The Study of Unmanned Twin-body Asymmetric Flying-Wing Aircraft for Monitoring Air Quality

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Introduction

- Traditional automatic air monitoring station
- Current Unmanned Aerial Vehicle (UAV)
- Twin-body Asymmetric Flying-Wing Aircraft (TAFA)

Traditional automatic air monitoring station

- Costly (labors, periodic maintenance...)
- Difficult to carry out large-scale measurement.
- Observation point is not representative.

Long endurance, high loading unmanned aerial vehicle(UAV)

Current Unmanned Aerial Vehicle (UAV)

(a) Monoplane

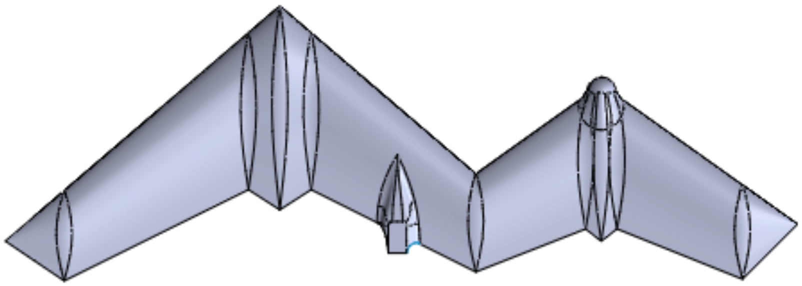
(b) Twin-body Aircraft

(c) Asymmetric Twin-body Aircraft

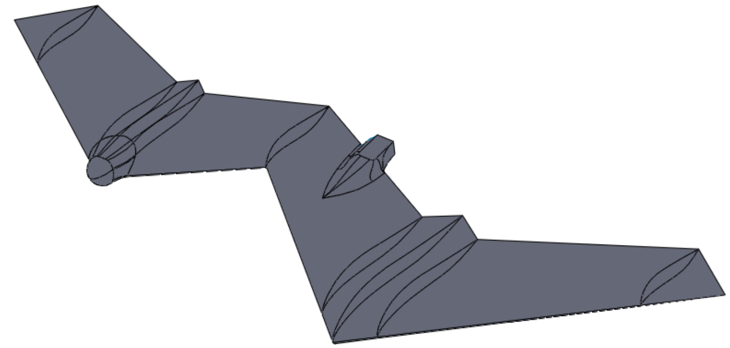
(d) Flying-Wing Aircraft

Problem:
Low load
Low voyage
Low Endurance
Low efficiency

Twin-body Asymmetric Flying-Wing Aircraft (TAFA)



TAFA



Advantage: high lift, high voyage, and high endurance.

Twin-body

Disadvantage: high mid-wing strength requirement, no usable airport, loading interfere with each other.

Asymmetric Arrangement

Solve the interference problem and no usable airport problem.

Flying-Wing Layout

Increase lift, voyage, and endurance, reinforce the mid-wing strength.

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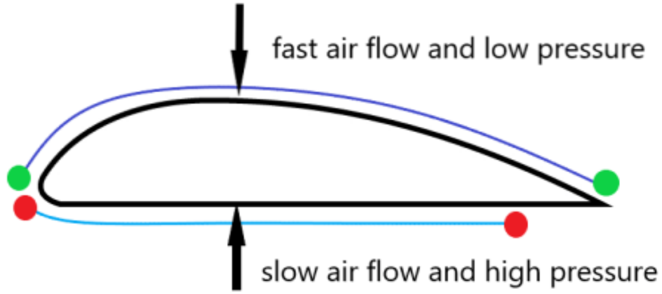
Aerodynamic Principle

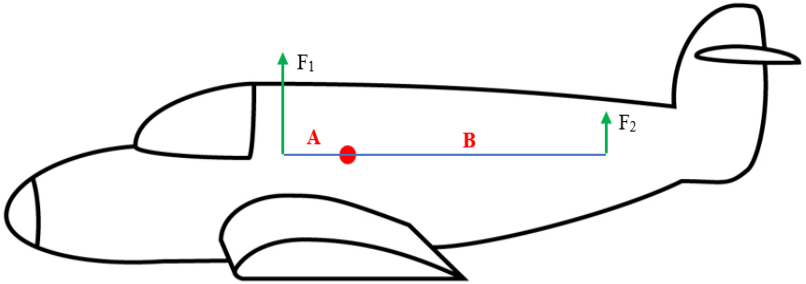
- Theory
- Design Process
- Simulation
- Results and Discussion

Theory

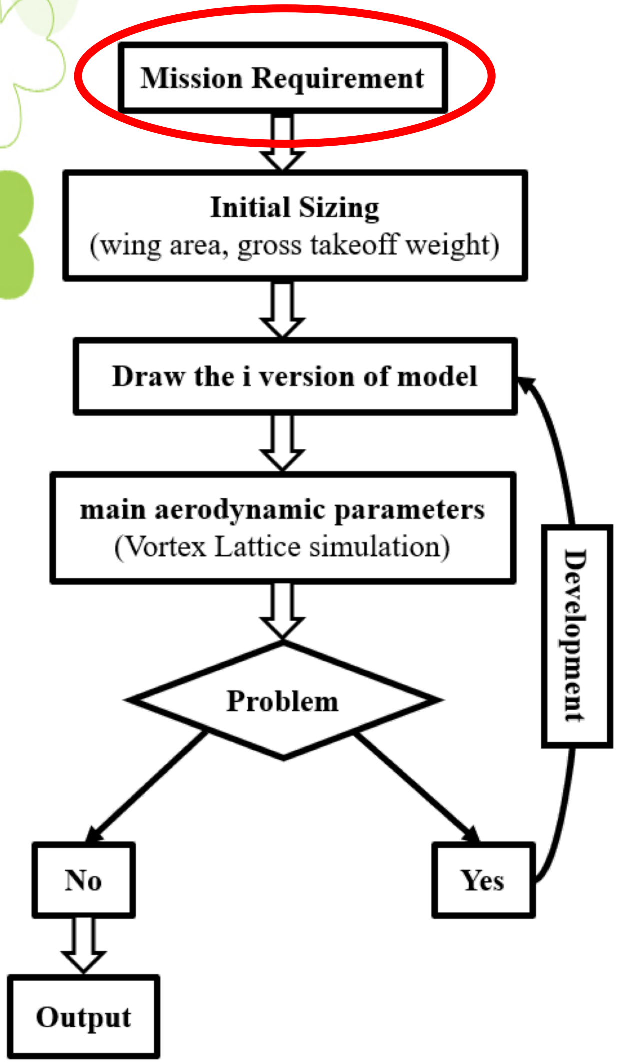
- **Principle of Flight Lift Generation**
  - $\frac{1}{2}\rho u_1^2 + \rho g z_1 + p_1 = \frac{1}{2}\rho u_2^2 + \rho g z_2 + p_2$
  - $\frac{1}{2}\rho u_1^2 + p_1 = \frac{1}{2}\rho u_2^2 + p_2$
  - The lift is proportional to the wing area.



- **Balance Control of Aircraft**
  - $F_1 \times A = F_2 \times B$
  - Put the engine on the center mass



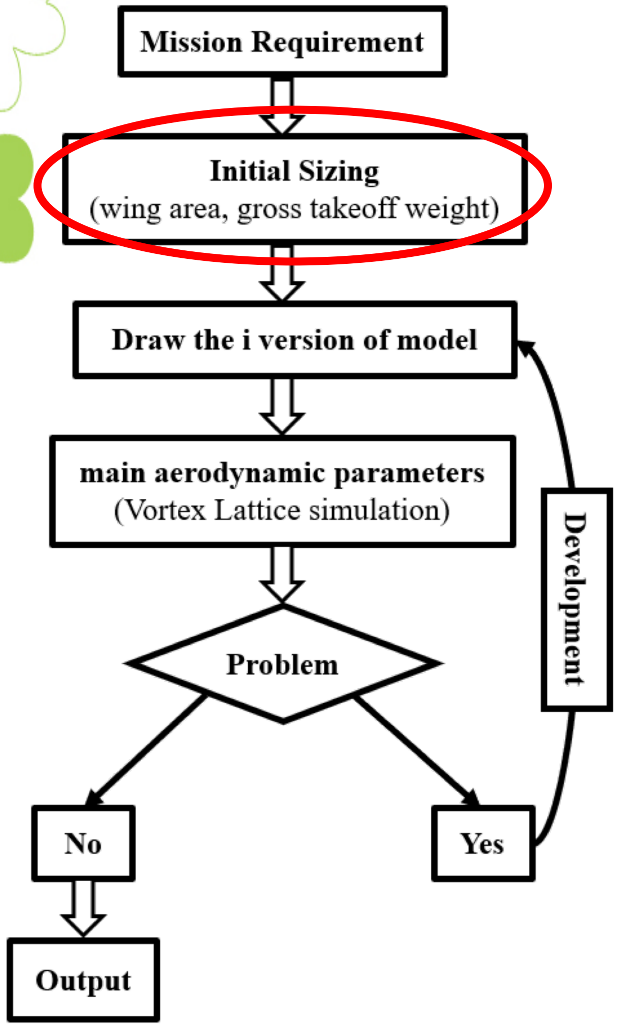
Design Process



Flight Requirements	
Payload weight	9.24kg
Endurance	8h(battery)/24h(fuel)
Loiter Speed	25m/s

Payload Requirements	
Radar	203*165*76mm, 2.44kg
Antenna	127*127*38mm, 0.29kg
Imaging processor	152.5*152.5*76mm, 1.41kg
Lidar	142*70*230mm, 2.2kg
Data link	290*179*161mm, 1.5kg
Multispectral camera	127*177.1mm, 1.4kg
Engine	60*161*93mm, 0.62 kg

Design Process



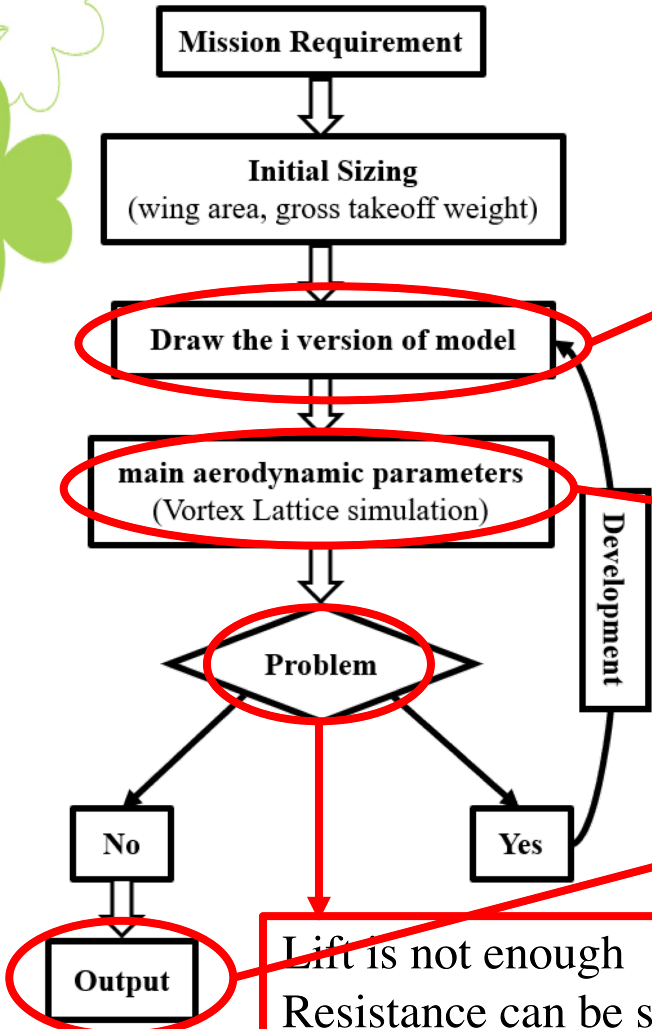
Total loading weight: 9.24 kg

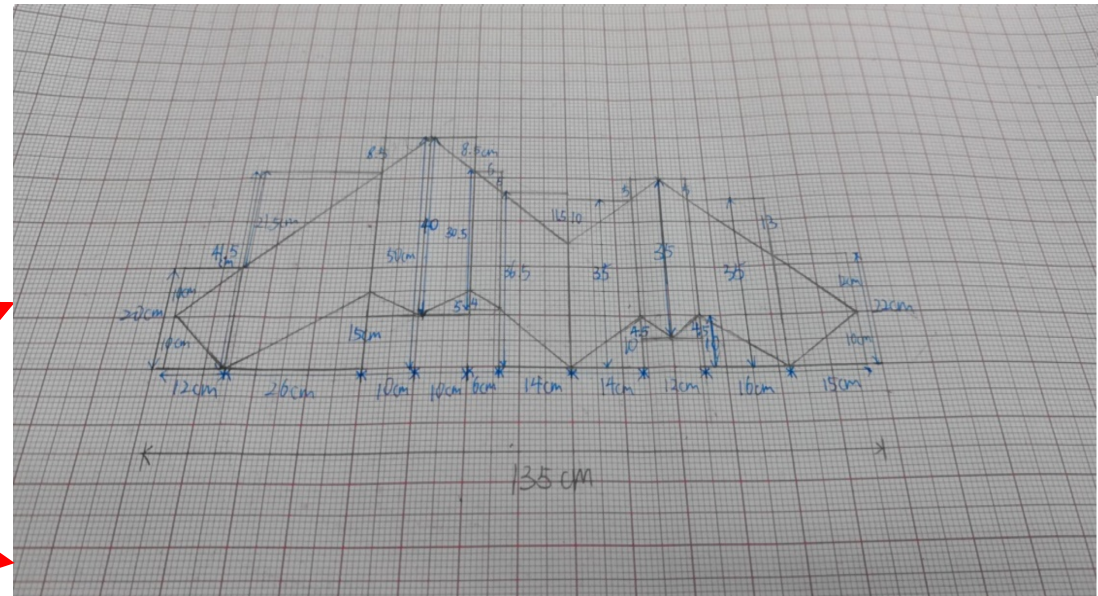
Estimate takeoff weight: 36kg

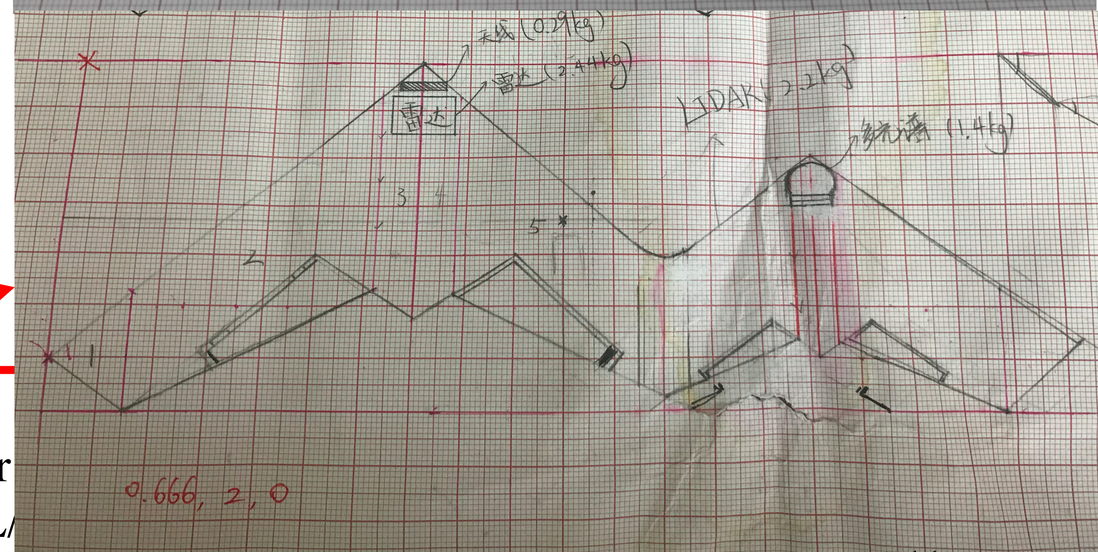
$$L = \frac{1}{2} C_y \rho v^2 S$$

Wing area = $2.39m^2$

Design Process

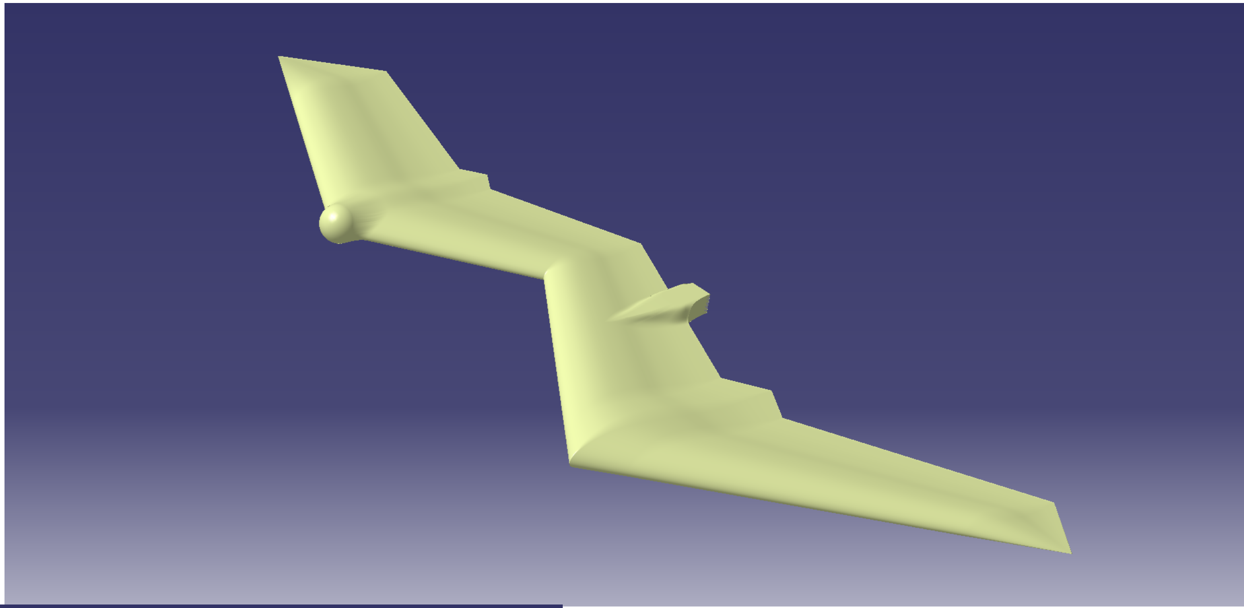


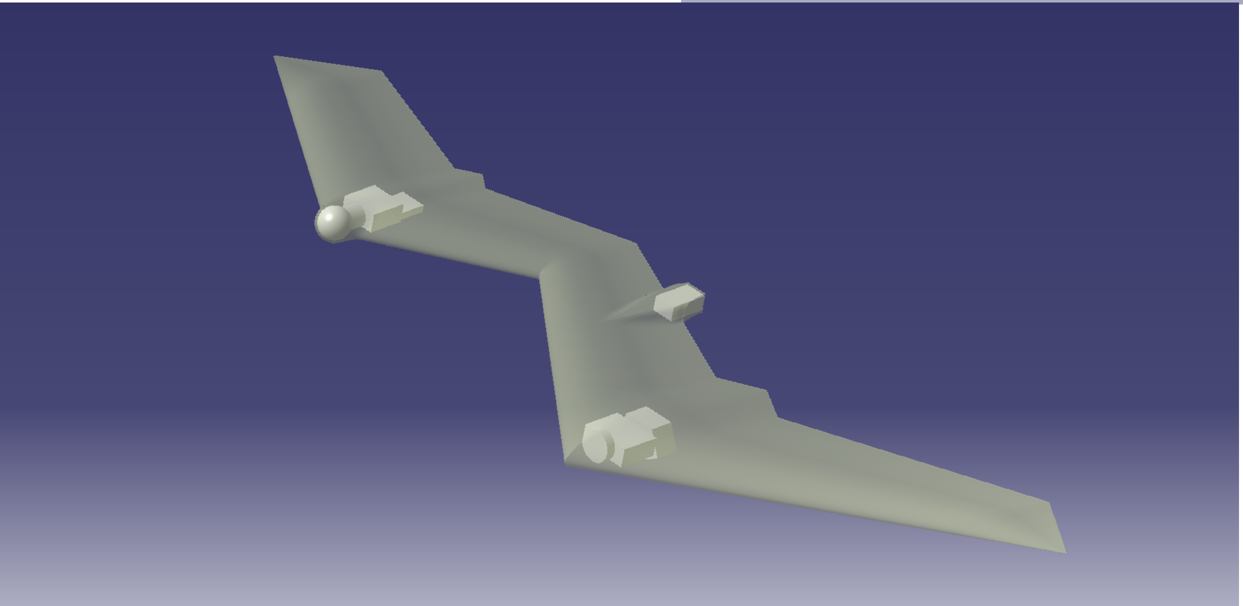




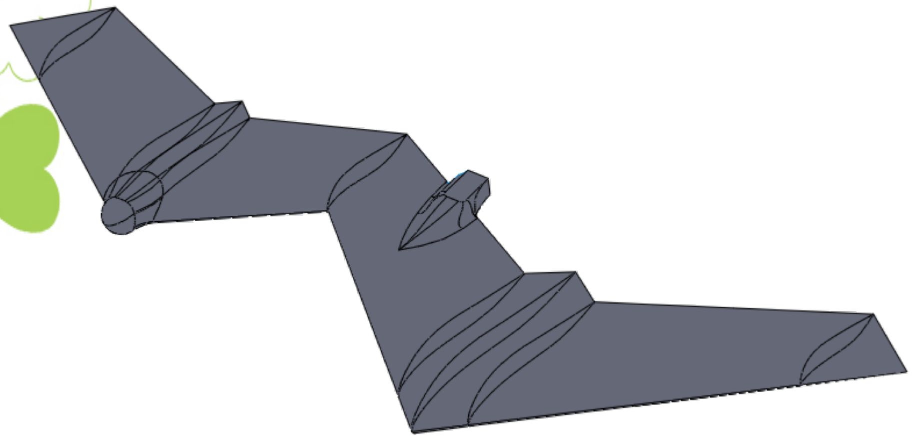
Lift is not enough
Resistance can be smaller
When lift=total weight, L/

Modeling

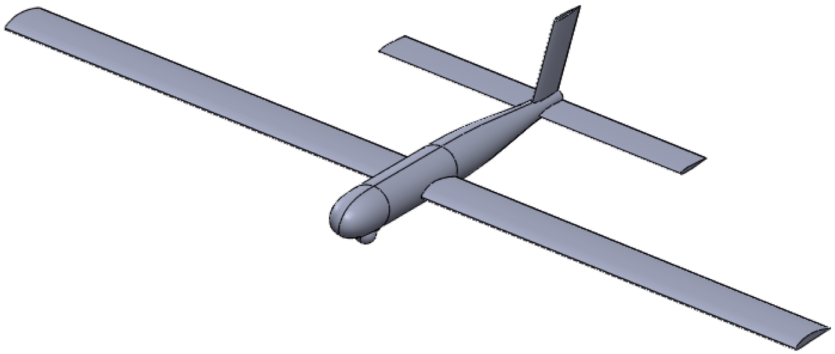




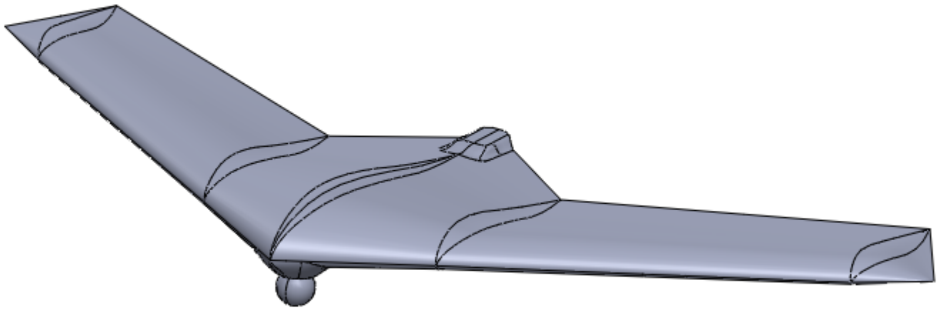
Models



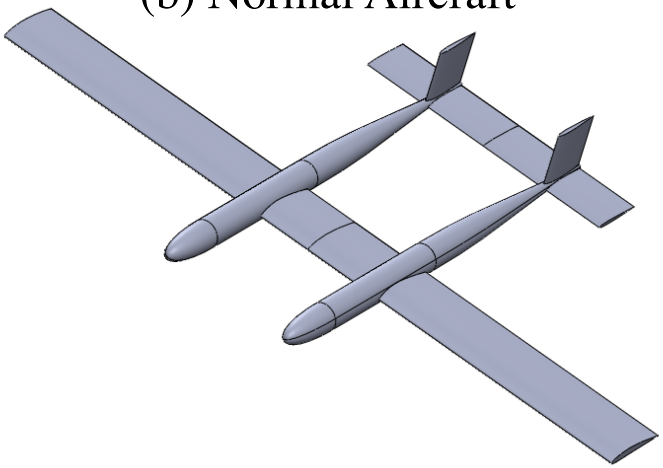
(a) TAFA



(b) Normal Aircraft



(c) Flying-Wing Aircraft



(d) Twin-Body Symmetric Airplane

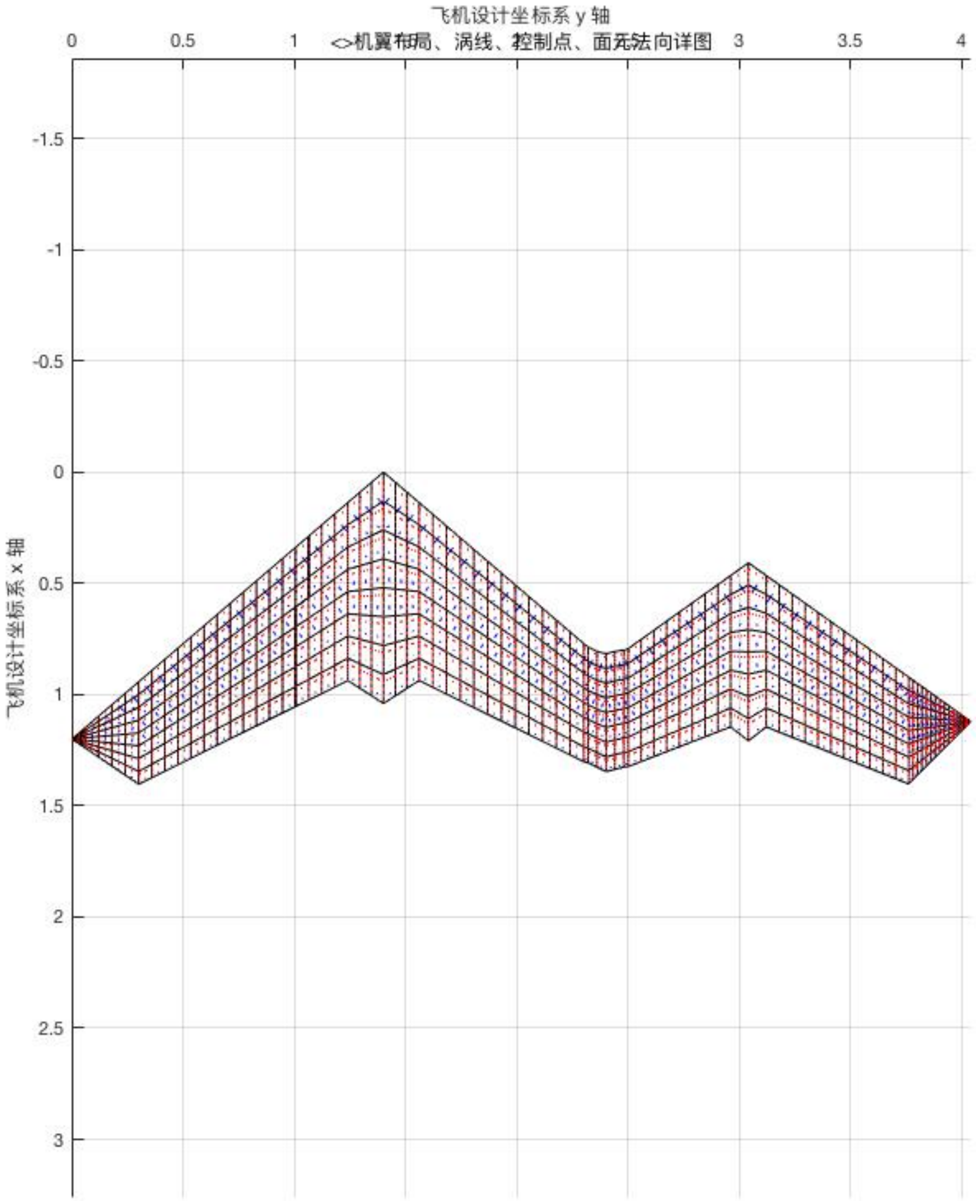
Simulation

- Vortex lattice method

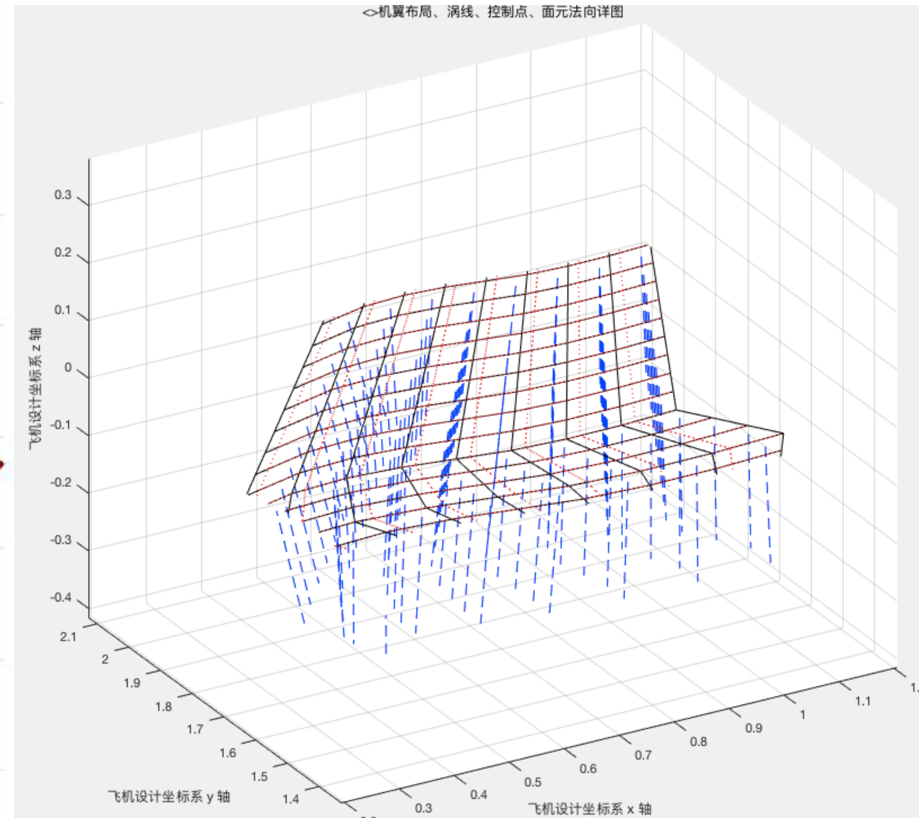
$$\omega(x,y) = -\frac{1}{4\pi}\iint_S \frac{(x-\xi)\gamma(\xi,\eta)+(y-\eta)\delta(\xi,\eta)}{[(x-\xi)^2+(y-\eta)^2]^{3/2}}\,d\xi d\eta - \frac{1}{4\pi}\iint_W \frac{(y-\eta)\delta_\omega(\xi,\eta)}{[(x-\xi)^2+(y-\eta)^2]^{3/2}}\,d\xi d\eta$$

- Computational Fluid Dynamics (CFD)

$$\begin{cases} \rho\dfrac{Du}{Dt} = -\dfrac{\partial p}{\partial x} + \dfrac{\partial \tau_{xx}}{\partial x} + \dfrac{\partial \tau_{yx}}{\partial y} + \dfrac{\partial \tau_{zx}}{\partial z} + \rho f_x \\ \rho\dfrac{Dv}{Dt} = -\dfrac{\partial p}{\partial y} + \dfrac{\partial \tau_{xy}}{\partial x} + \dfrac{\partial \tau_{yy}}{\partial y} + \dfrac{\partial \tau_{zy}}{\partial z} + \rho f_y \\ \rho\dfrac{Dw}{Dt} = -\dfrac{\partial p}{\partial z} + \dfrac{\partial \tau_{xz}}{\partial x} + \dfrac{\partial \tau_{yz}}{\partial y} + \dfrac{\partial \tau_{zz}}{\partial z} + \rho f_z \end{cases}$$



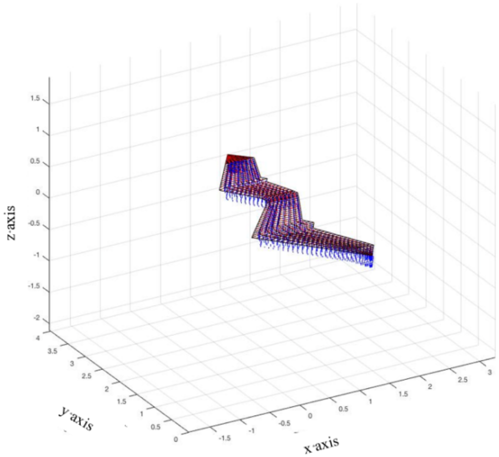
飞机设计坐标系 y 轴
<>机翼布局、涡线、控制点、面元法向详图
飞机设计坐标系 x 轴



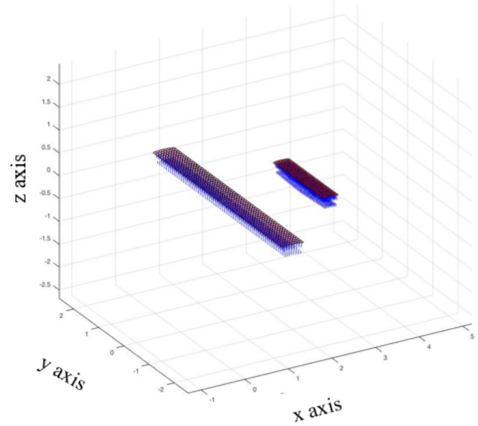
<>机翼布局、涡线、控制点、面元法向详图
飞机设计坐标系 z 轴
飞机设计坐标系 y 轴
飞机设计坐标系 x 轴

Results and Discussion

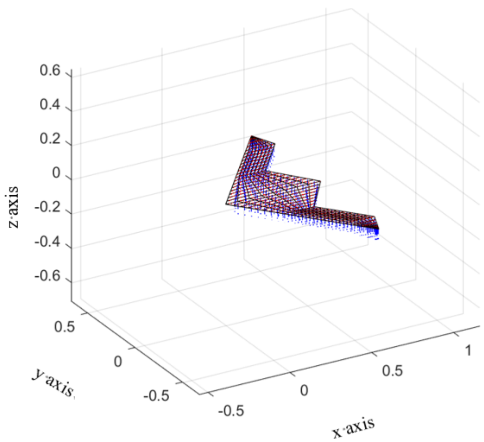
Vortex Lattice Method Data



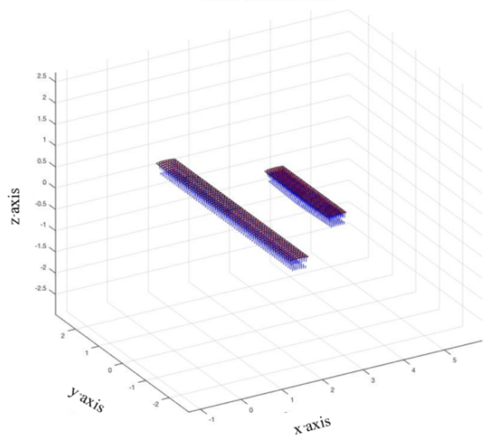
(a) TAFA



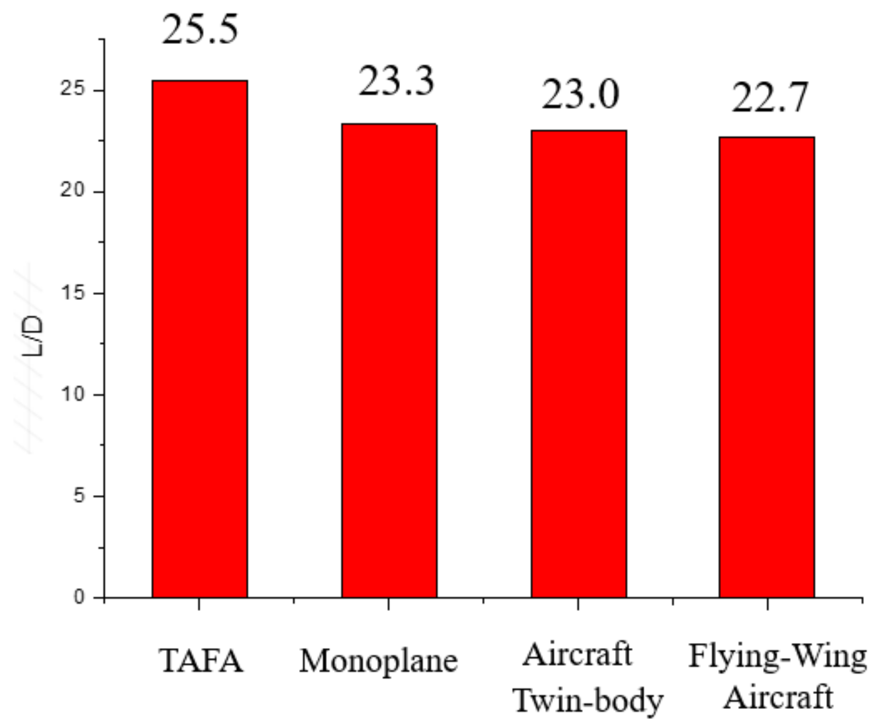
(b) Monoplane



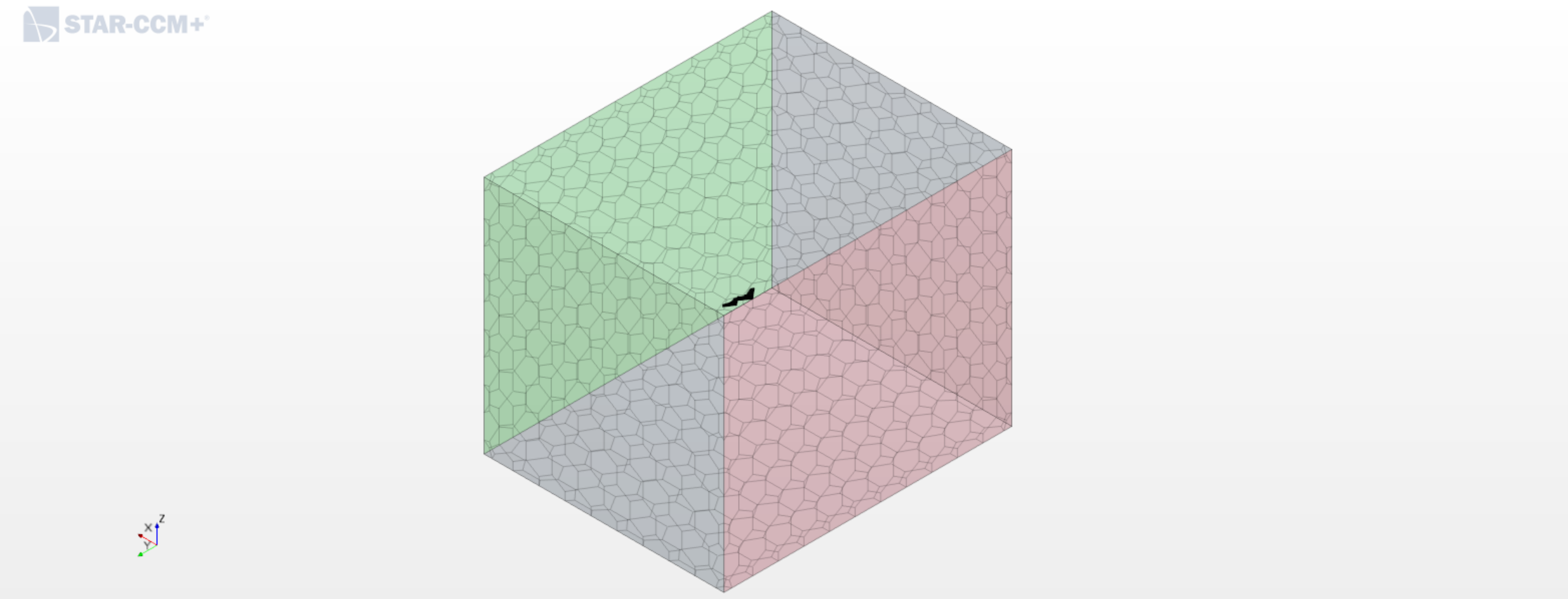
(c) Flying-Wing Aircraft

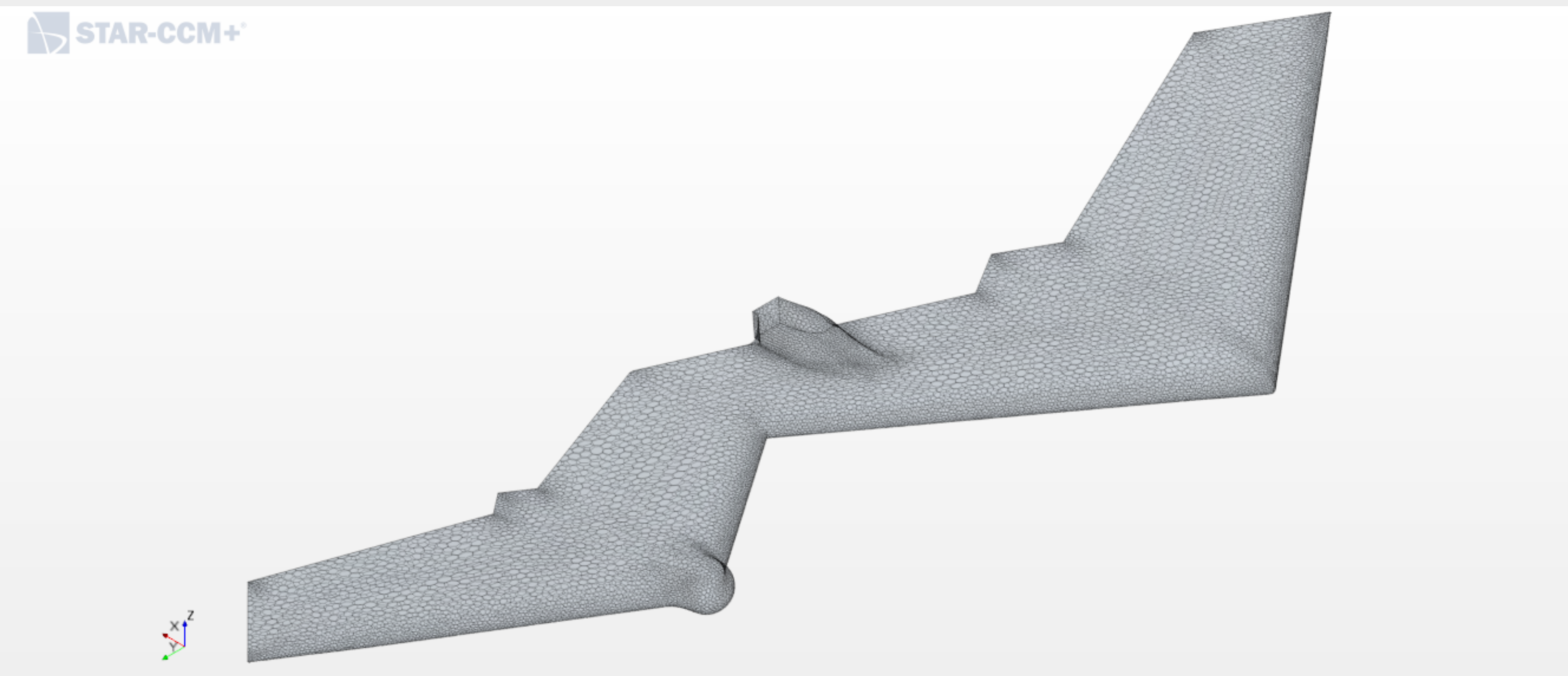


(d) Twin-body Aircraft



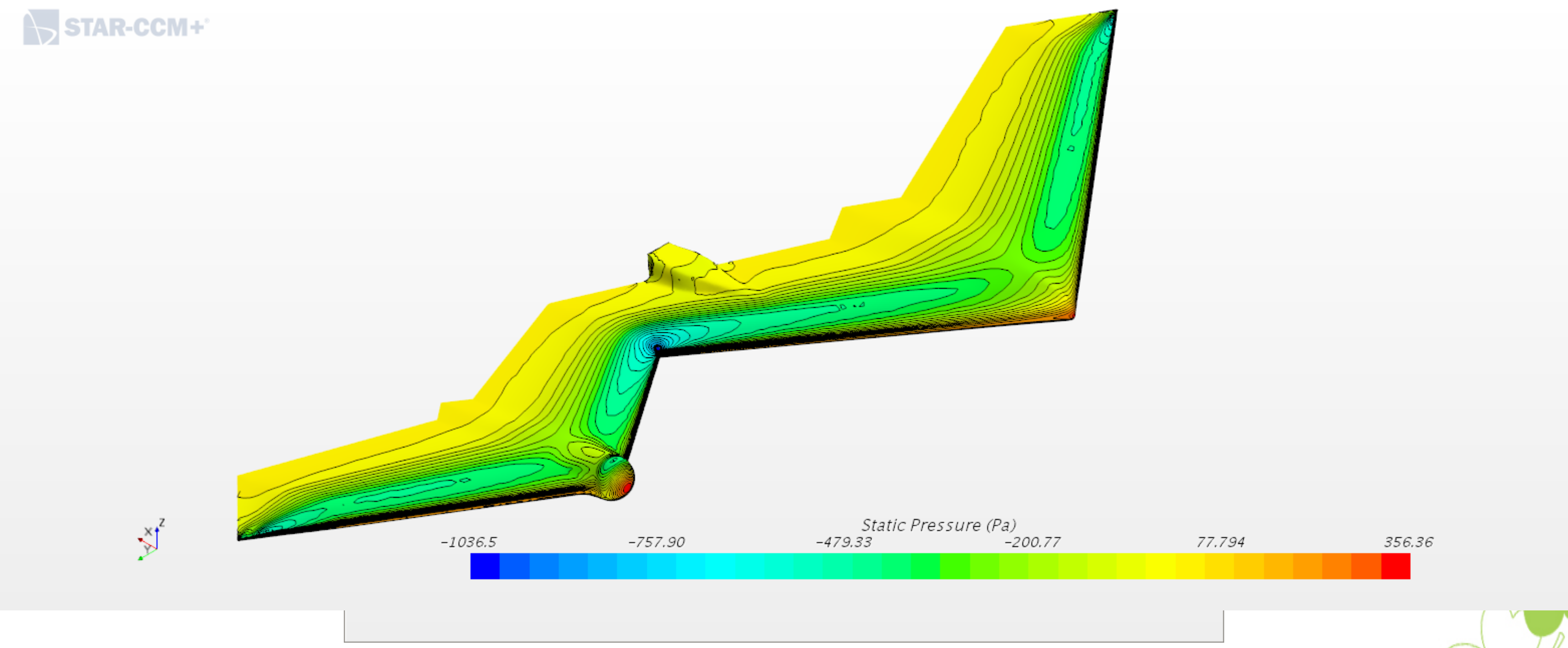
TAFA is the most efficient plane


STAR-CCM+
X
Y
Z


STAR-CCM+
X
Y
Z

Results and Discussion

CFD Simulation Pressure Distributing Figure



- **No large scale flow separation**
- **No stalled problem**
- **No obvious design problems**

Results and Discussion

CFD Simulation Data

	L (N)	D (N)	L/D
TAFA	329.2787	19.50406	16.88257
Flying-wing Aircraft	335.3814	24.20468	13.85709
Twin-body Aircraft	320.5712	24.93343	12.85709
Monoplane	321.6086	26.47643	12.14698

TAFA has the highest lift-drag ratio

↓

TAFA has the best flight performance

3

Fabrication & Flight Test

- Fabrication
- Flight Test

Fabrication

Draw the edge line on the EPP board
⇩
Cutting EPP board
⇩
Making delta wing using laser cutting machine
⇩
Paste delta wing
⇩
Cut EPP blocks
⇩
Make wingtip model and battery boxed by 3D printer
⇩
Paste the plates
⇩
Make ailerons
⇩
Fix the aileron on the aircraft
⇩
Fix the wastepaper on the aircraft and spray paint
⇩
Put the battery box, engine and propeller on this model
⇩
Reinforcing the hollowed-out structure

Flight Test

- ✓ Beijing University of Aeronautics and Astronautics
- ✓ Stable and controllable
- ✓ Control is sensitive and efficient
- ✓ **Successful and feasible**

4

Conclusion, Innovation, and Prospect

- Conclusion
- Innovation
- Prospect

Conclusion

(1) The combination of the three features can improve the lift, endurance, and efficiency of the twin-body aircraft.

(2) TAFA and other three aircraft models are designed and simulated. TAFA model is manufactured, and experimented. The results show that TAFA is well designed.

Innovation

(1) A new type of UAV

(2) Increase lift, endurance, and efficiency.

(3) Reinforce the structural strength of the mid-wing.

(4) Solve the equipment interference problem.

Prospect

- Applied into other tasks.
- Environmental-friendly.

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Acknowledgement

- Acknowledgement

Acknowledgement

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THANK YOU