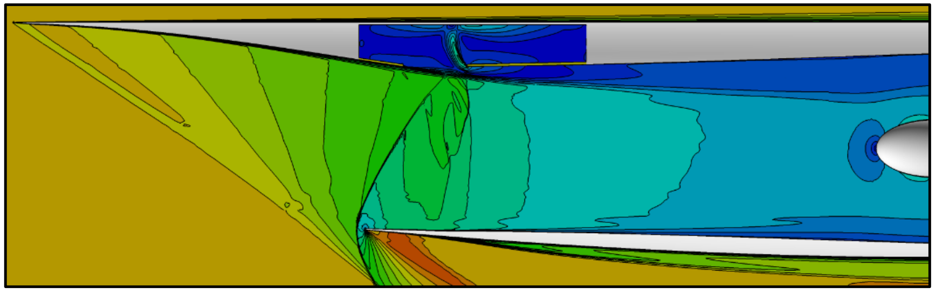

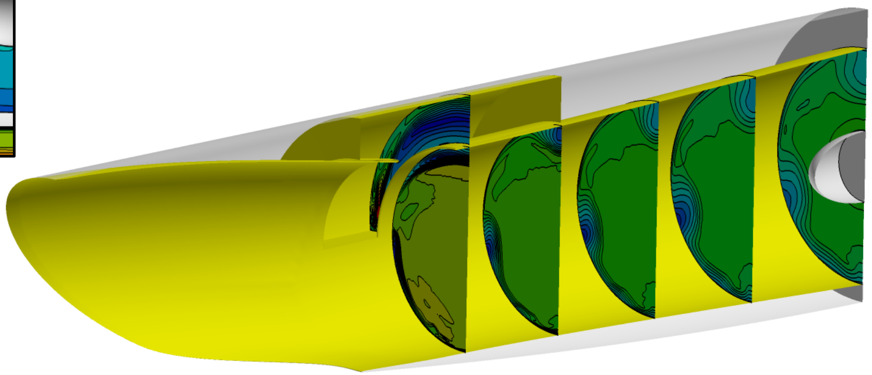

Streamline-Traced, External-Compression Supersonic Inlets for Mach 2

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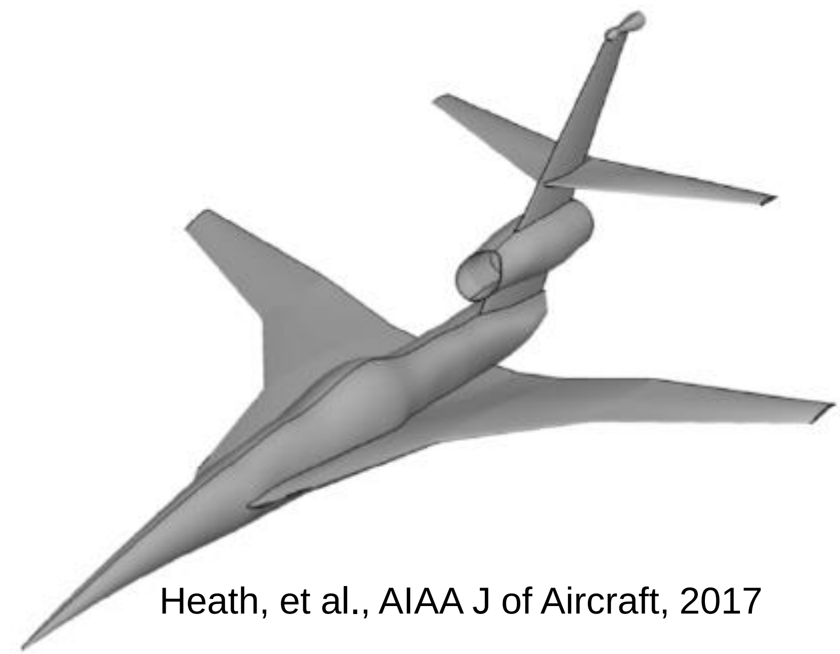
2022 ISABE

NASA Commercial Supersonic Technology

- NASA is studying technologies for quiet and efficient commercial supersonic flight for Mach 1.4 to 1.7+.
- The propulsion system (inlets, engines, and nozzles) is an important component.
- A major focus is on reducing sonic boom to allow supersonic flight over land.
- The low-boom flight demonstrator (QueSST) X-59 for Mach 1.4 flight.

QueSST X-59. NASA / Lockheed Martin, 2020

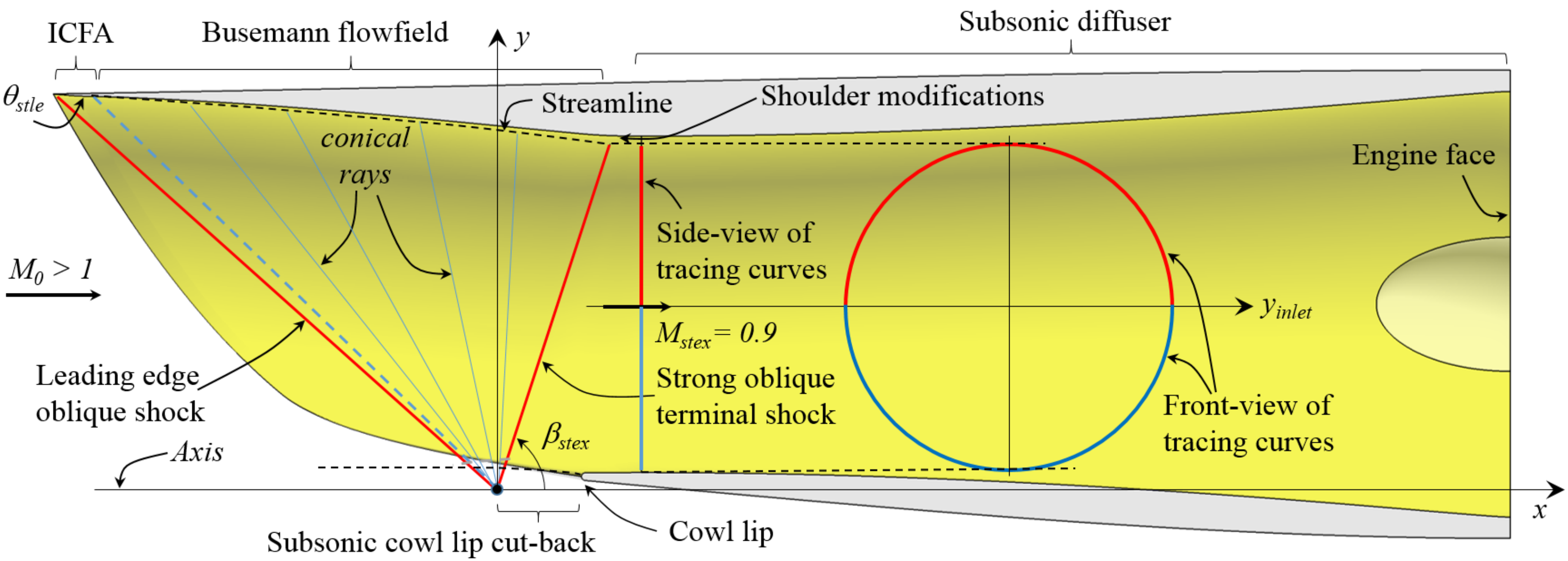
NASA / Boeing, 2014



Heath, et al., AIAA J of Aircraft, 2017

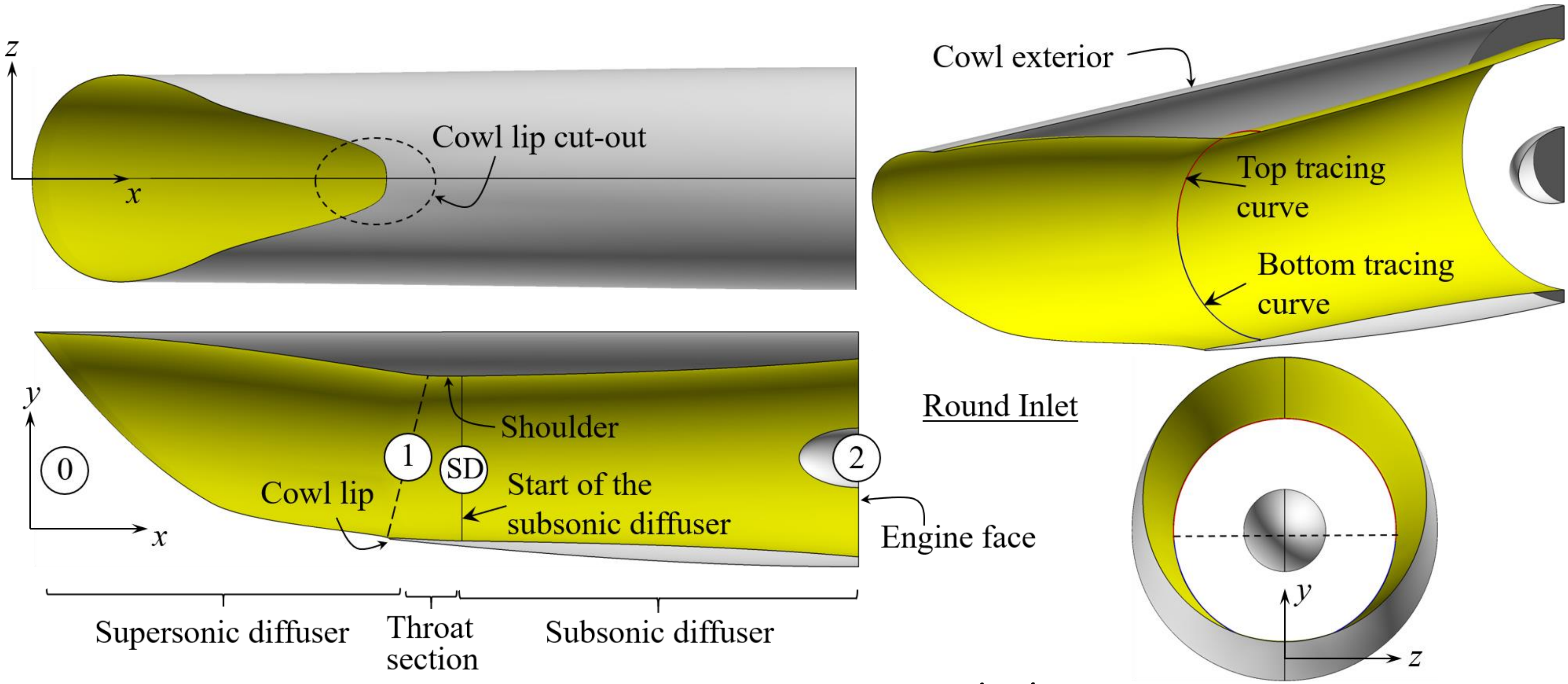
Streamline-Traced, External-Compression (STEX) Inlet

- M_0 = 2.0, h_0 = 60000 ft., M_{stex} = 0.9, M_2 = 0.5, D_2 = 3.625 ft
- Supersonic diffuser defined by tracing streamlines through an inward-turning, axisymmetric ICFA-Otto-Busemann flowfield. Axial inflow and axial outflow.
- Low external cowl angles results in low wave drag and less external disturbances that contribute to sonic boom.
- Strong oblique terminal shock structure creates subsonic internal flow.
- Use SUPIN to generate the inlet geometry.



Streamline-Traced, External-Compression (STEX) Inlet

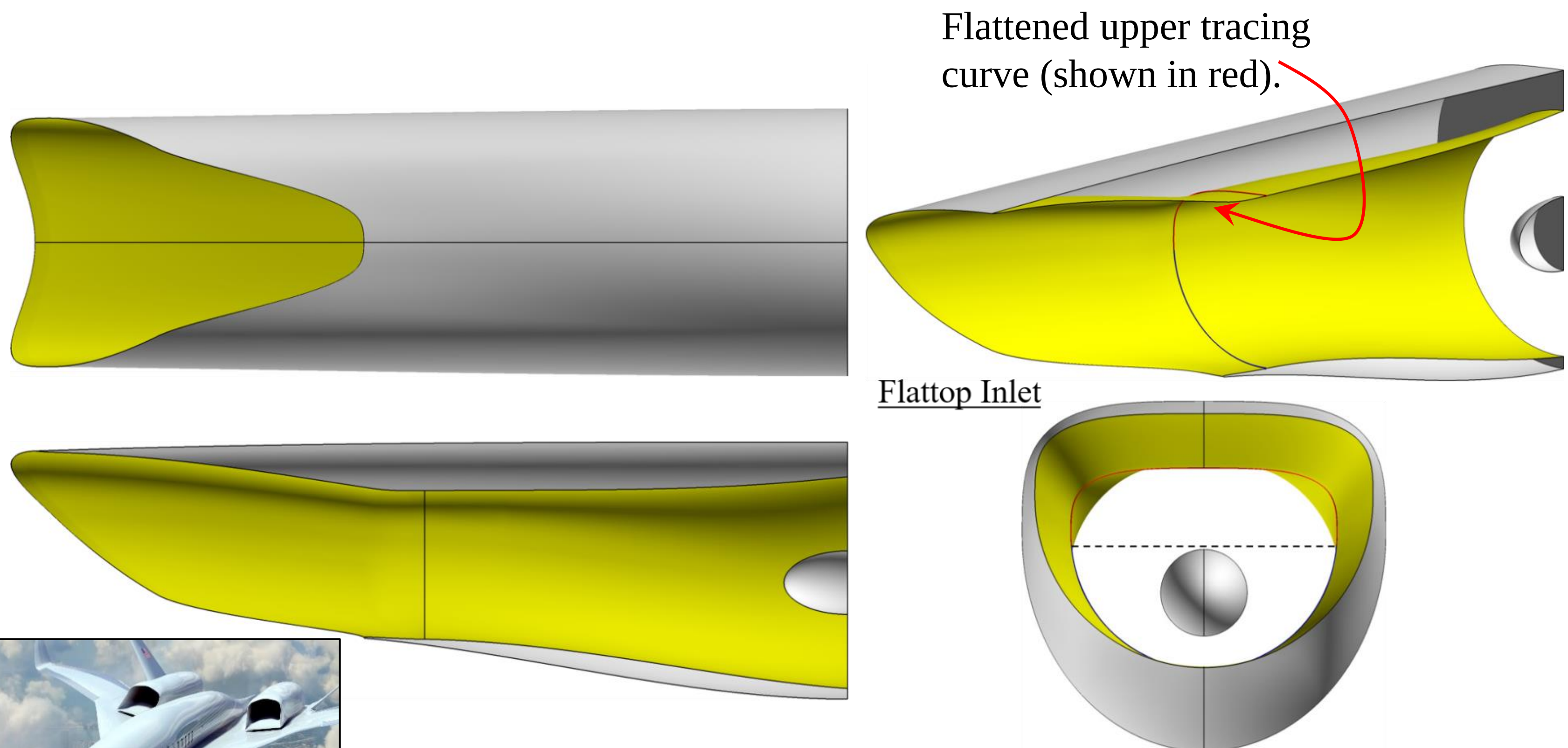
- Mach 2 STEX inlet generated from round tracing curves.
- Leading edge is highly scarfed.
- A cut-out at the bottom-center of the inlet allows for subsonic spillage.
- Spilled flow and disturbances are directed through the cut-out.



Round Inlet

Flattop STEX Inlet

- Stream-tracing allows for general shapes for the tracing curves to allow for variations in the capture cross-section.
- Investigate “flattop” tracing curves to create a STEX inlet with a flattened top surface that possibly could integrate better with a wing or fuselage.

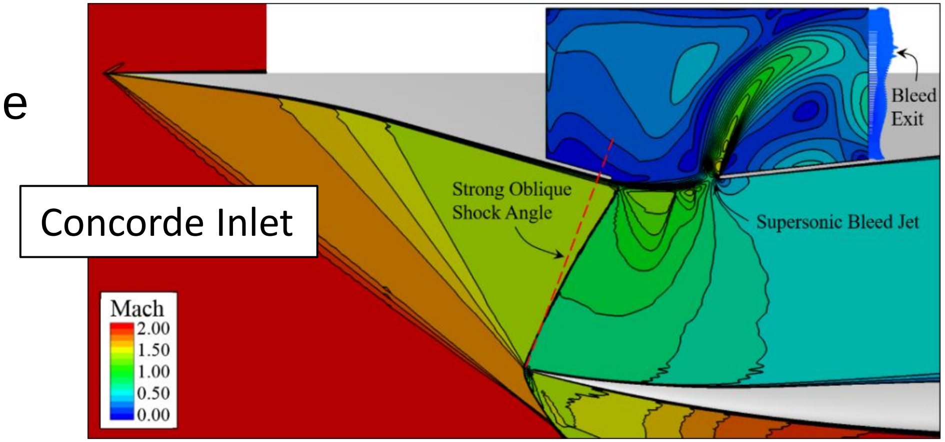


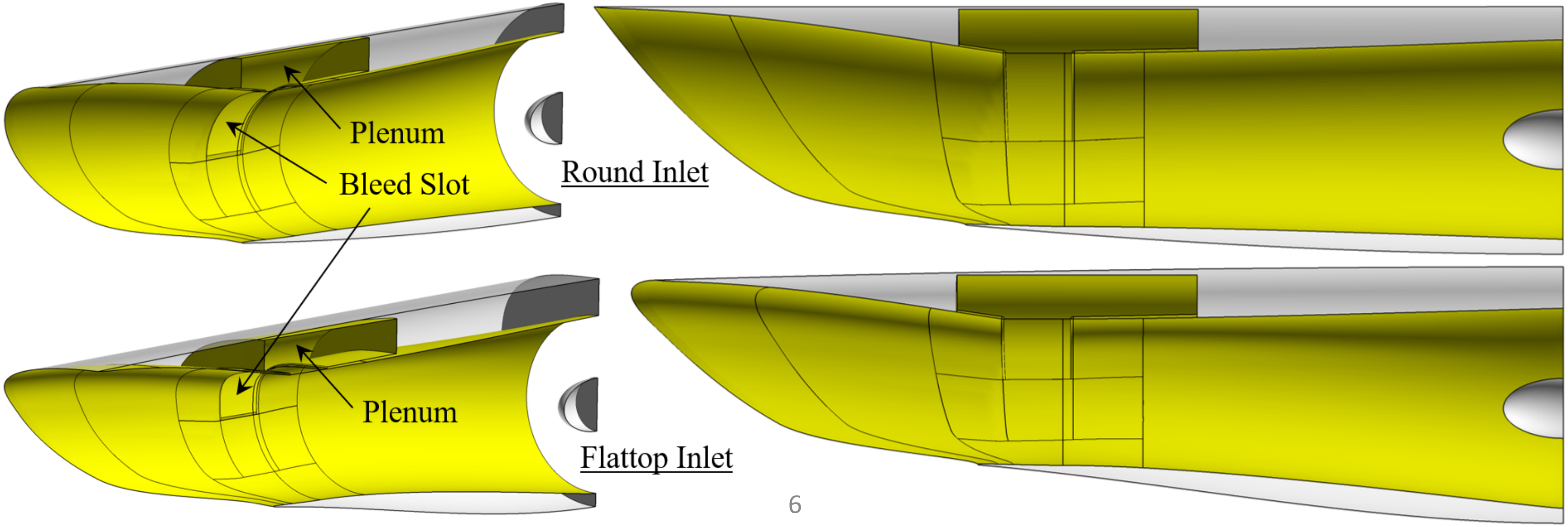
Flattop Inlet

NASA / Boeing, 2014

Use of a Bleed Slot for STEX Inlets

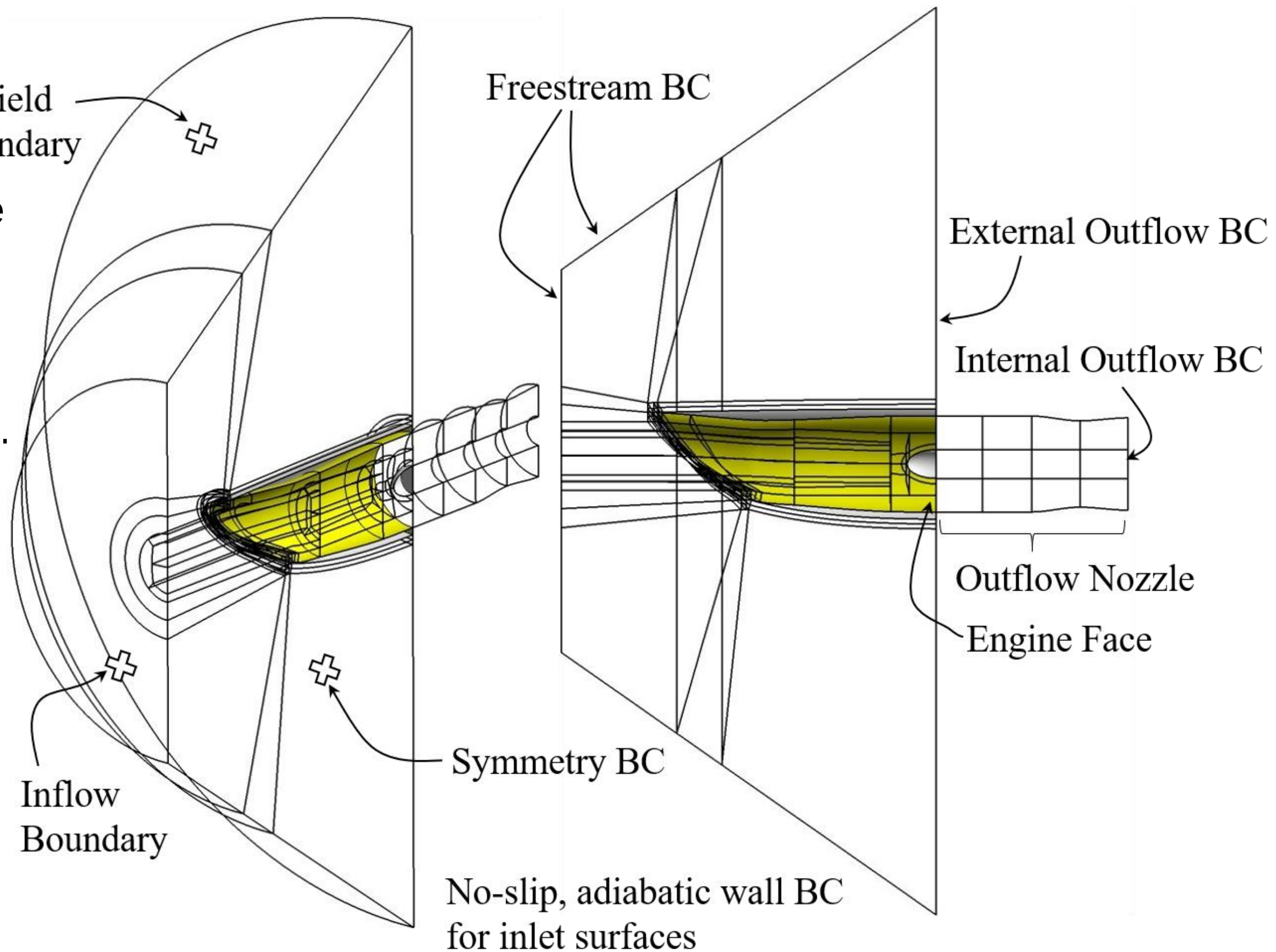
- Modeling of the Concorde inlet (AIAA-2020-3770, Slater) demonstrated advantages of a wide bleed slot for achieving a strong, oblique terminal shock with high total pressure recovery and low distortion.
- Apply a bleed slot at the shoulder of the STEX inlet with similar dimensions to the Concorde inlet and extending over half of the circumference of the inlet.



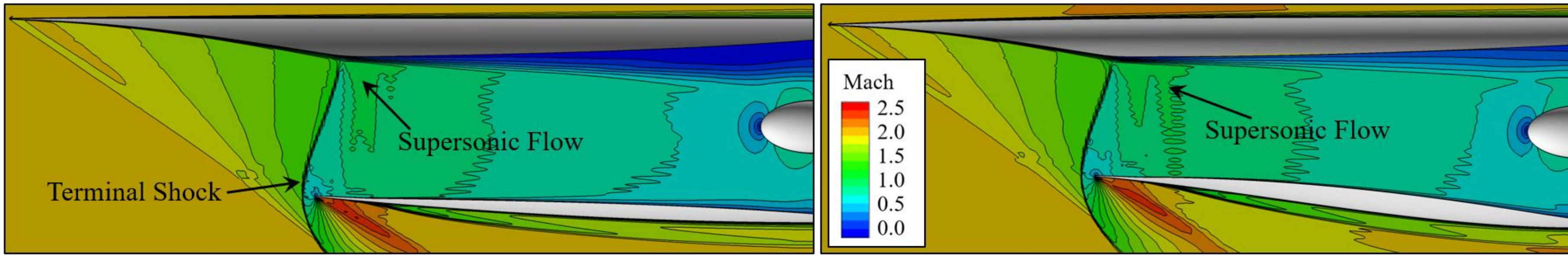


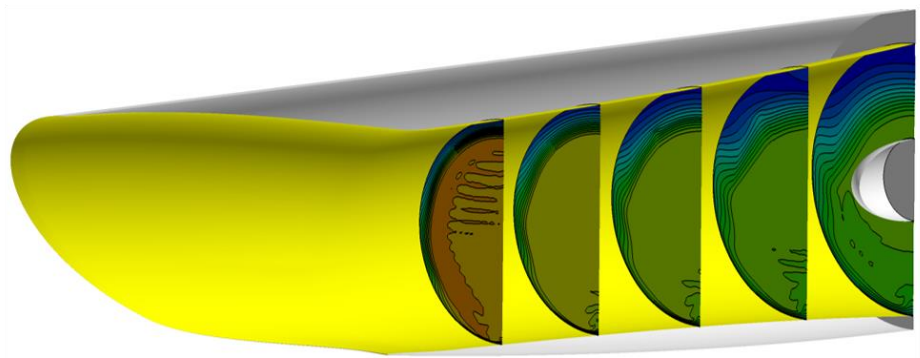
STEX Inlet CFD Analysis

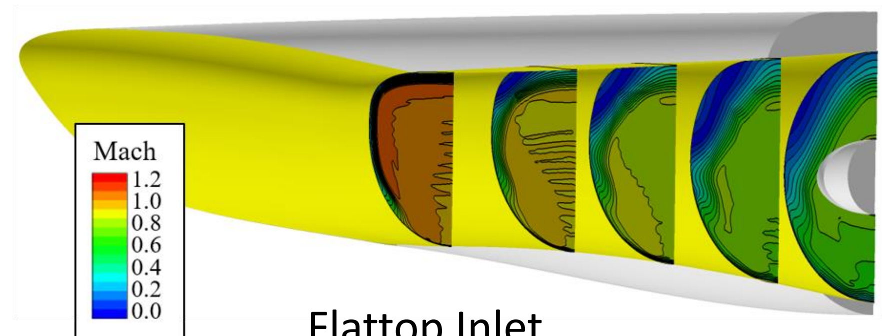
- Wind-US, steady-state RANS solver.
- Multi-block, structured grid.
- SST turbulence model.
- 15-30 million grid points.
- $\Delta y^{+}_{1} \approx 1$ to 2.
- Outflow is modeled with an outflow converging-diverging nozzle.



Performance of the Baseline STEX Inlets (No Slot)







Flattop Inlet

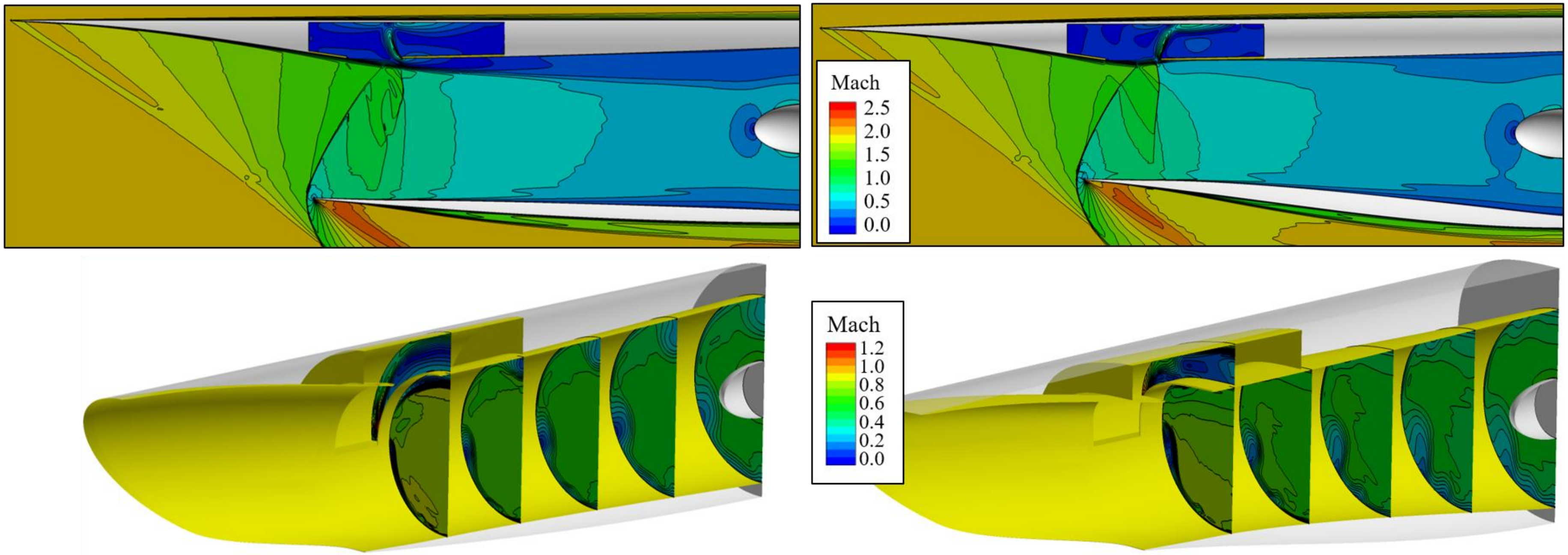
Round Inlet

Mil-Spec p_{t2}/p_{t0} = 0.92 SAE ARP 1420 Indices

Inlet	$W_{spillage}/W_{cap}$	W_{bleed}/W_{cap}	W_2/W_{cap}	p_{t2}/p_{t0}	DPR/P	DPC/P
Round: Baseline Inlet	0.0425	-	0.9575	0.8774	0.0900	0.1030
Flattop: Baseline Inlet	0.0526	-	0.9474	0.8732	0.1145	0.0939

The flattop STEX inlet had similar performance as the round STEX inlet.

STEX Inlets with Slots



Round Inlet

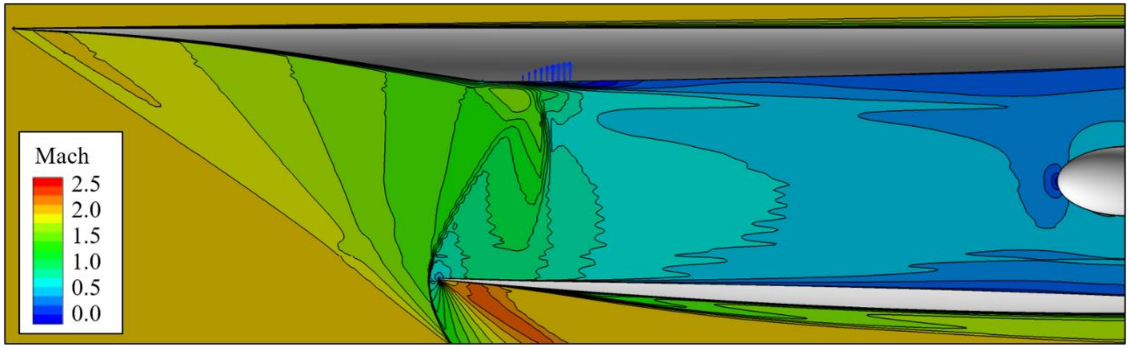
Mil-Spec p_{t2}/p_{t0} = 0.92

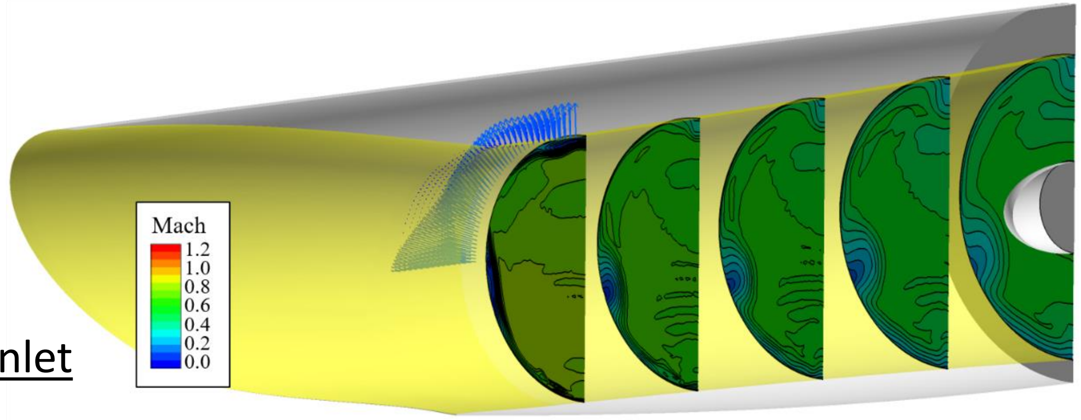
Flattop Inlet

Inlet	$W_{spillage}/W_{cap}$	W_{bleed}/W_{cap}	W_2/W_{cap}	p_{t2}/p_{t0}	DPR/P	DPC/P
Round: Baseline Inlet	0.0425	-	0.9575	0.8774	0.0900	0.1030
Flattop: Baseline Inlet	0.0526	-	0.9474	0.8732	0.1145	0.0939
Round: Bleed Slot	0.0376	0.0504	0.9120	0.9490	0.0493	0.0328
Flattop: Bleed Slot	0.0390	0.0518	0.9092	0.9456	0.0567	0.0285

The use of the bleed slot improved performance.

Round STEX Inlet with a Porous Bleed Region



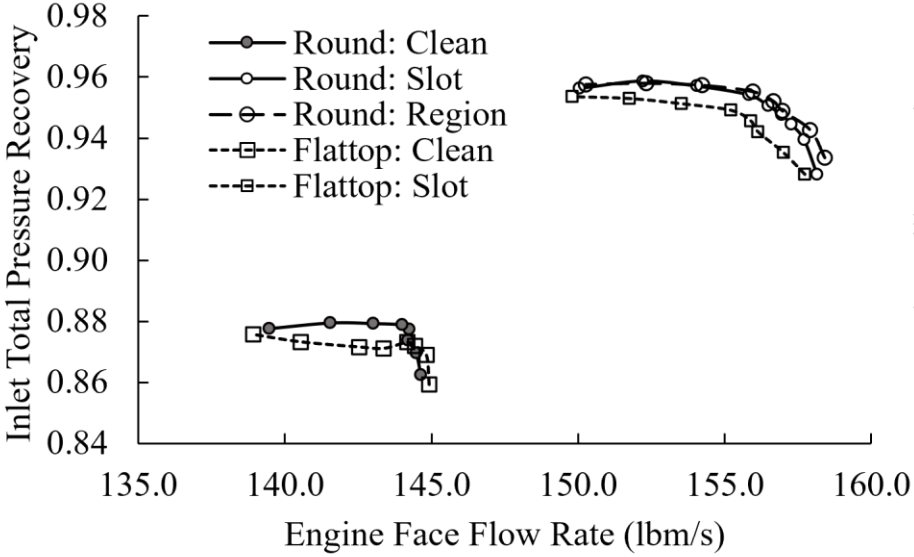


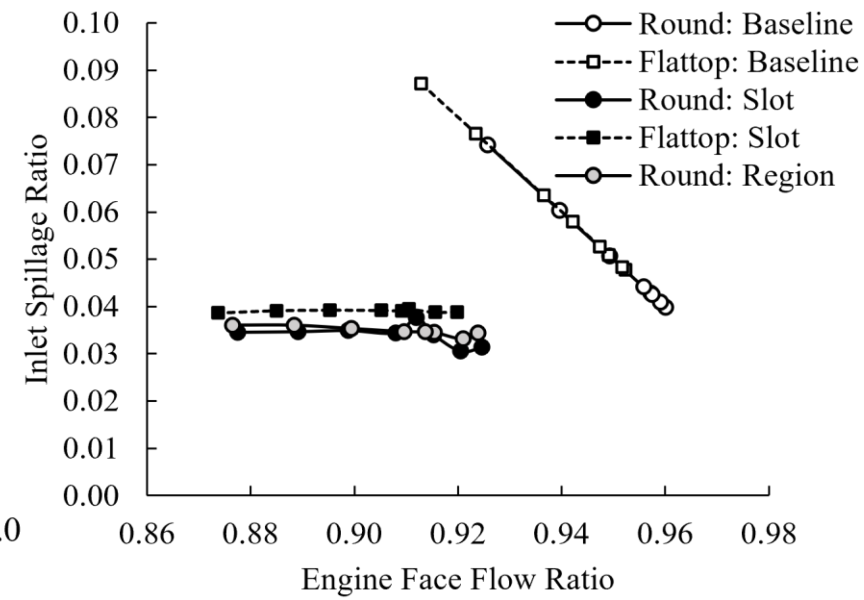
Round Inlet

Inlet	$W_{spillage}/W_{cap}$	W_{bleed}/W_{cap}	W_2/W_{cap}	p_{t2}/p_{t0}	DPR/P	DPC/P
Round: Bleed Slot	0.0376	0.0504	0.9120	0.9490	0.0493	0.0328
Round: Bleed Region	0.0346	0.0517	0.9137	0.9527	0.0478	0.0323

A porous bleed region provides similar performance as the bleed slot.

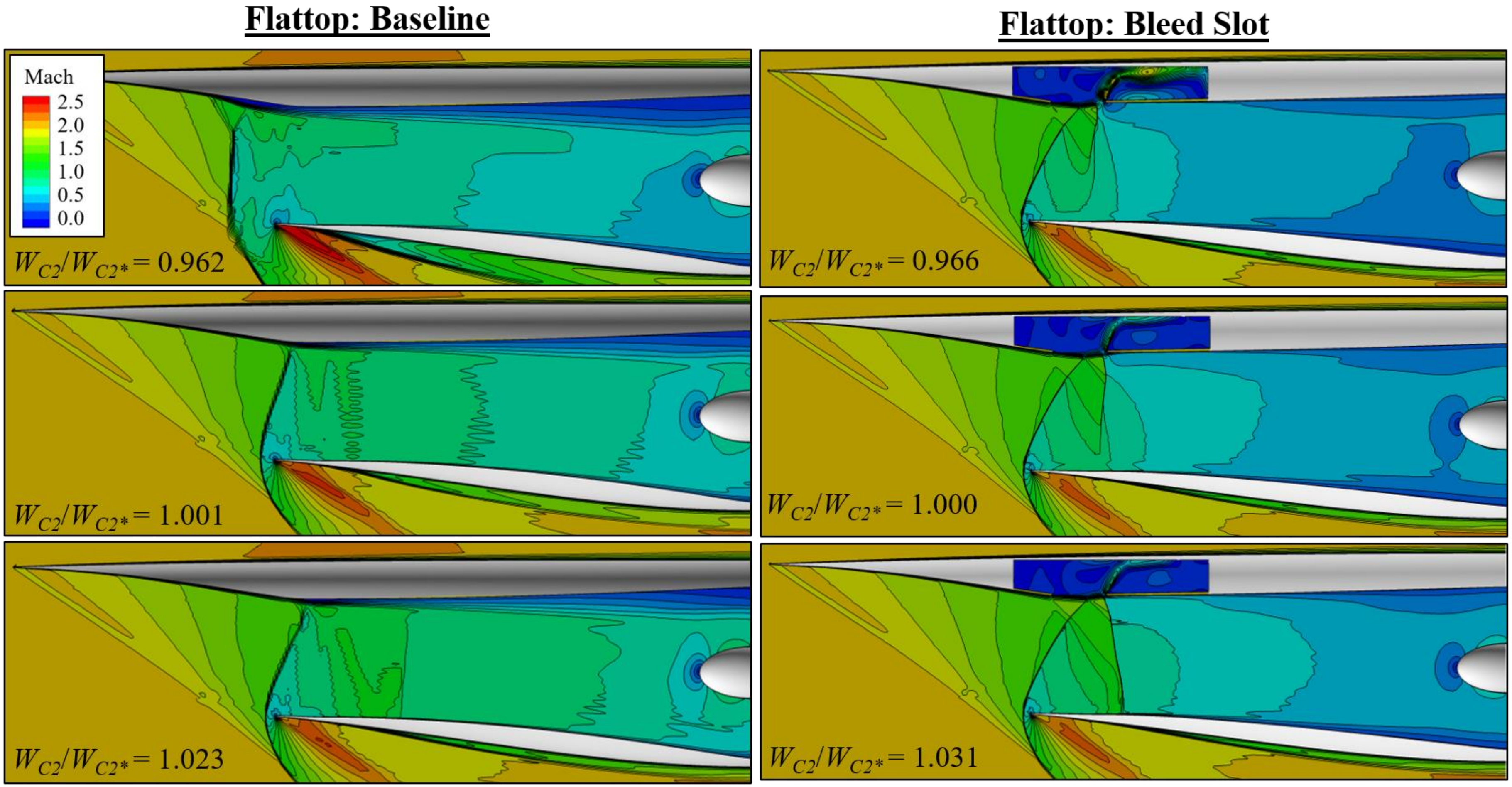
Characteristic Curves for the Inlets





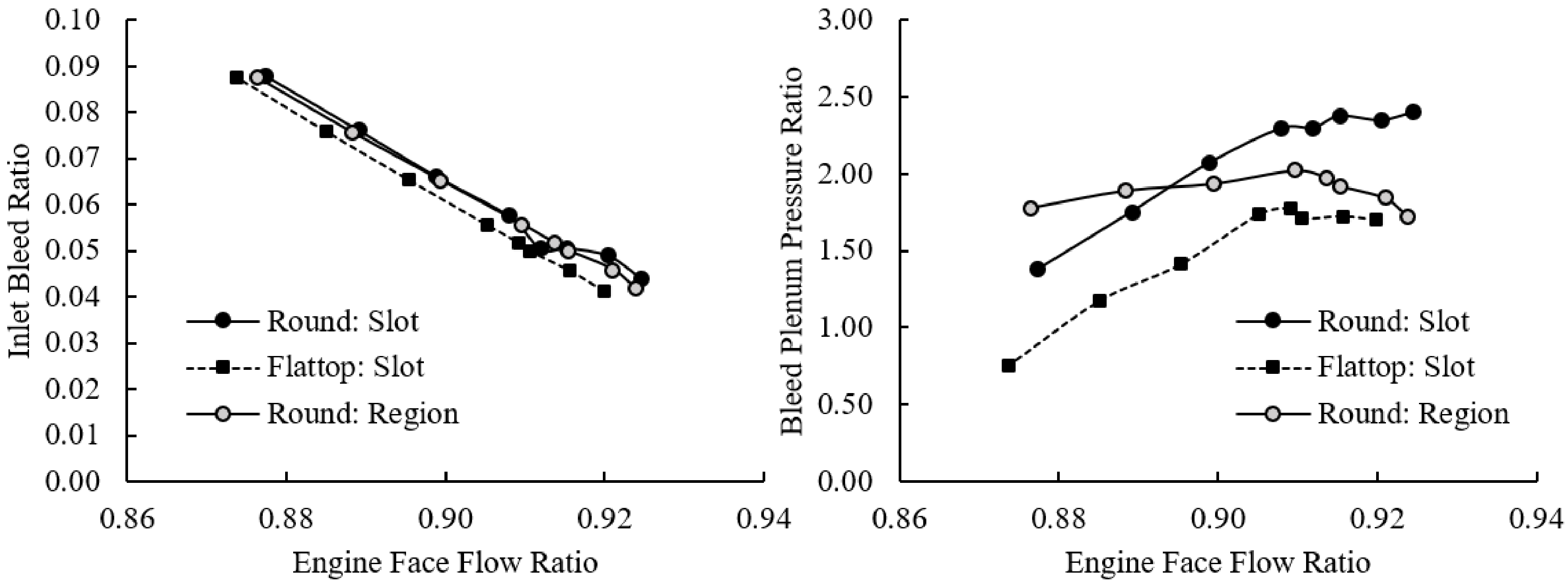
- *Use of 5% bleed provides an 7% increase in total pressure recovery.*
- *Use of bleed keeps the inlet spillage near constant.*

Characteristic Curves for the Inlets



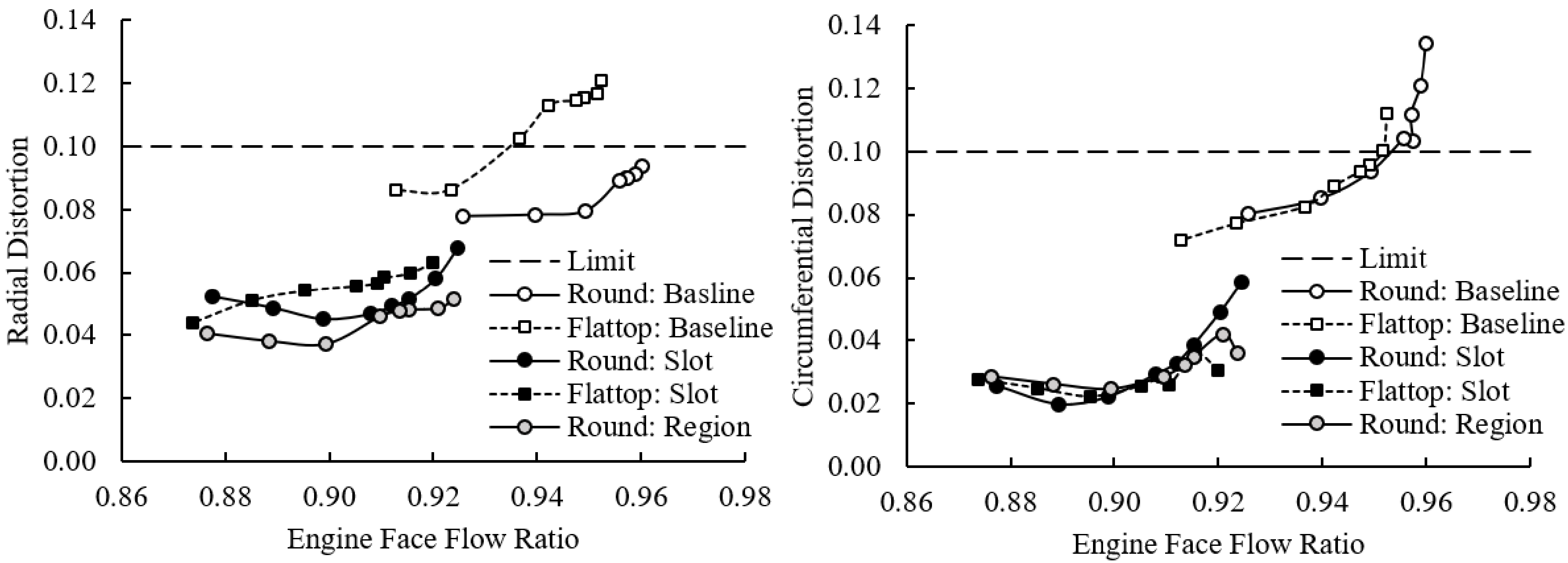
The use of bleed stabilizes the terminal shock position with a change in engine face flow.

Variation of Bleed for the Inlets



Linear variation of bleed may be beneficial for effective control systems.

Distortion Curves for the Inlets



Use of 5% bleed decreases radial and circumferential distortion well below limits.

Summary, Conclusions, and Future Work

- The similar levels of inlet performance for the round and flattop STEX inlets suggest there is flexibility in the shape of the capture cross-section, which may be of an advantage for integration of the inlets with an aircraft.
- The use of a wide bleed slot improved the inlet performance over a STEX inlet without a slot. Total pressure recoveries of 95% with about 5% bleed at the critical operating condition were achieved for the inlets. Further, the total pressure distortion indices were reduced well below acceptable limits.
- The change in bleed flow with the change in the engine flow help stabilize the position of the terminal shock.
- A porous bleed region achieved similar inlet performance than a bleed slot.
- The STEX inlets with a bleed slot suggests acceptable performance for future commercial supersonic aircraft.

Future Work:

- Compare the STEX inlets to axisymmetric and two-dimensional inlets.
- Examine integration of STEX inlets with aircraft and effects on drag and boom.
- Examine the off-design behavior of the STEX inlets with slots, such as at angle-of-attack and lower-speed (e.g., take-off) performance with variable geometry.