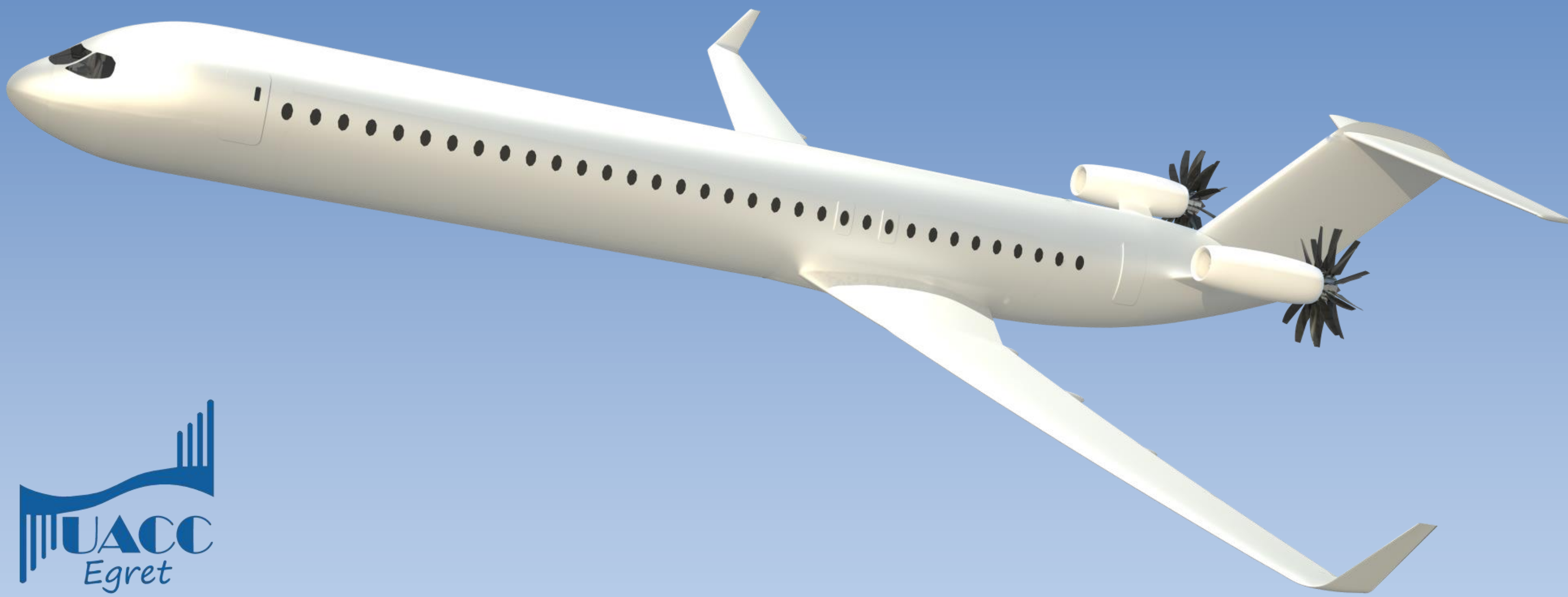
Egret

3rd Place Winner

AIAA Undergraduate Team Aircraft Design Competition



Multi Disciplinary Training for Engineering Students

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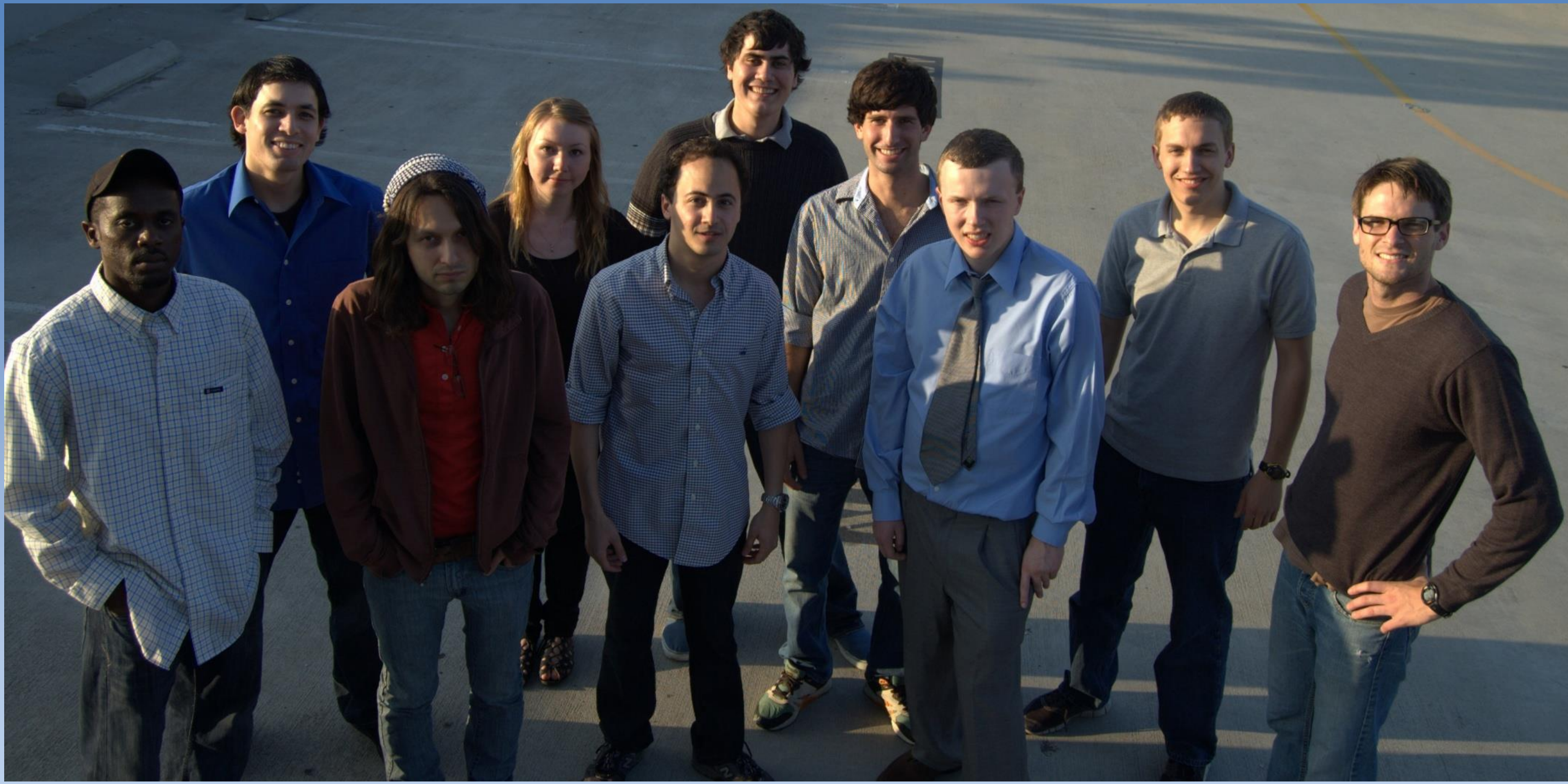
USC's Advanced Commercial Concepts

University of Southern California

USC's Advanced Commercial Concepts



-A team of 10 undergraduate students from various disciplines and college standings

-Training on various subjects pertaining to aircraft design

Requirements

- Reflecting a Boeing 737/ Airbus A320 replacement
- Emphasis on FAR's and Industry Practices

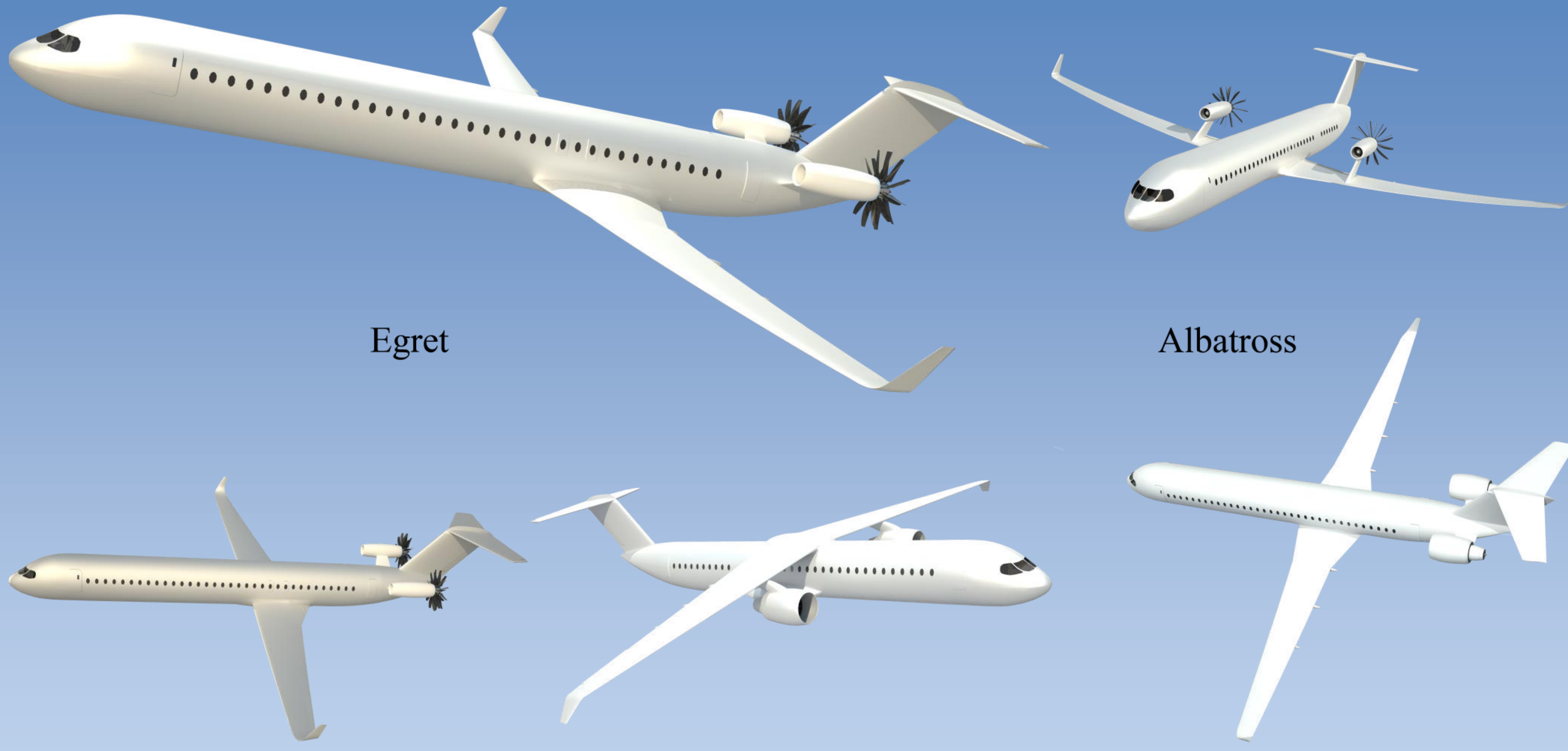
Parameter	Requirement	Egret
FAR		
§ 25.810 & § 25.117 Emergency Egress	Emergency door sizing	Satisfied
§ 25.903 Blade Loss	1/20 Rule Angular Blade Clearance	Satisfied
§ 25.121 Climb Performance	1.2%	1.9%
§ 25.111 OEI Climb Gradient	1.2%	1.9%
§ 25.105 Take-Off Climb	2.4%	2.8%
§ 25.335 Gust Loading	50 *ft./sec.* max	50 *ft./sec.* max
§ 25.925 Propeller Clearance	7 *in.* above the ground	Satisfied

Parameter	Requirement	Egret
RFP		
Take-Off Distance	8,200 *ft.*	7,323 *ft.*
Landing Speed	< 140 KCAS	138 KCAS
Cruise Speed	Mach 0.8	Mach 0.81
Max Operating Speed	Mach 0.83/ 340 KCAS	Mach 0.83/ 340 KCAS
Initial Cruise Altitude	>35,000 *ft.*	39,000 *ft.*
Max Cruise Altitude	>41,000 *ft.*	42,000 *ft.*
Max Range	3,500 *nm*	3,500 *nm.*
Nominal Range	1,200 *nm.*	1,200 *nm.*
Payload Capability	37,000 *lbs.*	37,000 *lbs.*
Alternative Fuel Capabilities	Compatible	HRJ related algae based biofuel
Passengers	~175	174
Cargo Volume	1,240 $ft.^3$	1,410 $ft.^3$
Materials	Composites 787	Carbon laminated composites
Cruise L/D	18.2 +25%(737-800) (used as baseline)	23.8 (18.2 +31 %)

Technology Level

- Goals:
  - -Reduce Fuel Burn (DOC↓)
  - -Reduce Emissions (DOC↓)
  - -Reduce Noise (Market↑)
- Modern Configuration Concepts:
  - *Natural Laminar Flow Wing Planforms*
  - *Laminar Flow Forebody*
- Modern Propulsion:
  - *Geared Turbofan Engines*
  - *Open Fan Engines*
- Modern Subsystem Architecture:
  - *Bleedless Architecture*
  - *Fully Electric Architecture*
- ***Achieved: -30 % TSFC, +30% L/D***
  -40% DOC ($2020)

Design Family



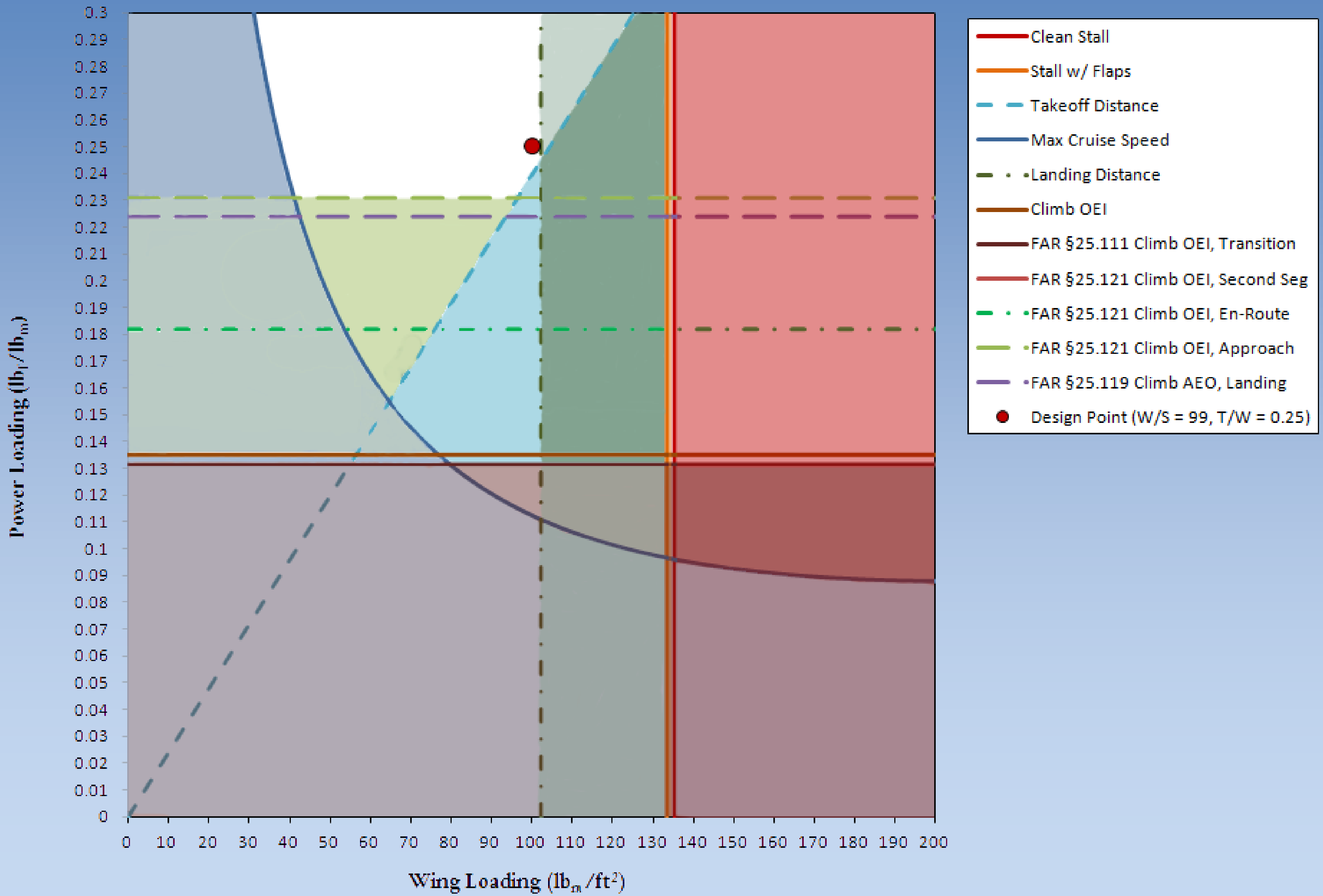
Egret Albatross

Ibis Levant Waxwing

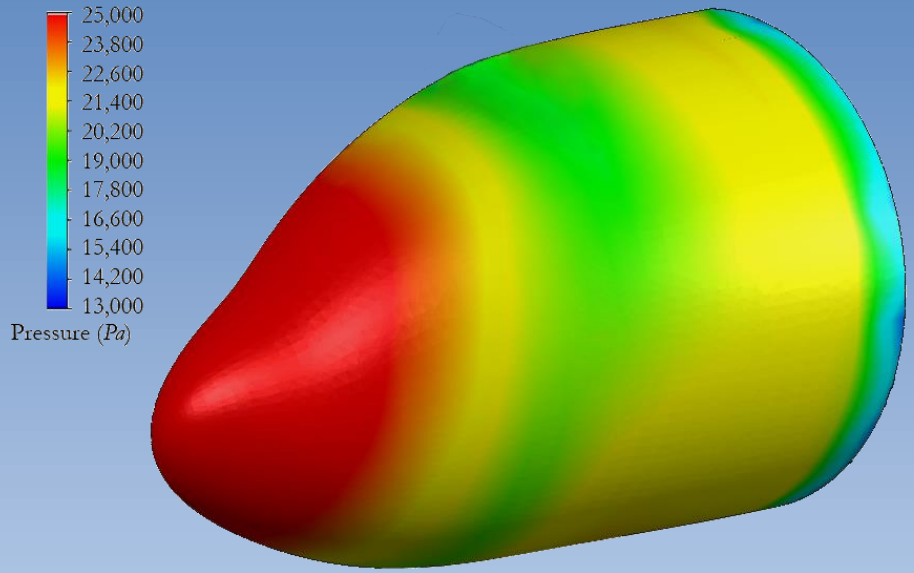
Concepts that could not be analyzed in a preliminary level (e.g. strut braced wings …) were not considered.

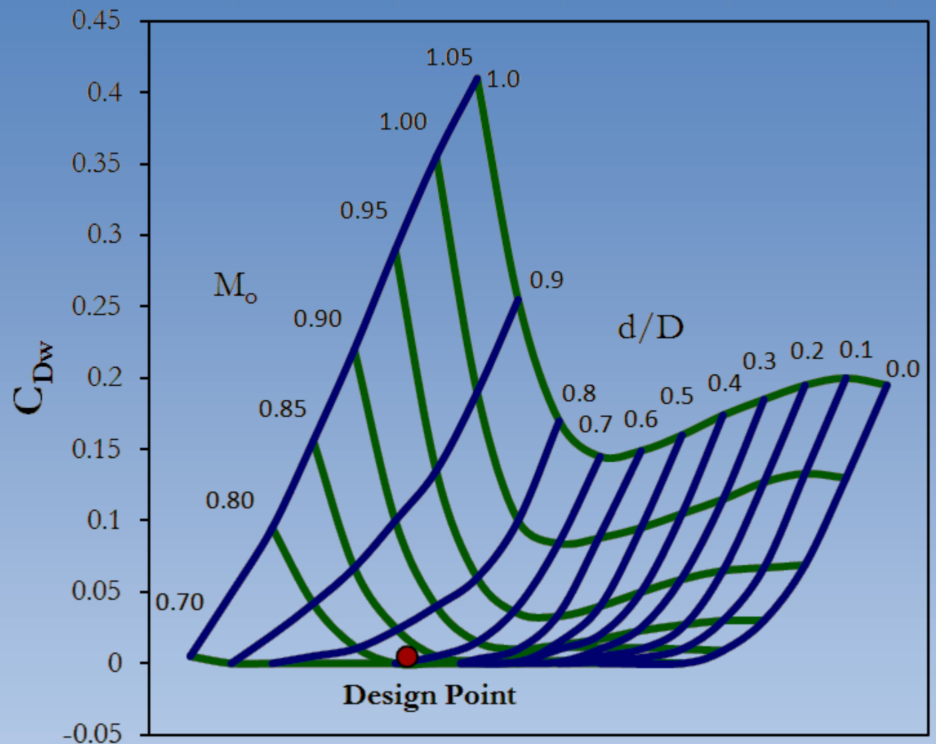
Performance Sizing

-Roskam's method used to size to RFP & FARs.



Forebody Optimization

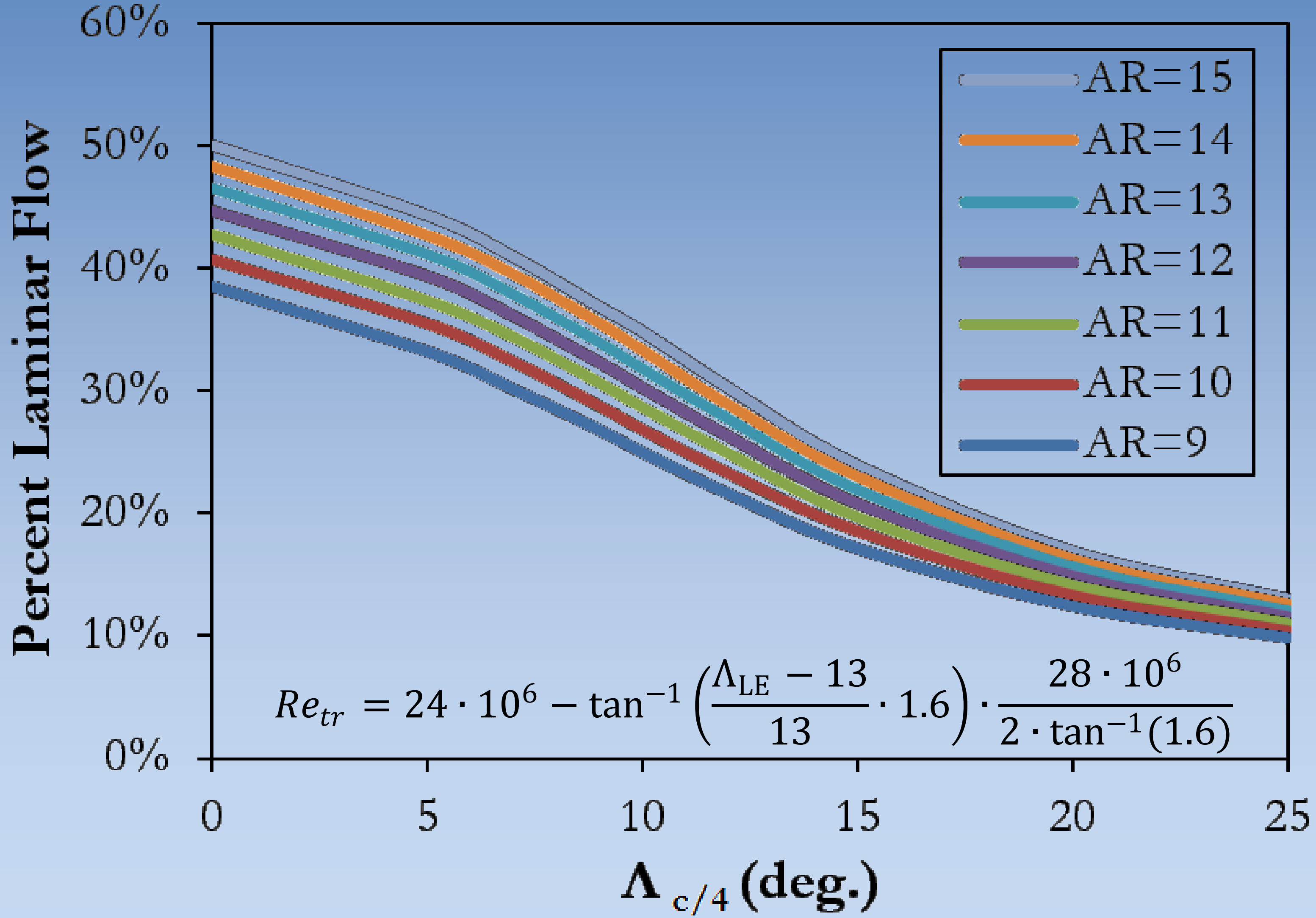




-To Minimize Wave & Pressure Drag, and Increase the extent of NLF, CFD and ESDU methods were adopted in design.

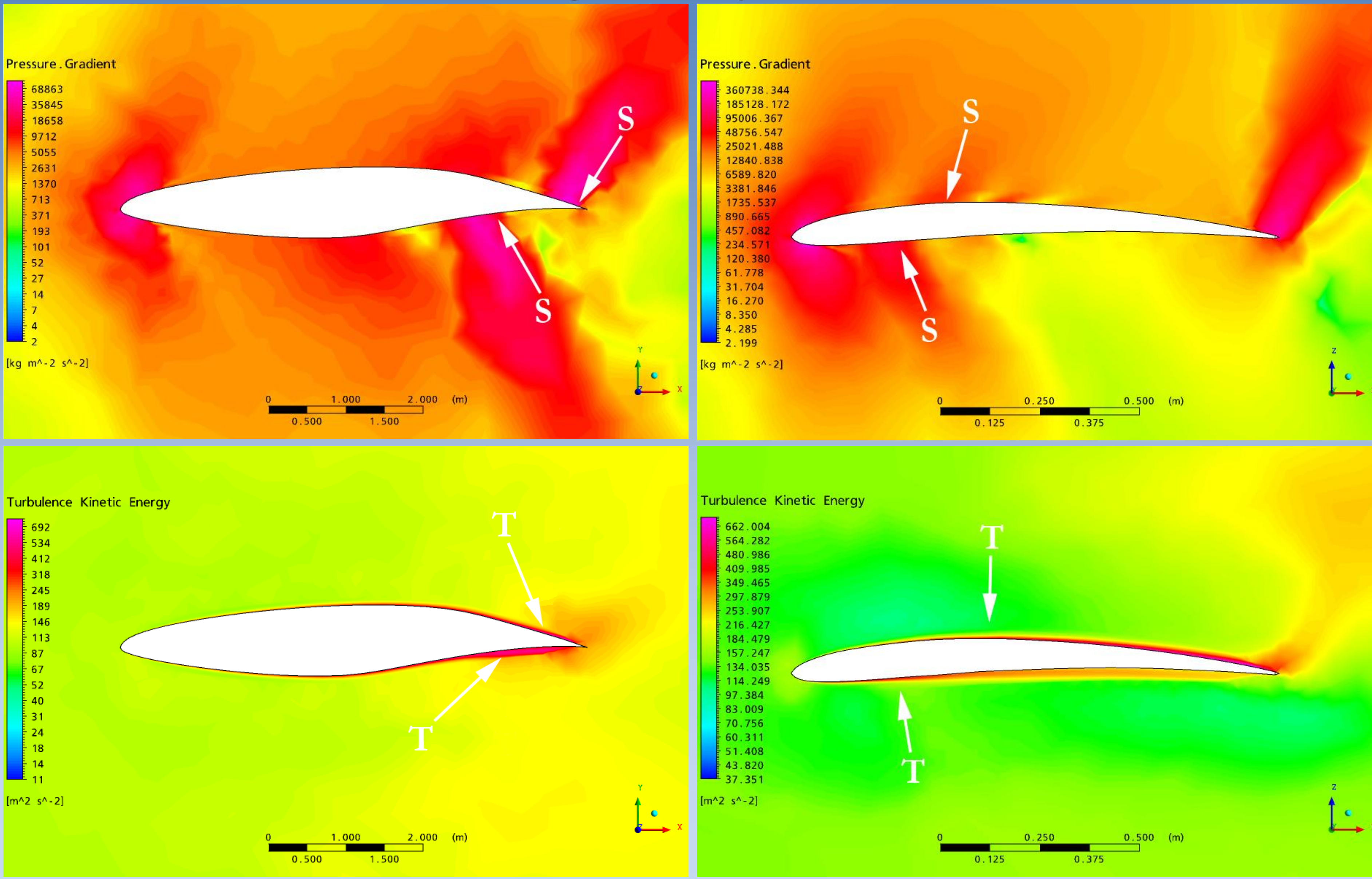
Integration of Natural Laminar Flow

Predicting transition to turbulence



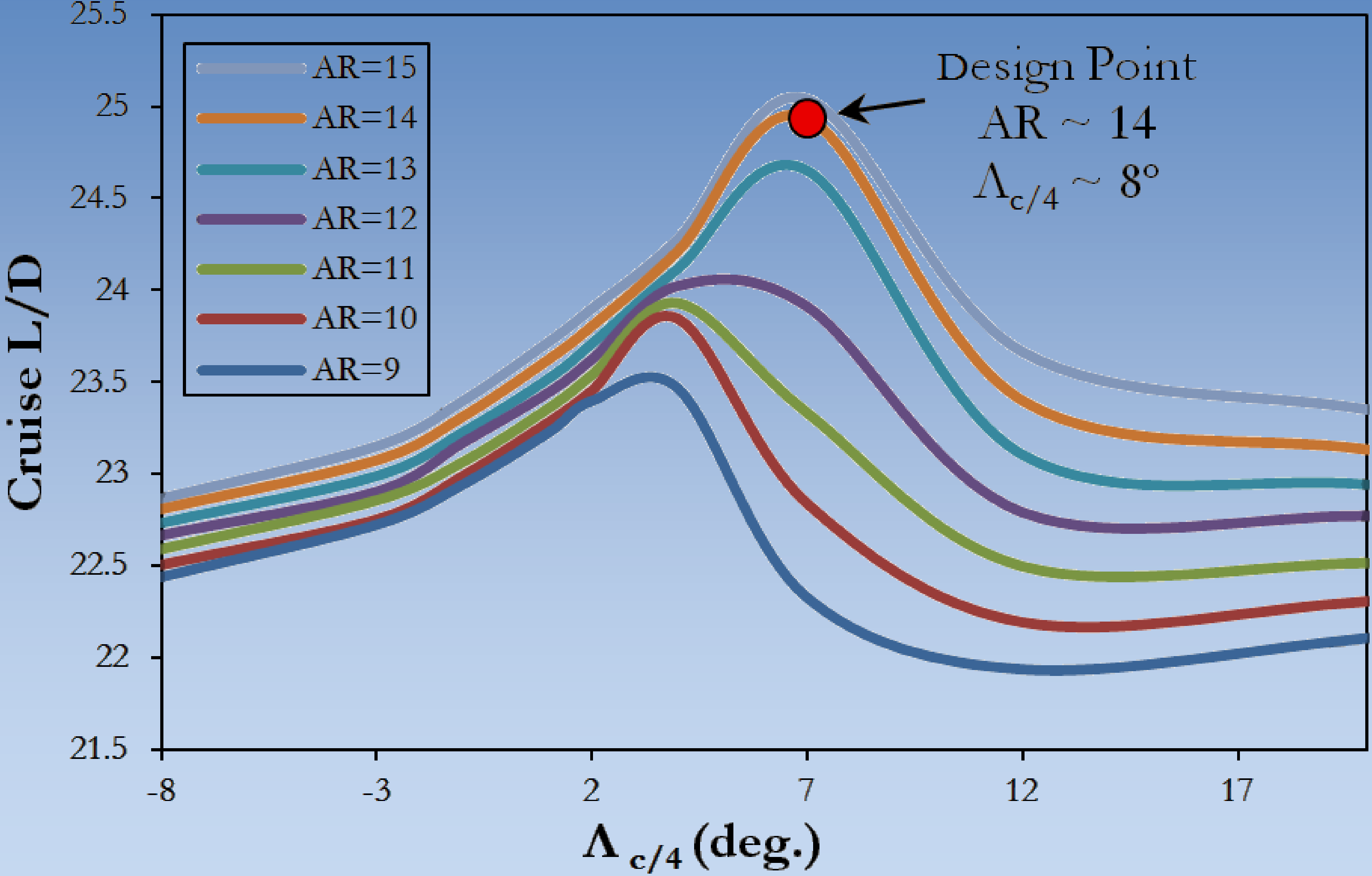
Integration of Natural Laminar Flow

Custom Airfoil Design & Optimization



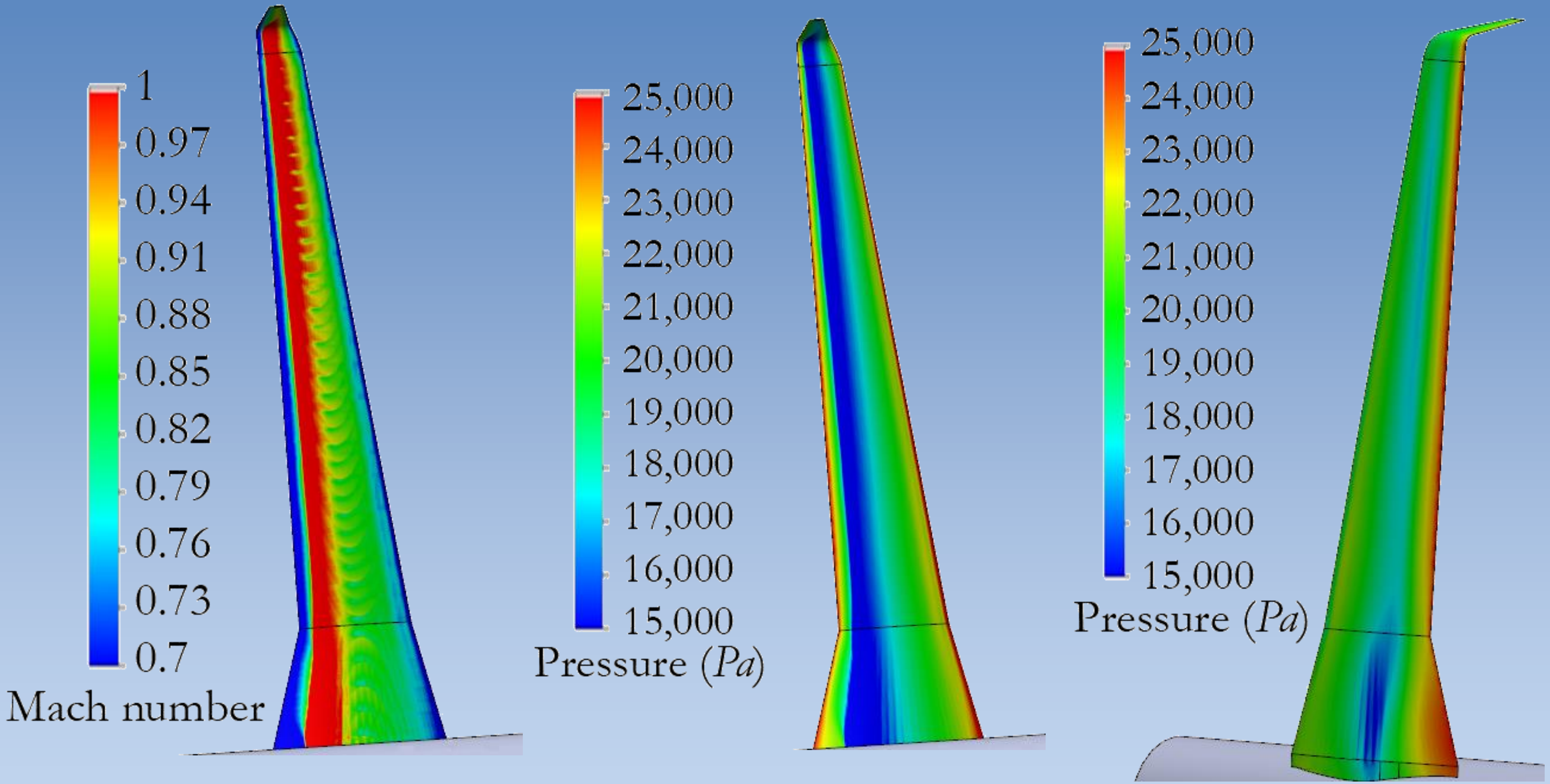
Integration of Natural Laminar Flow

Wing Planform: Trading wave drag for NLF



Integration of Natural Laminar Flow

Numerical Verification using COSMOS CFD

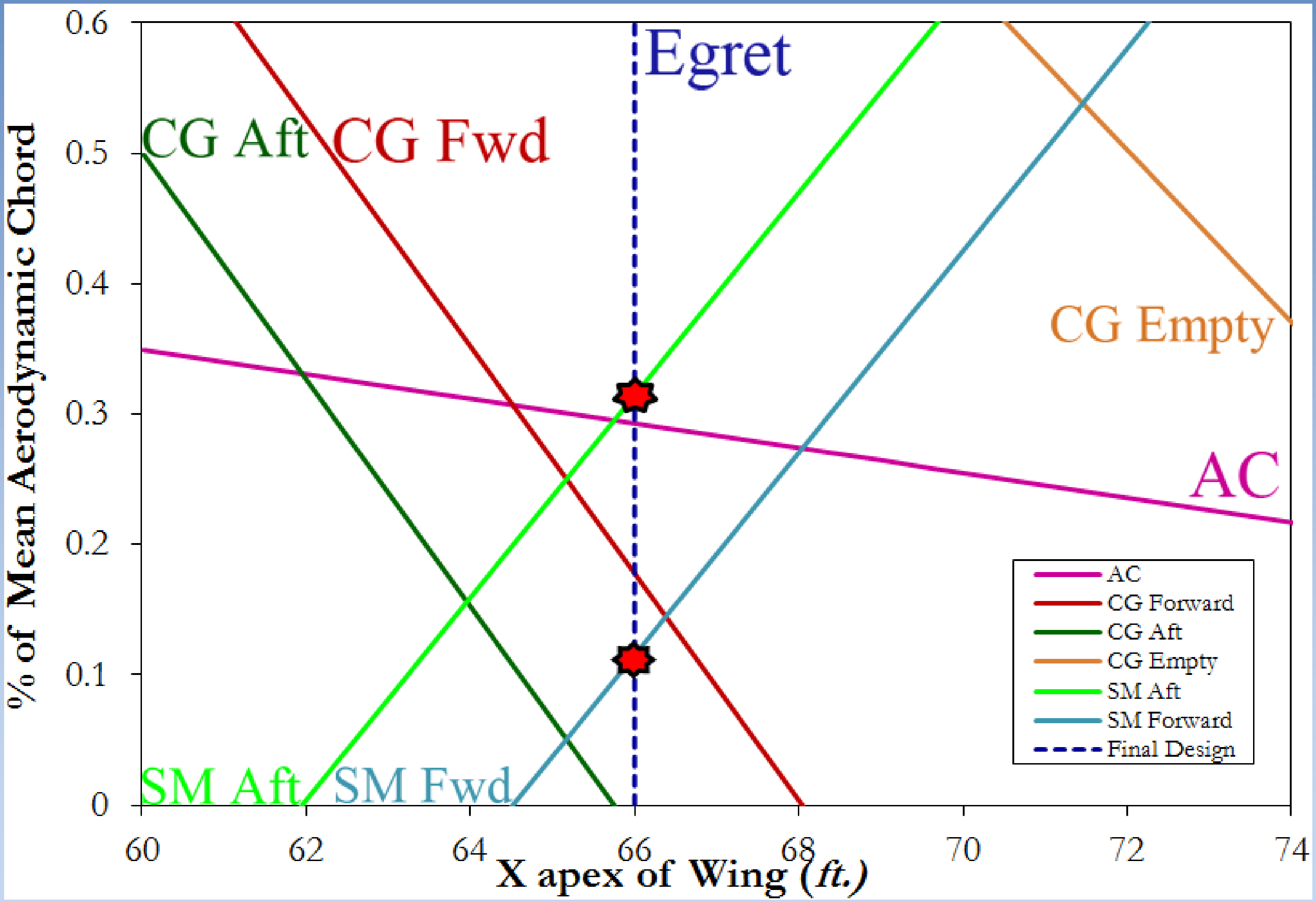


-Favorable Pressure Gradient Maintained, Shock delayed.

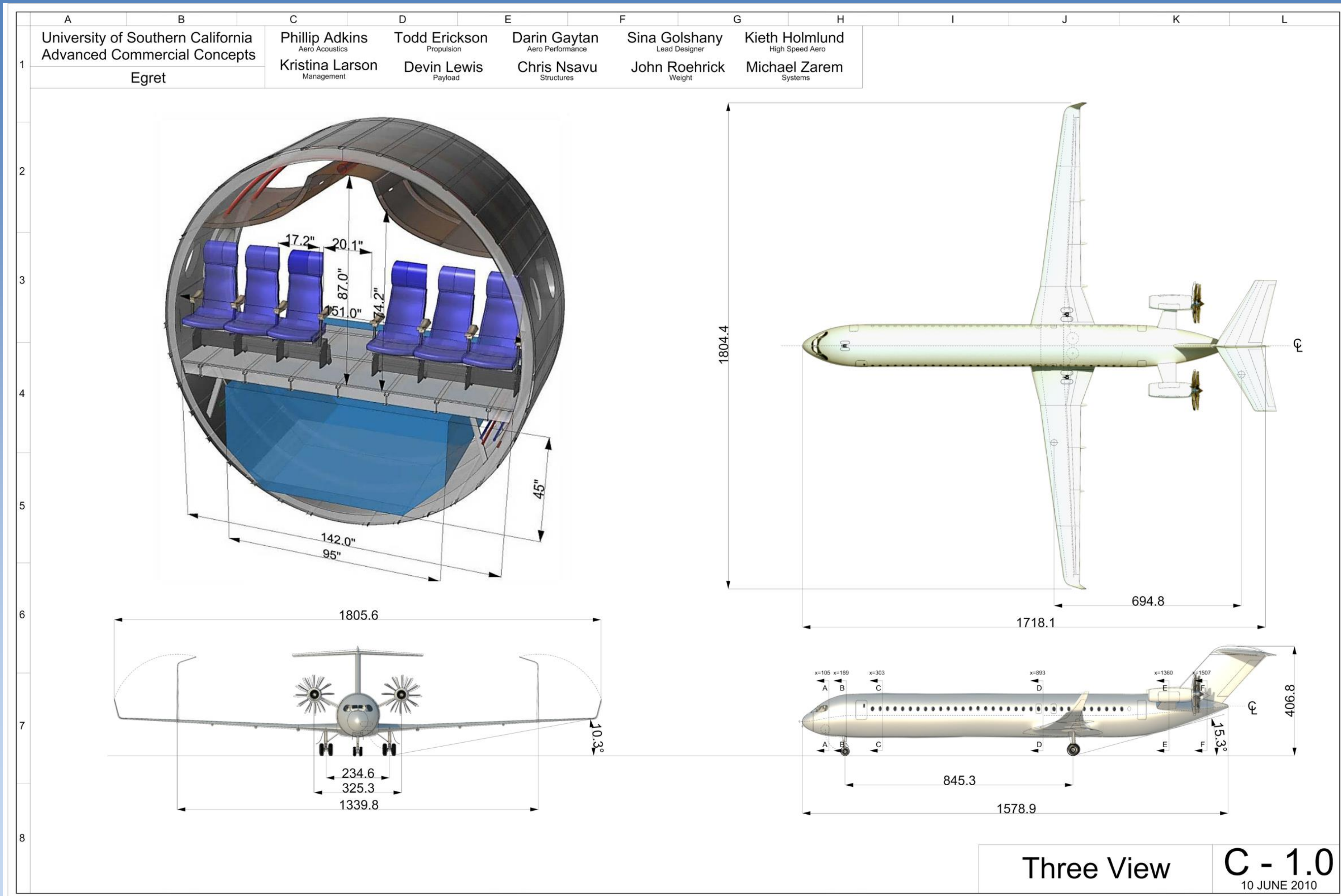
Balance & Wing Location

-Particularly aft ward wing apex to maintain proper SM.

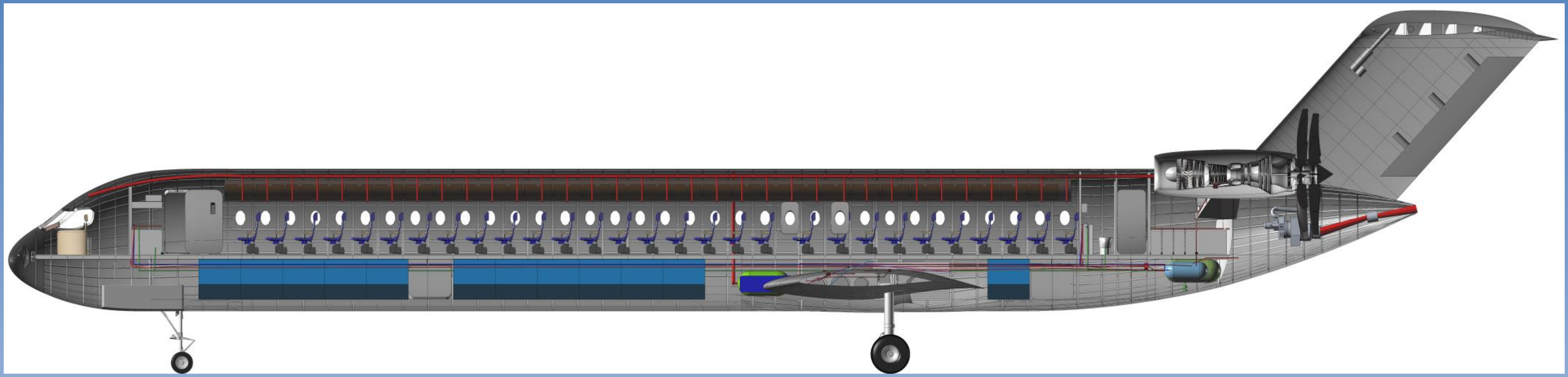
-Heavy open fan engines are not very suited for aft-mounting.

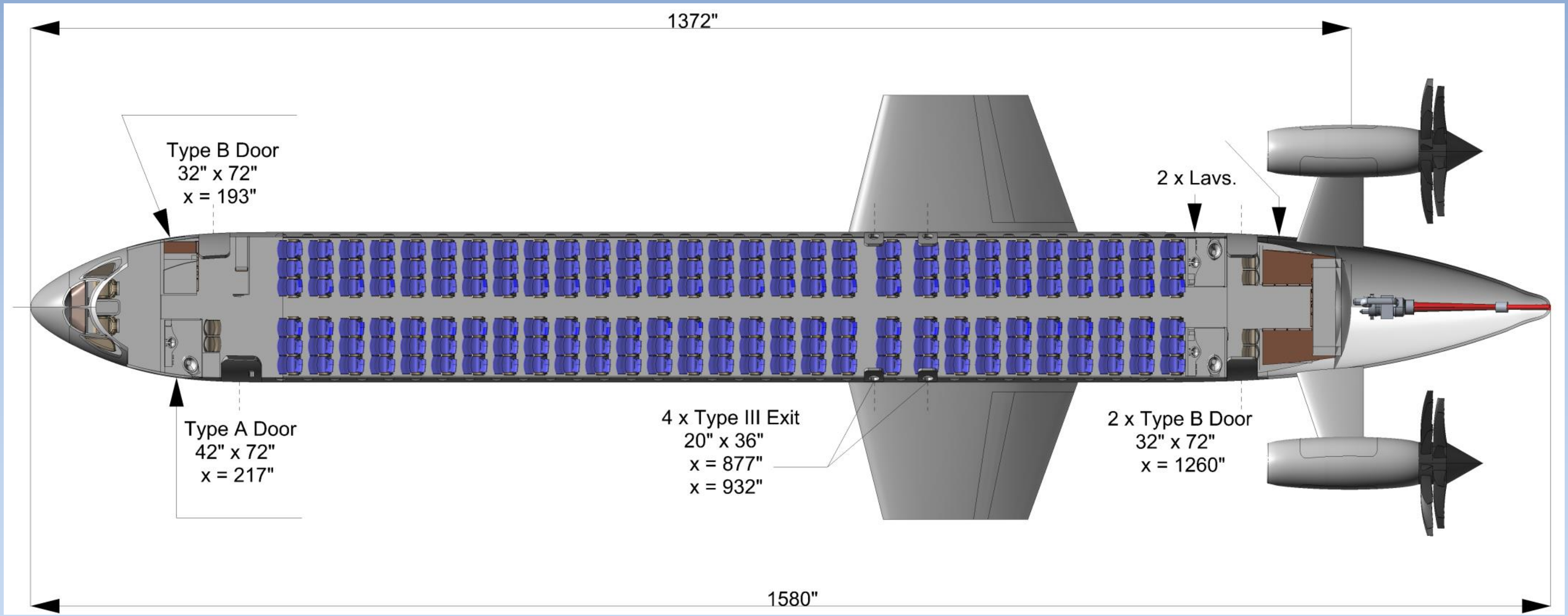


Configuration



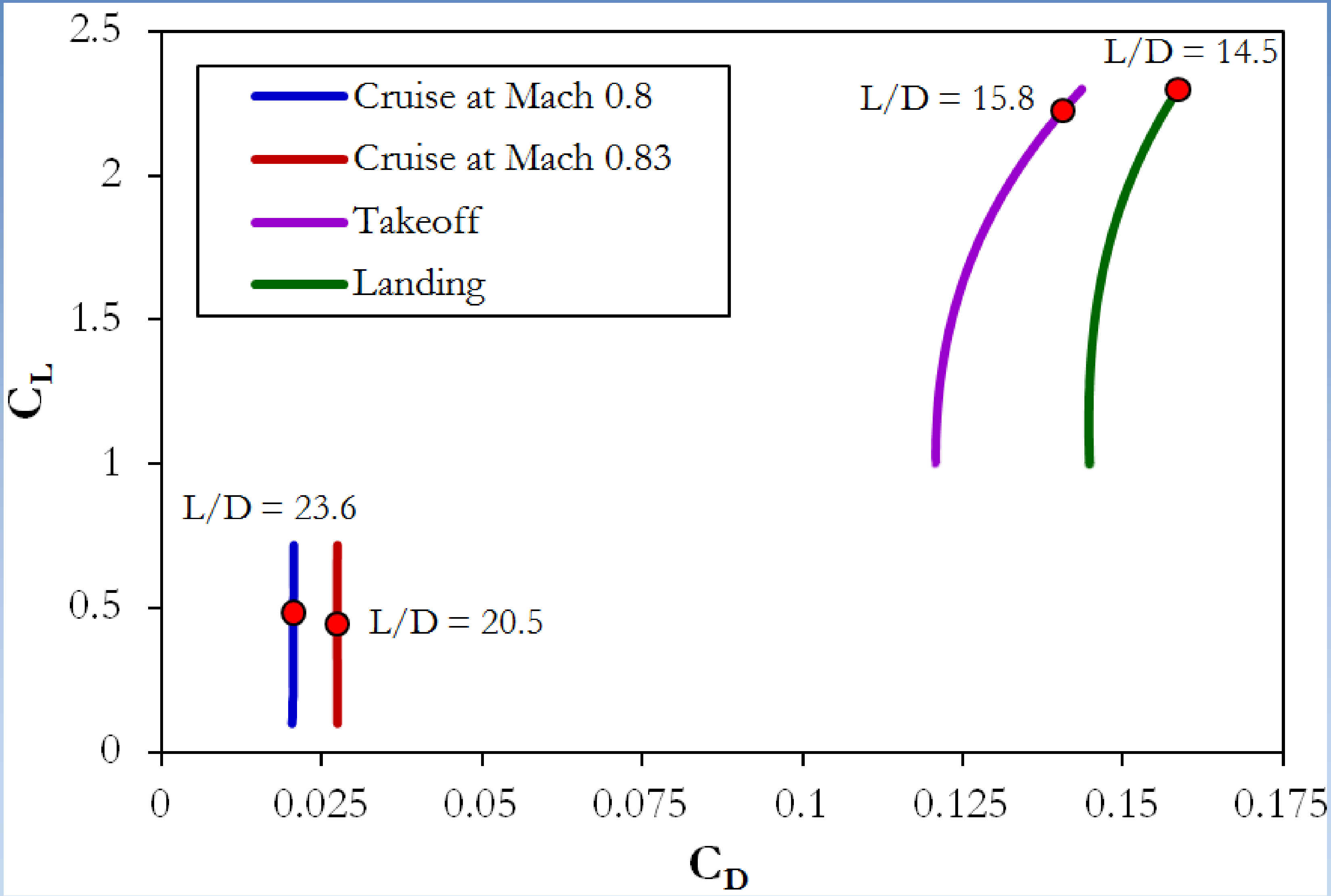
Inboard Profile/Interior Arrangement





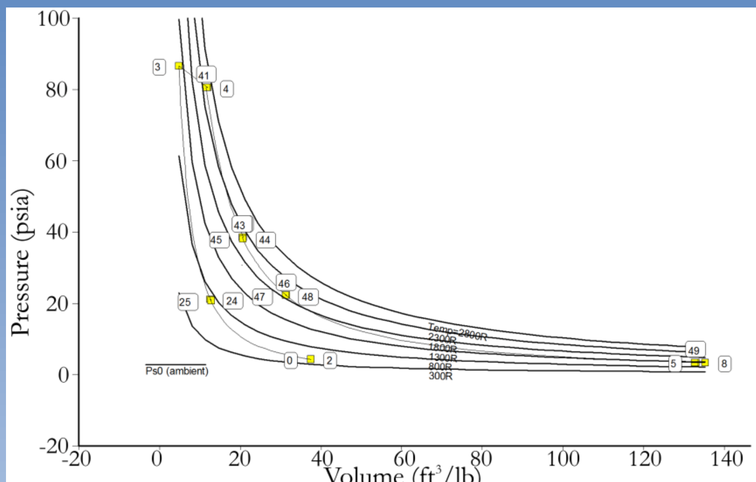
Detailed Drag Analysis

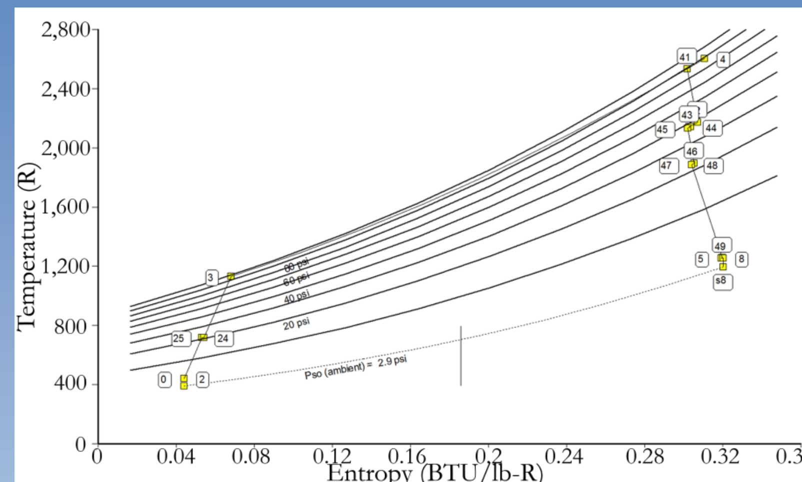
-ESDU Methods are used to verify aerodynamic performance

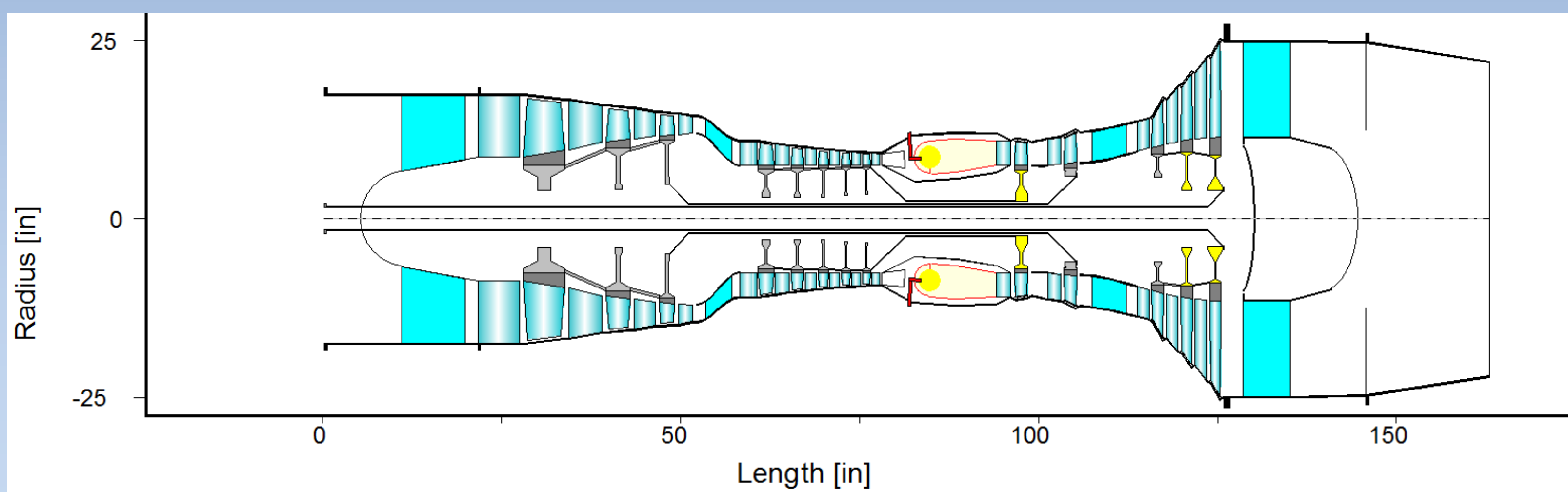


Propulsion

- Cycle analysis and preliminary engine configuration using GasTurb
-3-spool open fan core was developed and optimized using GasTurb software.

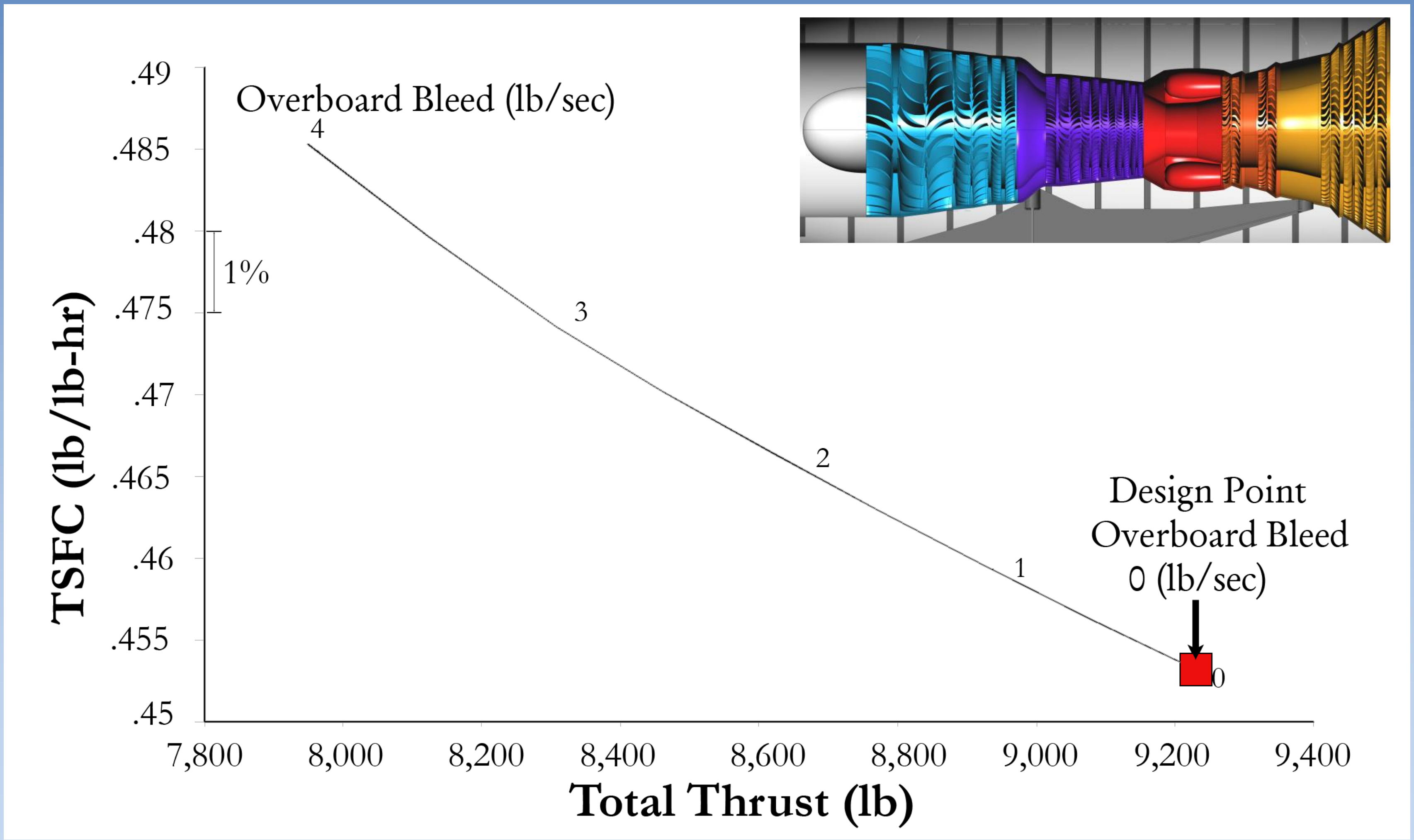






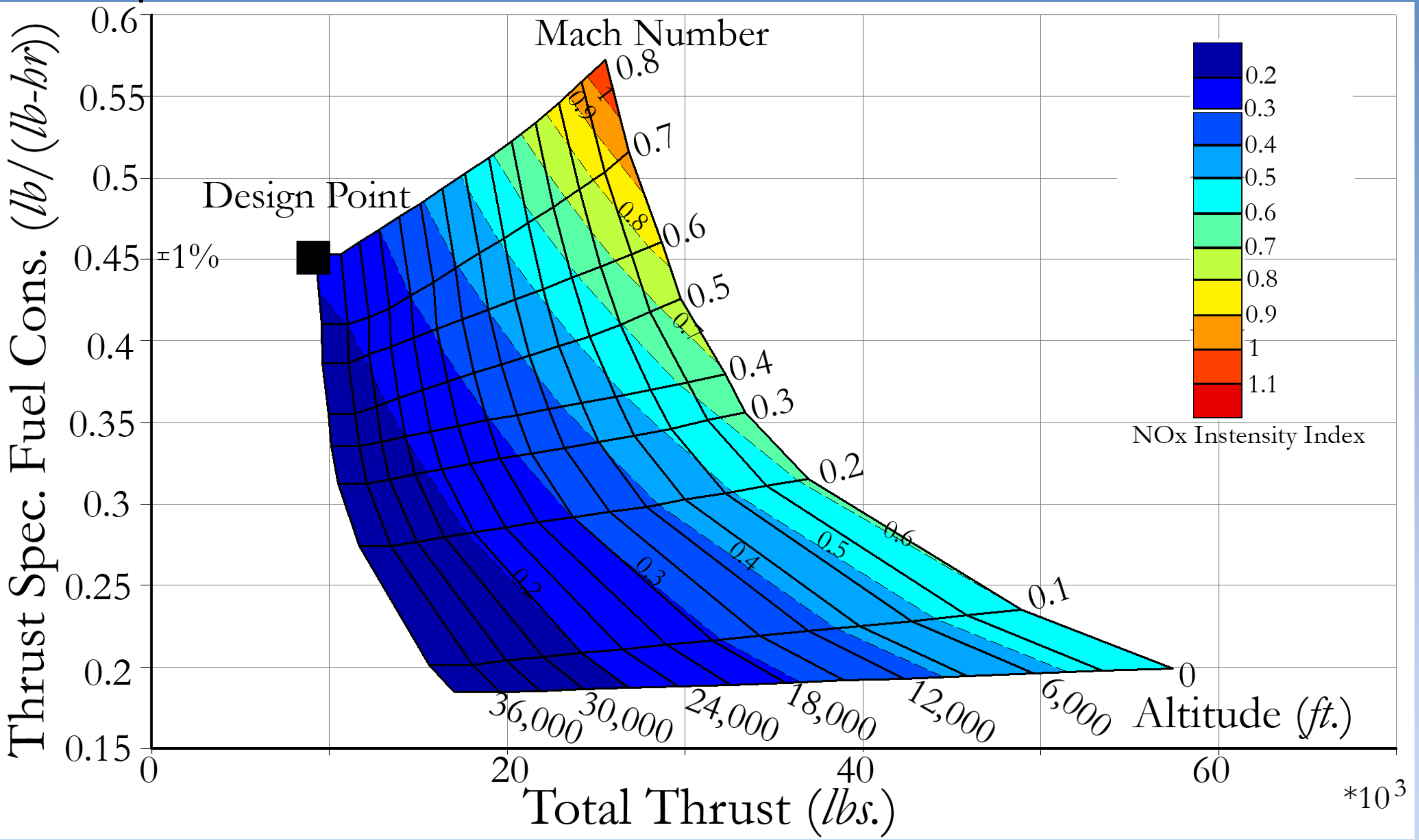
Propulsion

- Bleedless system architecture trade-offs:
- Substantial TSFC improvement observed for a small core high BPR engine.
- Bleedless architecture was chosen

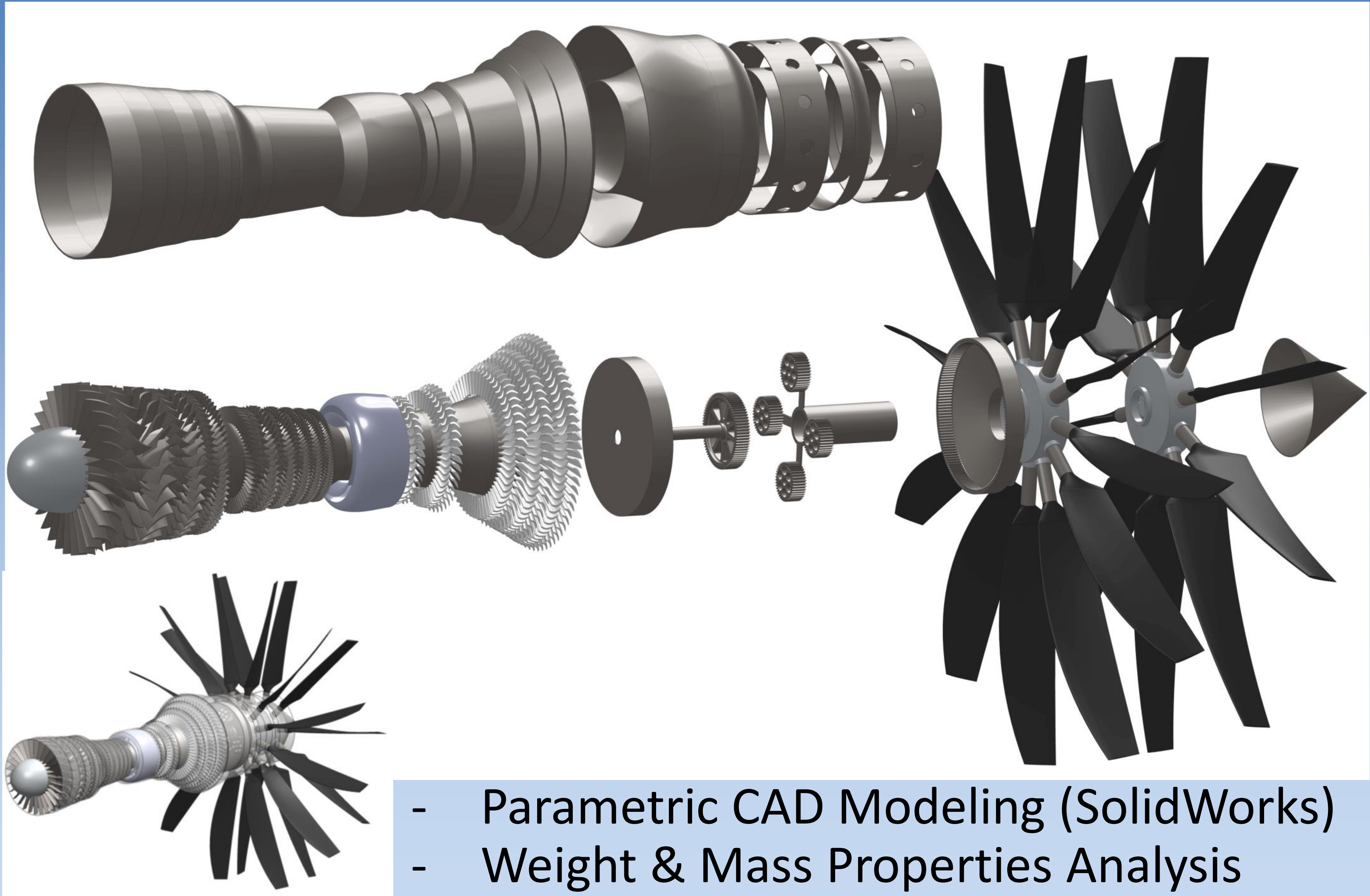


Propulsion: Engine Performance

- GasTurb was utilized
- Nox Intensity Index selected as a measure of environmental impact



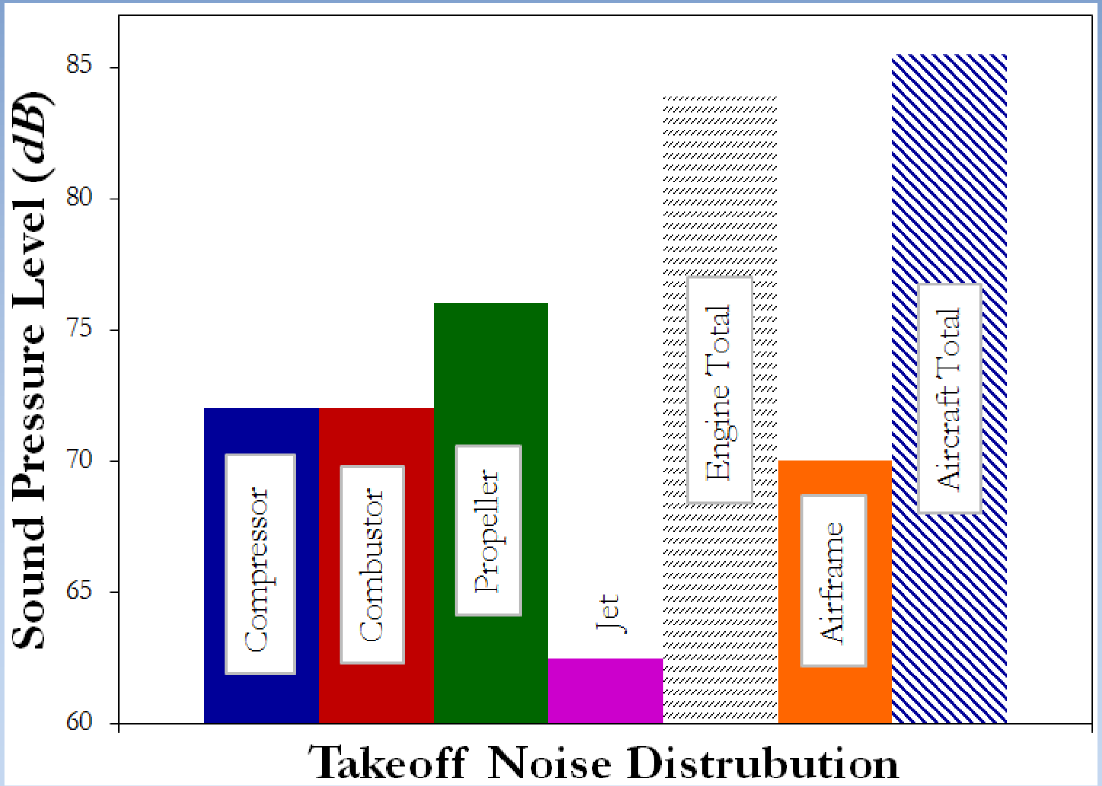
Propulsion



- Parametric CAD Modeling (SolidWorks)
- Weight & Mass Properties Analysis

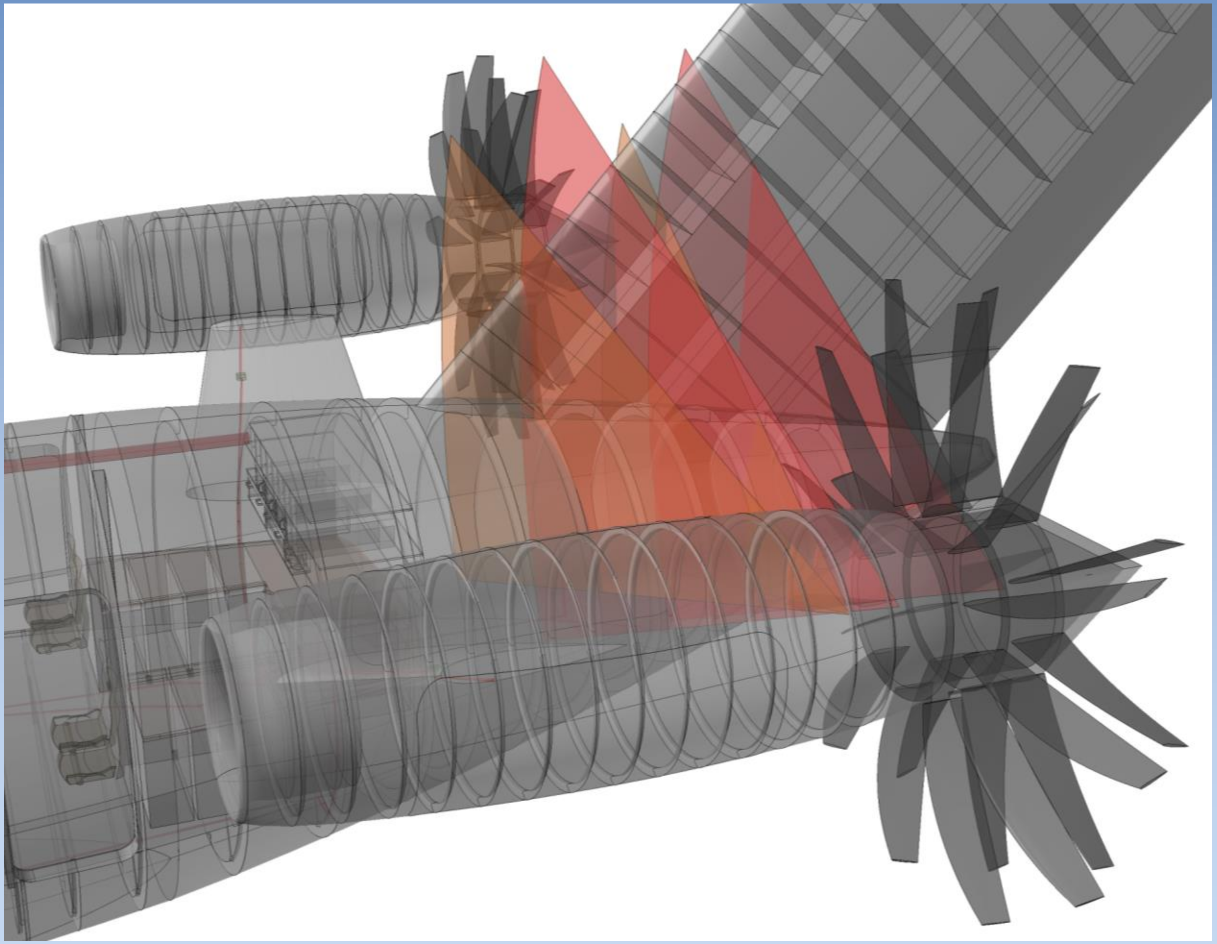
Noise

- Critical In case of an open fan engines.
- Numerical methods were developed per *Hanson* & ESDU items.
- Blade row interaction noise is determined to be the major source of open fan noise.
- Front rotor disengagement can cause substantial noise reduction
- 13 dB cumulative reduction has been observed from ICAO –Ch. 4.

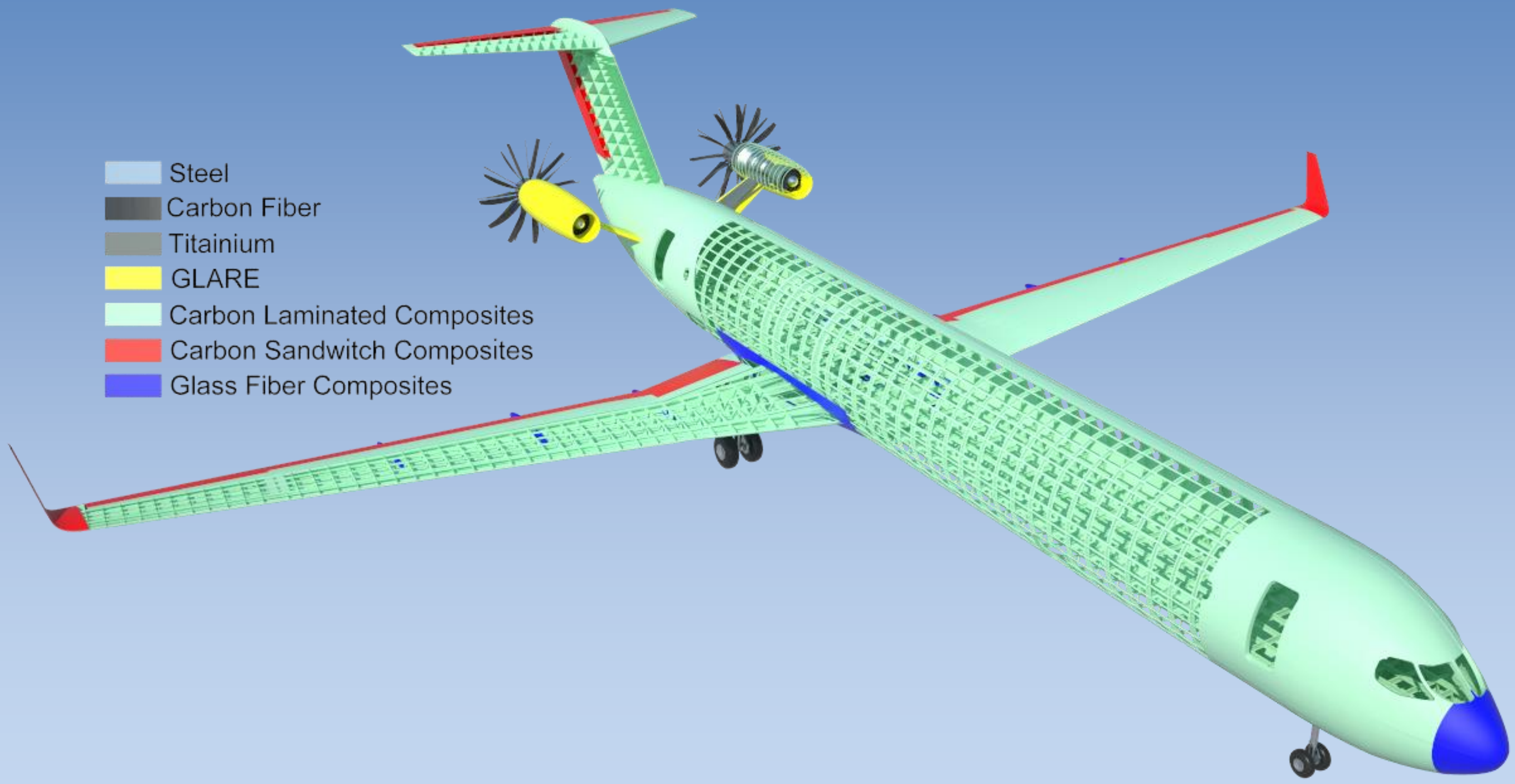


Blade Loss

- Critical In case of an open fan engines
- Appropriate clearances are maintained per FAR §25.903



Materials Selection

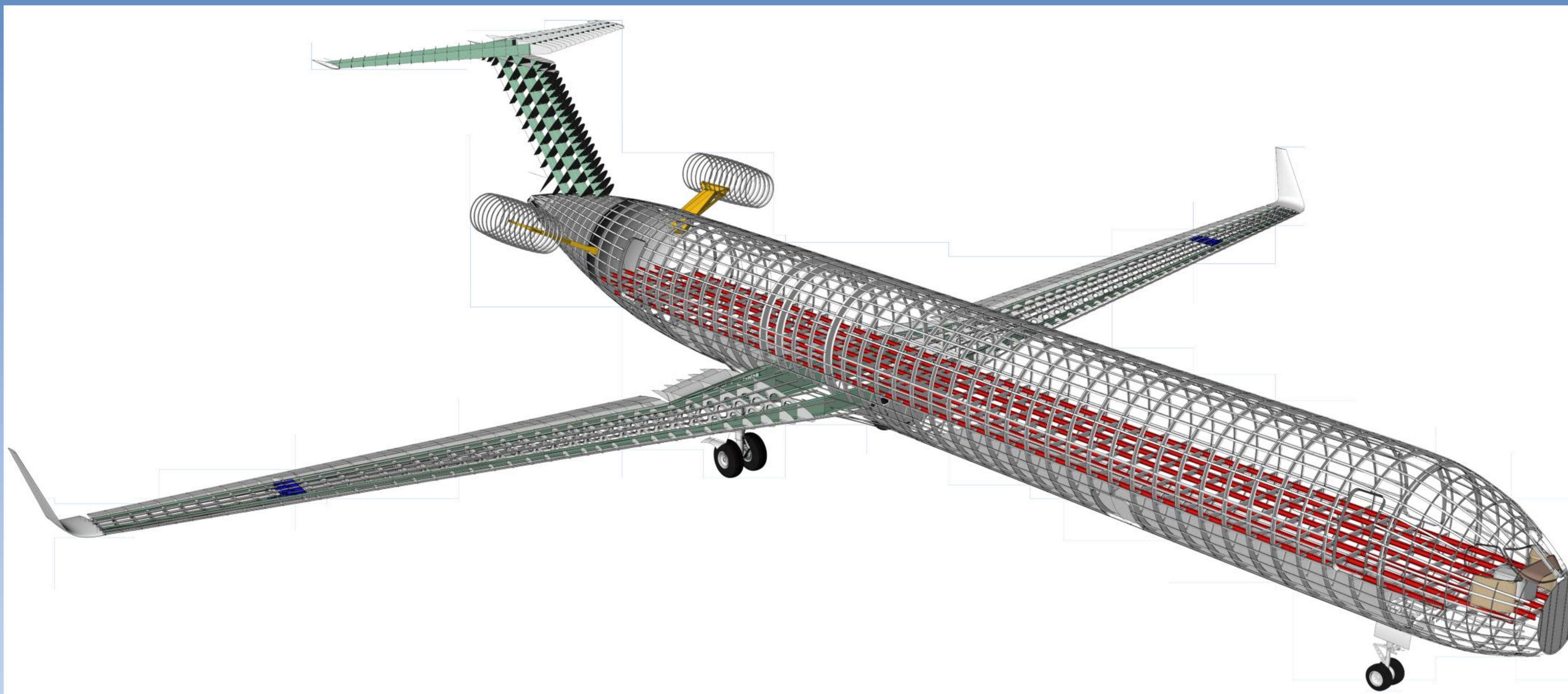


Conclusion

- Design contest provide great motivation for learning and application of engineering to real world problems in an academic setting.
- Future challenging rivalries in commercial aerospace will demand more capable, flexible and better trained engineers.
- Improving contests, advertisements and increasing the awards (FYI Contest) may be the most effective way to rapidly adopt such changes.
- Industry involvement in school curriculum development may be the solution for the long term.

Thank You !

Additional Slide – Structural Isometric

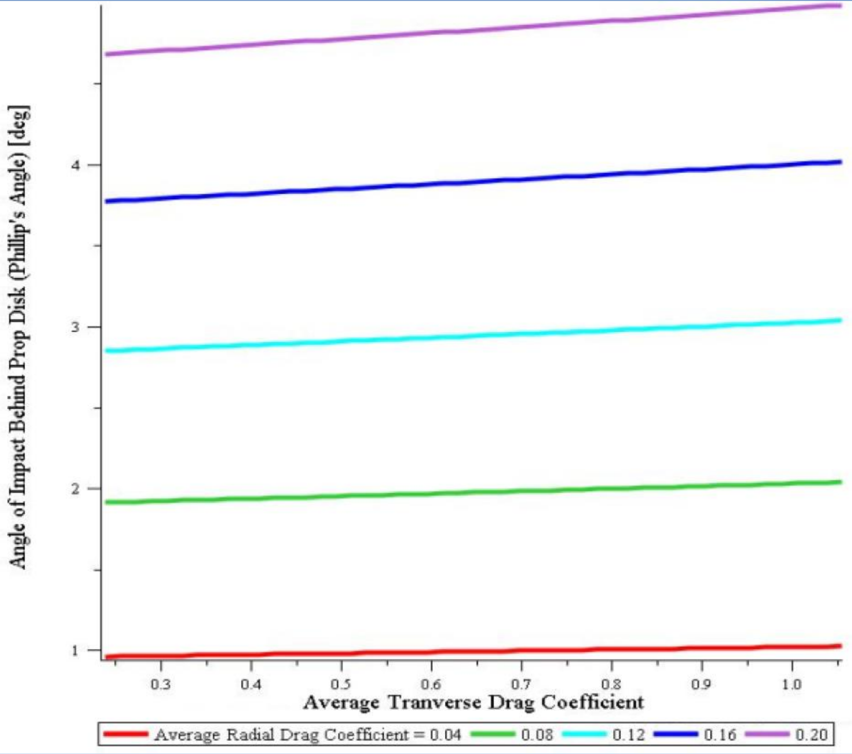


Additional Slides – Folding Wings

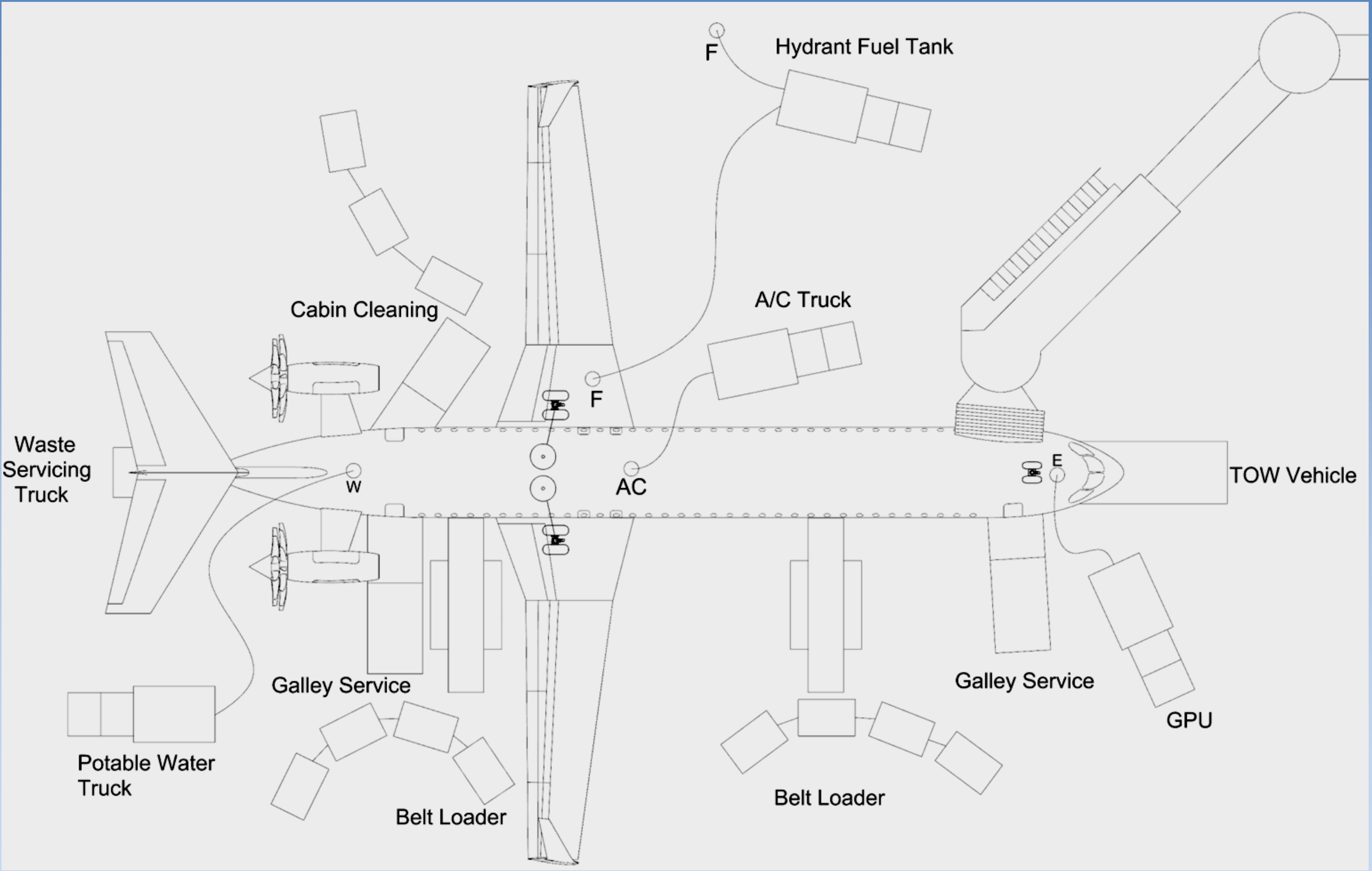
Blade Loss

- Physics based modeling to study the blade loss dynamics
- Clearance values are confirmed analytically

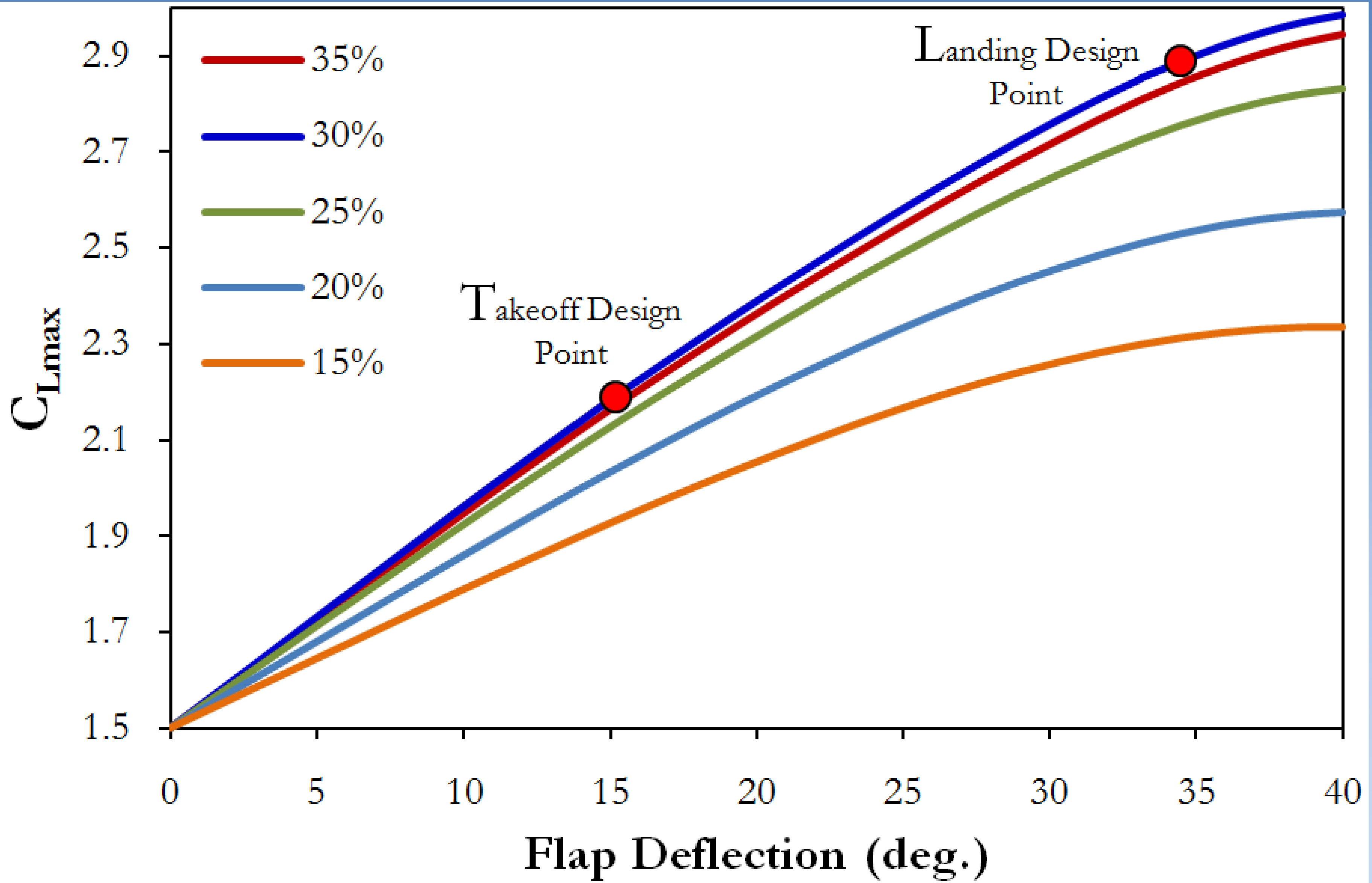
$$\Omega = \arctan\left(\frac{m_b}{P_2 D_p} \ln\left(\frac{P_2 v_{0,plane}}{P_1 v_{0,prop}} \left(e^{\frac{P_1 D_p}{m_b}} - 1 \right) + 1 \right) - \frac{m_b v_{0,plane}}{P_1 D_p v_{0,prop}} \left(e^{\frac{P_1 D_p}{m_b}} - 1 \right) \right)$$



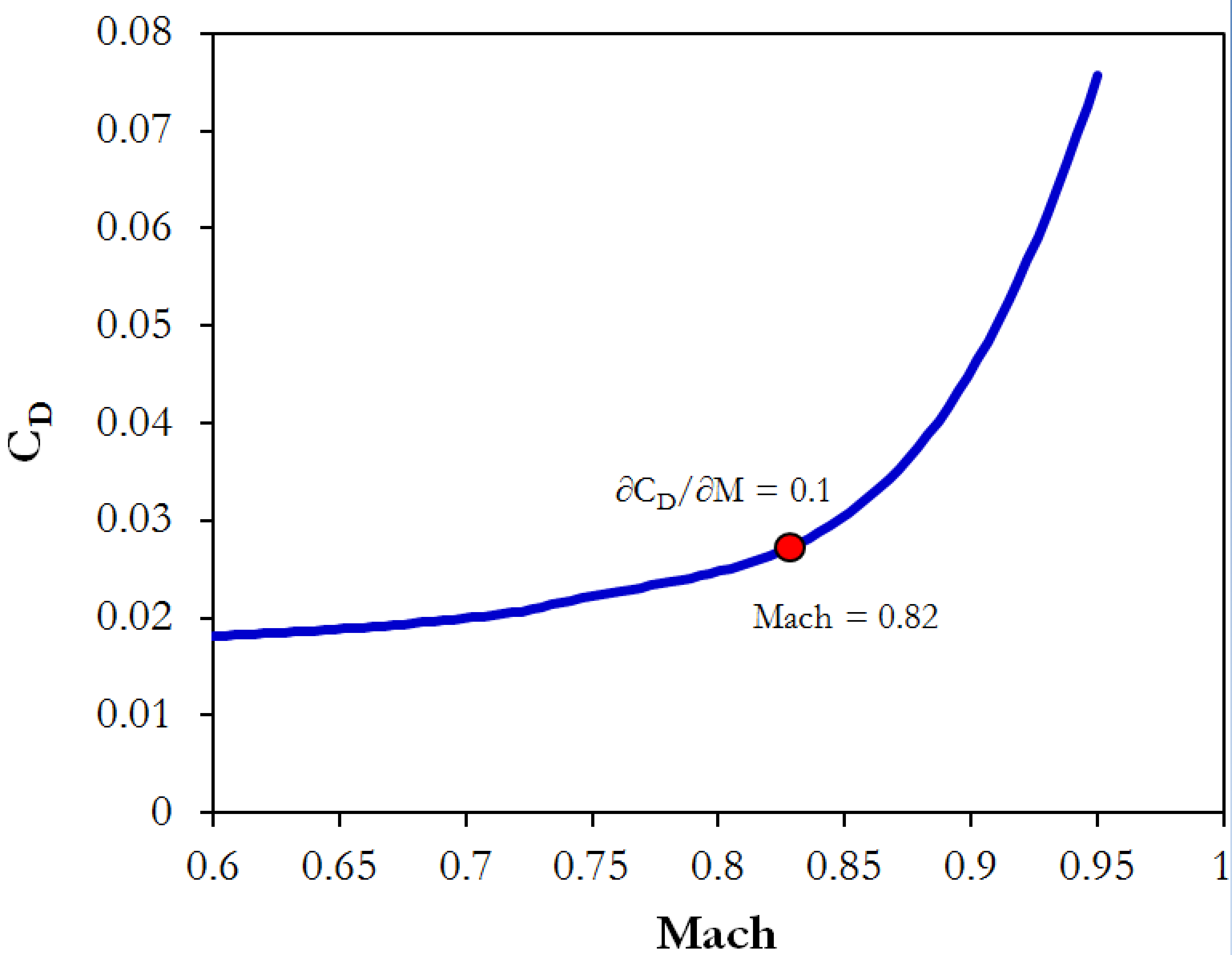
Additional Slides – Ground Operations



Additional Slides – Flap Sizing



Additional Slides – Drag Rise



Additional Slides – Tire Spray