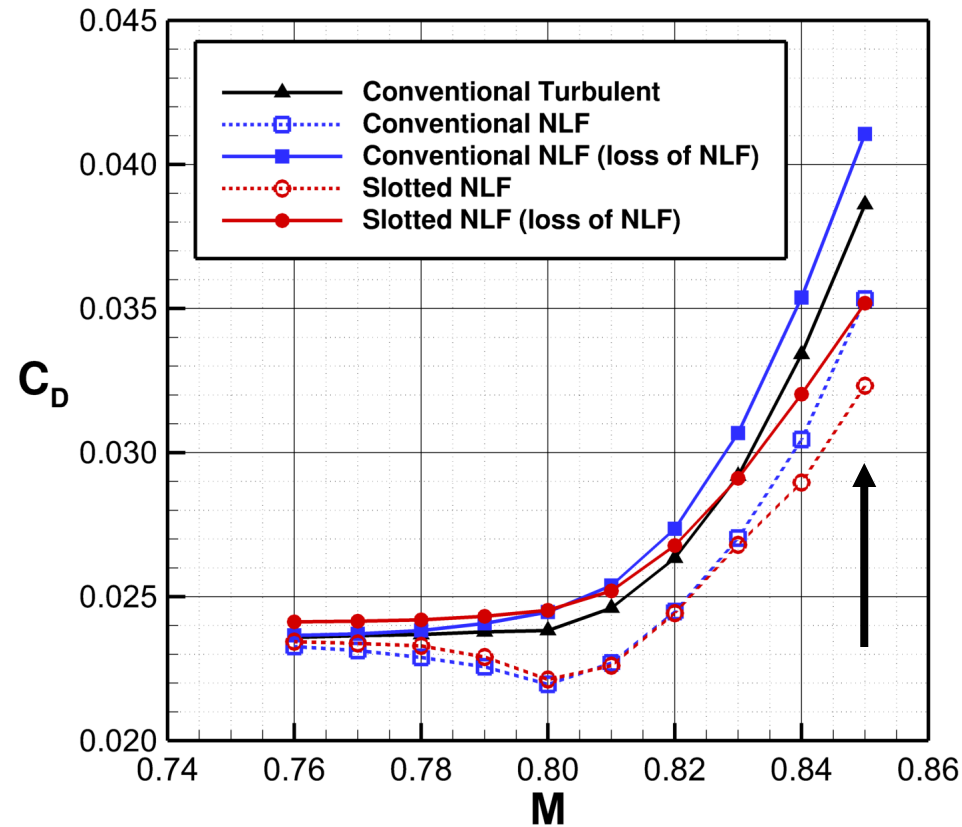
$\alpha = 3.5^\circ$, $C_L \approx 0.73$



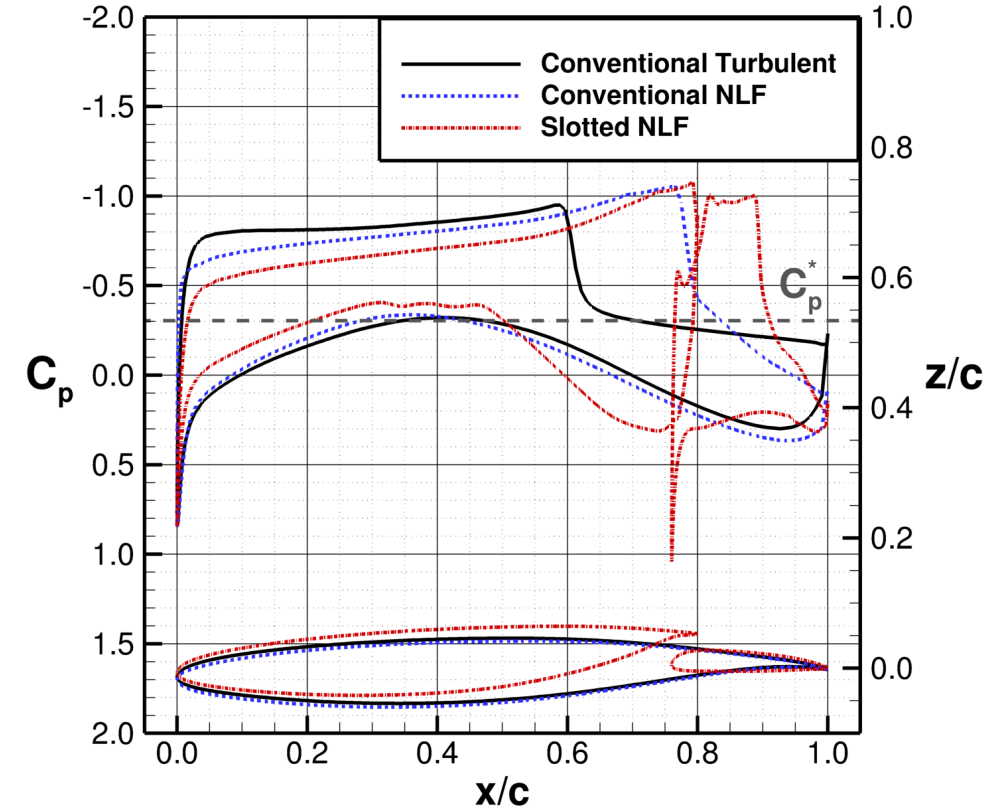
NLF CSW reduces shock-induced separation at higher α
 +15% in L/D compared to conventional turbulent wing near buffet criterion ($1.3 \cdot C_{L,cruise}$)
 +5% in L/D compared to conventional NLF wing near buffet criterion

Off-design Performance: Drag Rise

$C_L = 0.543$, $Re_{c_{ref}} = 21.1$ million



$M = 0.85$



NLF CSW reduces shock-induced separation at higher Mach numbers

+20% in L/D compared to conventional turbulent wing at $M = 0.85$

+9% in L/D compared to conventional NLF wing at $M = 0.85$

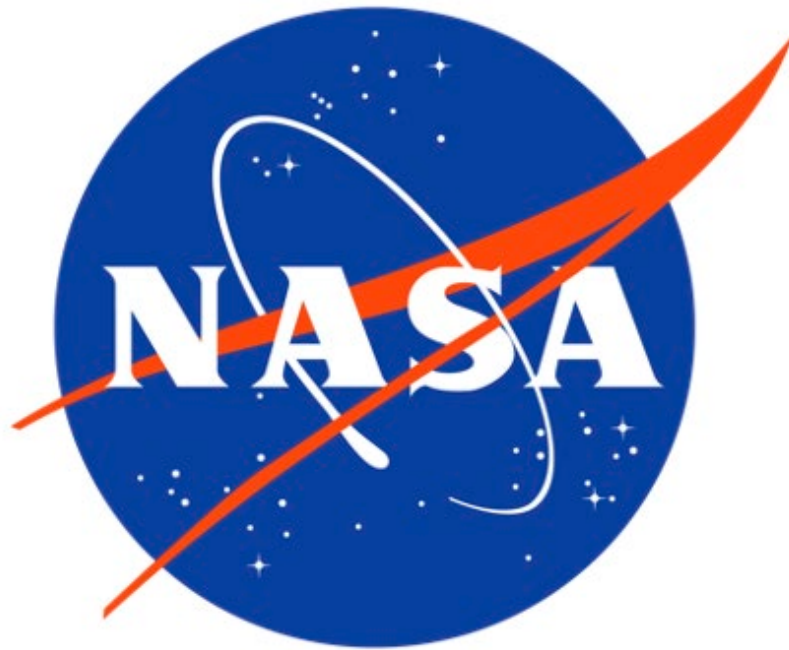
Concluding Remarks

- **Cruise Slotted Wing with Natural Laminar Flow designed for Mach-0.8 variant of the CRM**
 - Achieved 8% increase in NLF surface area compared to conventional NLF wing
 - 19.8 drag count reduction rel. to conventional turbulent wing
 - 1.4 drag count reduction rel. to conventional NLF wing
 - Limits shock-induced separation at off-design conditions
- **Future Research Opportunities**
 - Design trade space exploration
 - Increased speed → reduced travel time
 - Increased wing thickness → lighter wing
 - Continued industry interest, potential to examine performance benefits for alternative configurations
 - Transonic truss-braced wing
 - Transonic business jet

Cruise Slotted Wing with Natural Laminar Flow
for Mach-0.8 variant of the CRM



NASA/Boeing SUGAR
Transonic Truss-braced Wing (TTBW)
Photo: NASA



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