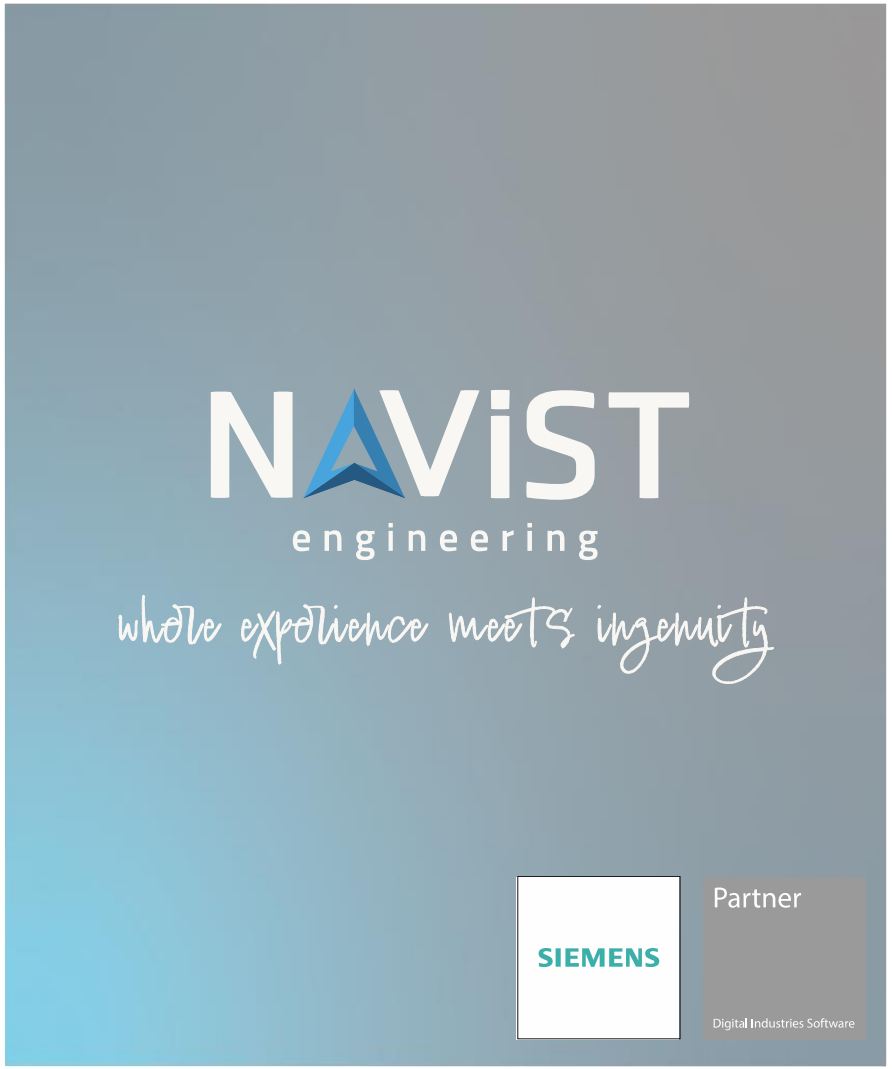
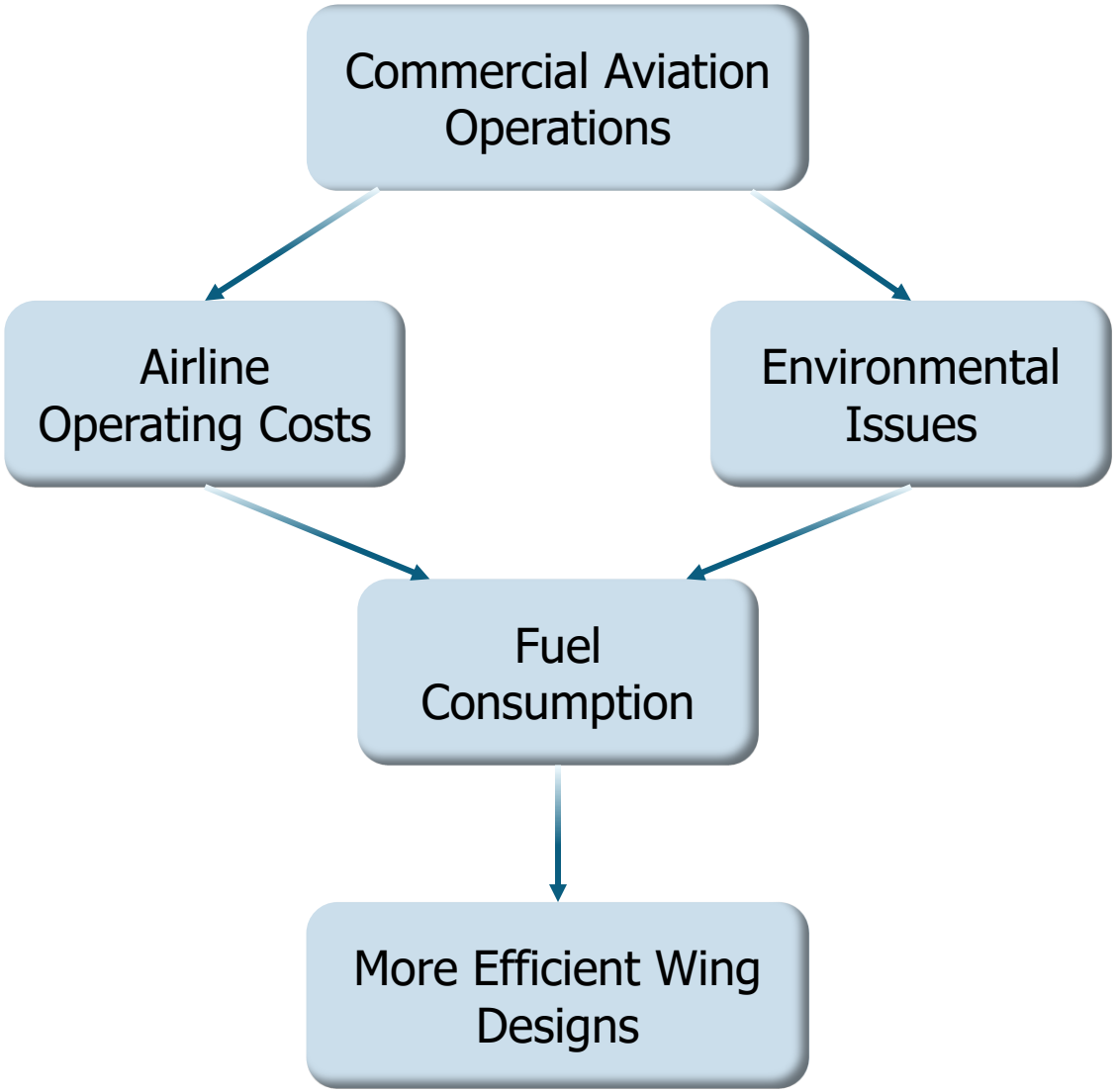



# AERODYNAMIC PERFORMANCE OPTIMIZATION OF A COMMERCIAL AIRCRAFT WITH A FULLY PARAMETRIC CAD MODEL

Osman GARGI
CAE Team Leader at NAVIST Engineering

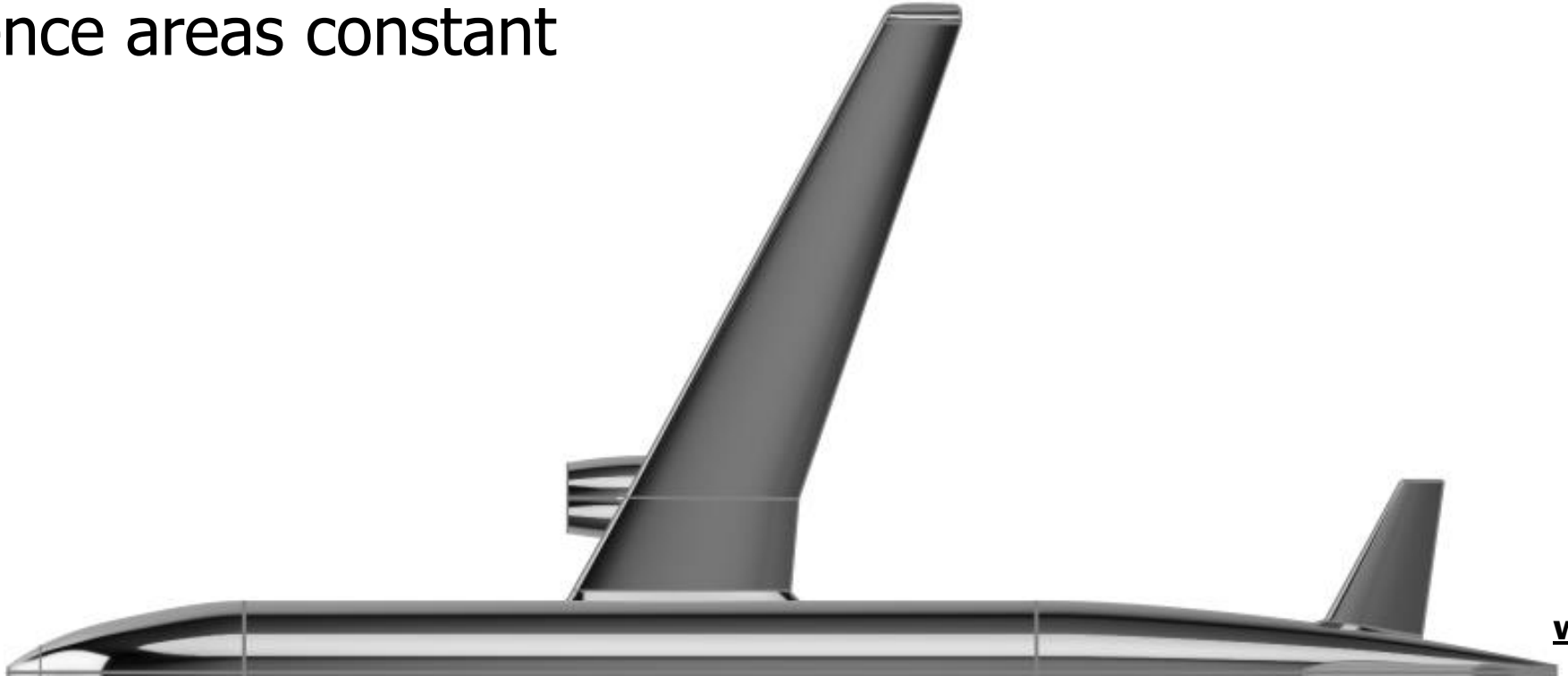
CAESES®

# Problem Description



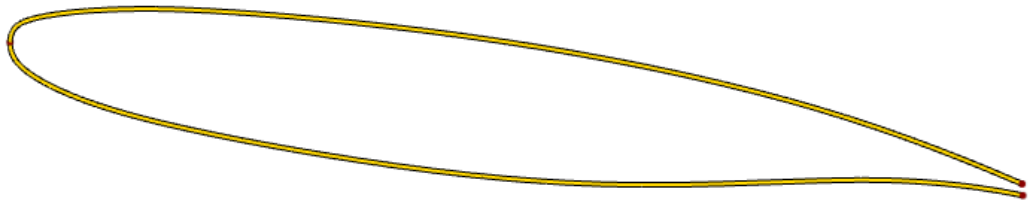
- Optimization of the aerodynamic performance at transonic cruise speed
  - Maximize Lift-to-drag (L/D) ratio

- Parametric model for wing and horizontal tail while keeping reference areas constant



- Parametric profile definition
  - For this study, scaling of profiles but no other shape variation

- Wing from three sections:
  - Root profile
  - Mid profile
  - Tip profile



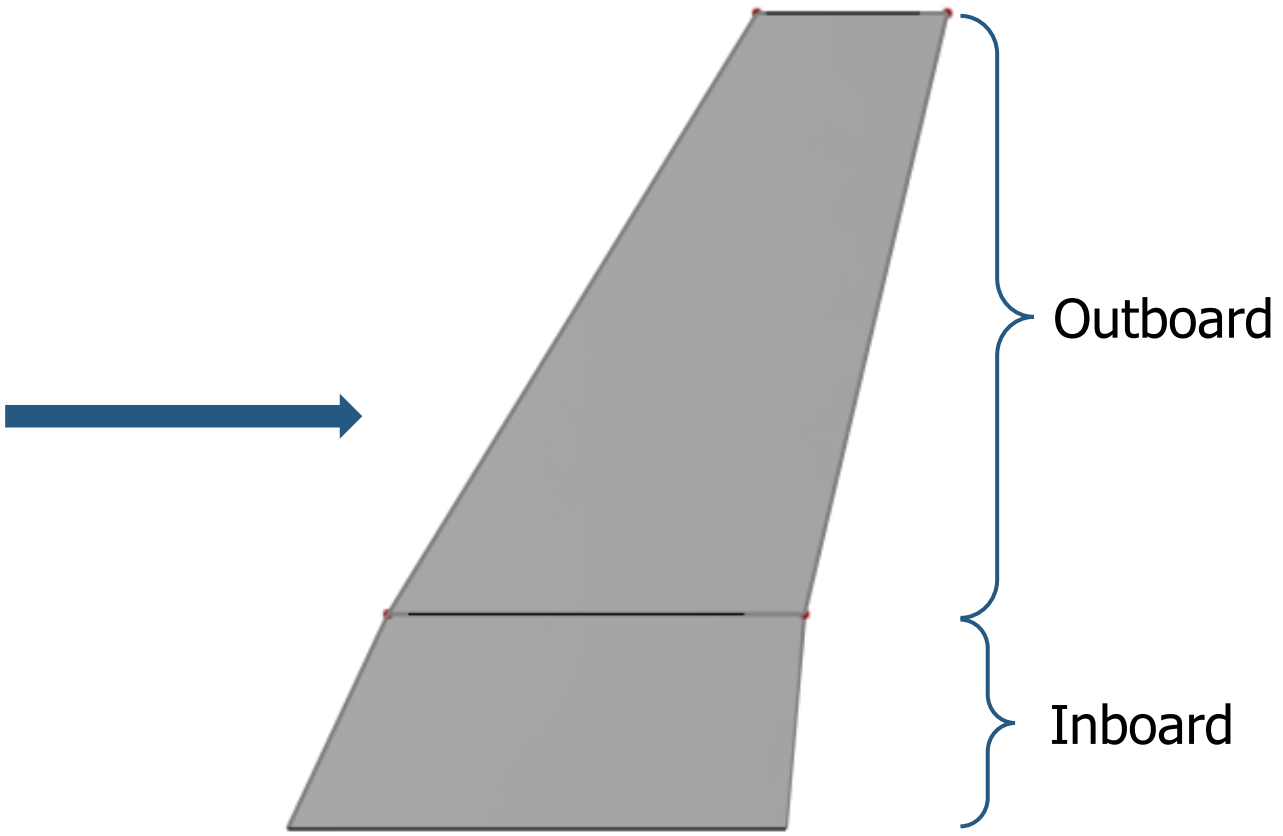
- Horizontal tail from two sections

# Parametric Model – Wing Reference Surface

Tip Profile

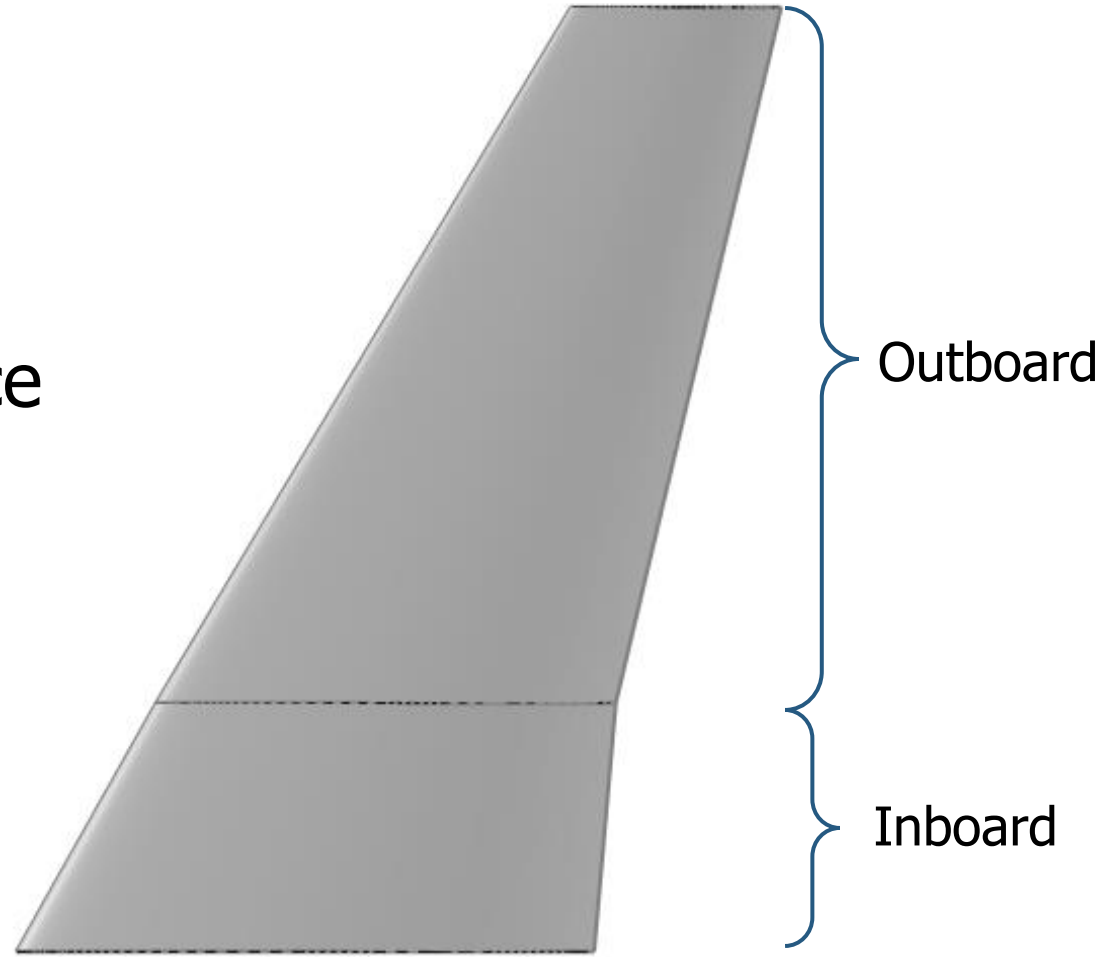
Mid Profile

Root Profile



- Internal optimization to ensure a constant reference area over all wings using the Brent algorithm
  - Objective: minimize difference between baseline reference area and reference are of generated wing and horizontal tail
  - Design variable: span length of the outboard part of the wing and span length of the horizontal tail

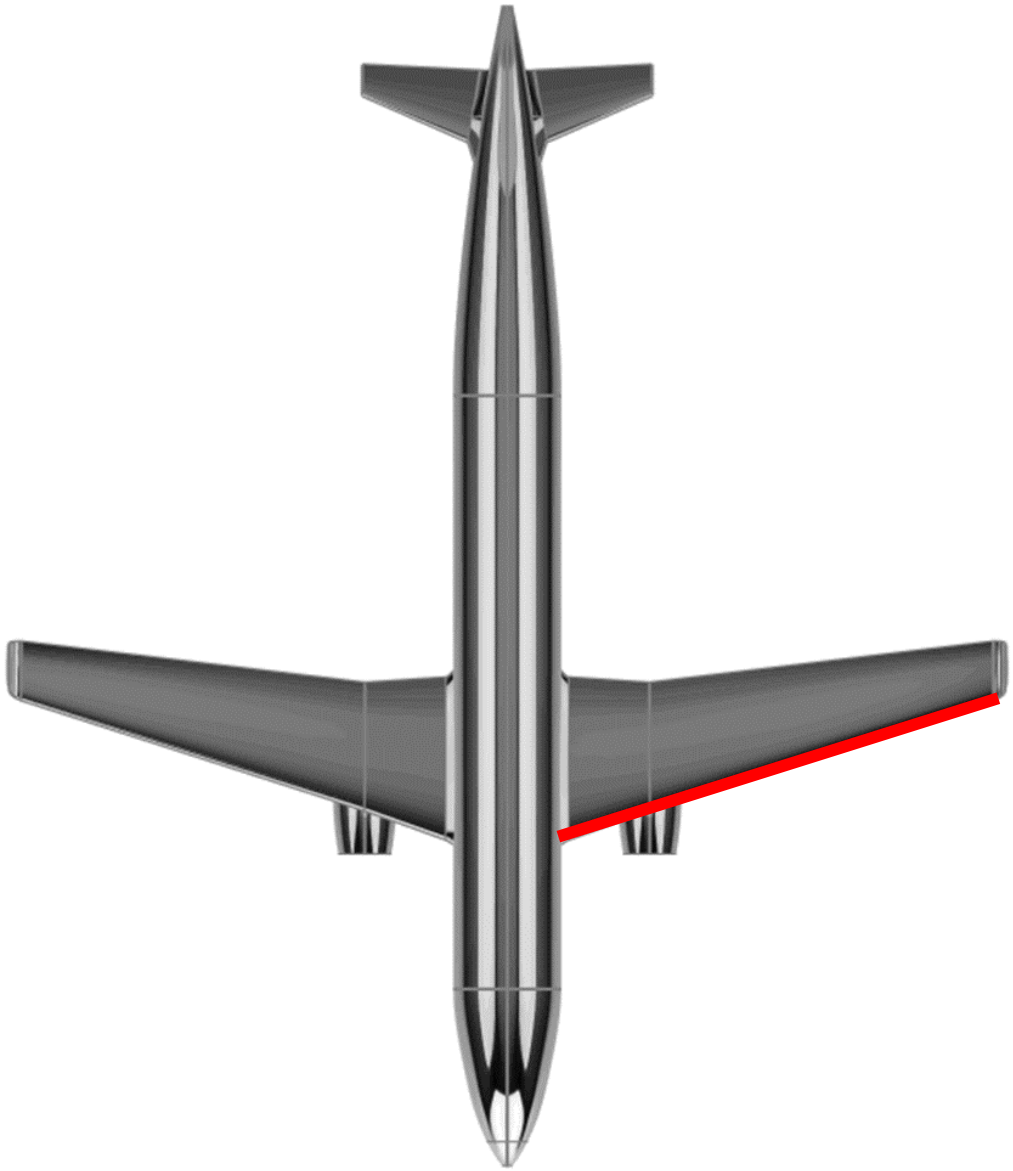
- Two ruled surfaces
  - Root to Mid profile
  - Mid to Tip profile
- Horizontal tail is one ruled surface

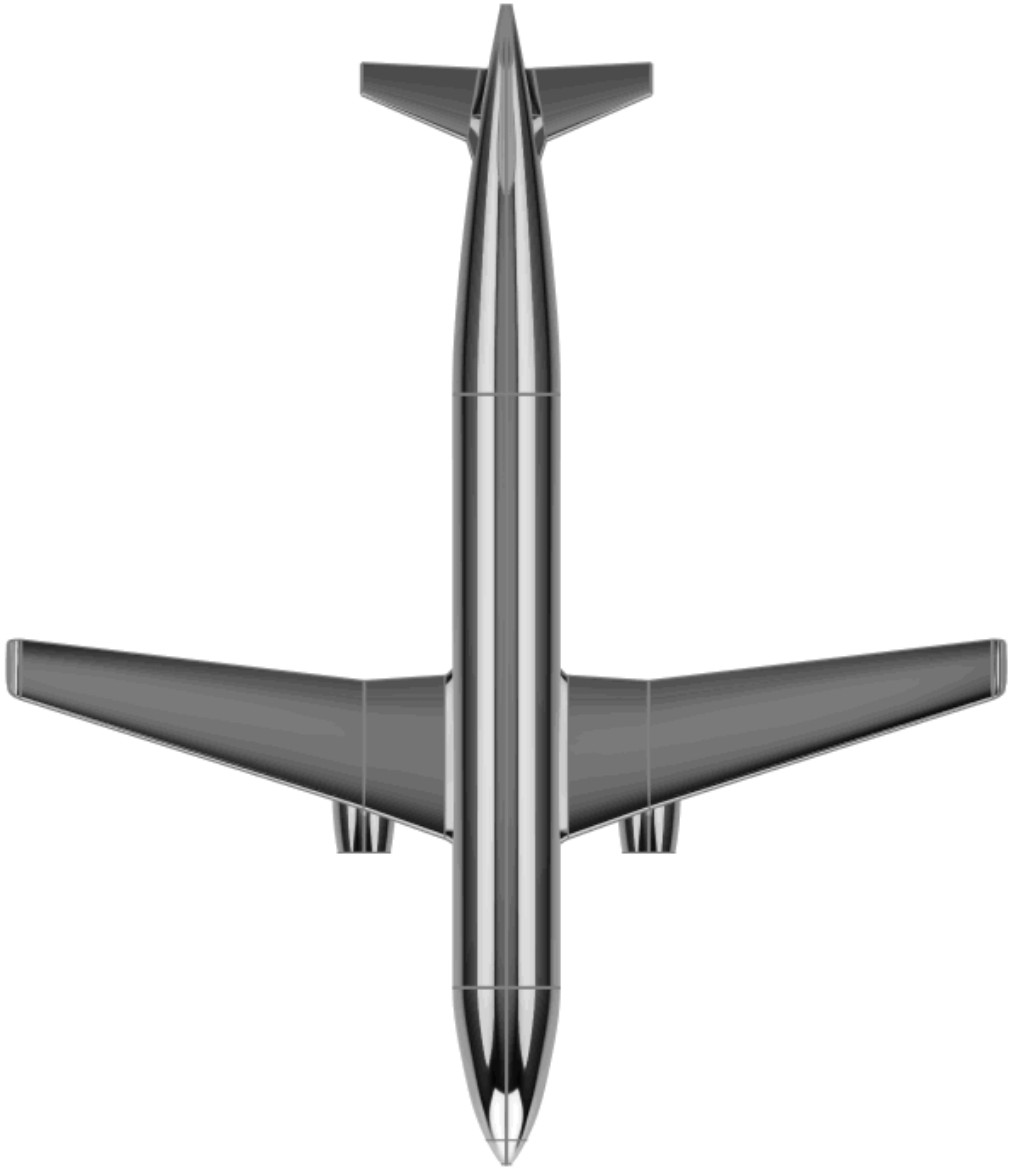


# Design Variables

| Design Variable | Lower Bound | Upper Bound |
|---|---|---|
| Wing Sweep Angle Leading Edge | 15.1° | 25.1° |
| Wing Sweep Angle Inboard Trailing Edge | -5° | 5° |
| Wing Inboard Span Length | 1.5 m | 3.35 m |
| Wing Location | 13.46 m | 20.46 m |
| Horizontal Tail Sweep Angle Leading Edge | 20° | 24° |
| Horizontal Tail Sweep Angle Trailing Edge | 0° | 8.2° |

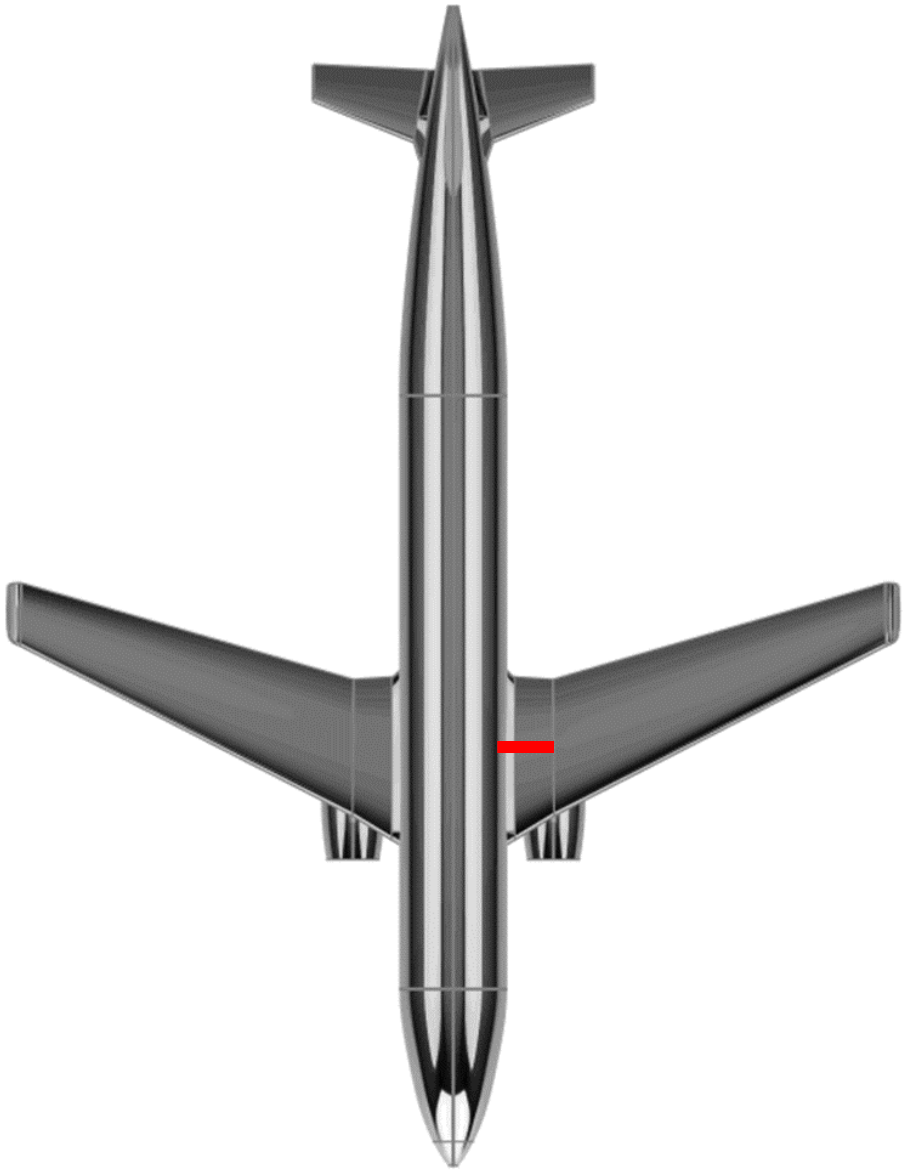
# Design Variables – Wing Sweep Angle Leading Edge

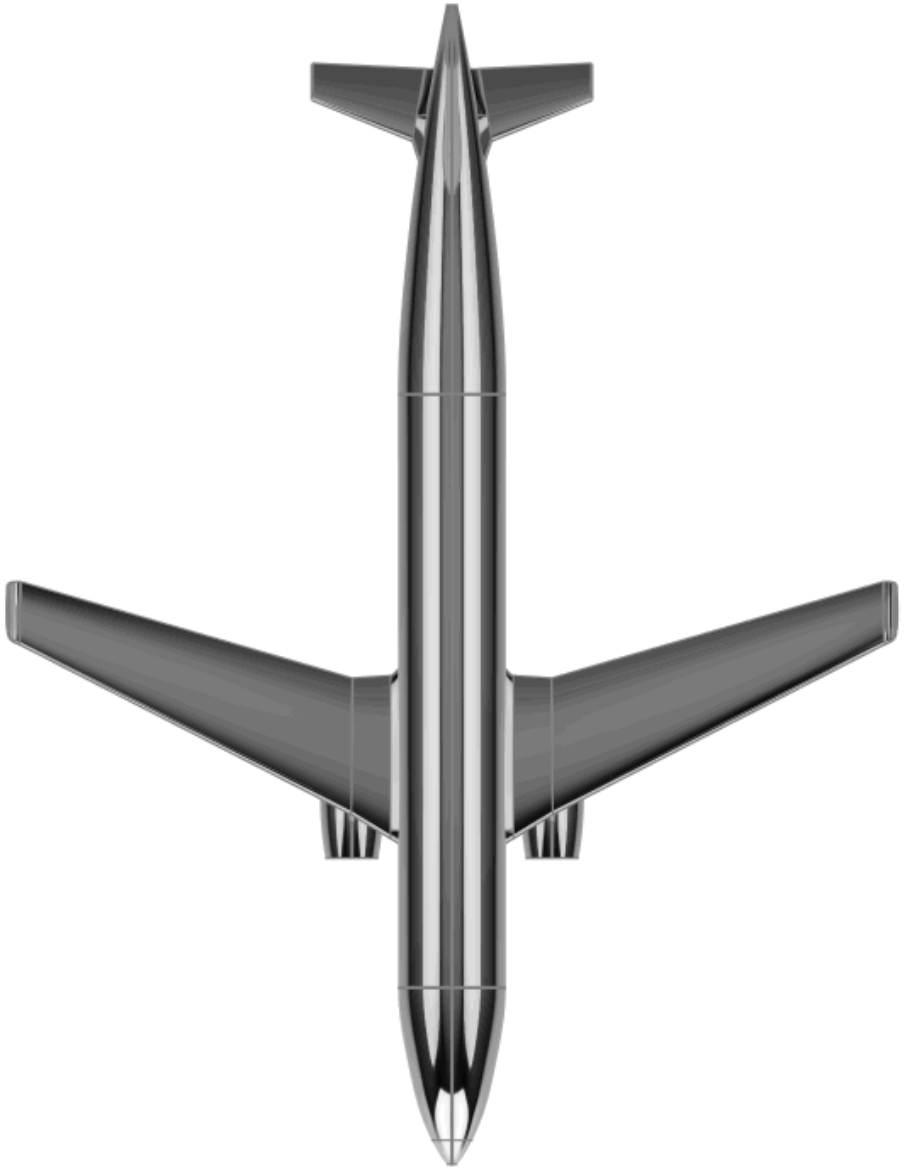




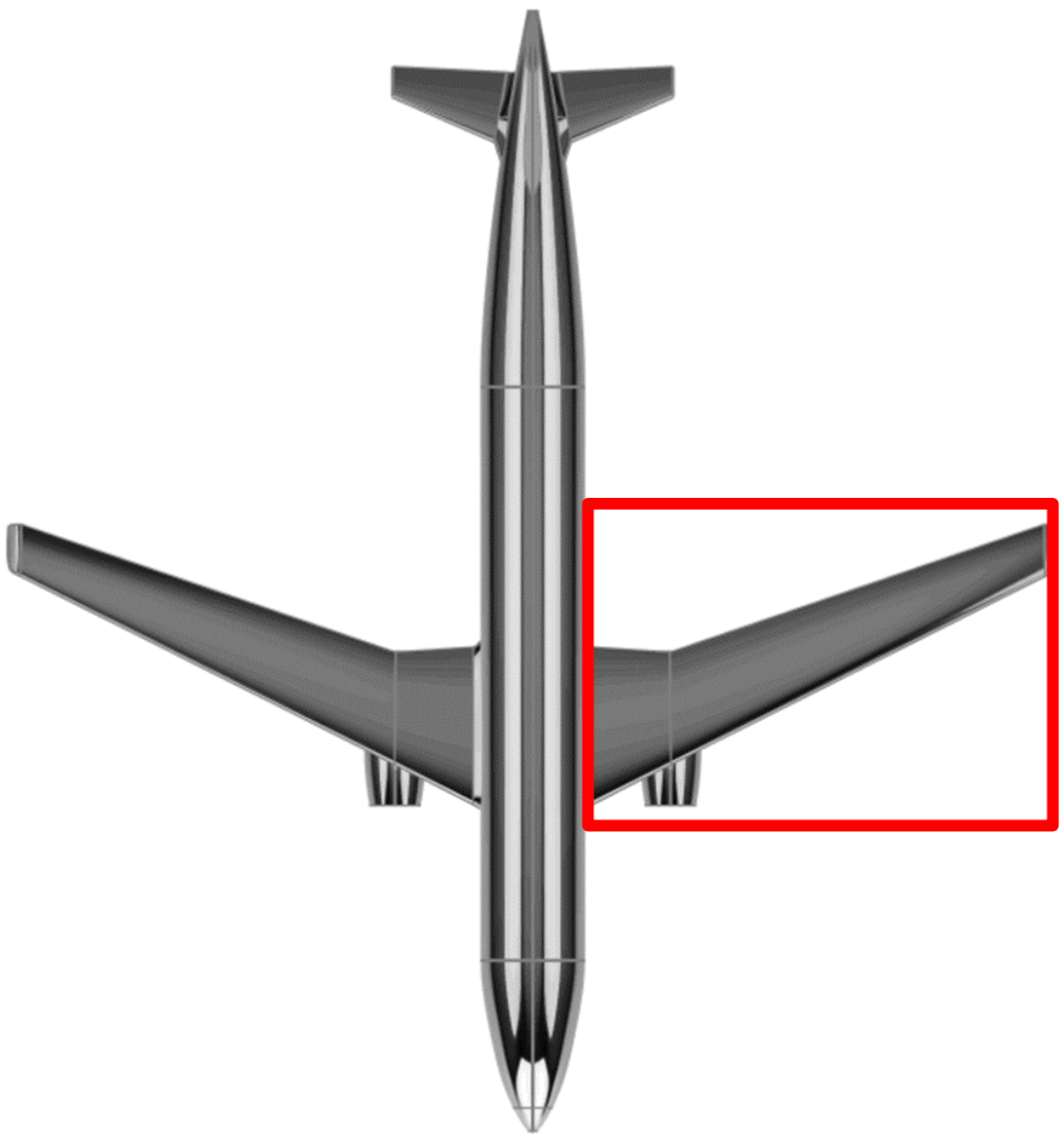
# Design Variables – Wing Sweep Angle Inboard Trailing Edge

# Design Variables – Wing Inboard Span Length

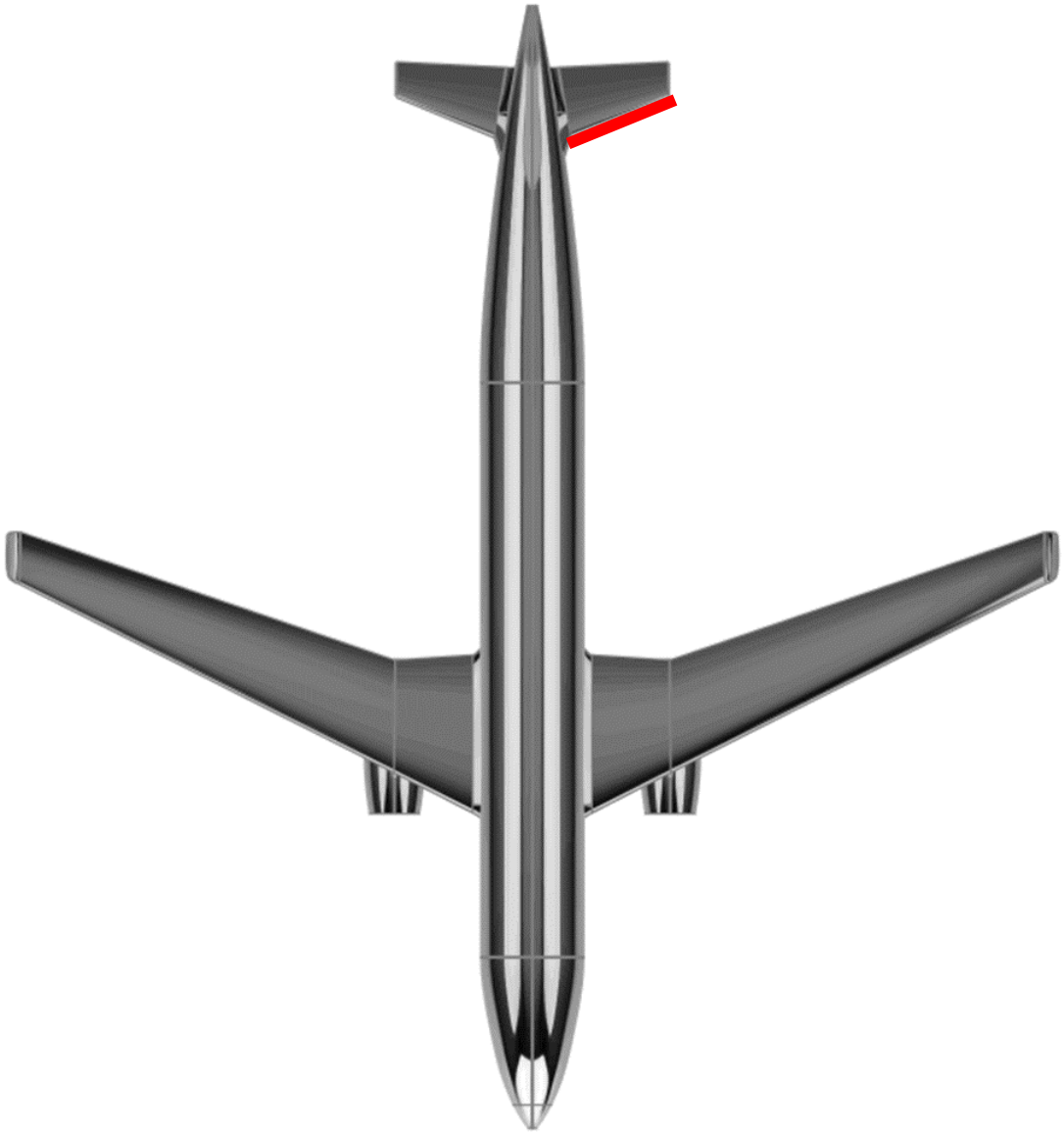




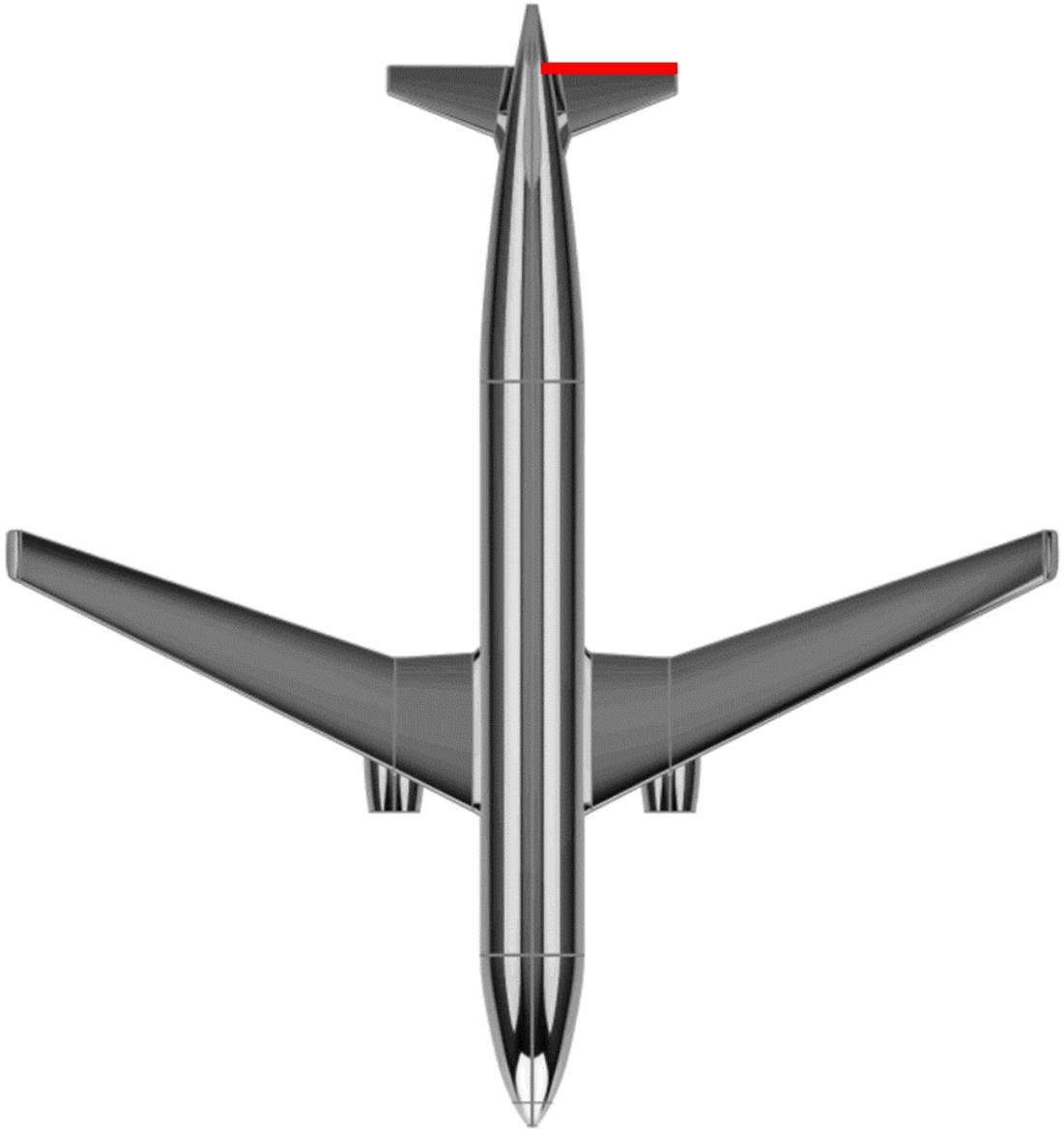
# Design Variables – Wing Location



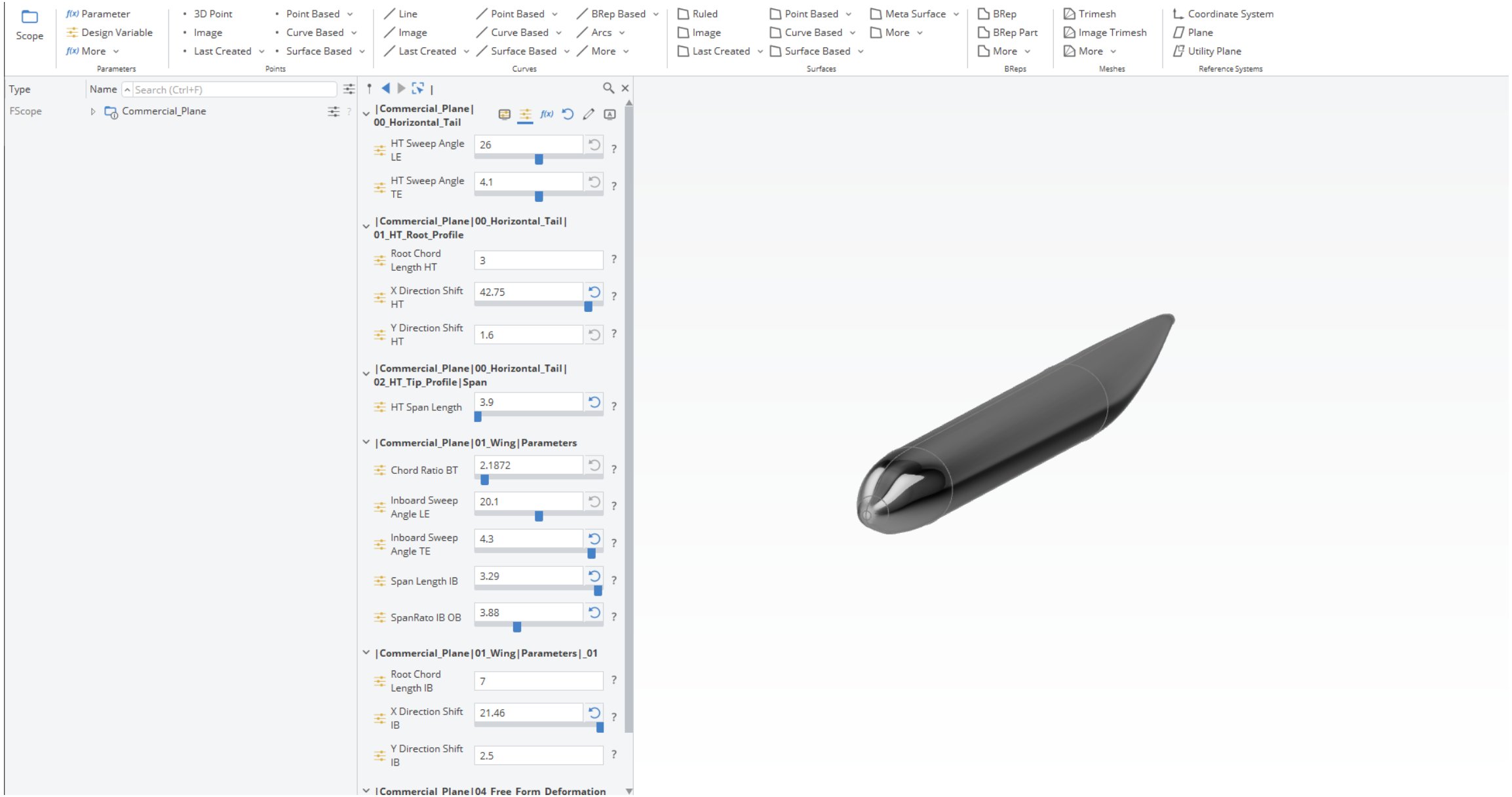
# Design Variables - Horizontal Tail Sweep Angle Leading Edge



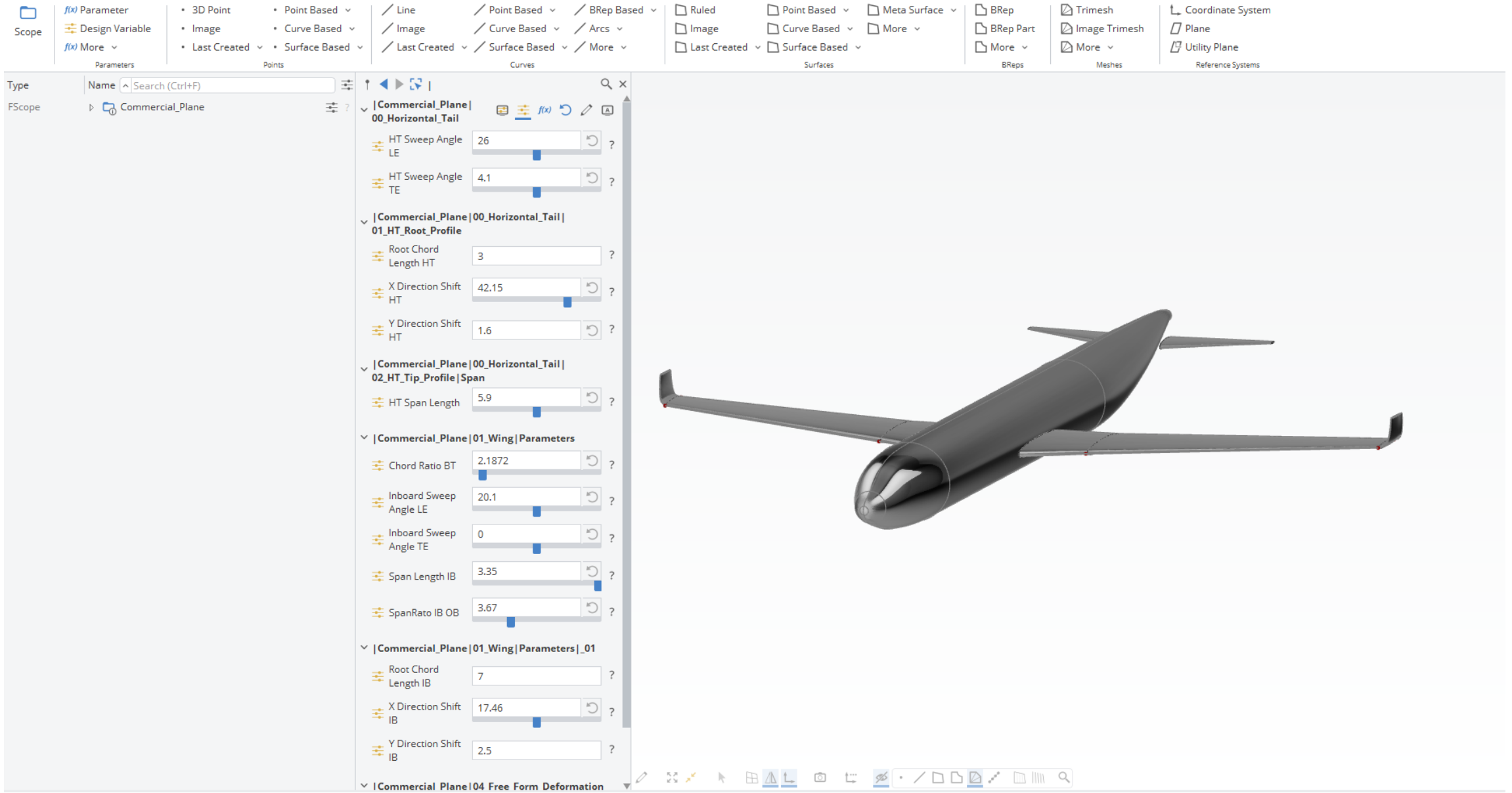
# Design Variables - Horizontal Tail Sweep Angle Trailing Edge



# Full Airplane Model



# Full Airplane Model



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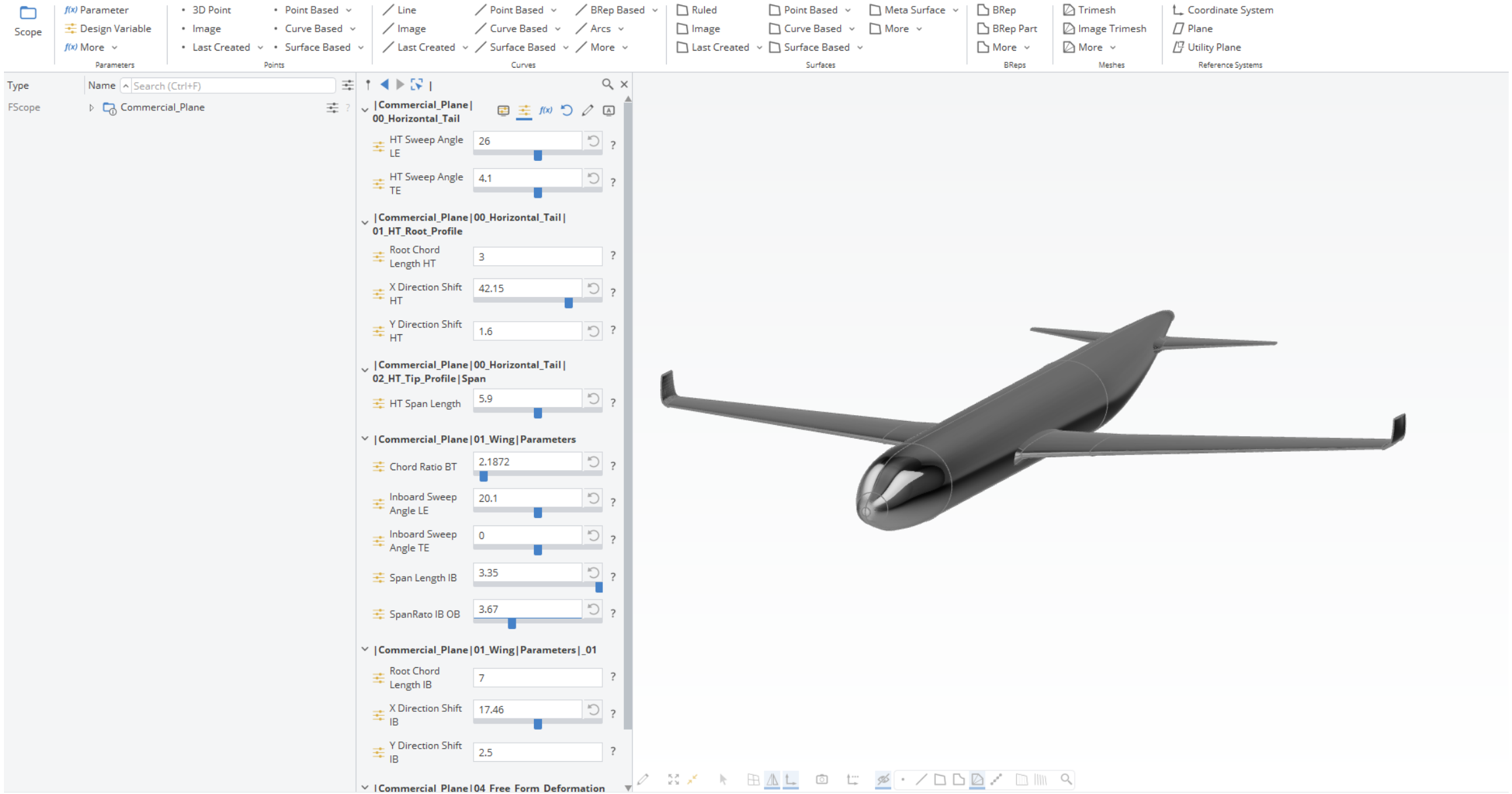
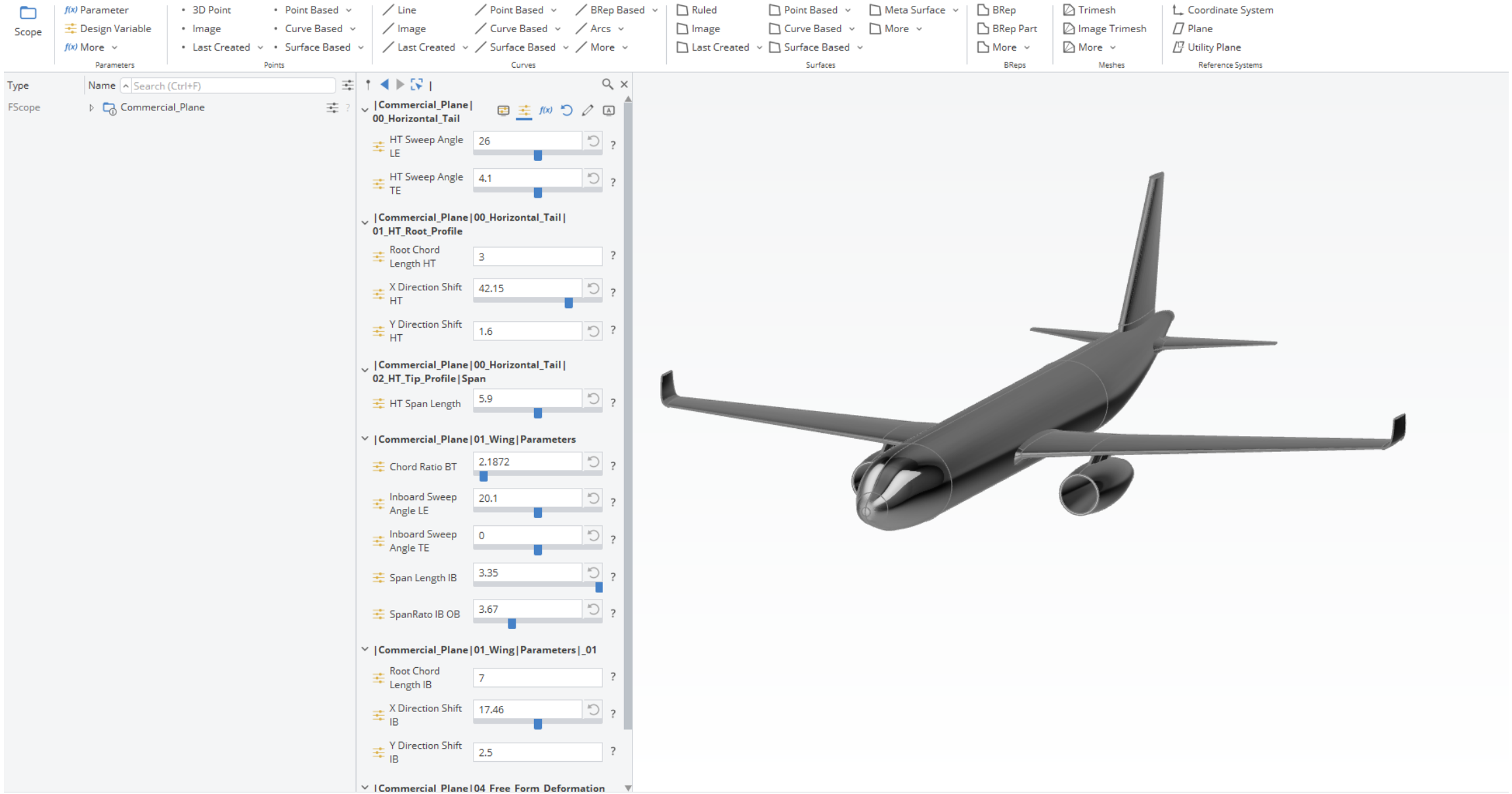


# Full Airplane Model



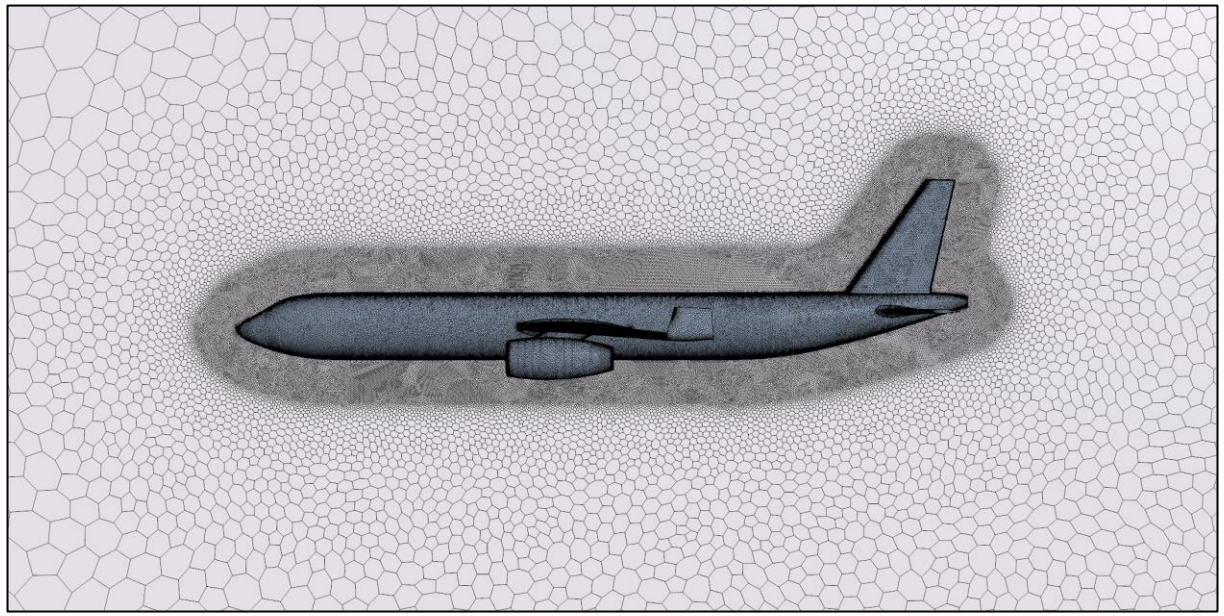
# Design Exploration

| X_Direction_Shift_IB | Inboard_Sweep_Angle_LE | Inboard_Sweep_Angle_TE | Span_Length_IB | HT_Sweep_Angle_LE | HT_Sweep_Angle_TE | f(x) Volume |
|---|---|---|---|---|---|---|
| 17.46 | 20.1 | 0 | 2.425 | 22 | 4.1 | 347.89638 |
| 20.46 | 23.85 | -3.75 | 2.65625 | 21.5 | 3.075 | 346.24067 |
| 18.46 | 16.35 | -1.25 | 2.19375 | 20.5 | 5.125 | 348.55426 |
| 14.46 | 21.35 | 3.75 | 3.11875 | 22.5 | 1.025 | 347.88579 |
| 14.96 | 18.225 | -1.875 | 2.771875 | 22.25 | 1.5375 | 347.62623 |
| 18.96 | 23.225 | 3.125 | 1.846875 | 20.25 | 5.6375 | 348.25765 |
| 20.96 | 15.725 | 0.625 | 3.234375 | 21.25 | 3.5875 | 348.69201 |
| 16.96 | 20.725 | -4.375 | 2.309375 | 23.25 | 7.6875 | 347.18344 |
| 15.96 | 16.975 | 4.375 | 2.540625 | 21.75 | 6.6625 | 349.30549 |
| 17.96 | 19.475 | -3.125 | 3.003125 | 22.75 | 4.6125 | 347.03835 |
| 20.21 | 17.2875 | -4.0625 | 1.7890625 | 22.125 | 0.76875 | 347.9688 |
| 16.21 | 22.2875 | 0.9375 | 2.7140625 | 20.125 | 4.86875 | 347.53733 |
| 17.21 | 16.0375 | -0.3125 | 2.0203125 | 22.625 | 5.89375 | 348.72995 |
| 15.21 | 23.5375 | -2.8125 | 2.4828125 | 23.625 | 3.84375 | 346.60467 |
| 14.71 | 16.6625 | 0.3125 | 3.0609375 | 23.375 | 3.33125 | 348.33584 |
| 18.71 | 21.6625 | -4.6875 | 2.1359375 | 21.375 | 7.43125 | 347.21136 |
| 20.71 | 19.1625 | -2.1875 | 2.5984375 | 20.375 | 1.28125 | 347.5265 |
| 19.71 | 22.9125 | 1.5625 | 2.3671875 | 22.875 | 0.25625 | 347.44561 |
| 17.71 | 15.4125 | 4.0625 | 2.8296875 | 23.875 | 6.40625 | 349.4819 |
| 13.835 | 17.75625 | 1.09375 | 2.5695312 | 22.8125 | 5.25312 | 348.52353 |
| 17.835 | 22.75625 | -3.90625 | 1.6445312 | 20.8125 | 1.15312 | 345.23782 |
| 19.835 | 15.25625 | -1.40625 | 3.0320313 | 21.8125 | 7.30312 | 348.48802 |
| 15.835 | 20.25625 | 3.59375 | 2.1070312 | 23.8125 | 3.20312 | 348.40664 |

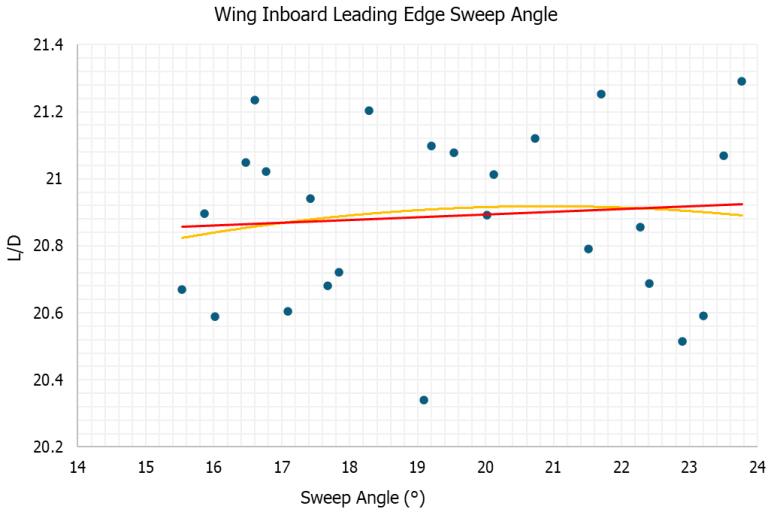
All designs are watertight and ready for simulation.

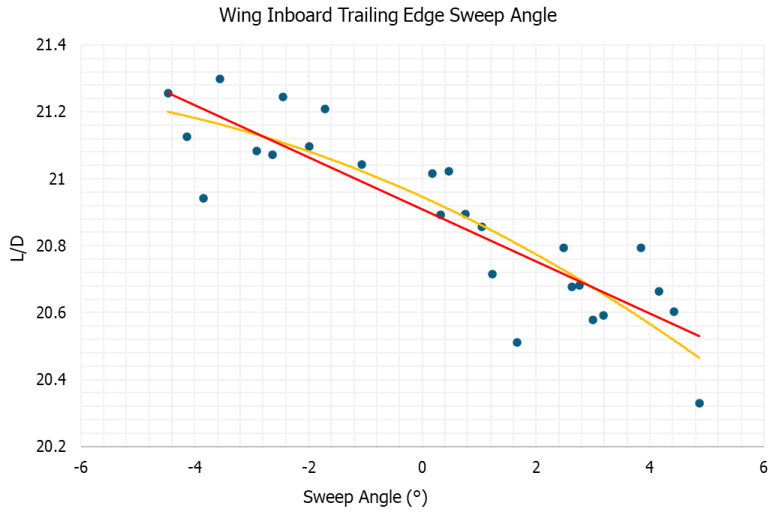
- Solver: StarCCM+
  - 1.5 hours for each simulation
- Aircraft’s speed: 0.8 Mach
- Altitude: 30000 ft
- Angle of attack: 2°

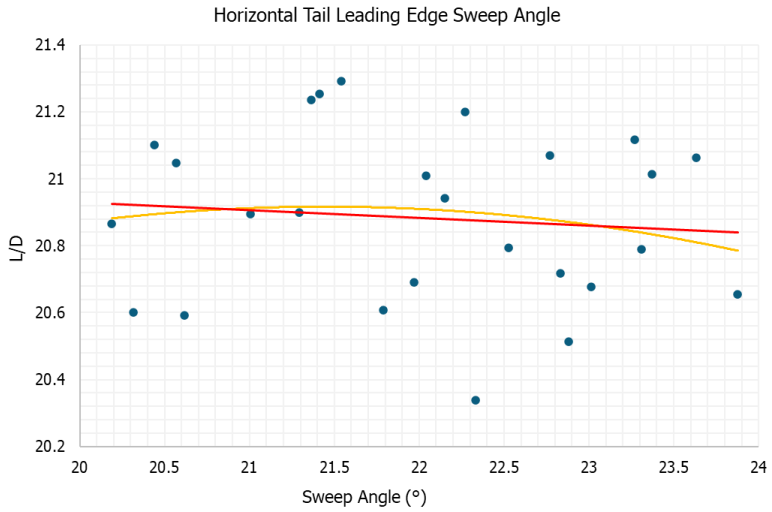
- DoE: 50 Sobol samples

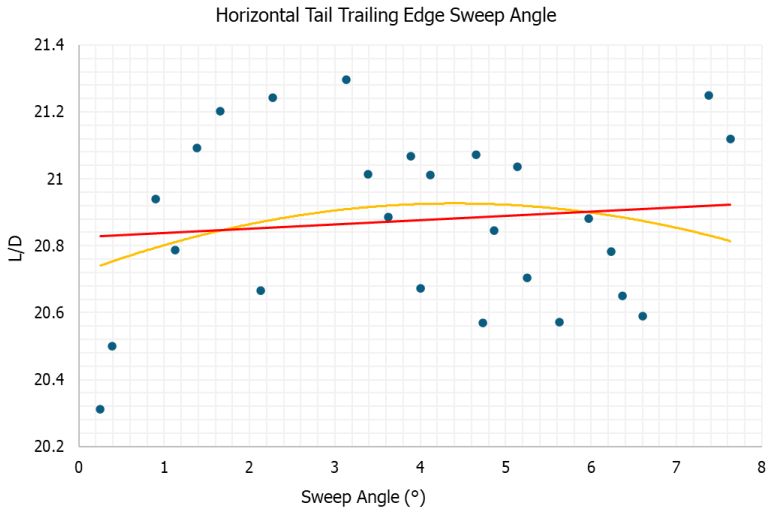


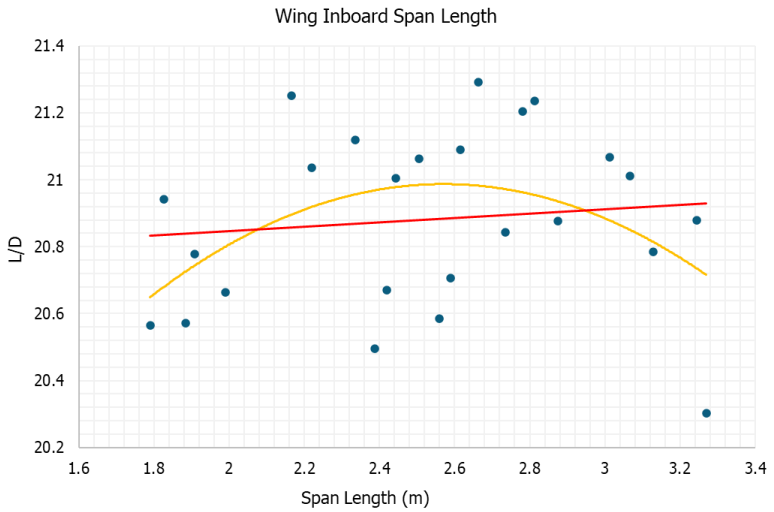
# Results - Sensitivity Analysis

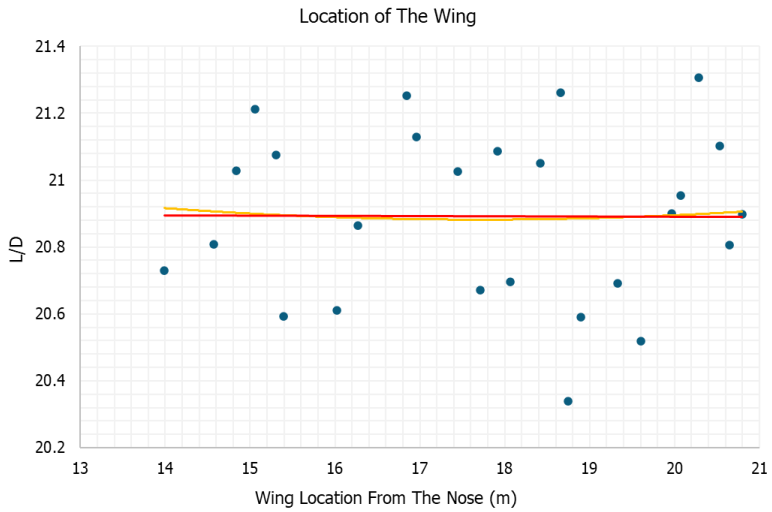


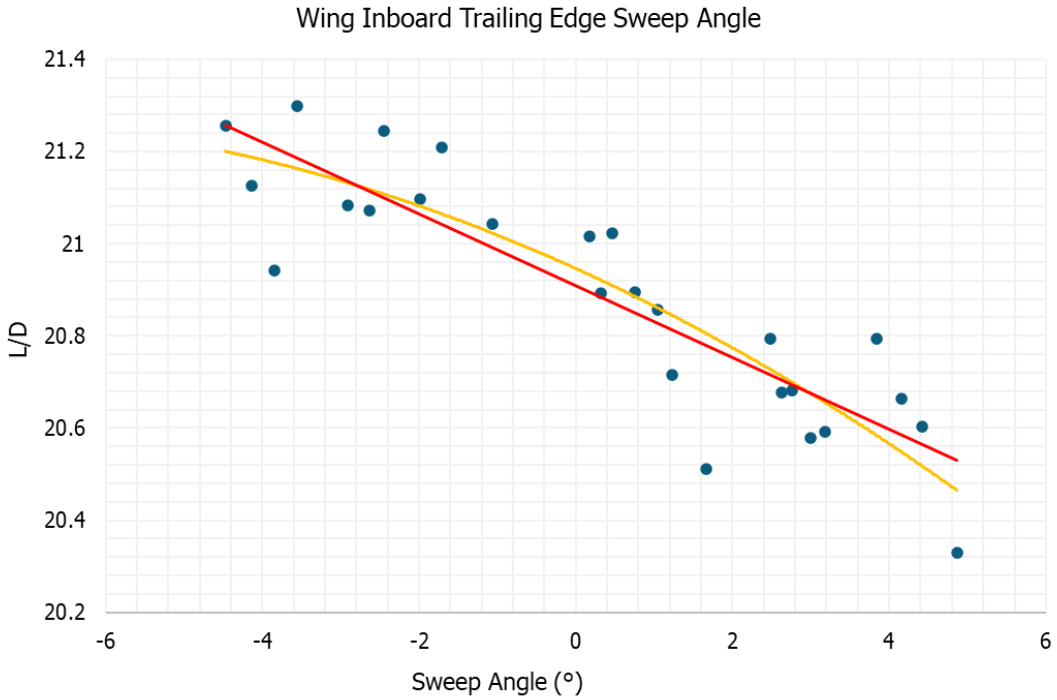



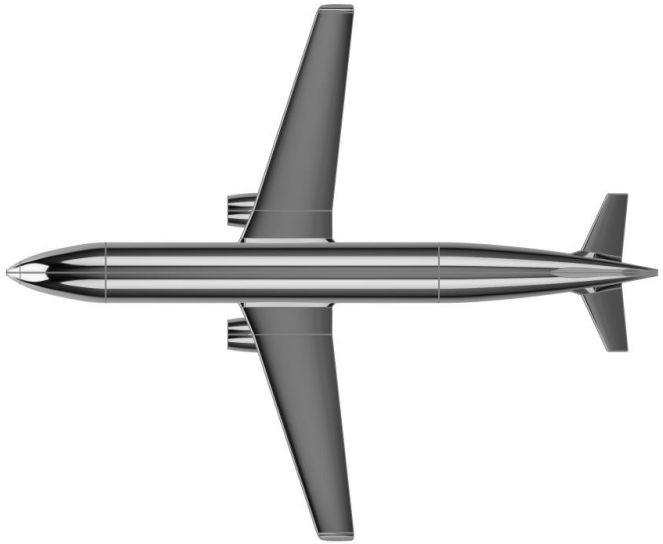



# Results - Sensitivity Analysis

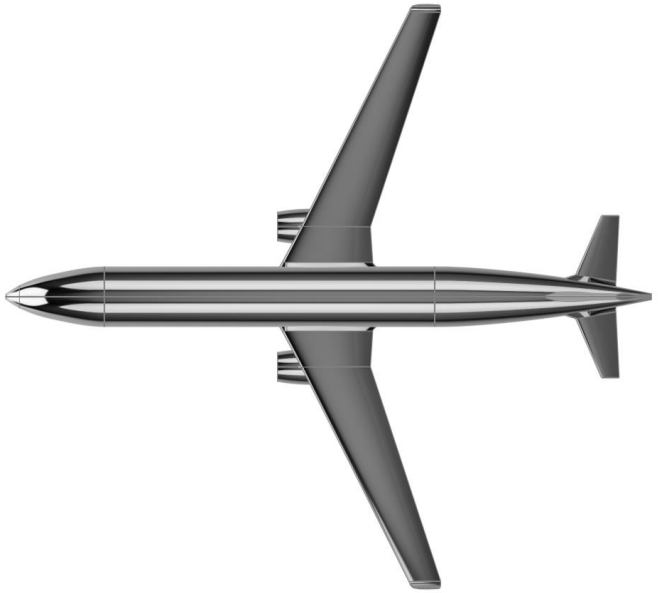


# Results



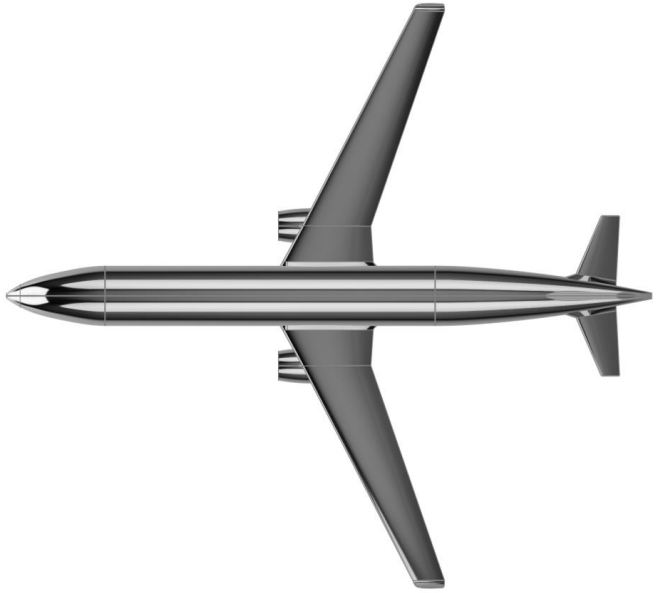
Base Model

L/D = 20.35



The Most Efficient
Model In The DoE

L/D = 21.29

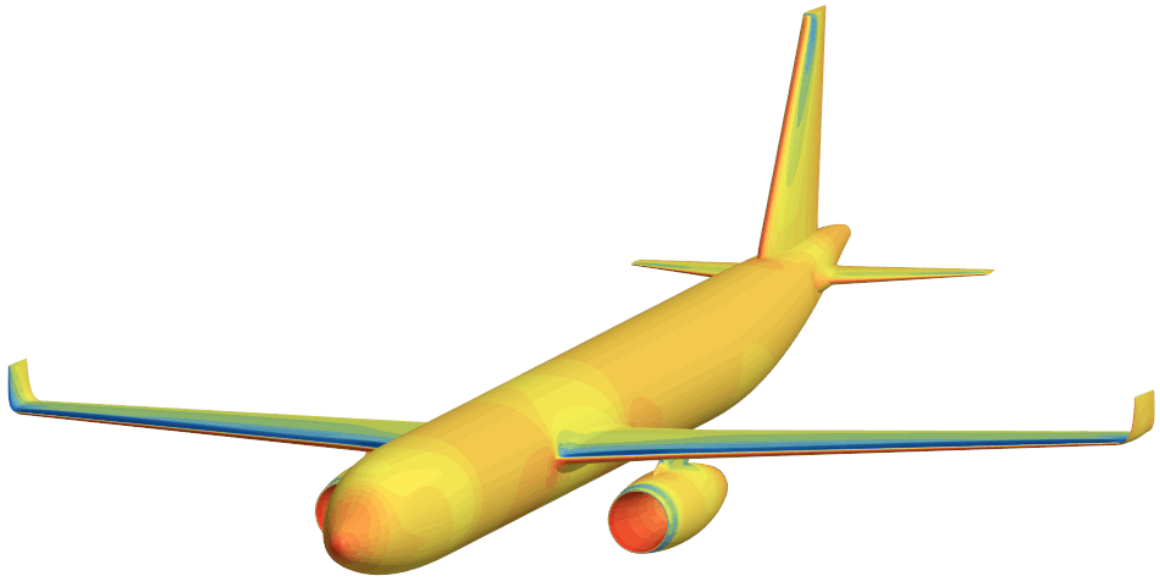


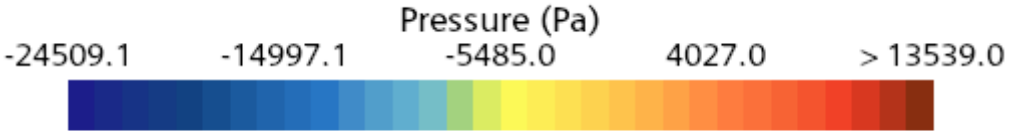
The Most Efficient
Model In The T-Search

L/D = 21.53

The L/D has been increased by **5.8%** as a result of single-objective optimization.

# Results





# Future Works

This study serves as a preliminary step for a more comprehensive study:

- Free form deformation study for the nose model
- Aerodynamic performance optimization of the wing and horizontal tail with more design variables for the profile sections
- Consideration of other effects on aerodynamic performance

# Thank You For Your Attention!

For further information: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