Department of
MECHANICAL ENGINEERING
機械工程學系

THE HONG KONG
POLYTECHNIC UNIVERSITY
香港理工大學

Development of an Aerial Air Quality Monitoring Platform Based on Vertical Takeoff and Landing (VTOL) Unmanned Aerial Vehicle (UAV)

18/03/2022

ME FYP Group 29: Cheung Hiu Ching, Athena
Fung Ka Chun, Tim
Liu Sum Yin, Kylie

https://github.com/Athenachc/2021_FYP_ME_VTOL-UAV

Contents

1. Project Background (Gantt chart)
2. Current progress
    1. Flight log analysis
    2. Reinforcement – composited wings
    3. Simulation – CFD
3. Future plan
    1. Final report
    2. Final demonstration – video(s)

Project background

Introduction

- Background
  - Referring to the Innovation and Technology Fund (ITF) project
  - Air pollution monitoring in the Great Bay Aera by a VTOL UAV
  - Airframe selection of the VTOL UAV
  - Reinforcement of the mechanical structure of a VTOL UAV

- Objectives
  - Complete the flight task with the requirements
  - Redesign the wings
  - Manufacturing the wings with composited materials

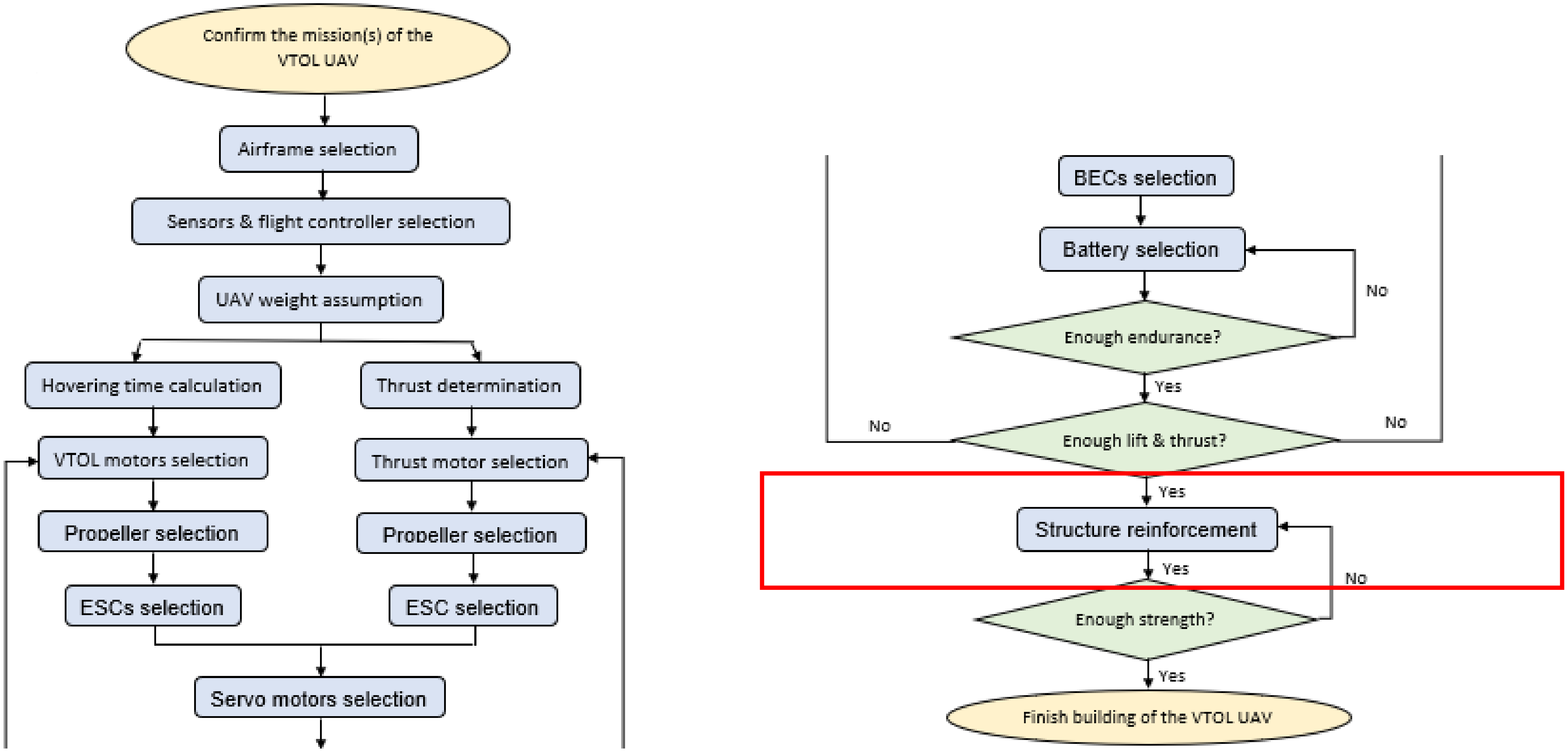
	Fixed Wing UAV	FWR-Hybrid UAV	Quadcopter
			
Flying Mechanism	Take-off and Landing, and Flying: A pair of wings & a pusher rotor	Take-off and Landing: Four rotors besides the fuselage Flying: A pair of wings, a pusher rotor & VTOL part	Take-off and Landing, and Flying: Four rotors as VTOL part
Shape	Streamlined shape	Hybrid of drone and fixed wing UAV	X shape or Plus shape
Type(s) of motors	DC brushless motors & servo motors	DC brushless motors & servo motors	DC brushless motors
Duration	Very High	High	Low
Speed	Very High	High	Low
Maneuverability	Low	High	Very High

Aseem Saini and Mukul Chhabra, "Hybrid VTOL-UAV for Air Delivery and Sampling Purposes", B.Tech dissertation, Dept. Elect & Com. Eng., Indraprastha Institute of Information Technology,. New Delhi, 2018.

Chika Yinka-Banjo and Olasupo Ajayi, "Sky-Farmers: Applications of Unmanned Aerial Vehicles (UAV) in Agriculture," IntechOpen, 2019.

D. Baek, Y. Chen, A. Bocca, A. Macii, E. Macii, and M. Poncino, "Battery-Aware Energy Model of Drone Delivery Tasks," in Proceedings of the International Symposium on low power electronics and design, 2018, pp. 1–6, doi: 10.1145/3218603.3218614.

Methodology: Design flowchart of building a VTOL UAV



Project schedule (updated)

Description	Start date	End date	Duration (days)
Planning	01/08/2021	22/08/2021	22
Understanding the requirements of the flight mission	01/08/2021	01/08/2021	1
Self-learning of VTOL UAV and quadcopters	08/08/2021	22/08/2021	15
VTOL UAV Design	23/08/2021	31/12/2021	131
Do simulation and calculation of VTOL Skywalker X8	22/08/2021	22/09/2021	32
Building VTOL Skywalker X8	23/08/2021	05/11/2021	75
Fly test & data analysis with CFD's results of VTOL Skywalker X8	10/11/2021	31/12/2021	52
Interim report	01/09/2021	22/11/2021	83
Composited VTOL UAV Design	22/09/2021	05/03/2022	165
Do simulation and calculation of our composited VTOL UAV	22/09/2021	31/12/2021	101
Draw 3D CAD drawing of our composited VTOL UAV	01/11/2021	04/12/2021	34
Design the CF mold and manufacturing the composited VTOL UAV	04/12/2021	05/04/2022	123
Fly test & data analysis with CFD's results of composited VTOL UAV	04/02/2022	12/04/2022	68
Final report	05/03/2022	19/04/2022	46

Gantt chart (updated)

Planning

Understanding the requirements of the flight mission

Self-learning of VTOL UAV and quadcopters

VTOL UAV Design

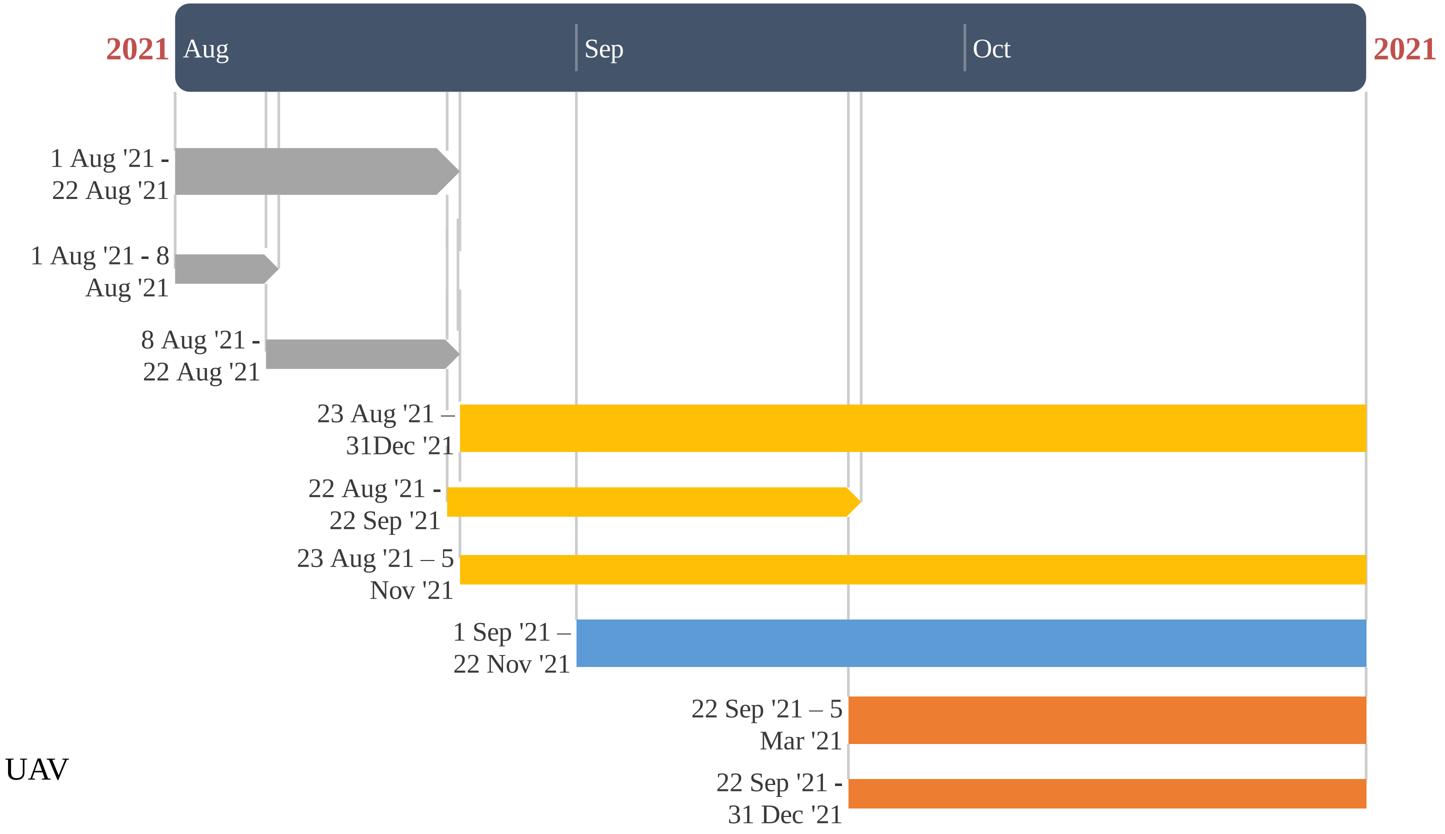
Do simulation and calculation of VTOL Skywalker X8

Building VTOL Skywalker X8

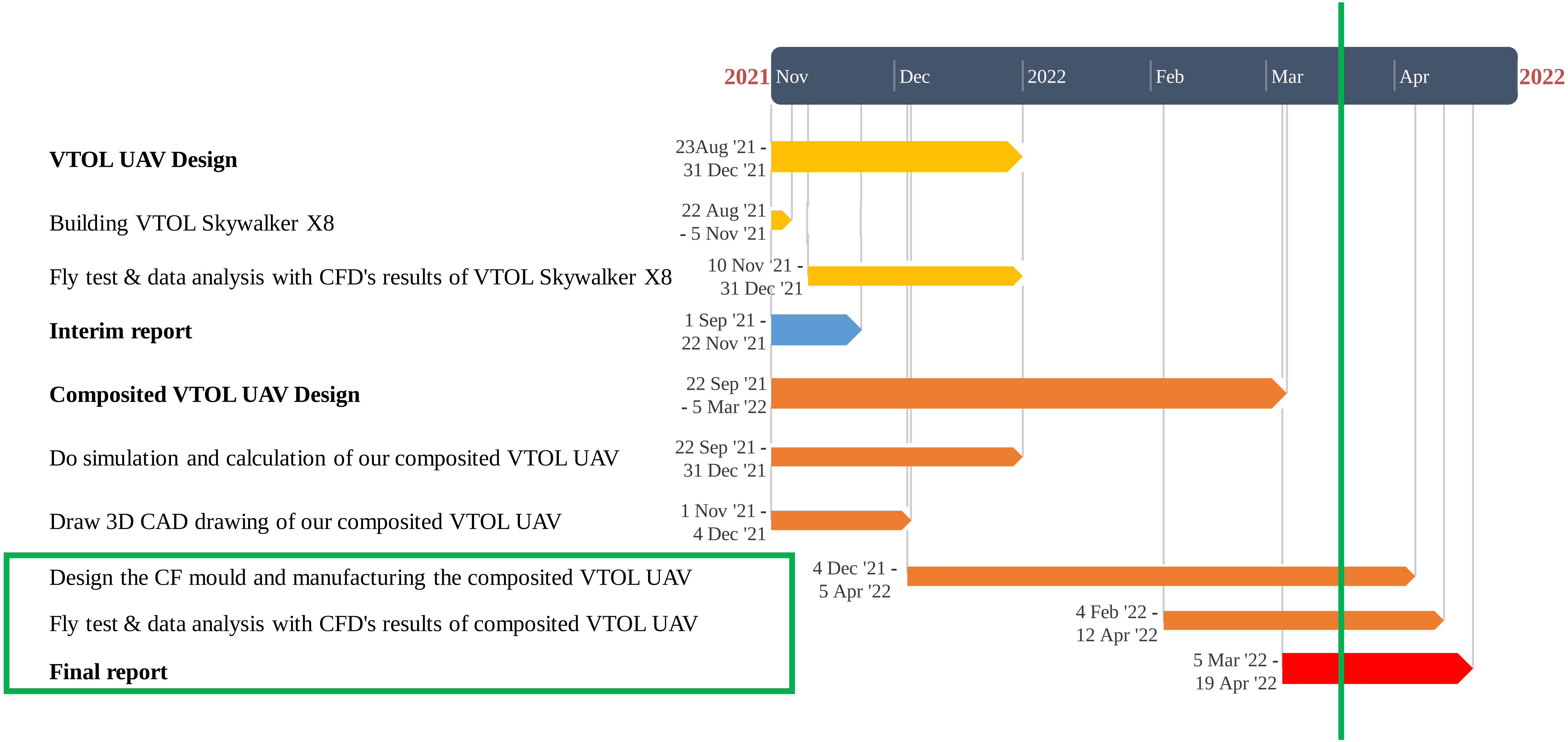
Interim report

Composited VTOL UAV Design

Do simulation and calculation of our composited VTOL UAV



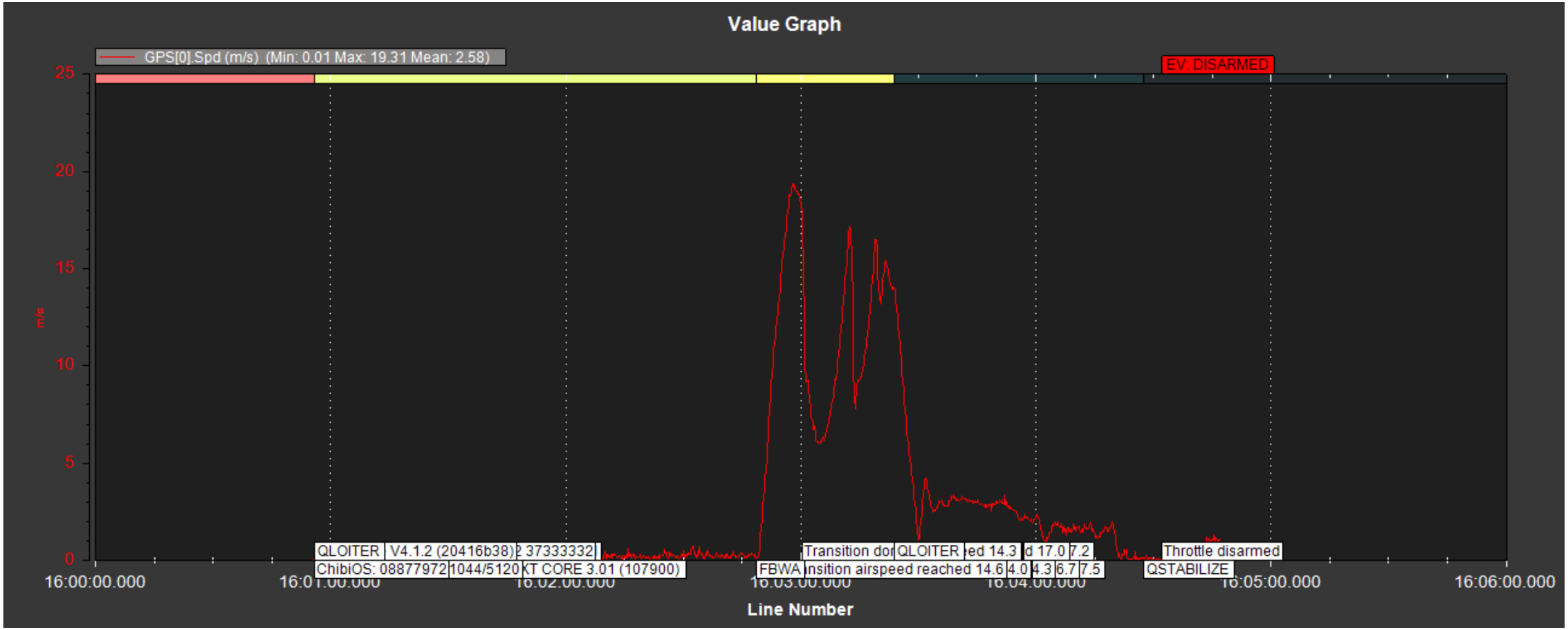
Gantt chart (updated)



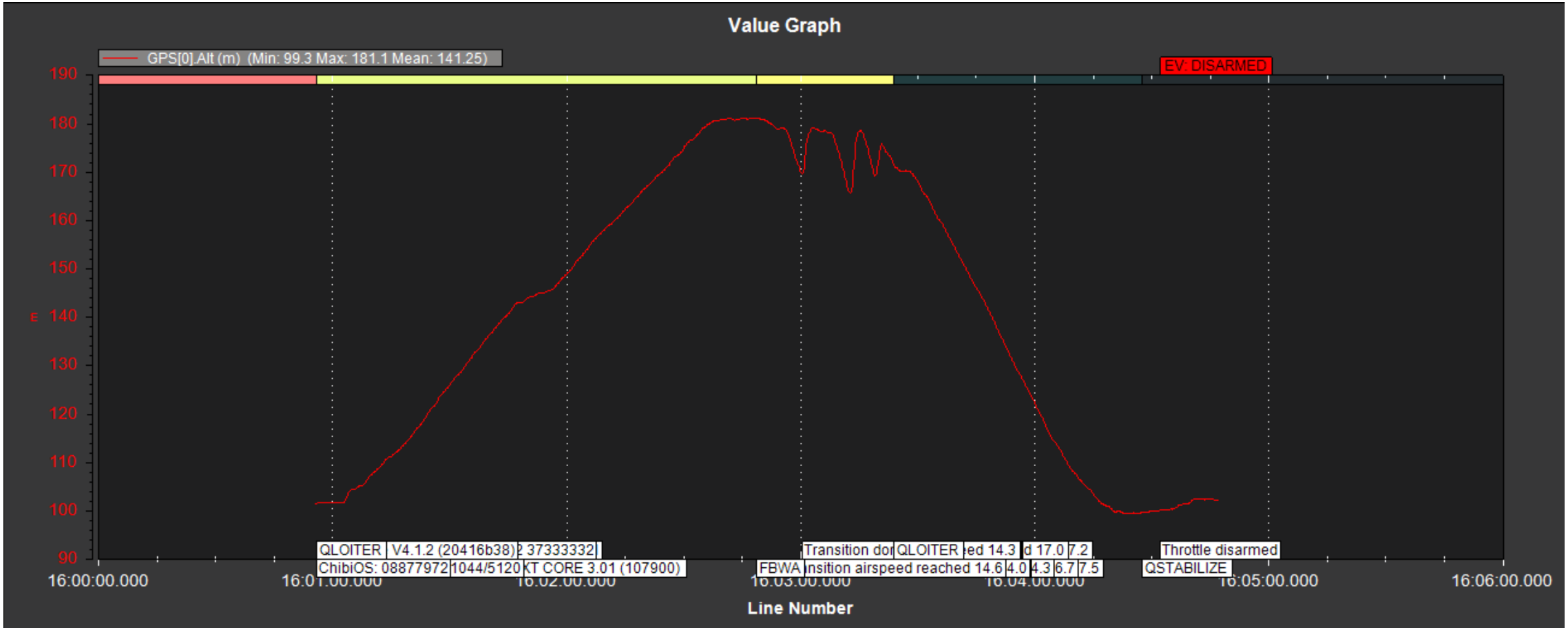
Current progress

Flight log analysis

The speed during the flight:



Altitude during the flight:



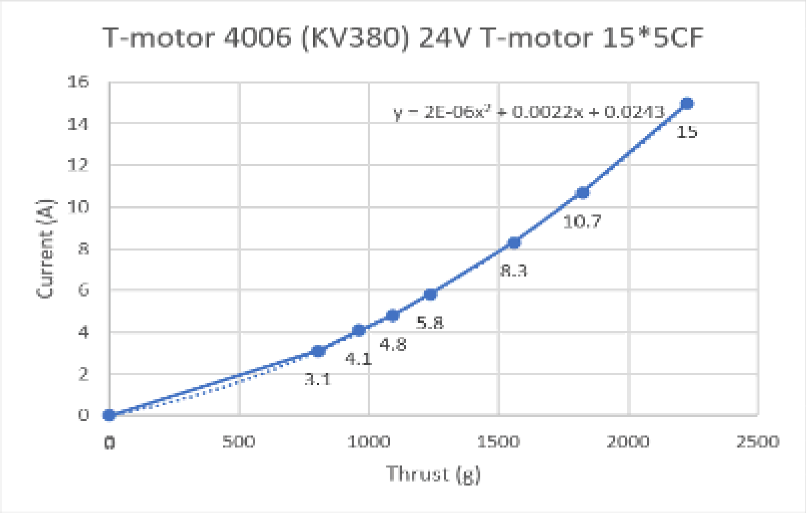
Estimation of the motor before flight

Motor	Propeller	Voltage (V)	Weight (g) (4 motors)	Weight (g) (4 propellers)
T-motor 4006 (KV380)	T-motor 15*5CF	24	272	106

Thrust (g)	Current (A)
0	0
805	3.1
959	4.1
1093	4.8
1236	5.8
1561	8.3
1823	10.7
2228	15

Required equation: ax^2+bx+c		
a	b	c
2.00E-06	0.0022	0.0243

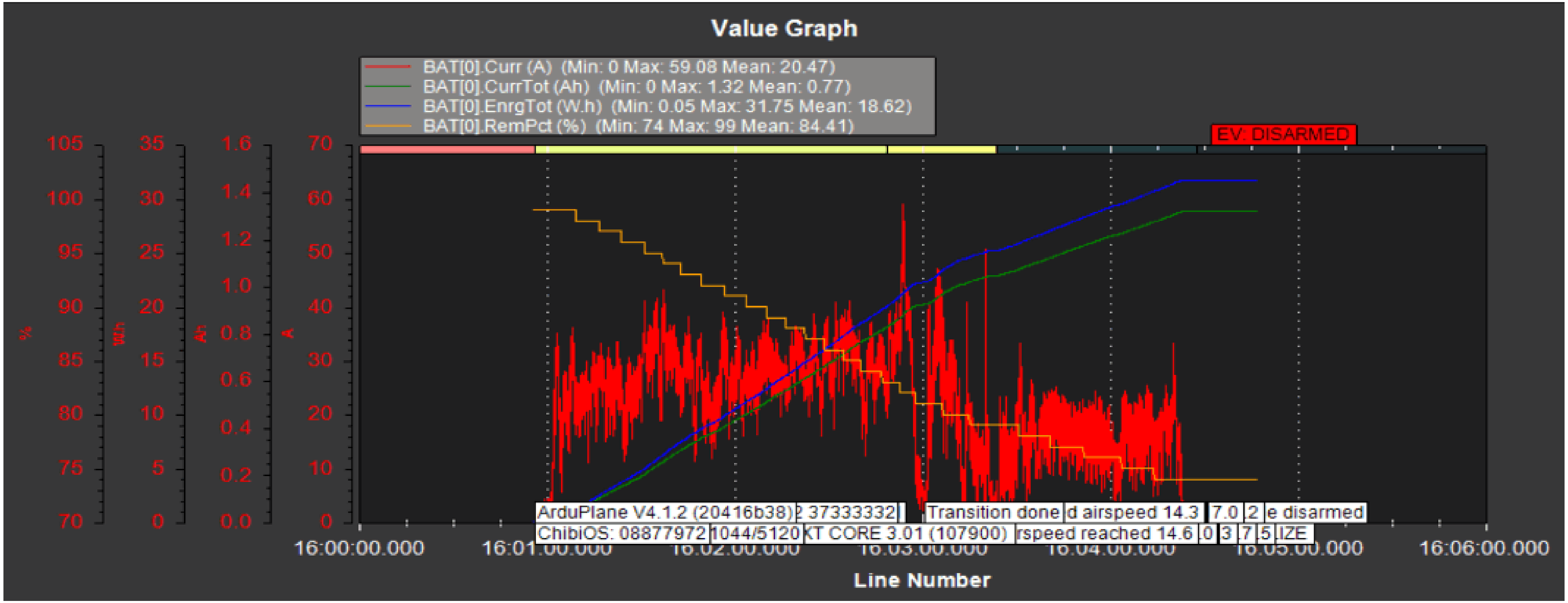
Assume total weight (g)	3567.9
Assume total current (A)	14.31
Assumed Depth of discharge (DOD)	0.70
Required energy capacity (mAh)	20445.05029
Hovering time (min)	64.56330413
Weight/Thrust (%)	40.03478456



Department of
MECHANICAL ENGINEERING
機械工程學系

THE HONG KONG POLYTECHNIC UNIVERSITY
香港理工大學

Battery log graph:



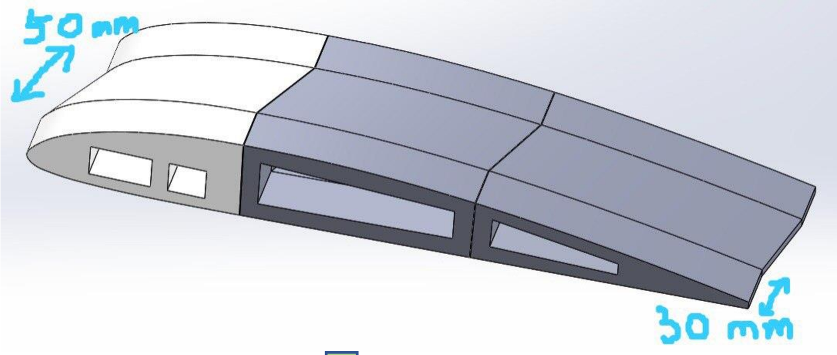
Current progress

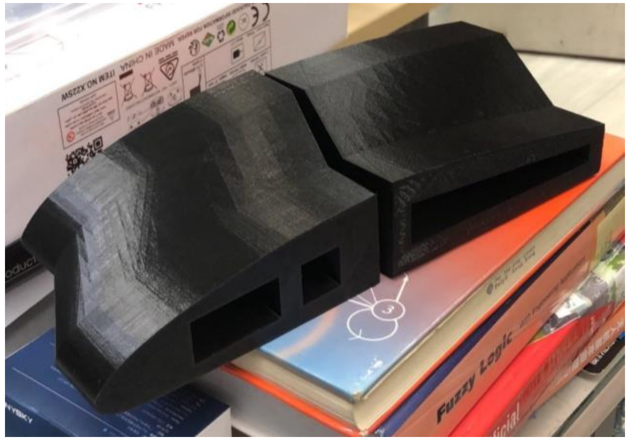
Reinforcement – composited wing

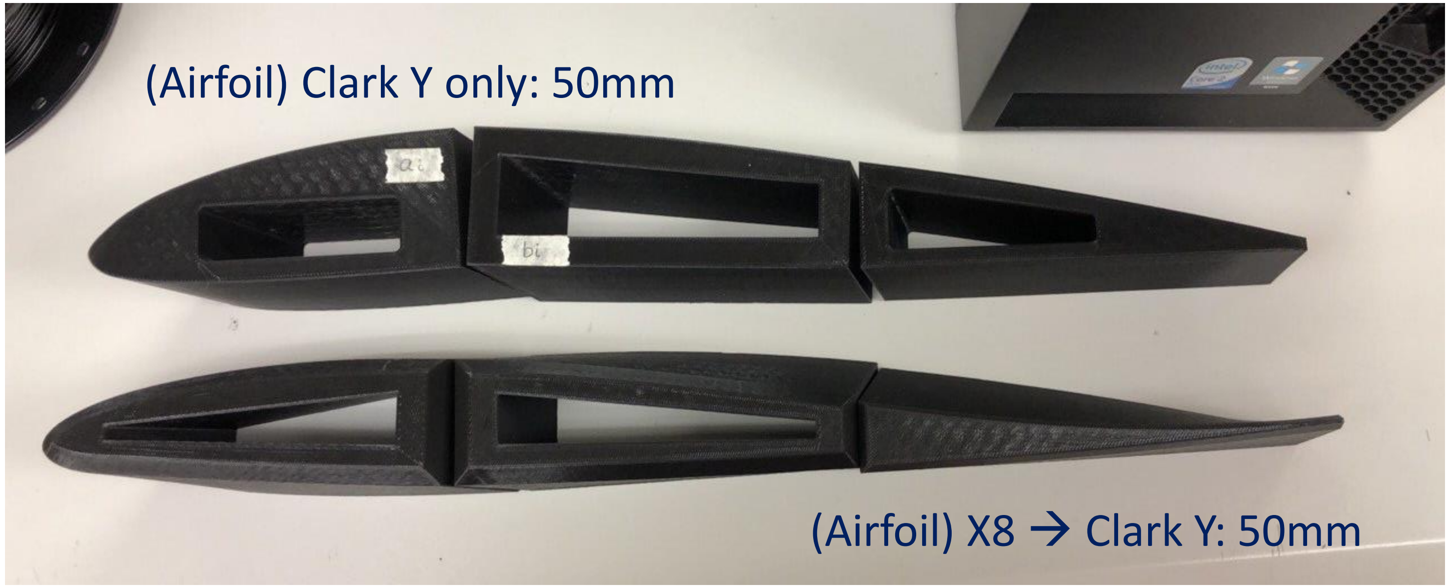
Department of
MECHANICAL ENGINEERING
機械工程學系

THE HONG KONG POLYTECHNIC UNIVERSITY
香港理工大學

Mold design for testing:



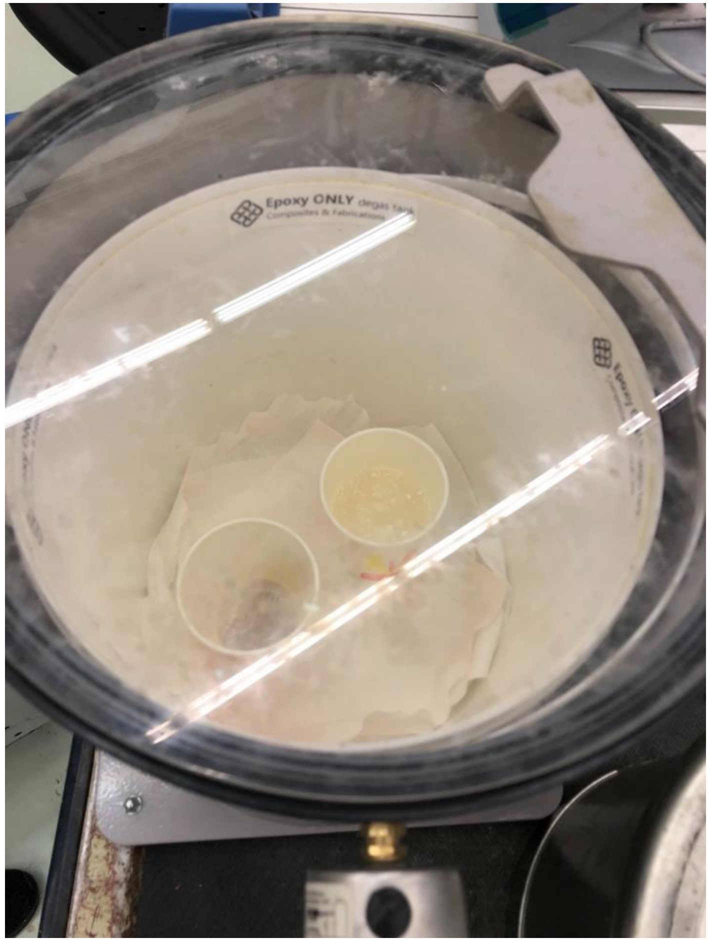




Manufacturing (test):

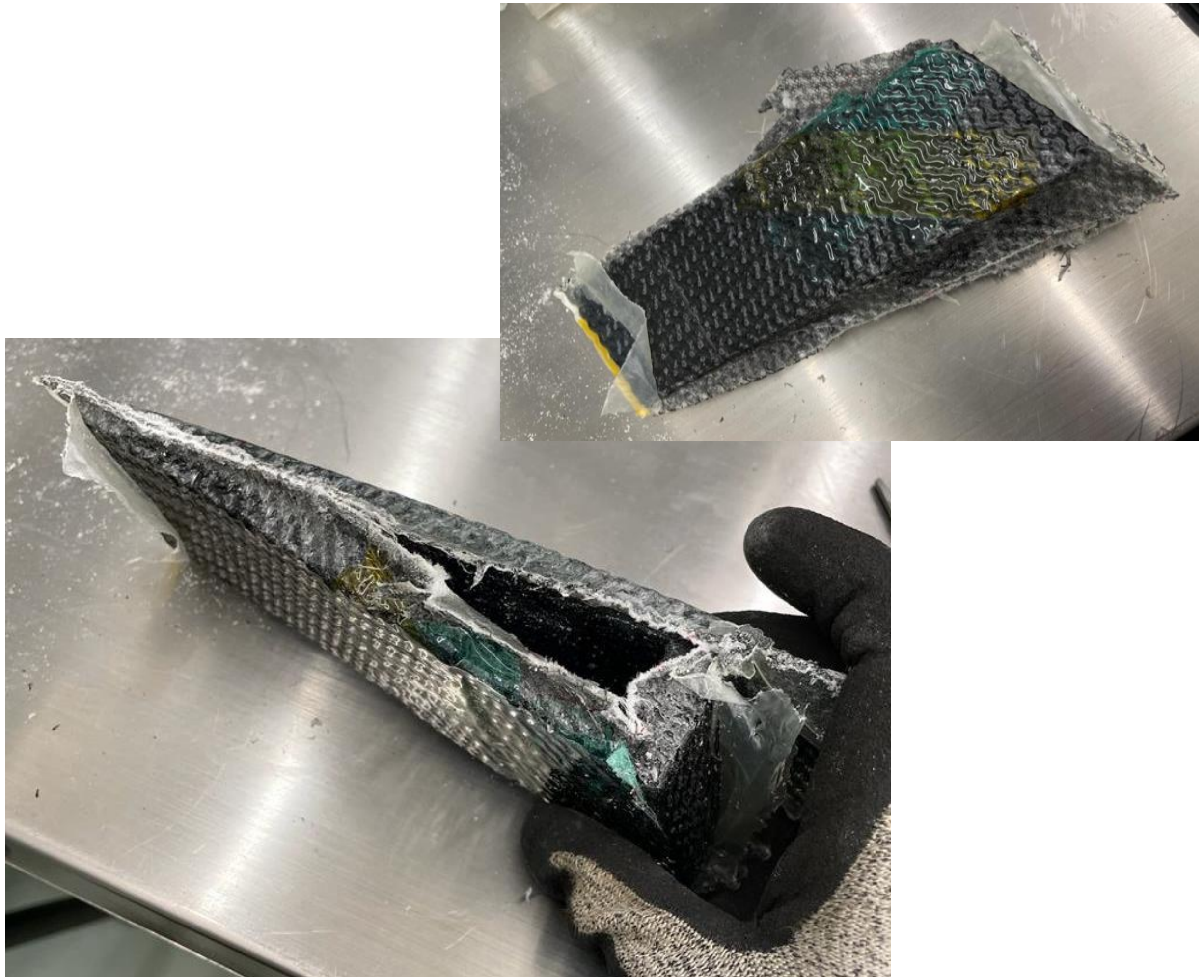
Adding releaser

Ply cutting

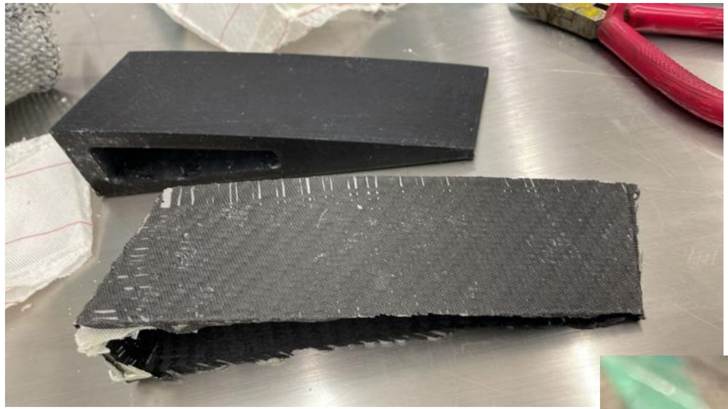


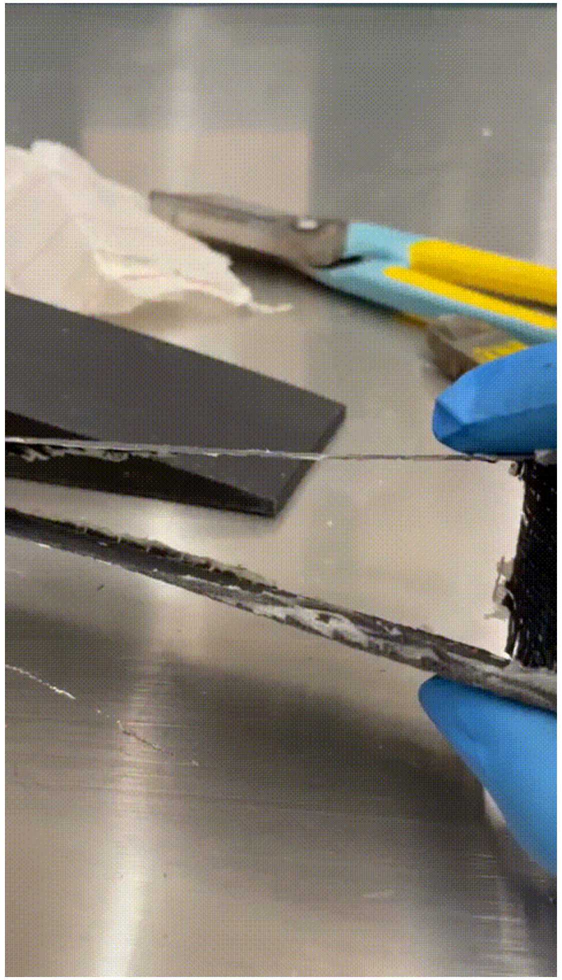
200g “WS 105” Resin + 54.35g “WS 209” hardener
(Referring to “Matrix Ratio Guide” in IC)

Vacuum bagging



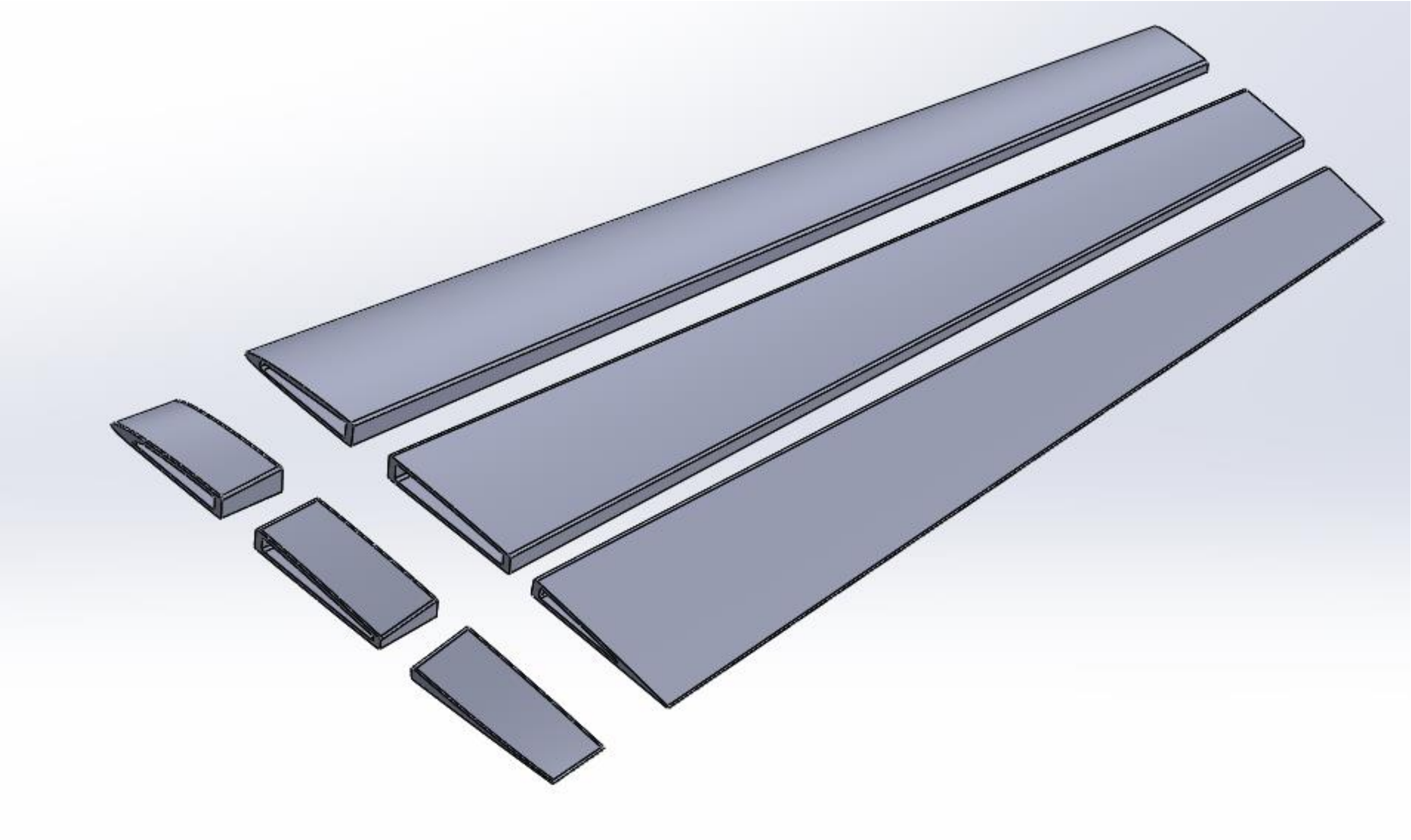
De-bagging





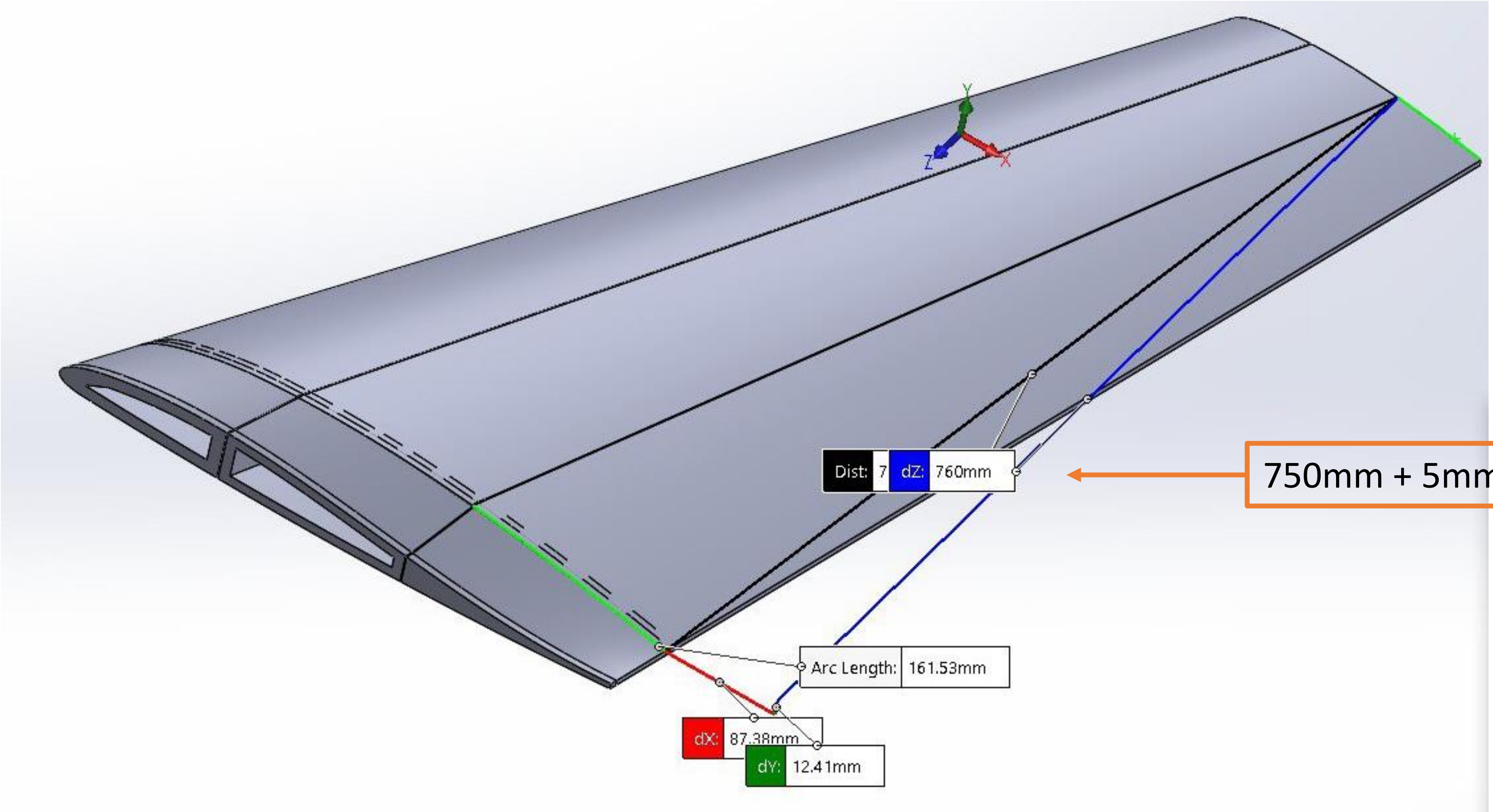
1 layer of 3K CF sheet

Modified mold design:



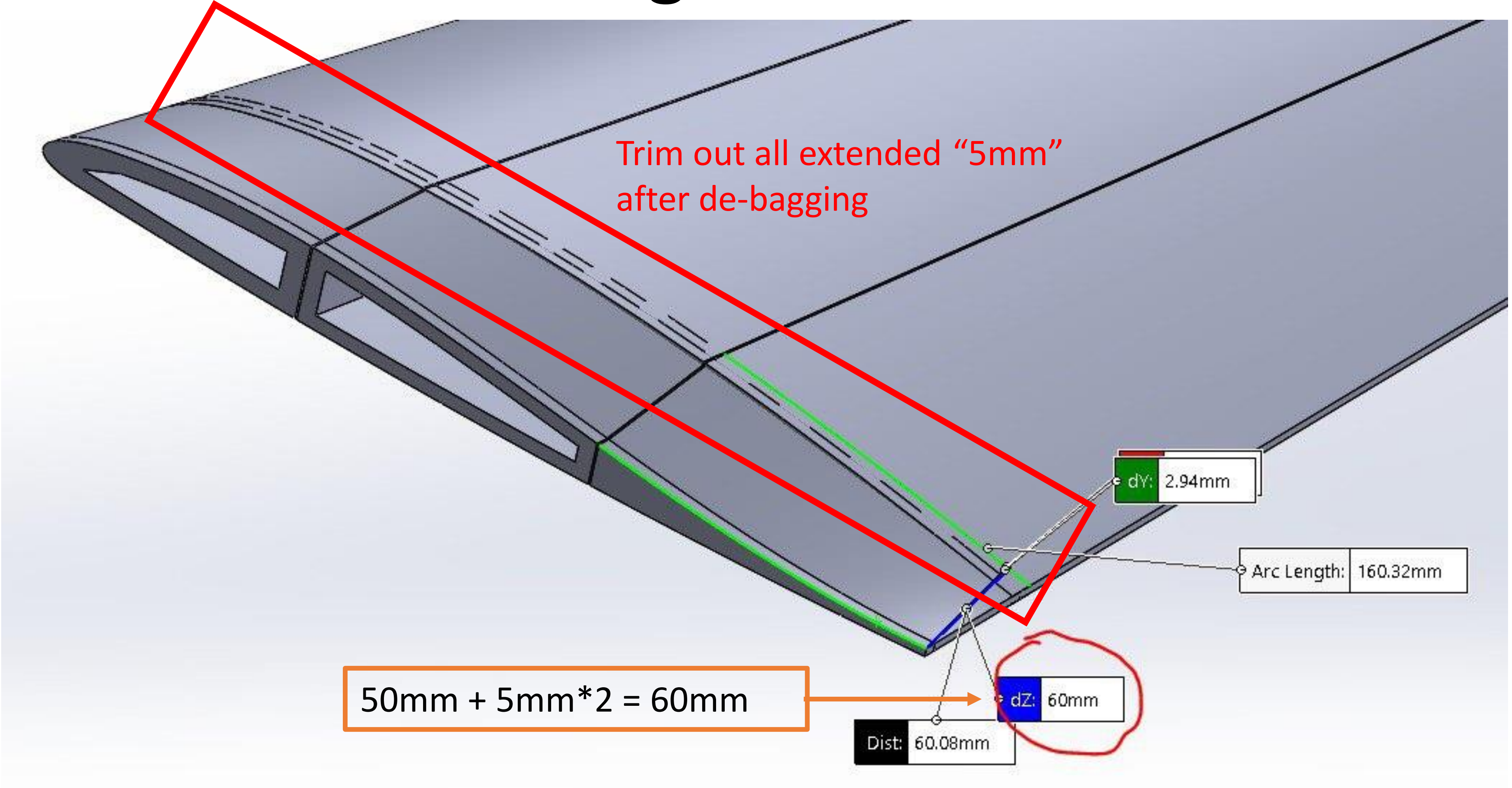
6 parts (PLA)

Modified mold design:

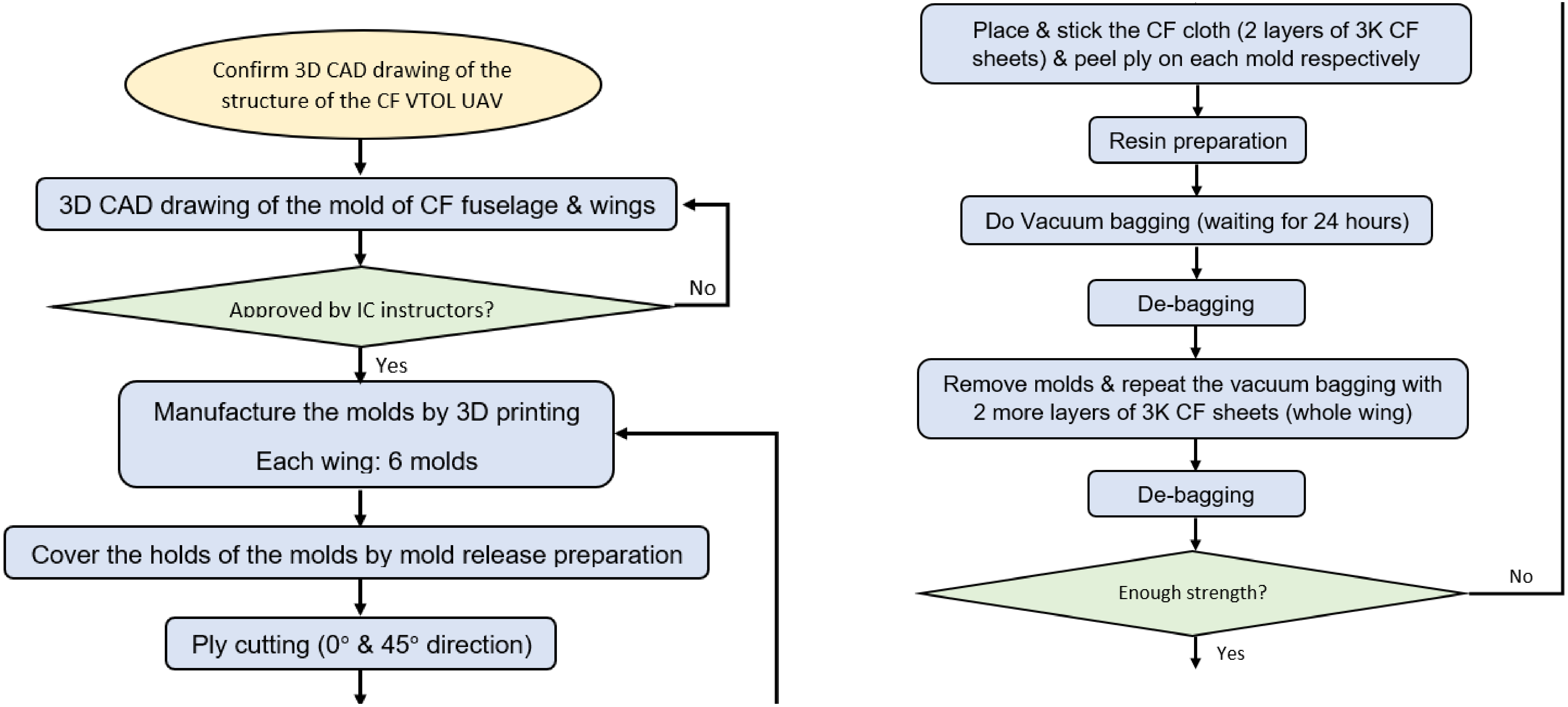


750mm + 5mm*2 = 760mm

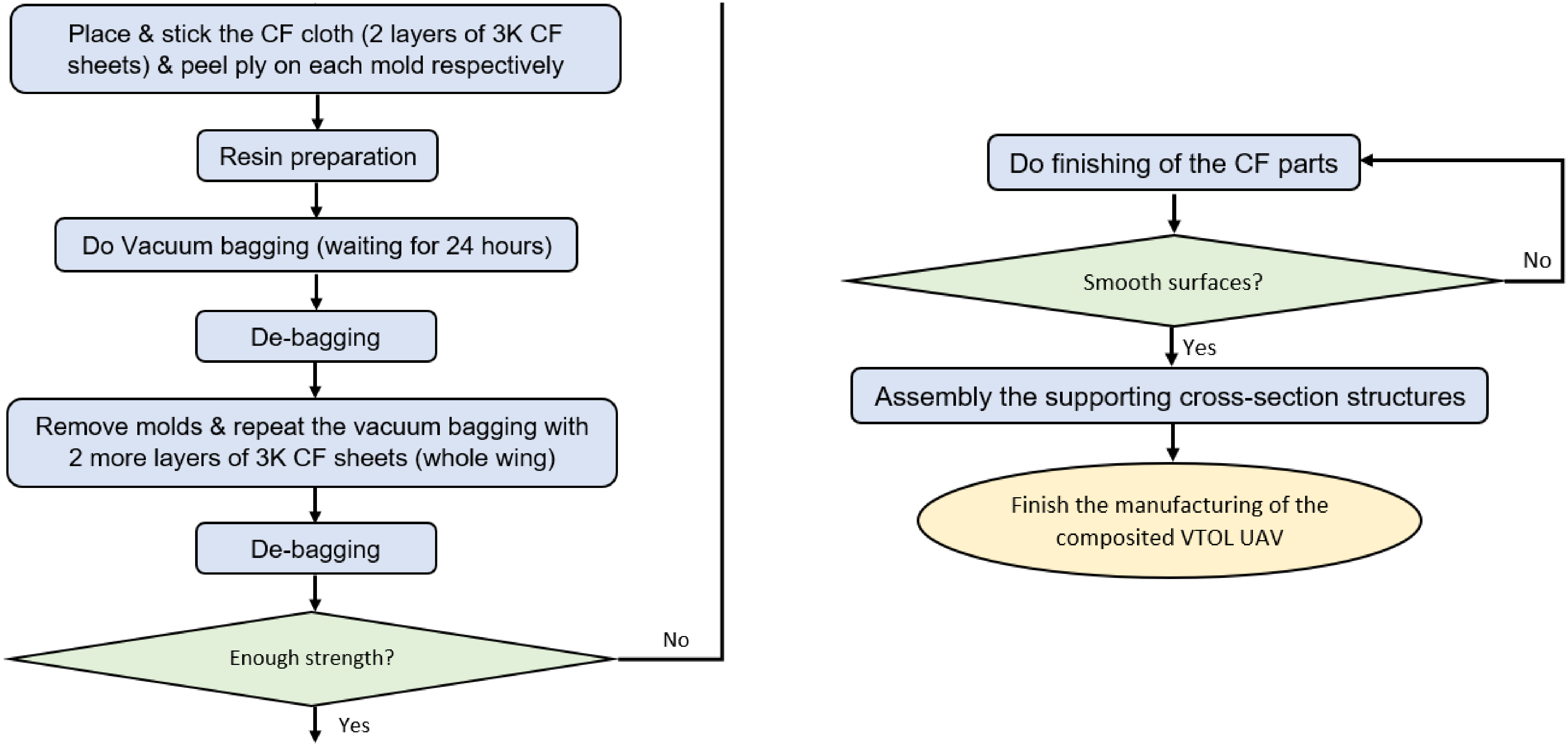
Modified mold design:



Design flowchart of structure reinforcement by manufacturing a composited VTOL UAV (updated)



Design flowchart of structure reinforcement by manufacturing a composited VTOL UAV (updated)



Current progress

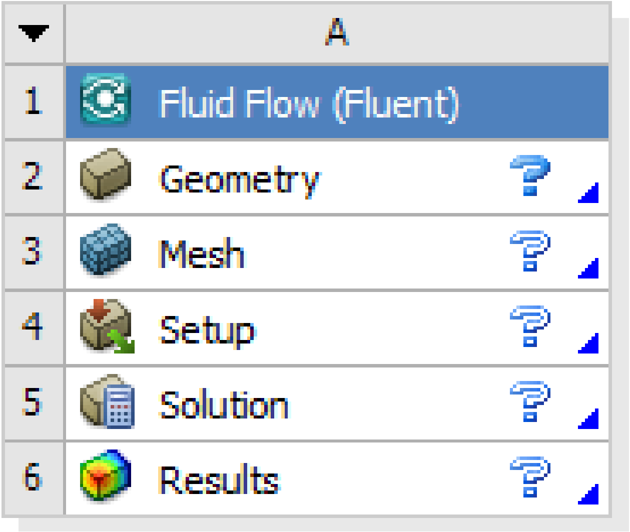
Simulation – CFD

Ansys Fluent

ANSYS FLUENT

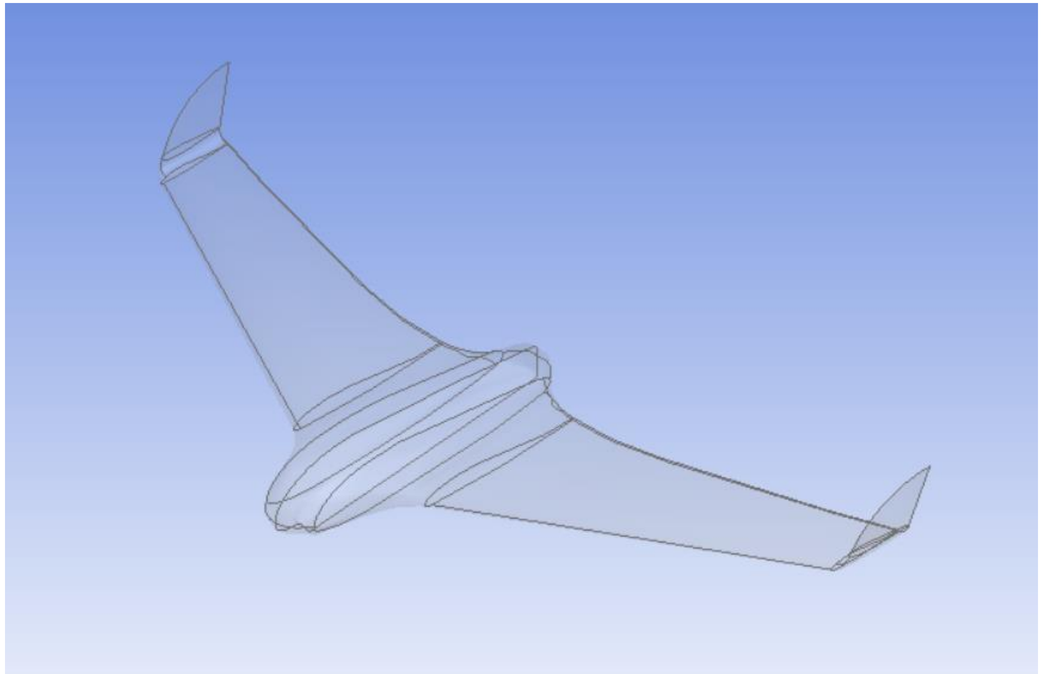
Steps:

1. Import CAD & draw wind tunnel (Geometry)
2. Create mesh (Mesh)
3. Launch FLUENT (Setup)



1. Import CAD & draw wind tunnel (Geometry)

- Import UAV from SolidWorks (.STEP) to “DesignModeler”
- Wind Tunnel created by "Enclosure" function
- Do subtraction by “Boolean” function



Import1 → Generate (right click)
MUST import 1 body ONLY (SW: combine all parts into 1 part by “Combine → Add” function)

1. Import CAD & draw wind tunnel (Geometry)

- Import UAV from SolidWorks (.STEP)

- Wind Tunnel created by "Enclosure" function

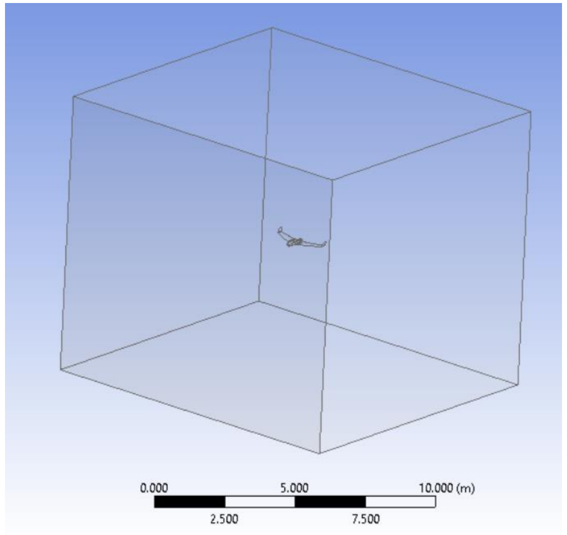
- Do subtraction by “Boolean” function

Details View

Details of Enclosure1	
Enclosure	Enclosure1
Shape	Box
Number of Planes	0
Cushion	Non-Uniform
FD1, Cushion +X value (>0)	5 m
FD2, Cushion +Y value (>0)	5 m
FD3, Cushion +Z value (>0)	5 m
FD4, Cushion -X value (>0)	5 m
FD5, Cushion -Y value (>0)	5 m
FD6, Cushion -Z value (>0)	5 m
Target Bodies	All Bodies
Export Enclosure	Yes

1. Import CAD & draw wind tunnel (Geometry)

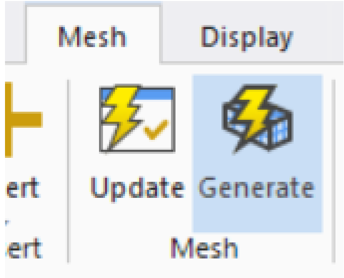
- Import UAV from SolidWorks (.STEP)
- Wind Tunnel created by "Enclosure" function
- Do subtraction by “Boolean” function



Details View

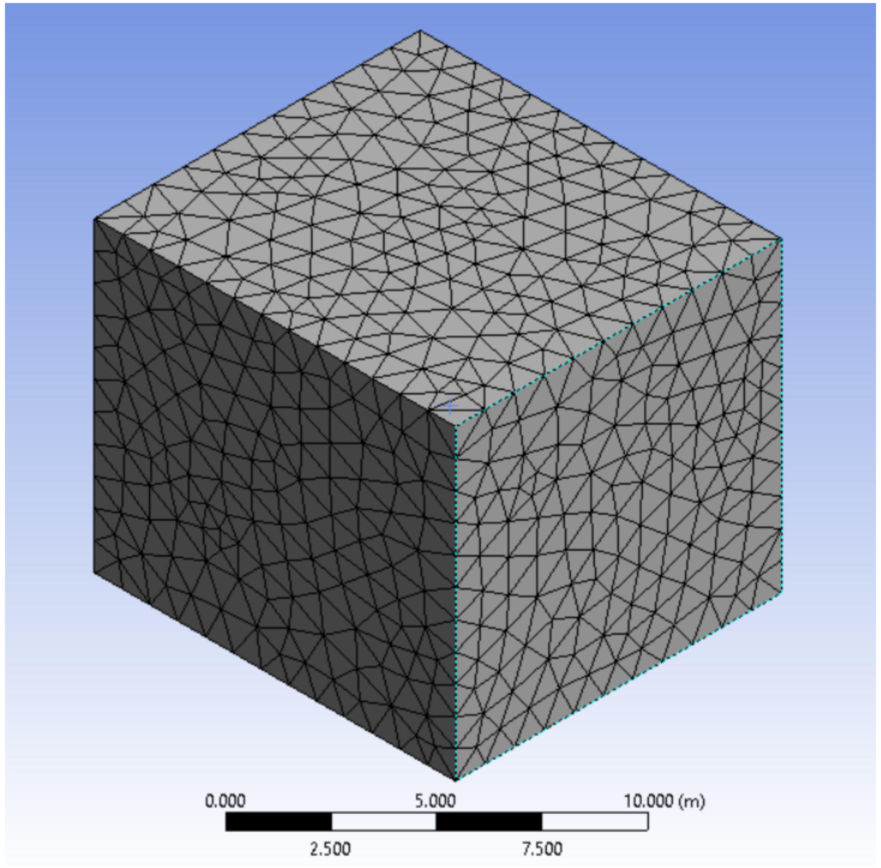
Details of Boolean1	
Boolean	Boolean1
Operation	Subtract
Target Bodies	1 Body
Tool Bodies	1 Body
Preserve Tool Bodies?	No

2. Create mesh (Mesh)



- Mesh creation

- Inlet, Outlet, Walls (wall left, wall right, wall up, wall down) and the aircraft are defined

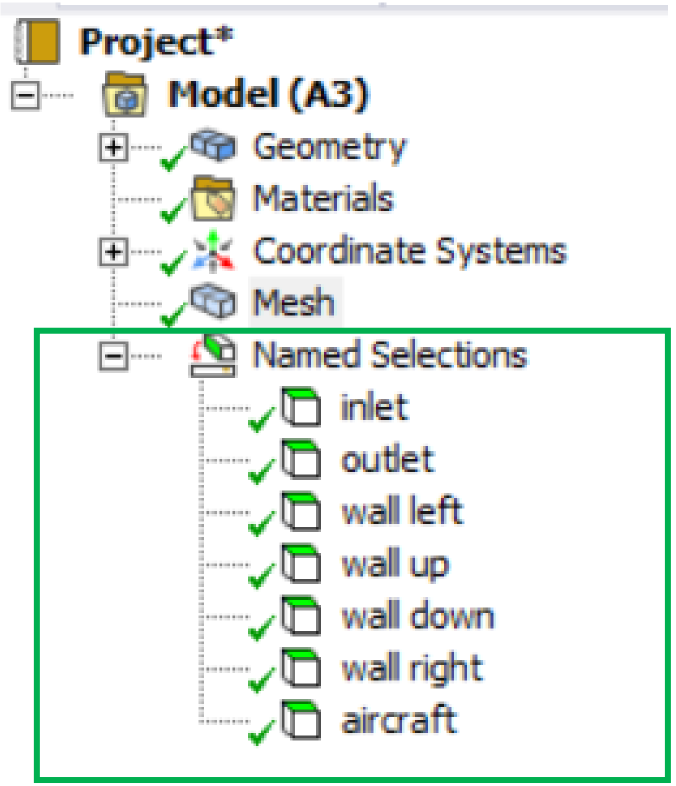


2. Create mesh (Mesh)

- Mesh creation

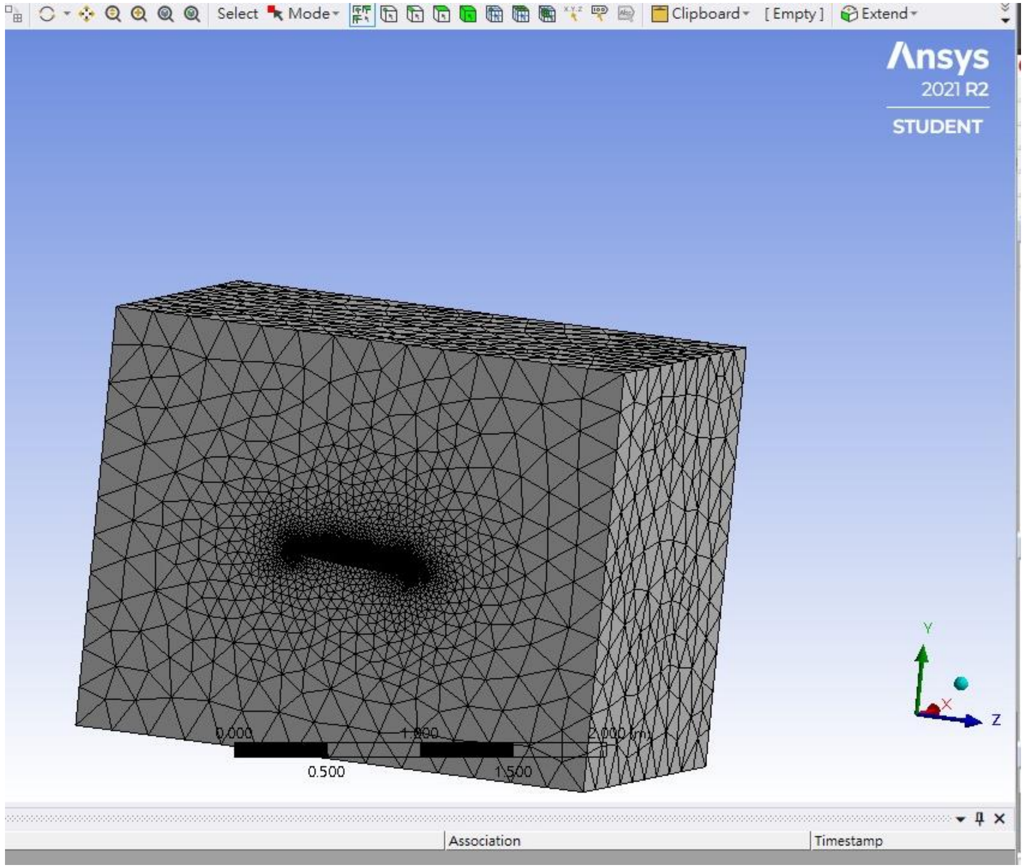
- Name Selections creation:

  Inlet, Outlet, Walls (wall left, wall right, wall up, wall down) and the aircraft are defined



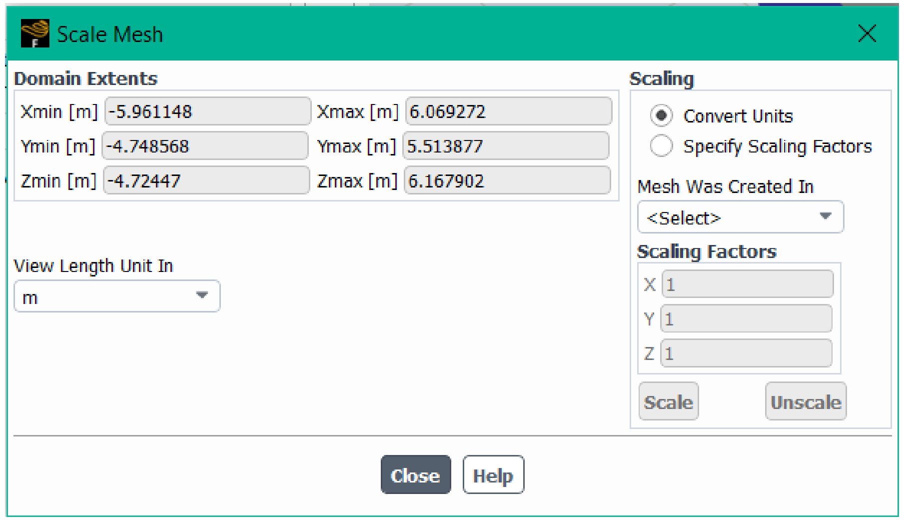
2. Create mesh (Mesh)

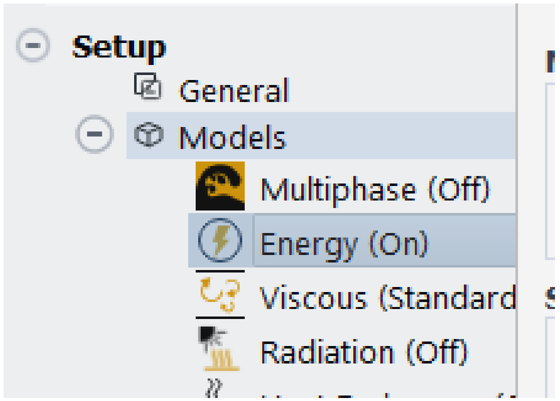
- Mesh creation
- Inlet, Outlet, Walls (wall left, wall right, wall up, wall down) and the aircraft are defined



3. Launch FLUENT (Setup)

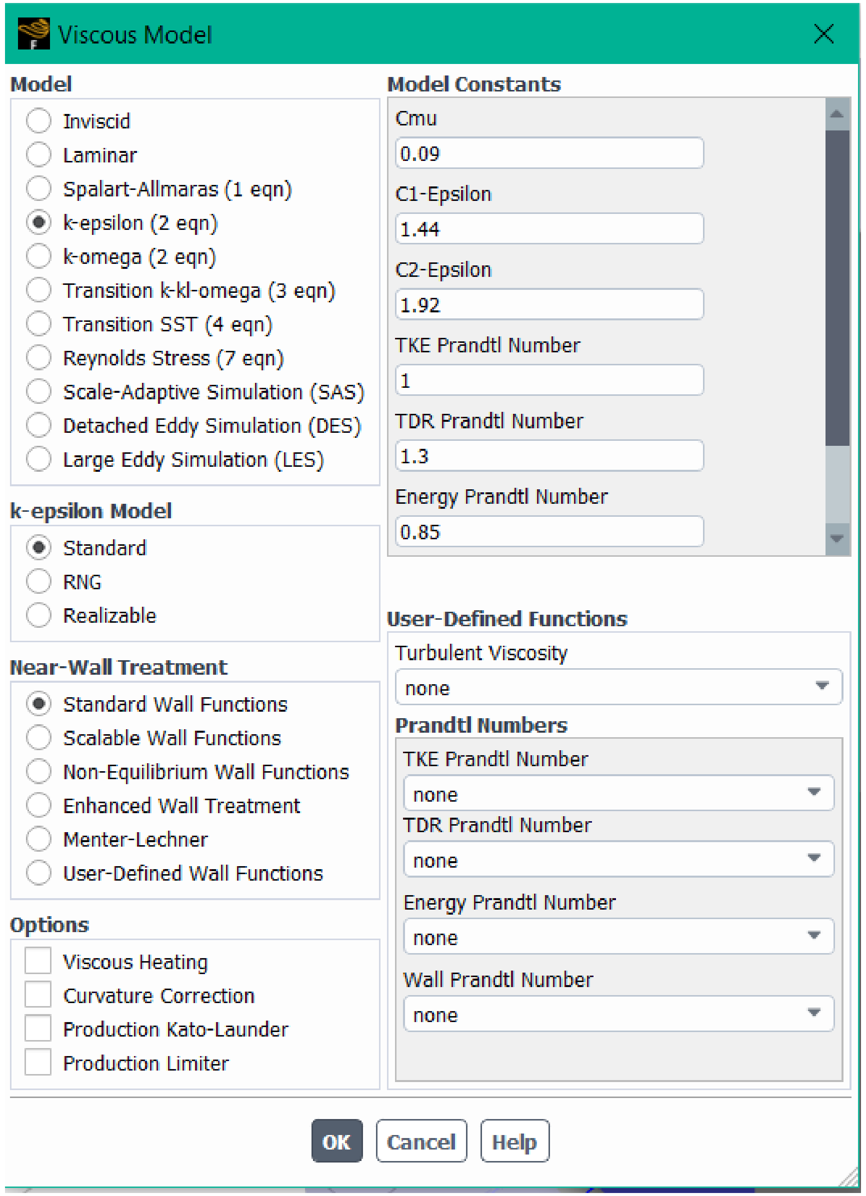
1. Scale Mesh: unit = m
2. Model: Energy On
3. Set K-epsilon model
4. Air as fluid
5. Inlet velocity: 15m/s
6. Set report Definitions
7. Set Solution Methods
8. Set Residual Monitors
9. Set Initialization





3. Launch FLUENT (Setup)

1. Scale Mesh: unit = m
2. Model: Energy On
3. Set K-epsilon model (Common model for Turbulent flow (Re ~=4.3 x 10^5))
4. Air as fluid
5. Inlet velocity: 15m/s
6. Set report Definitions
7. Set Solution Methods
8. Set Residual Monitors
9. Set Initialization

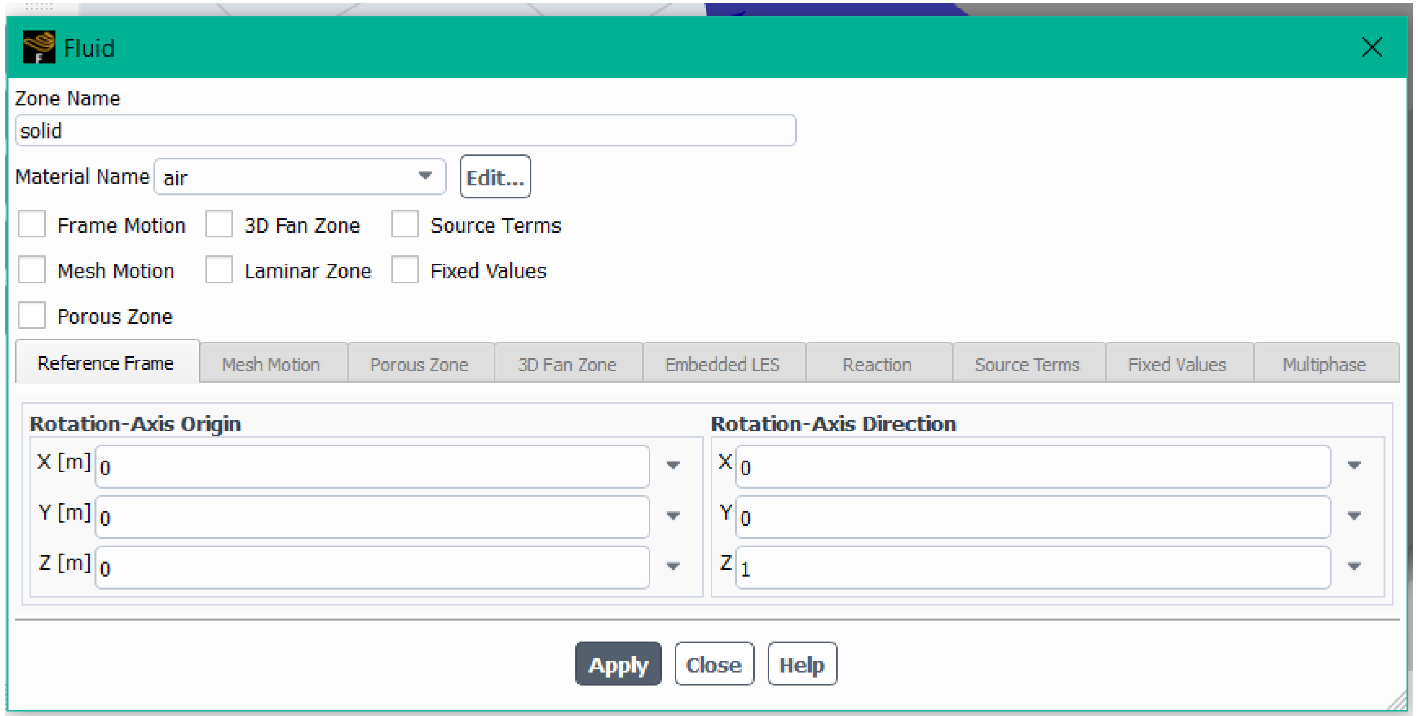


Department of
MECHANICAL ENGINEERING
機械工程學系

THE HONG KONG POLYTECHNIC UNIVERSITY
香港理工大學

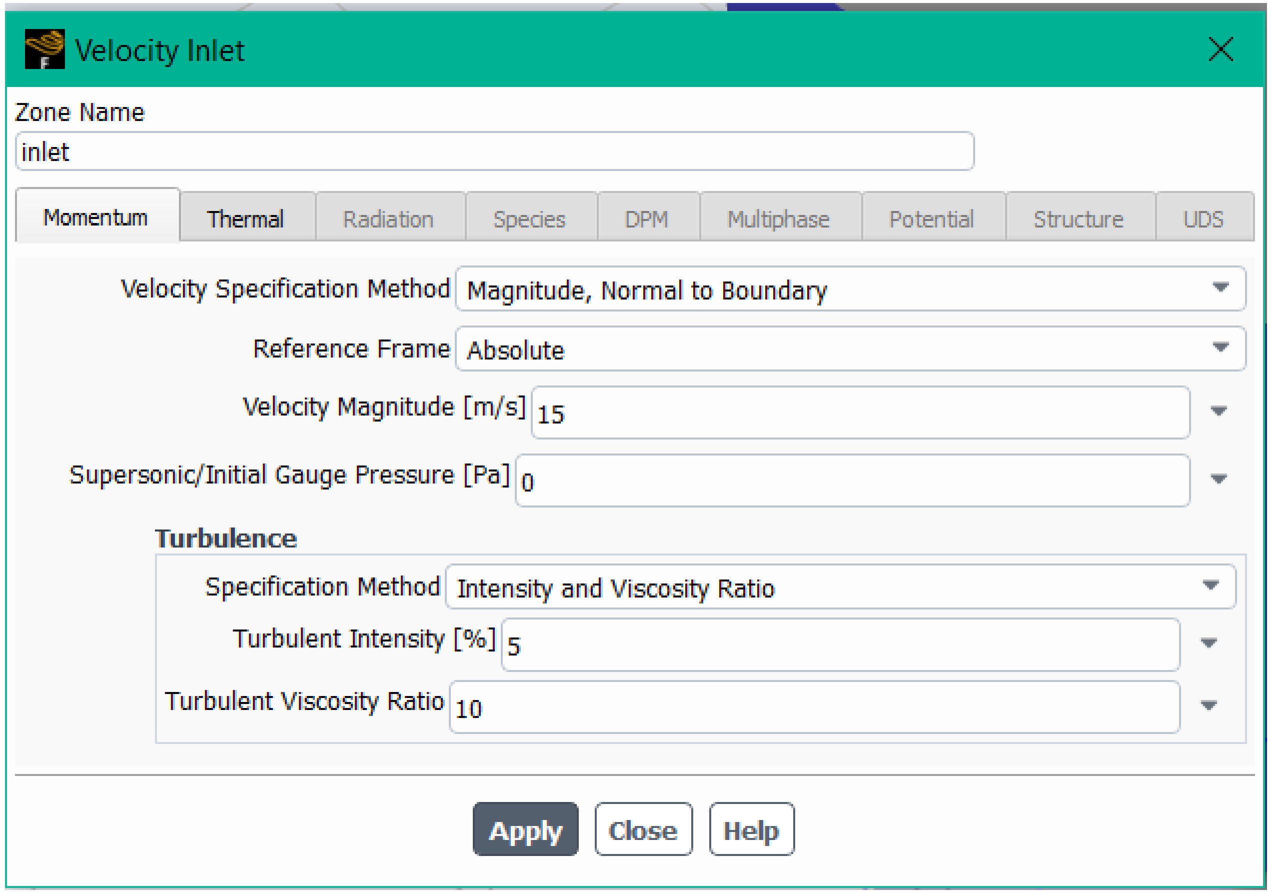
3. Launch FLUENT (Setup)

1. Scale Mesh: unit = m
2. Model: Energy On
3. Set K-epsilon model
4. Air as fluid
5. Inlet velocity: 15m/s
6. Set report Definitions
7. Set Solution Methods
8. Set Residual Monitors
9. Set Initialization



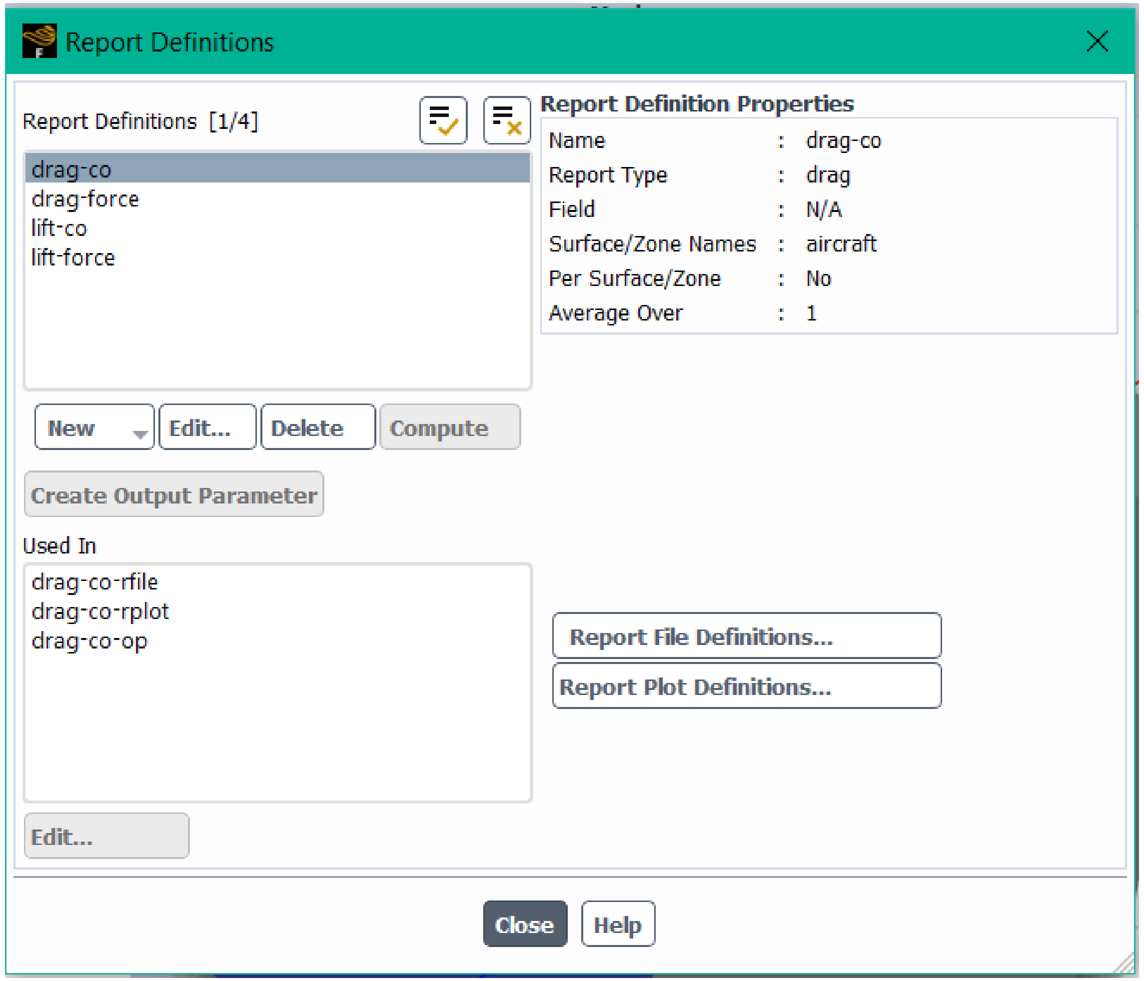
3. Launch FLUENT (Setup)

1. Scale Mesh: unit = m
2. Model: Energy On
3. Set K-epsilon model
4. Air as fluid
5. Inlet velocity: 15m/s
6. Set report Definitions
7. Set Solution Methods
8. Set Residual Monitors
9. Set Initialization



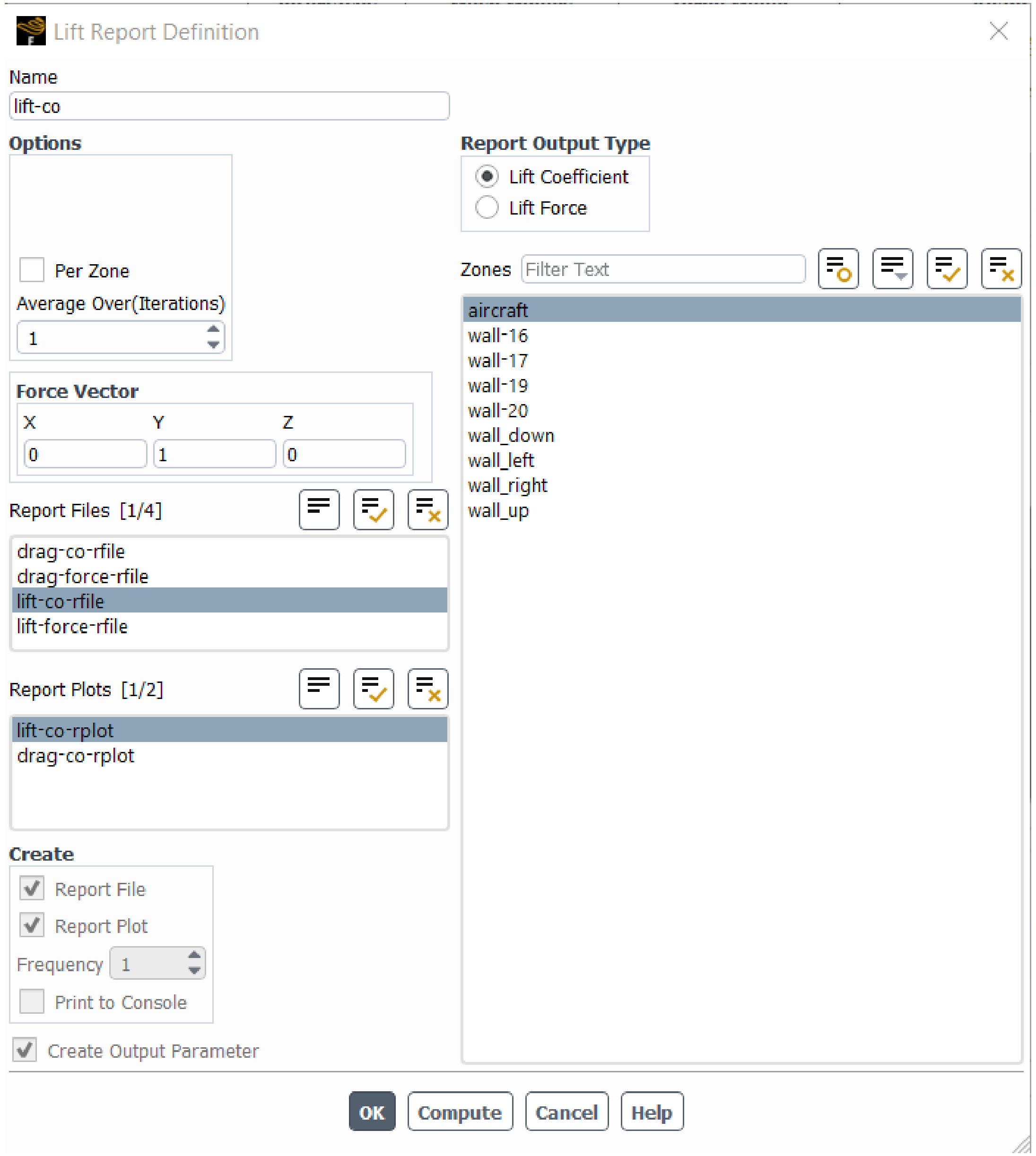
3. Launch FLUENT (Setup)

1. Scale Mesh: unit = m
2. Model: Energy On
3. Set K-epsilon model
4. Air as fluid
5. Inlet velocity: 15m/s
6. Set report Definitions (lift force, drag force, c_l, c_d)
7. Set Solution Methods
8. Set Residual Monitors
9. Set Initialization



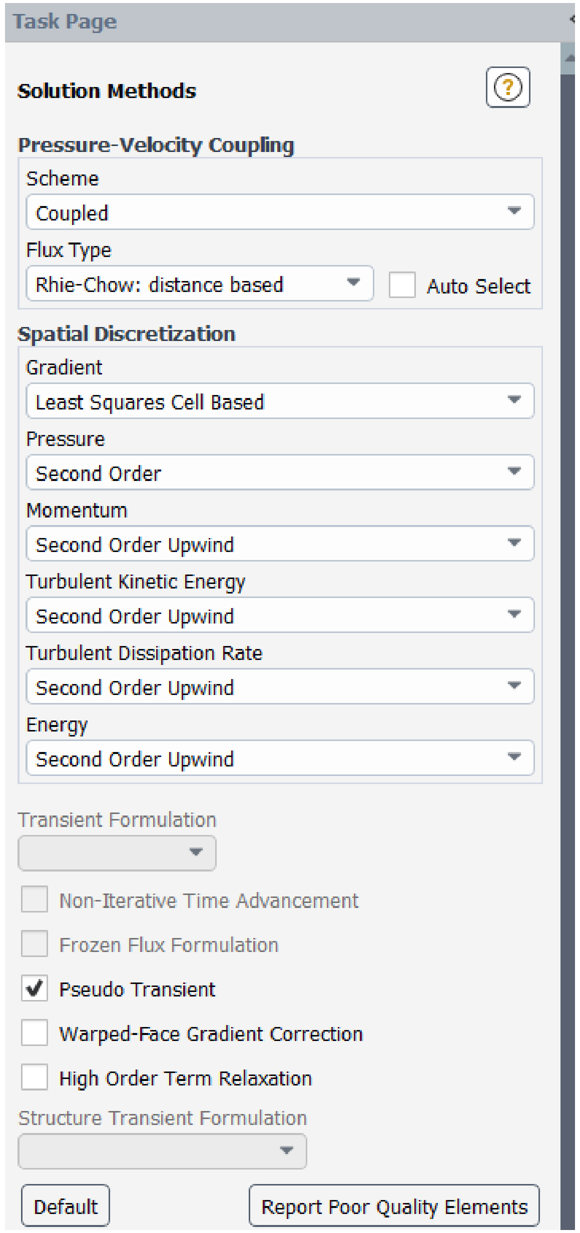
3. Launch FLUENT (Setup)

1. Scale Mesh: unit = m
2. Model: Energy On
3. Set K-epsilon model
4. Air as fluid
5. Inlet velocity: 15m/s
6. Set report Definitions (lift force, drag force, c_l, c_d)
7. Set Solution Methods
8. Set Residual Monitors
9. Set Initialization



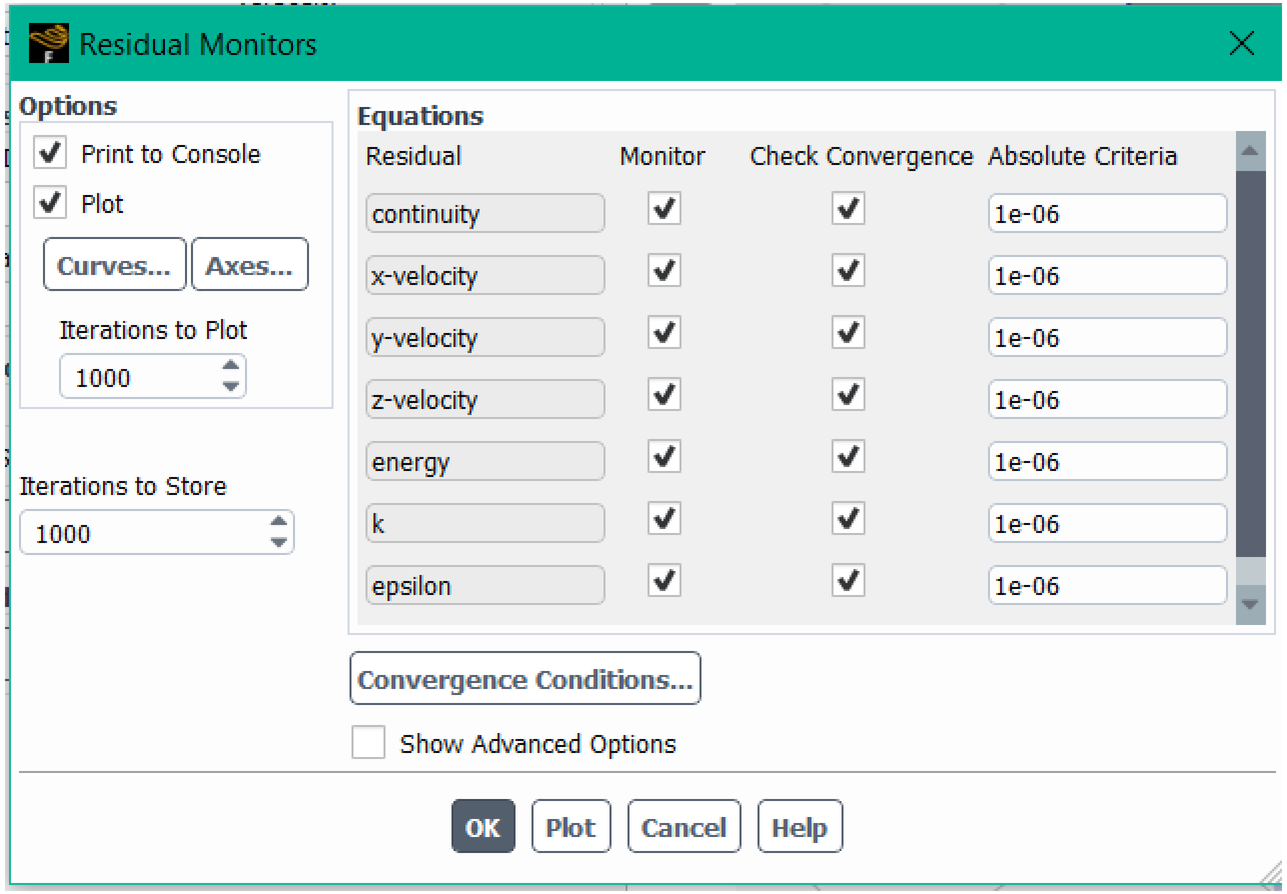
3. Launch FLUENT (Setup)

1. Scale Mesh: unit = m
2. Model: Energy On
3. Set K-epsilon model
4. Air as fluid
5. Inlet velocity: 15m/s
6. Set Report Definitions
7. Set Solution Methods
   Second Order → more accurate solution
8. Set Residual Monitors
9. Set Initialization (Compute from inlet)



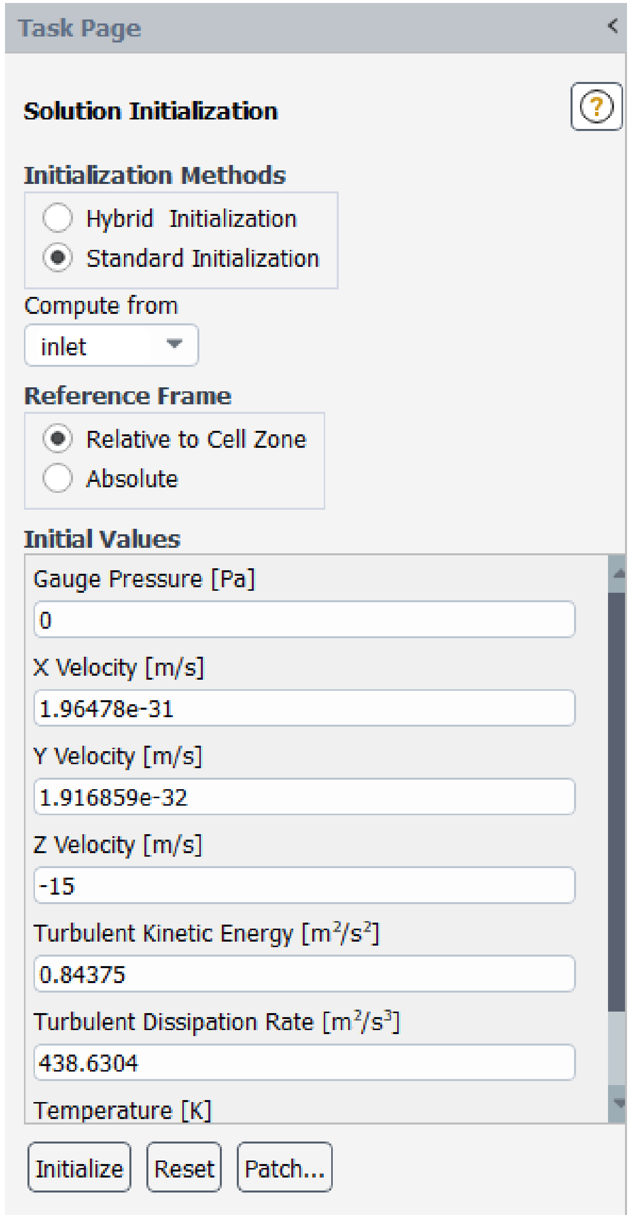
3. Launch FLUENT (Setup)

1. Scale Mesh: unit = m
2. Model: Energy On
3. Set K-epsilon model
4. Air as fluid
5. Inlet velocity: 15m/s
6. Set Report Definitions
7. Set Solution Methods
8. Set Residual Monitors
9. Set Initialization



3. Launch FLUENT (Setup)

1. Scale Mesh: unit = m
2. Model: Energy On
3. Set K-epsilon model
4. Air as fluid
5. Inlet velocity: 15m/s
6. Set Report Definitions
7. Set Solution Methods
8. Set Residual Monitors
9. Set Initialization (Compute from inlet)

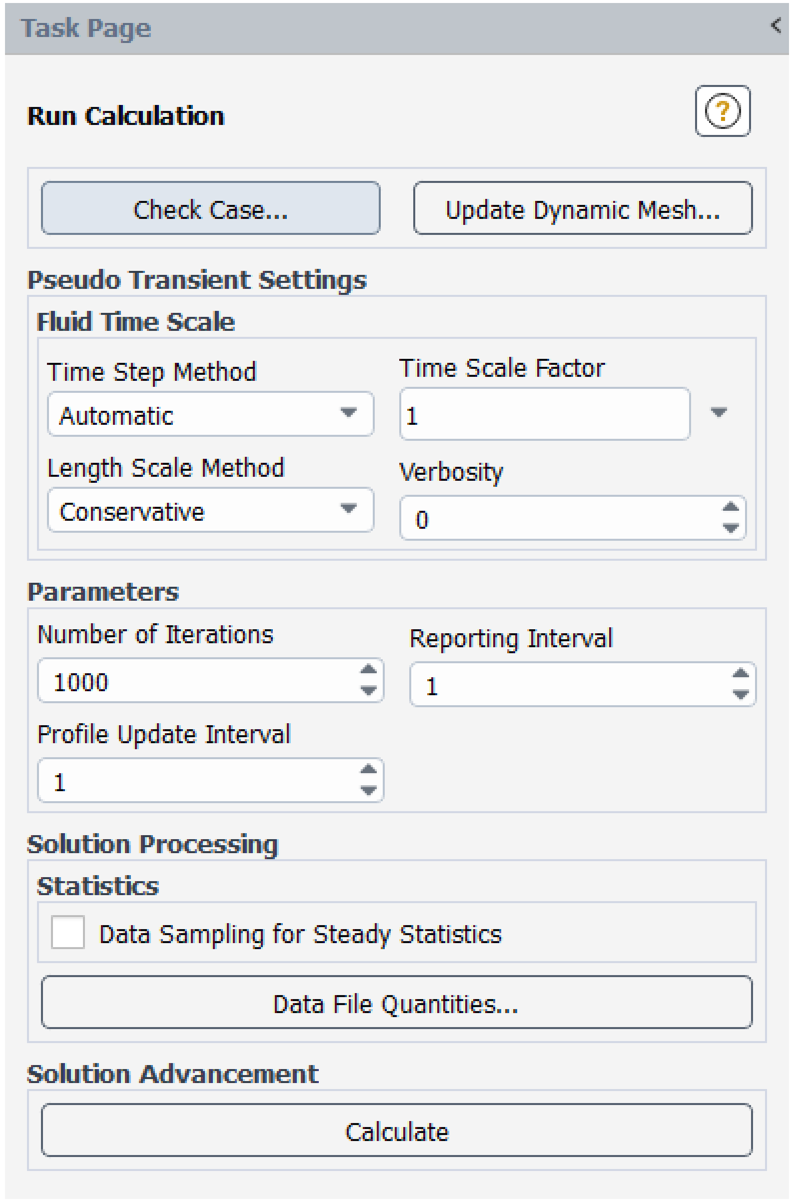


Results

- Run Calculation

  Number of iterations: 1000

- Generate Report

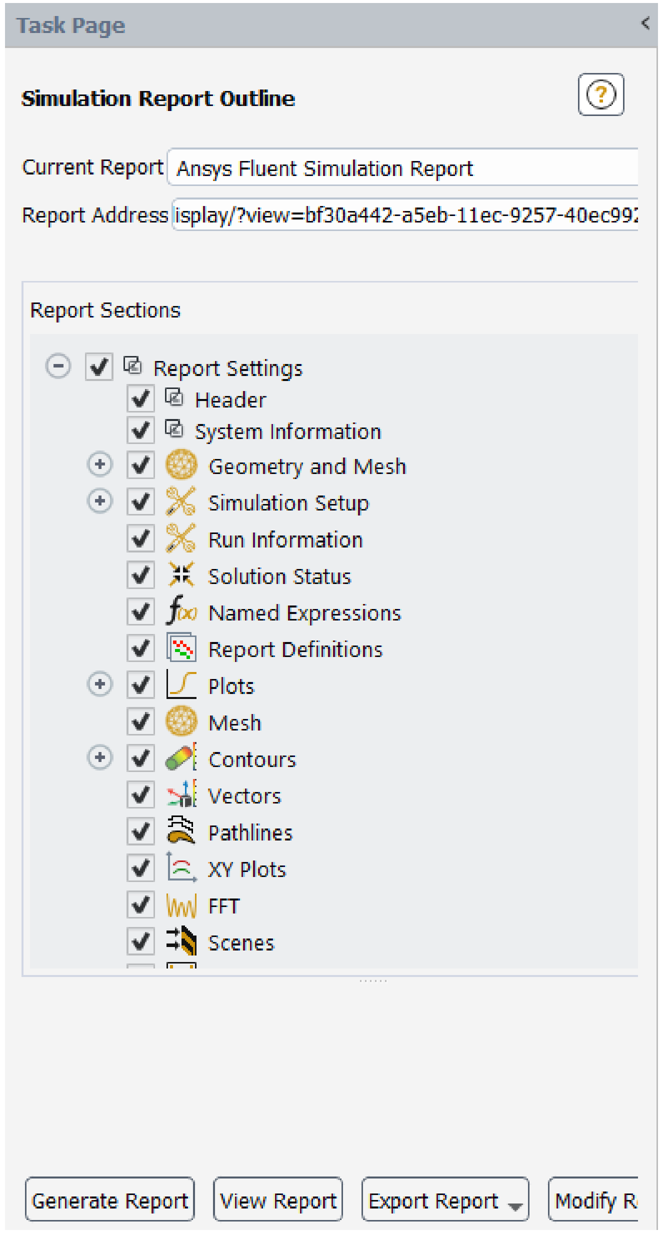


Results

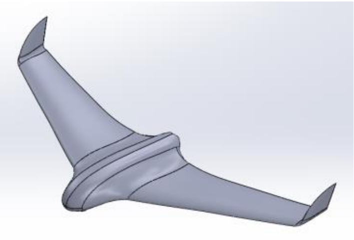
- Run Calculation

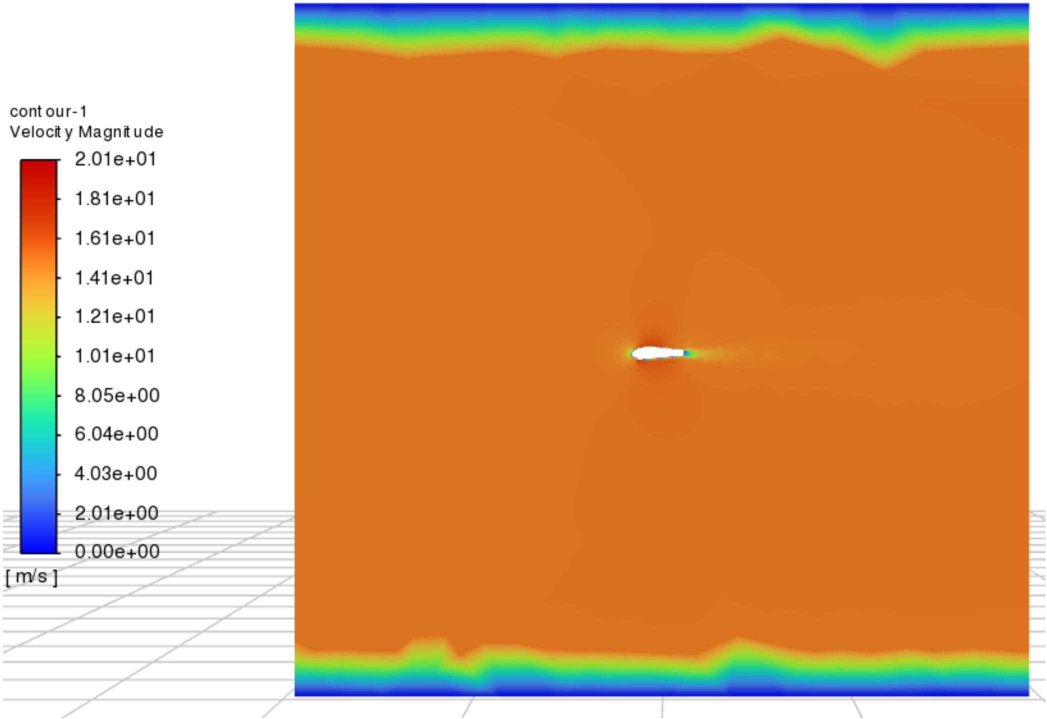
  Number of iterations: 1000

- Generate Report → Export Report

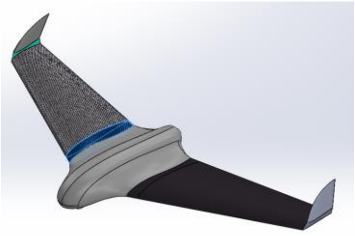


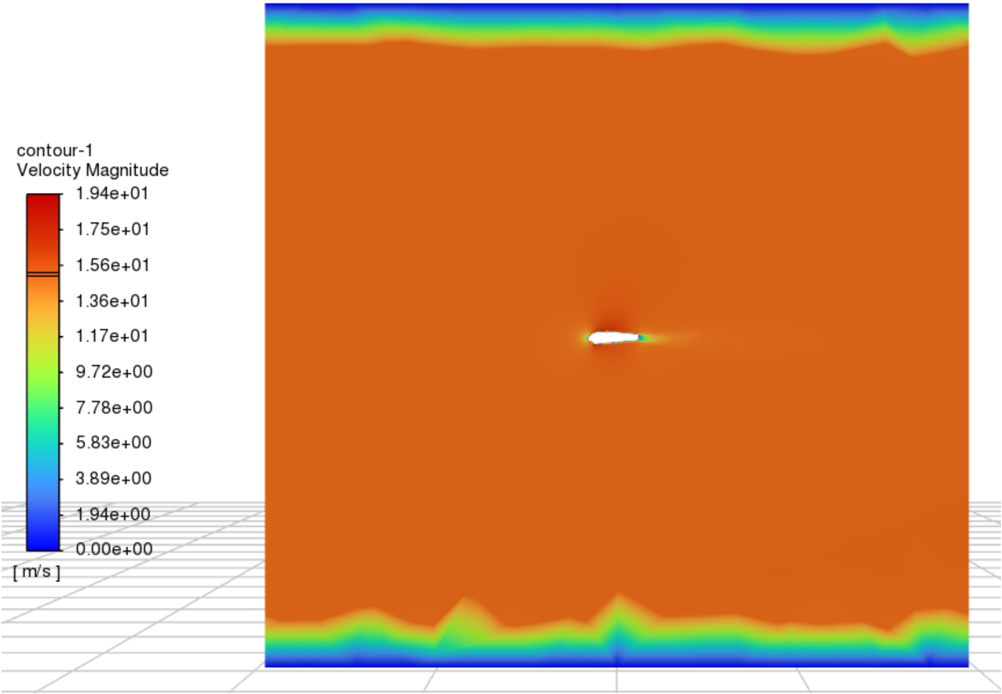
Skywalker X8





CF (Clark Y)



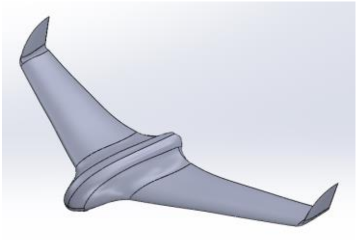


Contours of Velocity Magnitude (m/s)

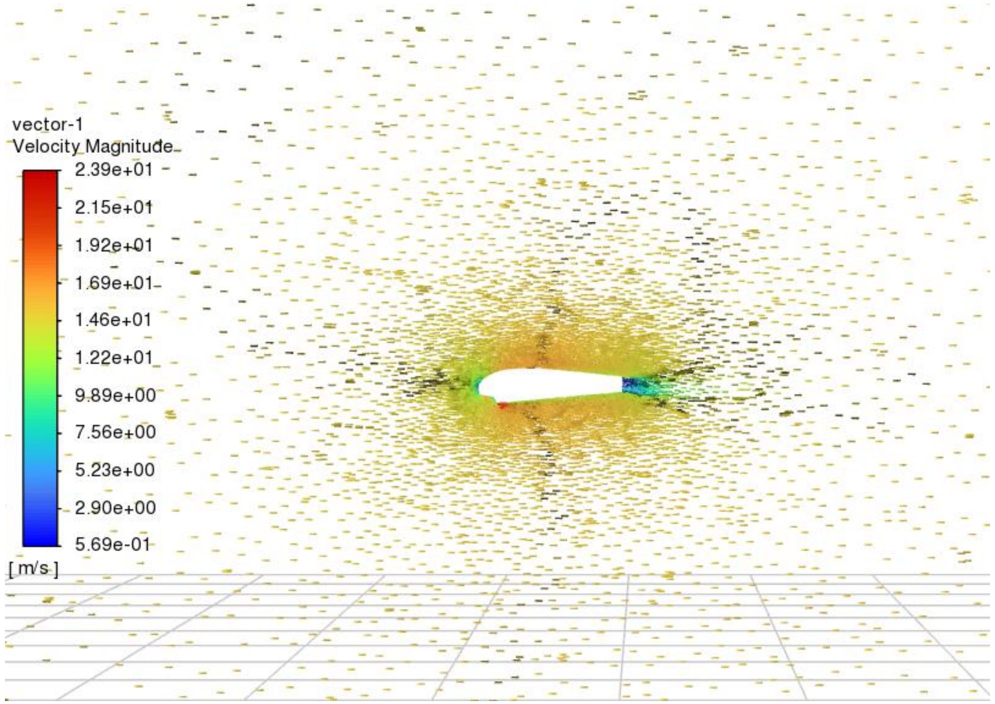
Department of
MECHANICAL ENGINEERING
機械工程學系

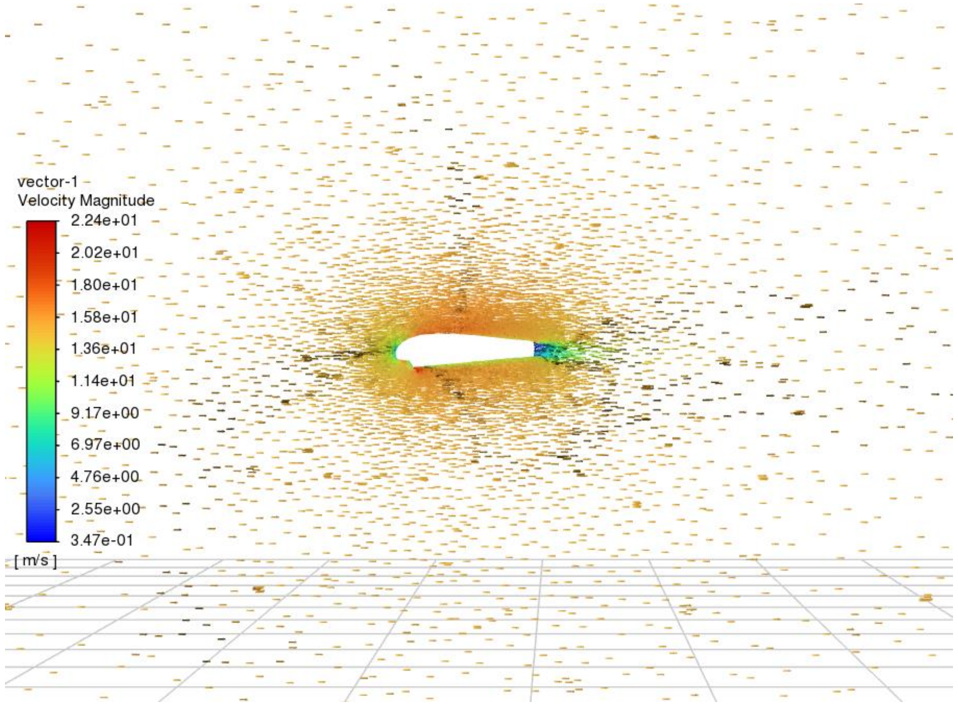
THE HONG KONG POLYTECHNIC UNIVERSITY
香港理工大學

Skywalker X8



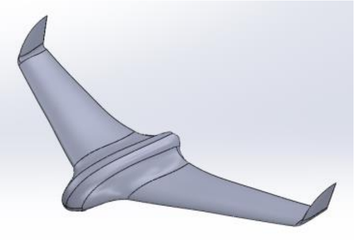
CF (Clark Y)



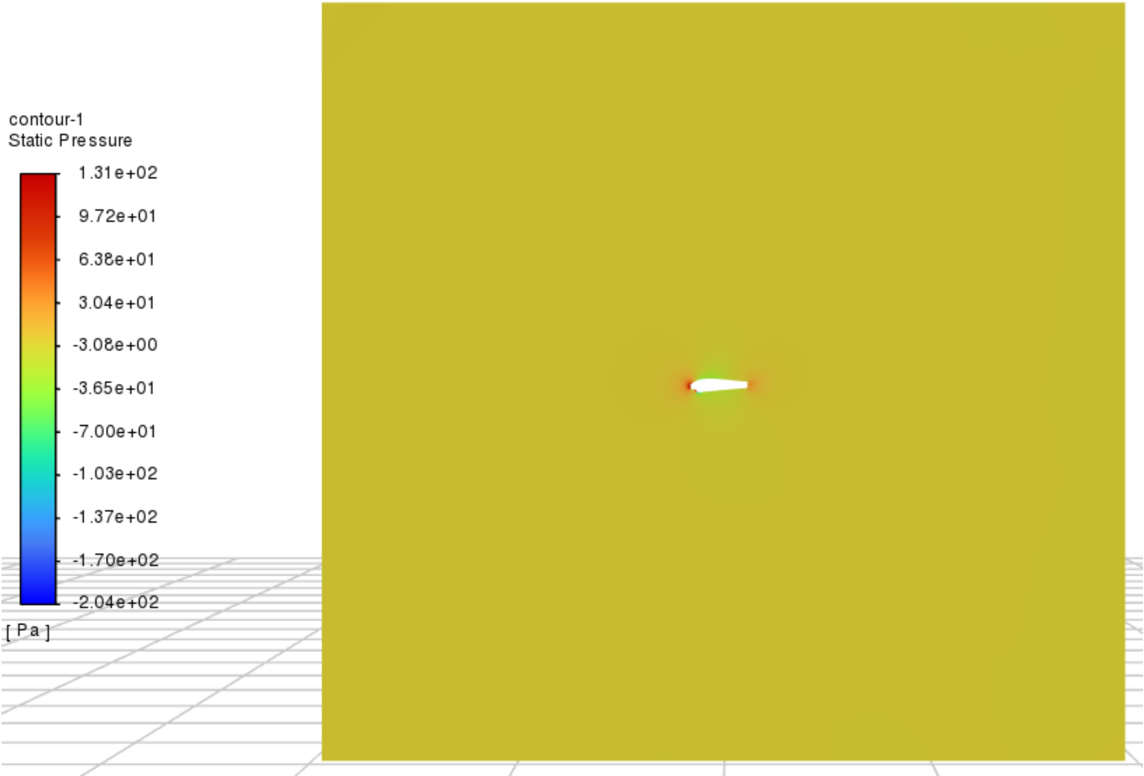


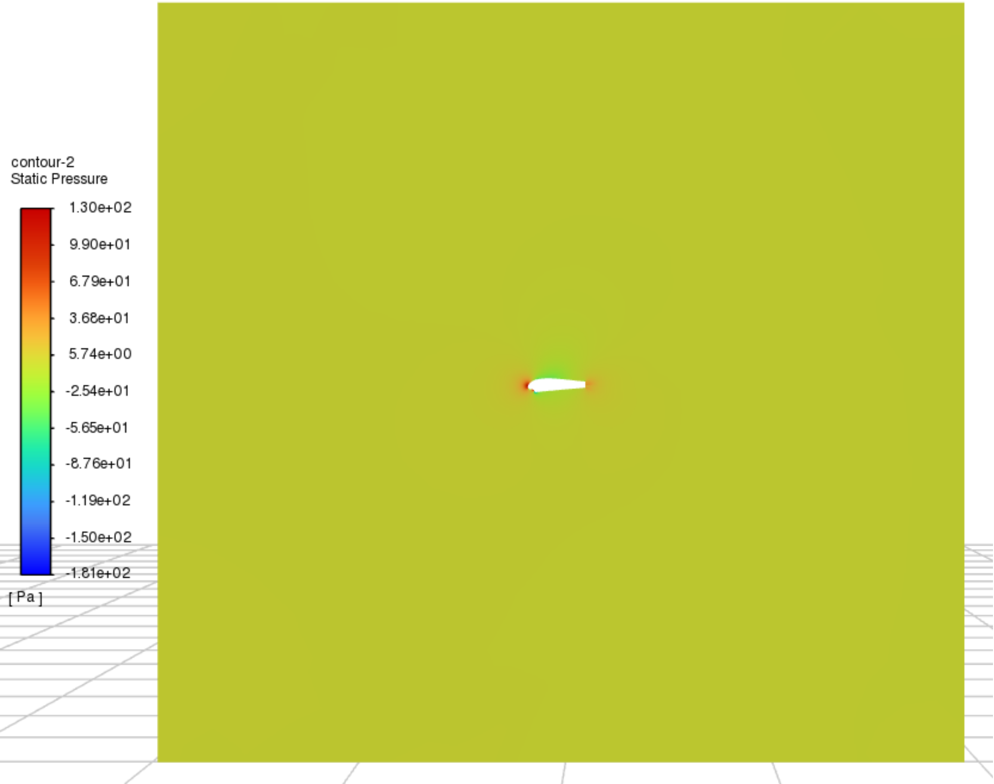
Vectors Colored by Velocity Magnitude (m/s)

Skywalker X8



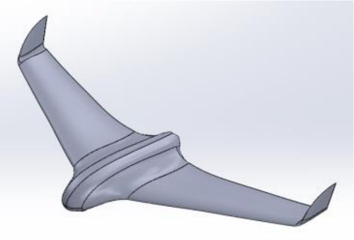
CF (Clark Y)



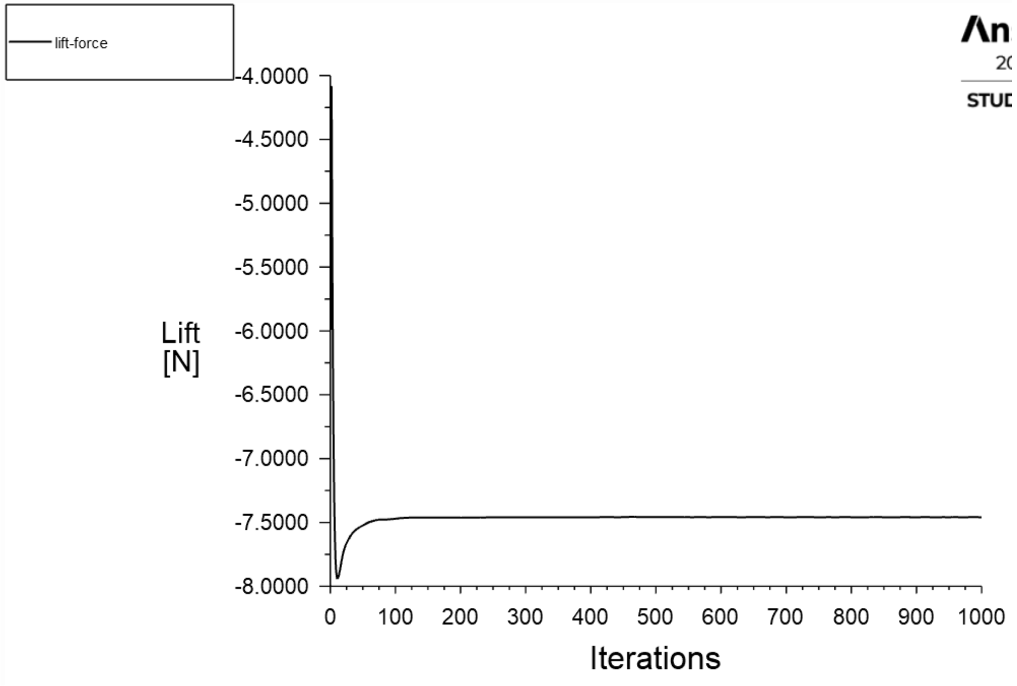


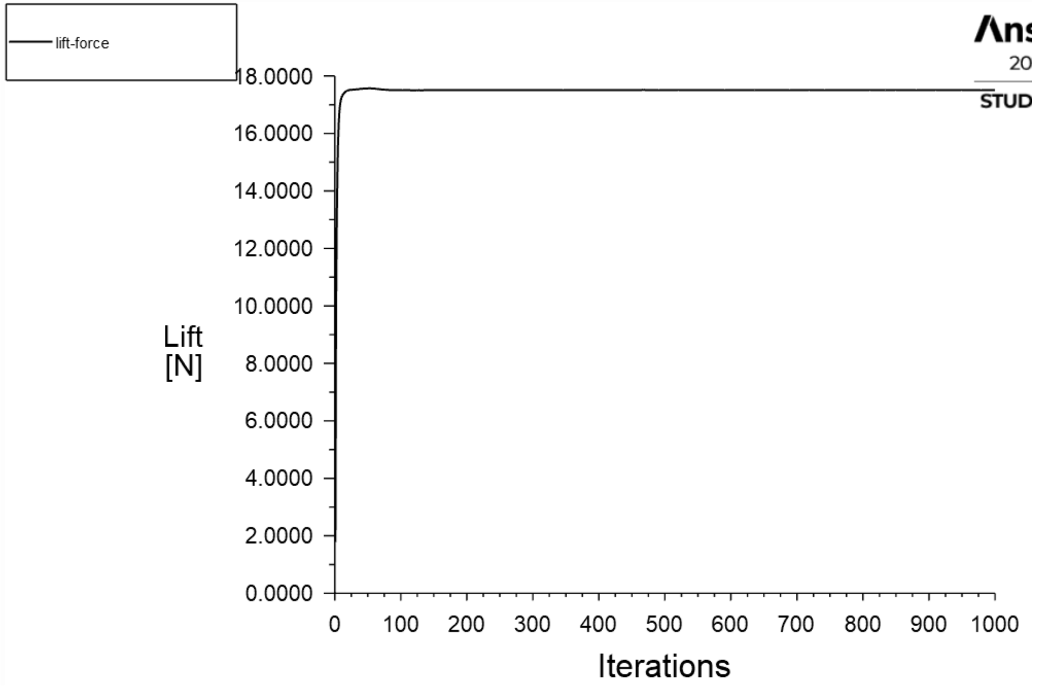
Contours of Static Pressure (Pa)

Skywalker X8



CF (Clark Y)



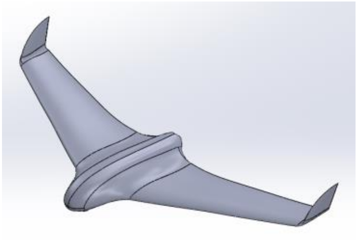


Lift force

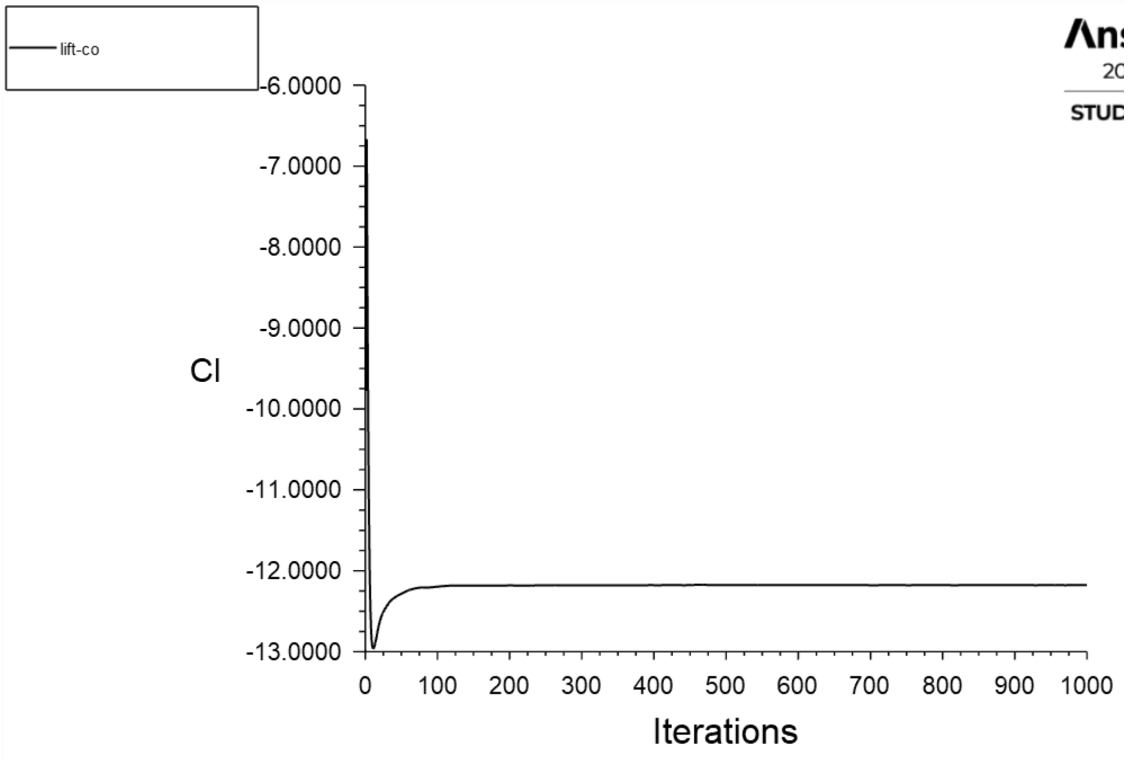
Department of
MECHANICAL ENGINEERING
機械工程學系

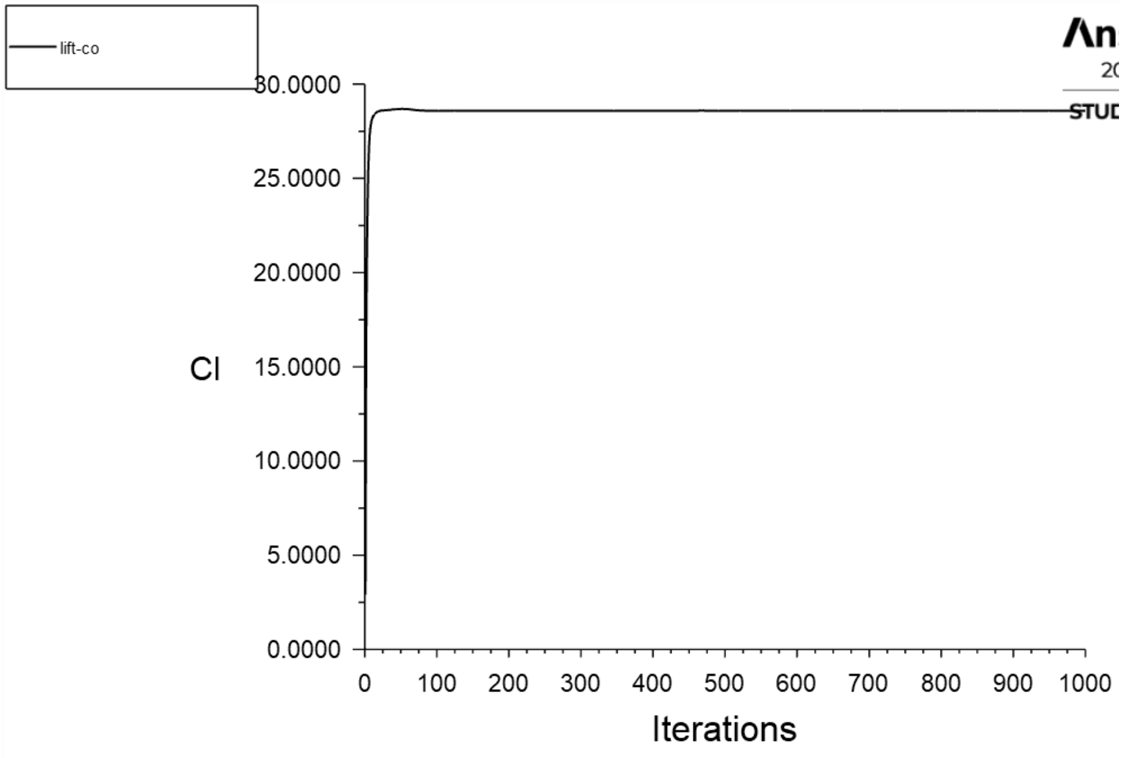
THE HONG KONG POLYTECHNIC UNIVERSITY
香港理工大學

Skywalker X8



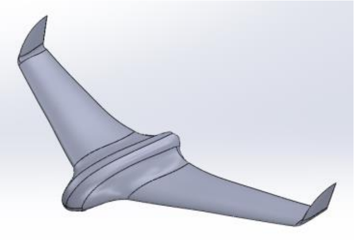
CF (Clark Y)



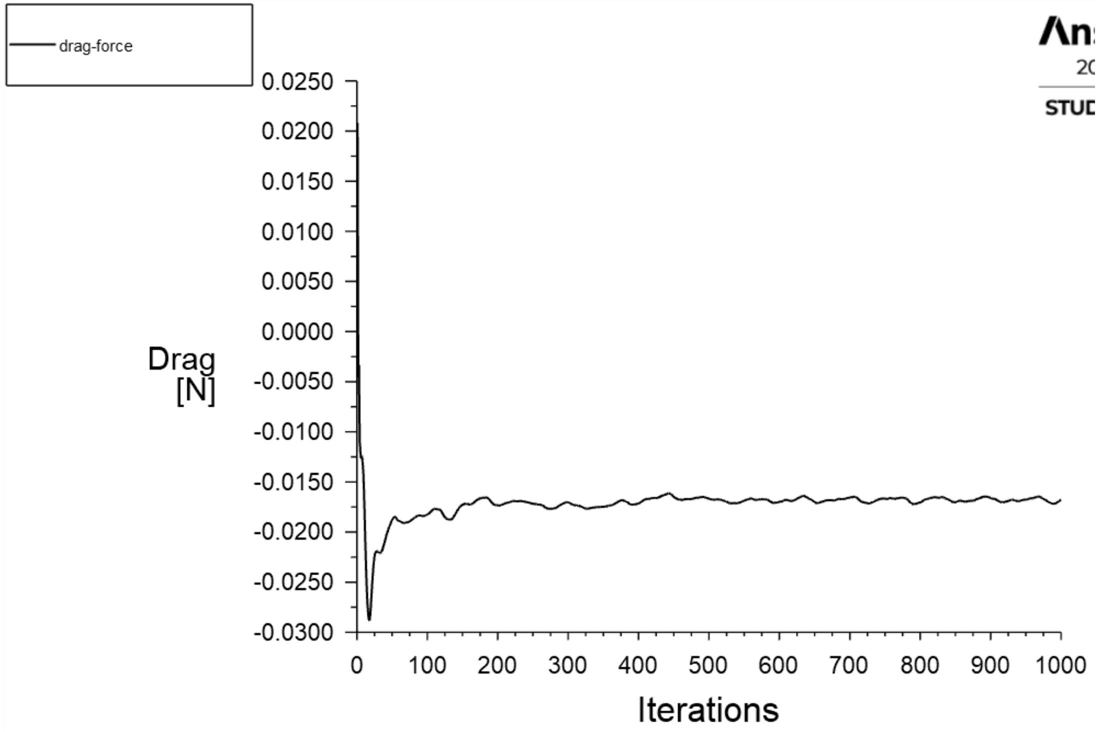


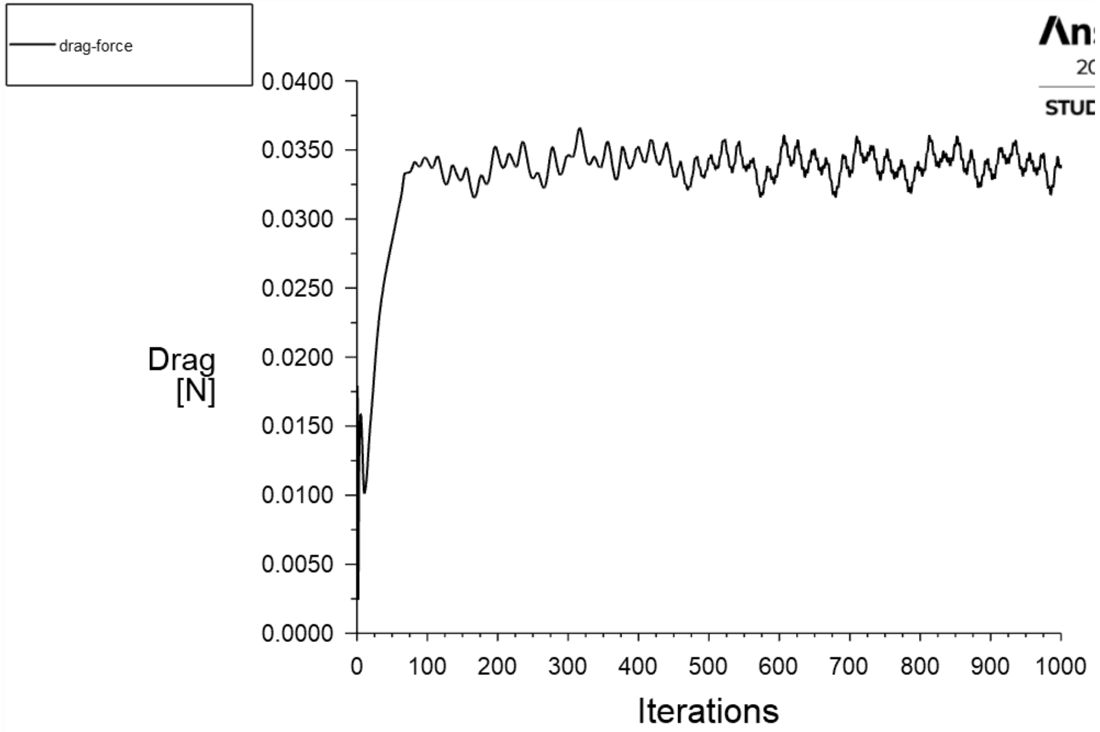
Lift coefficient

Skywalker X8



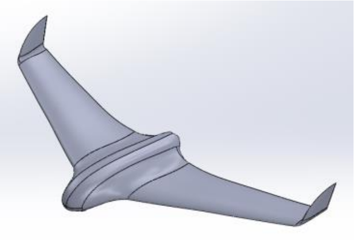
CF (Clark Y)



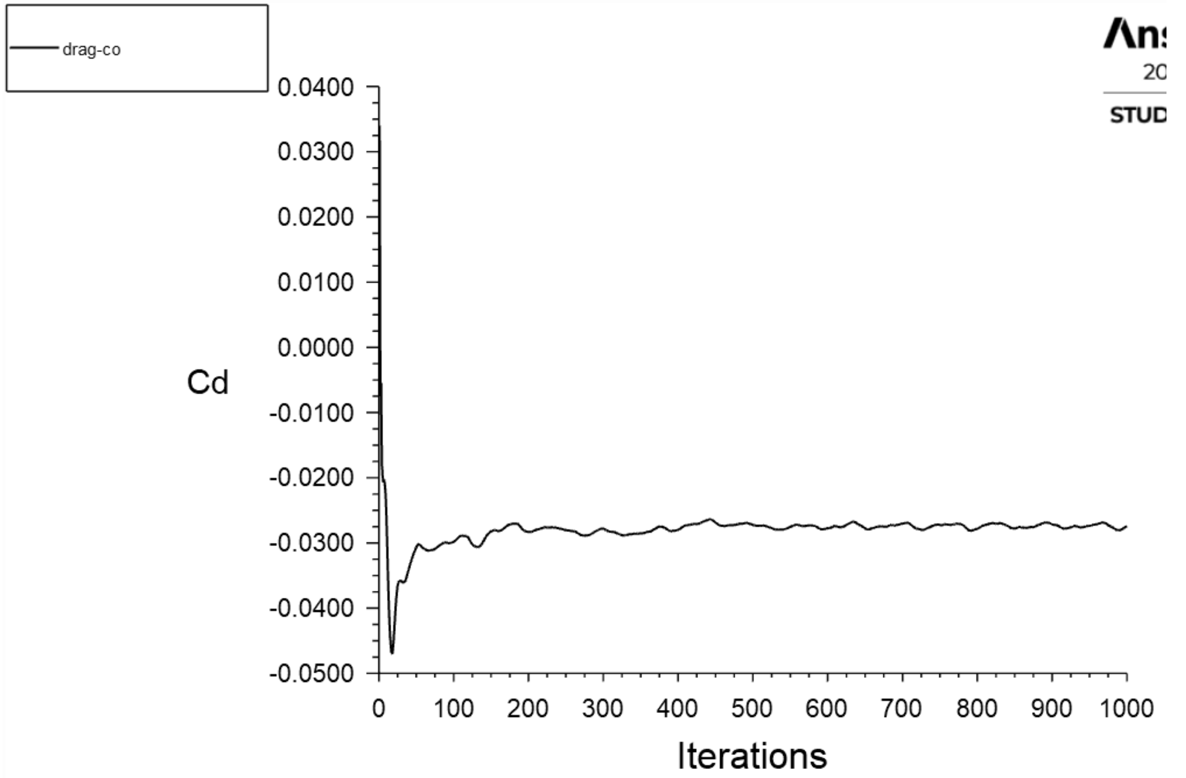


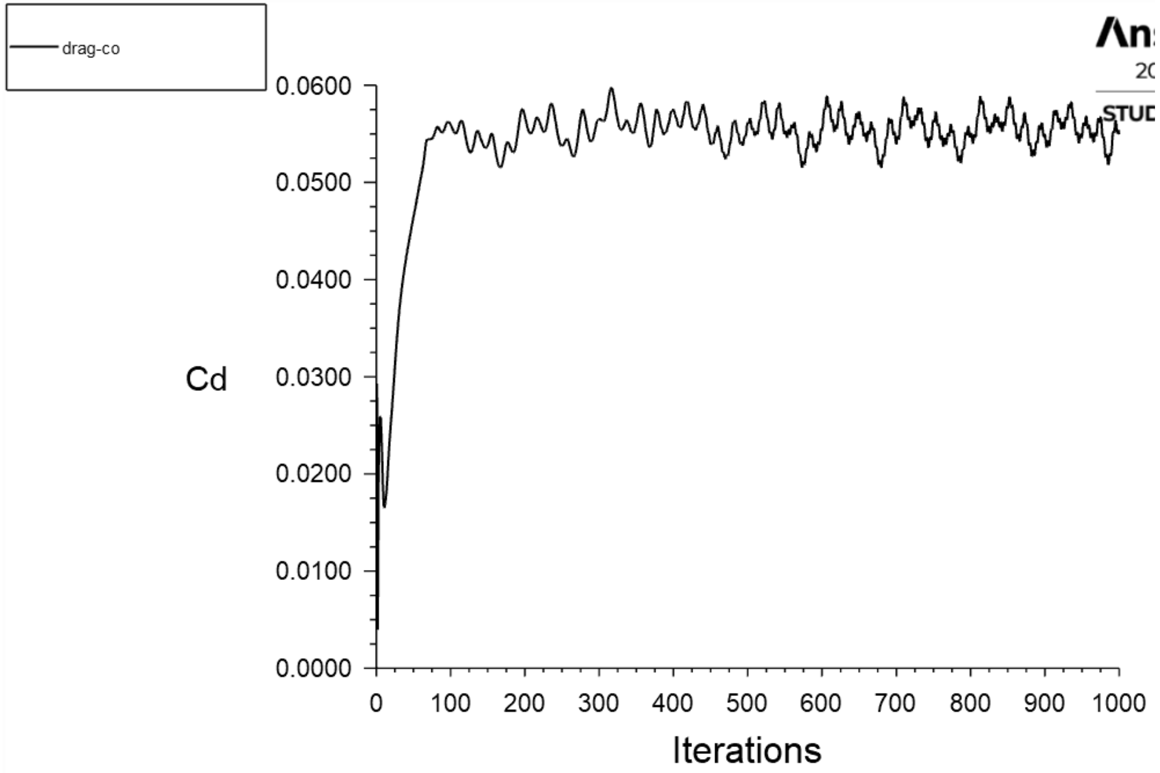
Drag force

Skywalker X8



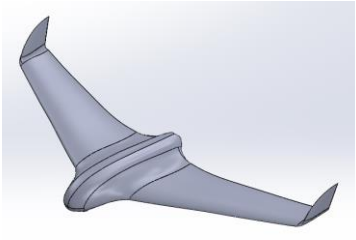
CF (Clark Y)



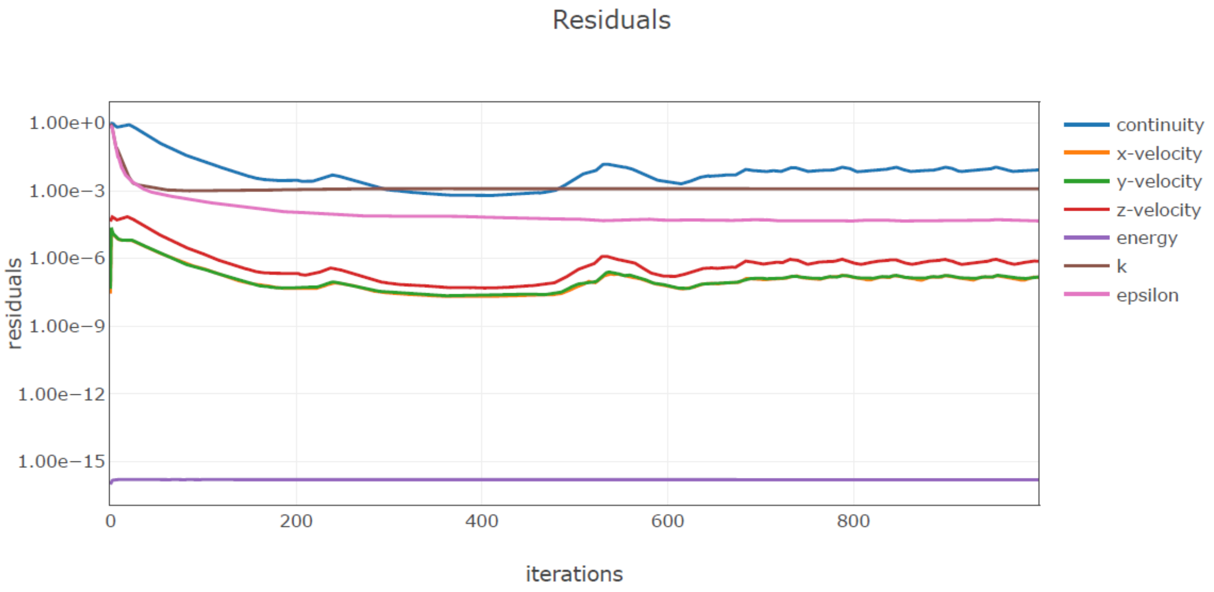


Drag coefficient

Skywalker X8

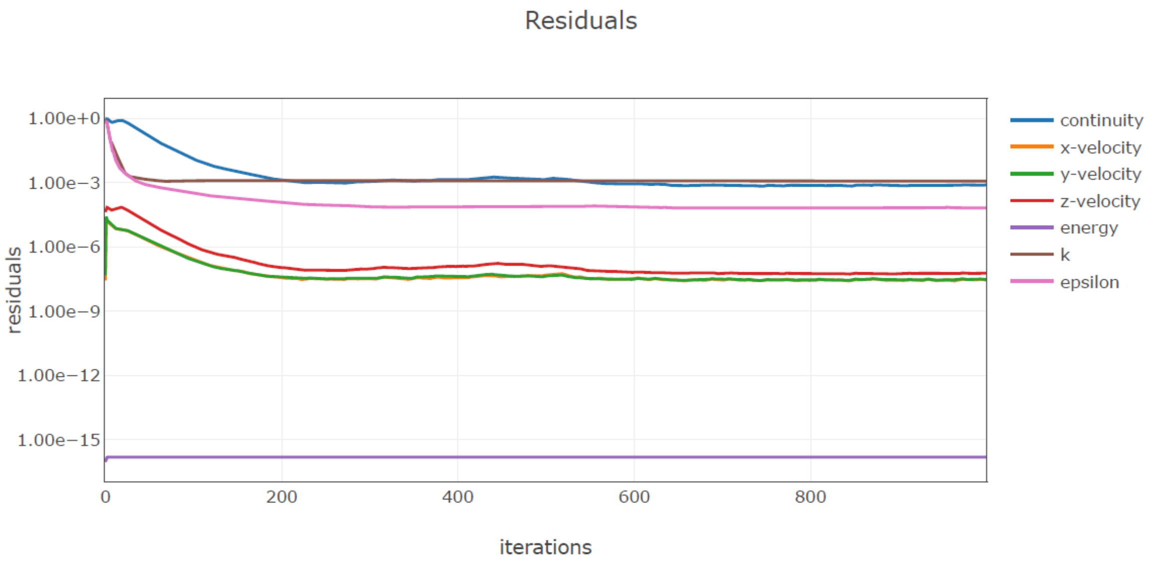


Residuals



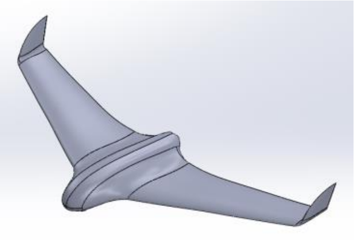
CF (Clark Y)

Residuals



Simulation Report

Skywalker X8

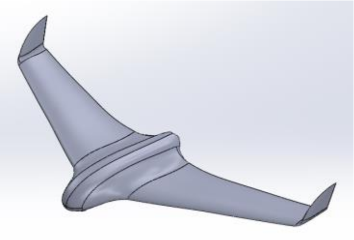


CF (Clark Y)

lift-force	-7.458751 N
lift-co	-12.17755
drag-force	-0.01678963 N
drag-co	-0.02741164

lift-force	17.51005 N
drag-force	0.03366275 N
lift-co	28.58784
drag-co	0.0549596

Skywalker X8



CF (Clark Y)

Iterations: 1000

	Value	Absolute Criteria	Convergence Status
continuity	0.008320905	1e-06	Not Converged
x-velocity	1.437123e-07	1e-06	Converged
y-velocity	1.486843e-07	1e-06	Converged
z-velocity	7.396273e-07	1e-06	Converged
energy	1.545174e-16	1e-06	Converged
k	0.001218344	1e-06	Not Converged
epsilon	4.562565e-05	1e-06	Not Converged

Iterations: 1000

	Value	Absolute Criteria	Convergence Status
continuity	0.0008046752	1e-06	Not Converged
x-velocity	2.879304e-08	1e-06	Converged
y-velocity	3.068185e-08	1e-06	Converged
z-velocity	5.979942e-08	1e-06	Converged
energy	1.564403e-16	1e-06	Converged
k	0.001199351	1e-06	Not Converged
epsilon	6.687712e-05	1e-06	Not Converged

Simulation Report

Future plan

Final report

Things will be added in Final Report

- Acknowledgement*:*
  Prof. Wen
  Jeremy, Patrick, Bailun Jiang, Yurong Feng (UAV)
  IC instructor, Dr Mabel Ho (Composites)
  ME Senior Instructor, Ir Elsa Tang (CFD)
- Summary of Contribution
- Abstract
- Aerodynamics calculations
- Flight log analysis
- CFD
- Manufacturing of the composited wing(s)
- Possible recommendations for future work

Future plan

Final demonstration – video(s)

Brief ideas of the video(s) for online oral presentation

- C.G. test with payload & composited wings (if possible)
- Hovering test in CF005 (without payload)
- Flying test in Yuen Long in Dec 2021 (without payload)

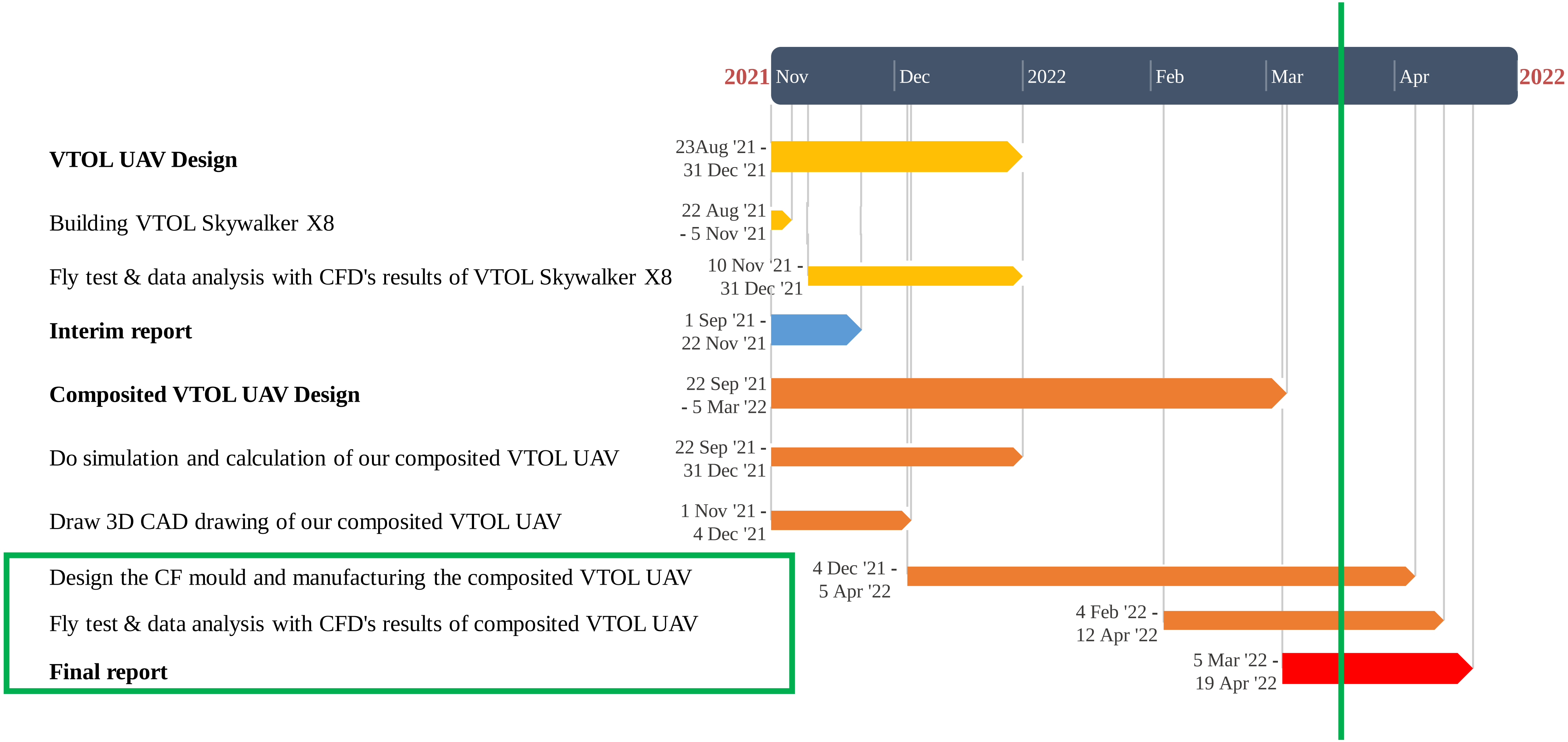
Brief ideas of the video(s) for online oral presentation

- C.G. test with payload & composited wings (if possible)
- Hovering test in CF005 (without payload)
- Flying test in Yuen Long in Dec 2021 (without payload)

Brief ideas of the video(s) for online oral presentation

- C.G. test with payload & composited wings (if possible)
- Hovering test in CF005 (without payload)
- Flying test in Yuen Long in Dec 2021 (without payload)

Gantt chart (updated)



Thank you