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THE MODEUS TEAM

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FFD 2013 MODEUS AIRCRAFT

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- ✓ Results
- ✓ Flight Test

Conclusion

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MODEUS Aircraft

Planned as;

- ✓VTOL
- ✓Tilt rotor mechanism
- ✓At most 2 kg payload capacity for the FFD competition
- ✓Examine flight characteristics
- ✓Gain experience

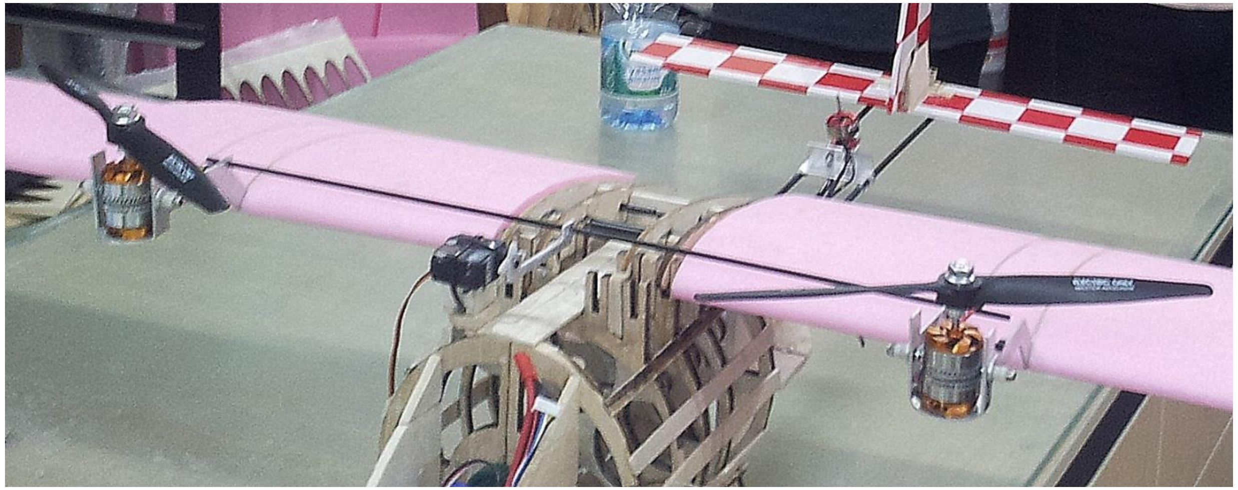


Figure 1: MODEUS Manufacturing

FFD 2013

Missions:

1. 2 laps with 1 bottle of water
2. 1 lap with 4 bottles of water
3. 1 lap with the dropping of 3 bottles of water

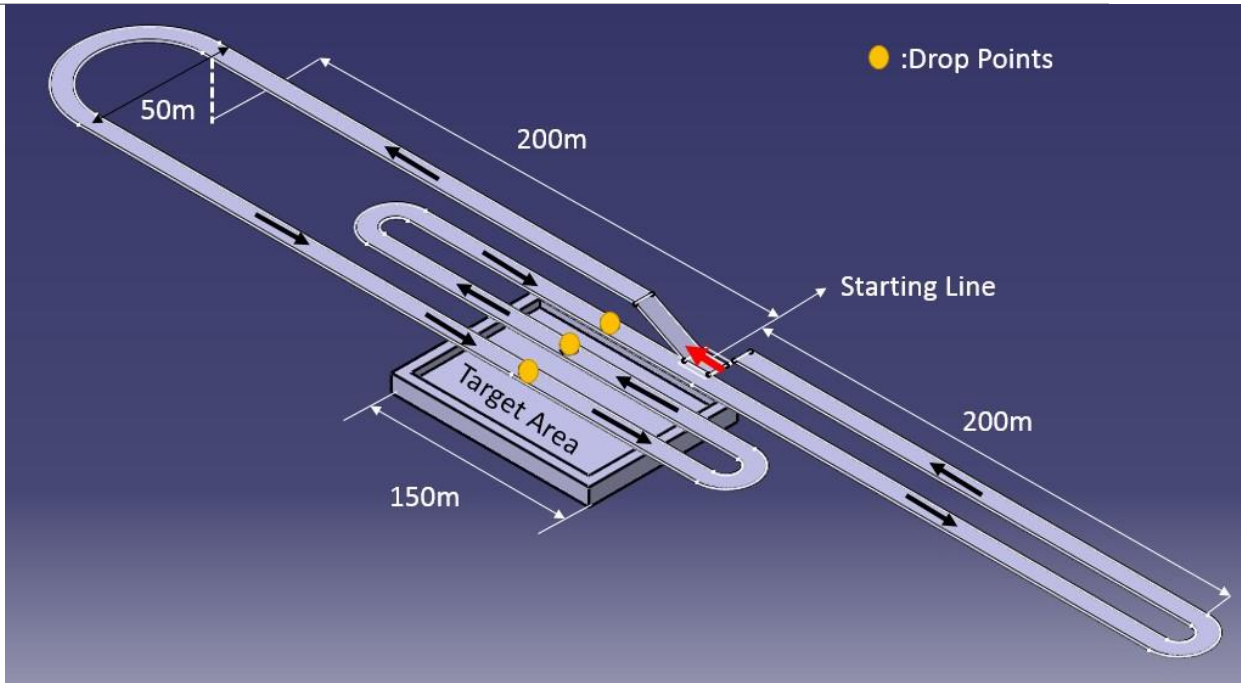


Figure 2: Mission Profile

ESSENTIAL CRITERIA ABOUT THE PROJECT

Essential Criteria about the Project Structure

- ✓Resistant to turns
- ✓Durable mechanism
- ✓Durable structure
- ✓Light

Figure 3: MODEUS Flight Test

Essential Criteria about the Project
Propulsion System

High thrust during hover

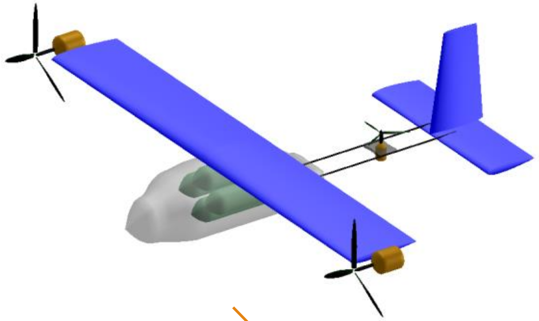
Powerful and efficient

- Engine
- Batteries
- Electronic Speed Controllers

Figure 4: MODEUS Manufacturing

The Design Procedure

- ✓Conceptual
- ✓Preliminary
- ✓Detailed
- ✓Manufacture



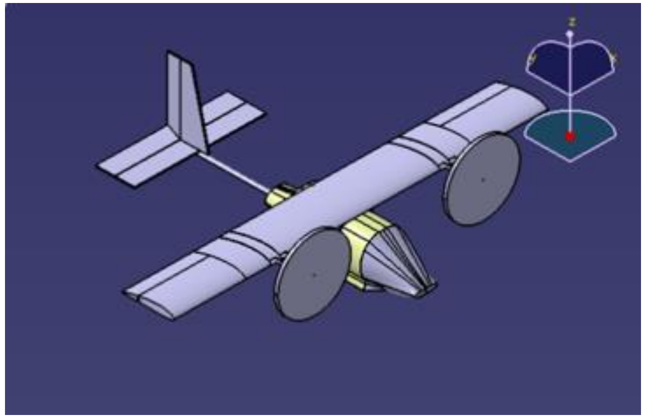


Figure 5: Design Procedure

Aims of The Project

Long term (Spring 2013-Fall 2014);

- ✓Design Procedure
- ✓Production Techniques
- ✓Flight experience
- ✓Optimization
- ✓Tilt rotor VTOL Project

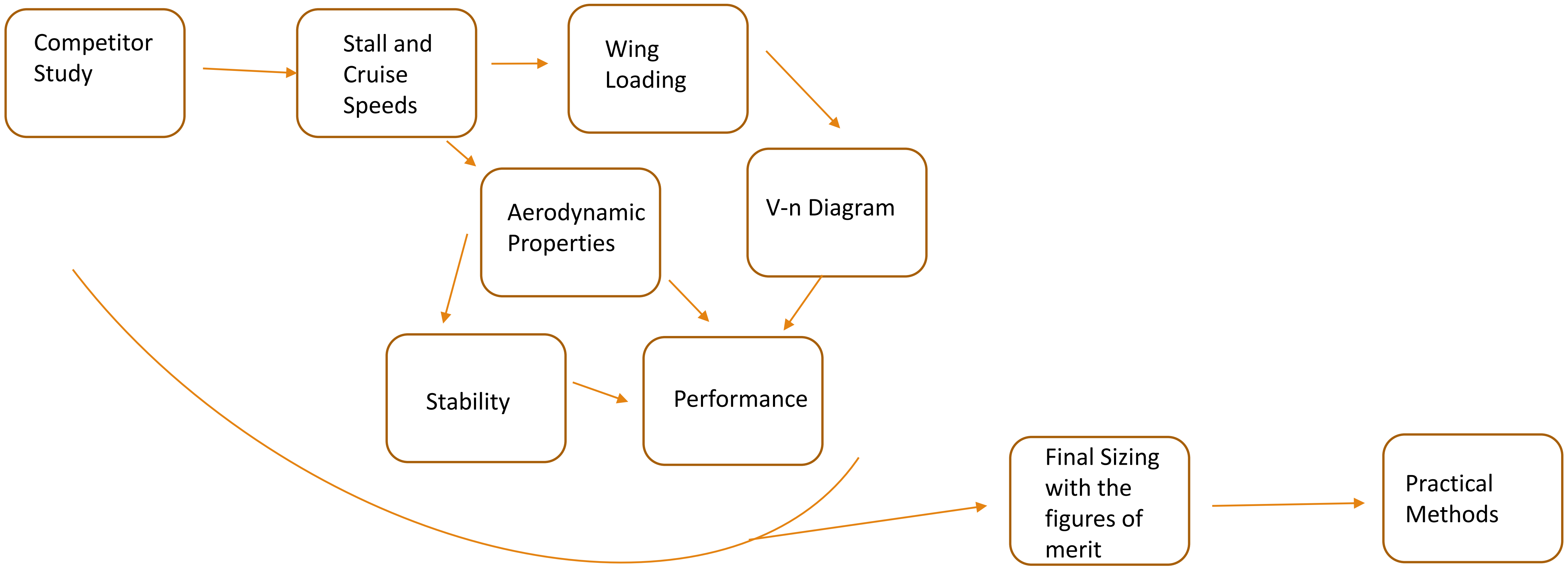
Short Term (Mid February 2013-May 2013);

✓Excellent ranking in FFD 2013

Methodology

Theoretical Methods

Theoretical Methods
Determinatives of Theoretical Methods



Determinatives of Theoretical Methods
Stall and Cruise Speeds

- ✓ Performance
- ✓ Wing Loading
- ✓ Aerodynamics

Stall and Cruise Speeds Example

Equate weights on takeoff and cruise (Conduct W=L for takeoff and cruise) (small a.o.a. assumption for steady flight)

$V_{TO} = 1.1\ V_{stall}$ (Ref 1)

$$\frac{W}{S} = \frac{1}{2}\rho V_{stall}^2 C_{Lmax}$$

Plug into W/S (Wing Loading) eqn

$$V_{TO}\ C_{LTO} = V_{cruise}\ C_{Lcruise}$$

With above equation, Cruise takeoff and Stall speeds are estimated for initial design.

With estimated cruise velocity, the level flight performance of aircraft could be estimated

CL for cruise and takeoff could be estimated from above relations and they provide foundation for detailed aerodynamic calculations

Determinatives of Theoretical Methods
Wing Loading

- ✓ Sizing initiation → Set weight cst on W/S then change S with estimated wing loading
- ✓ Connection with stall and cruise
- ✓ G loads for manuevers

→ Instantaneous Turn W/S [1]

$$\frac{W}{S} = \frac{qC_{Lmax}}{n}$$

$$n = \sqrt{\frac{ROT.V}{g} + 1}$$

ROT: Rate of Turn

Determinatives of Theoretical Methods Aerodynamic Properties

- ✓Airfoil Analysis (XFLR5)
- ✓Aerodynamic Coefficients
- ✓Aerodynamic Calculations

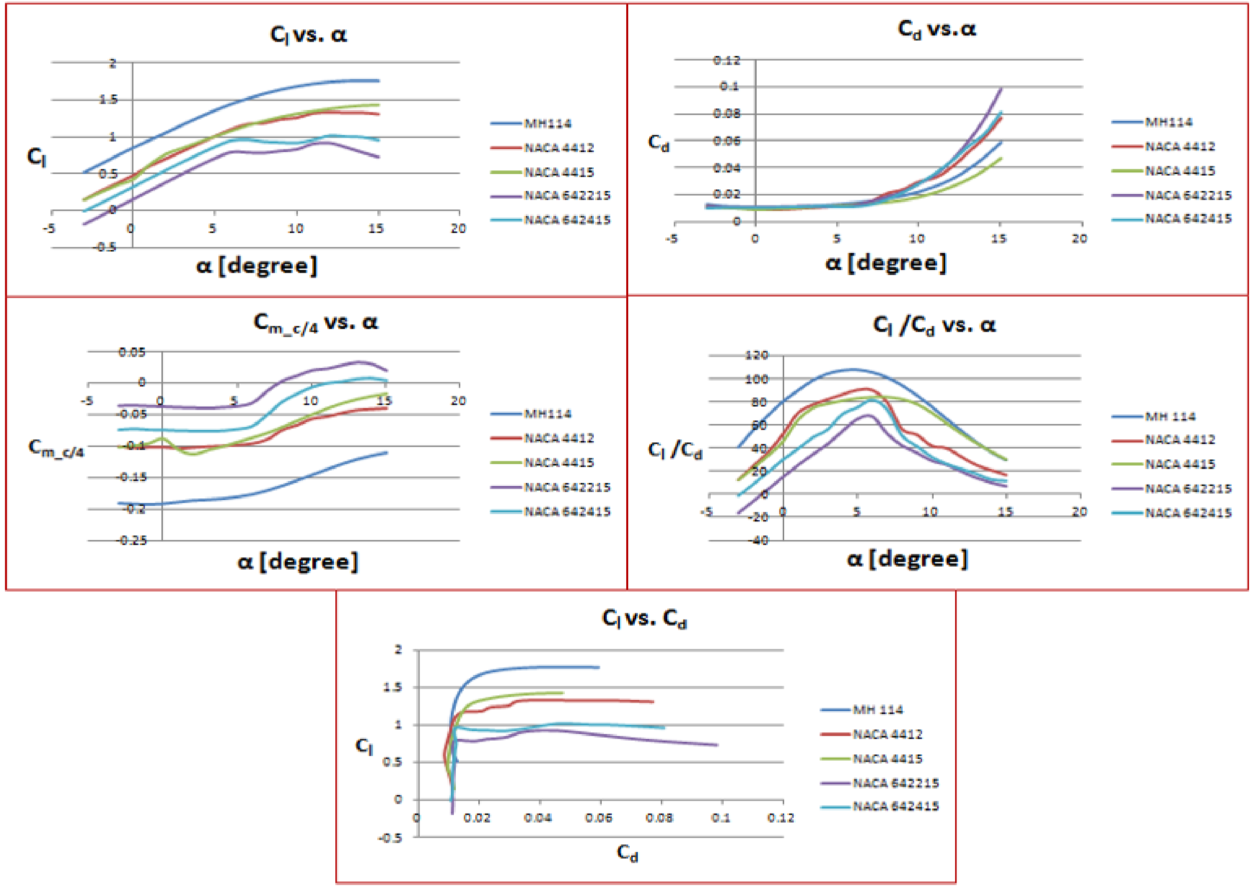


Figure 6: Airfoil Analysis

Determinatives of Theoretical Methods
V-n diagram

- ✓ Loads during high manuevers
- ✓ Structure determination
- ✓ Performance

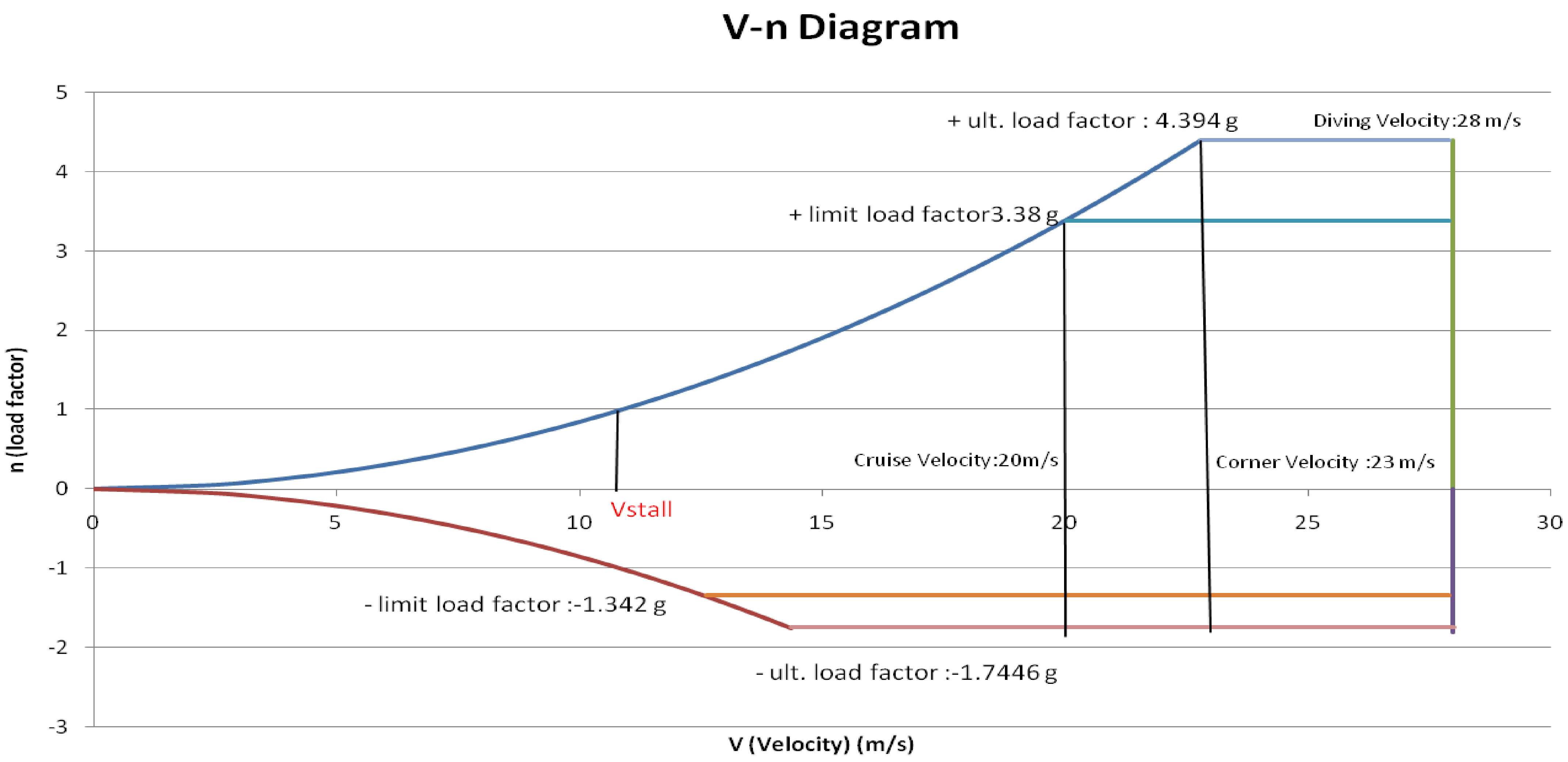


Figure 7: V-n Diagram

Determinatives of Theoretical Methods Performance

Performance ⟷

Propulsion
Wing Loading
Aerodynamics
g loads

Determinatives of Theoretical Methods Stability

- ✓Theoretically satisfied
- ✓Aerodynamics coefficients
- ✓Stall and Cruise Speeds
- ✓Dimensions

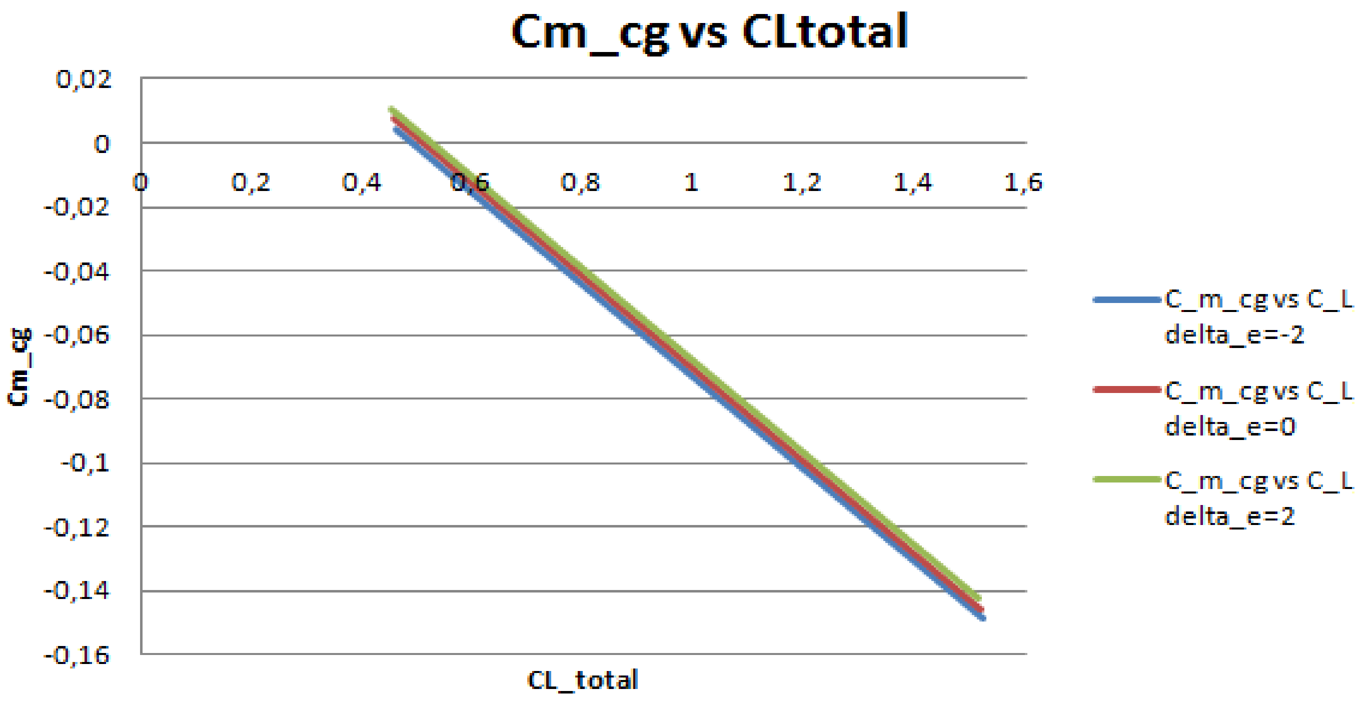


Figure 8: Stability Curve

Samples for Figure of Merit

Table 1: Wing Configuration Figures of Merit

Merit	Weight	High-Wing	Mid-Wing	Low-Wing
Ground Clearance	25%	5	3	1
Stability	25%	5	4	4
Weight and Drag	25%	3	5	5
Payload Loading	25%	5	3	2
Total	100%	4.5	3.75	3

Practical Methods

- ✓Material and Production
- ✓Systems on the Aircraft
- ✓Flight Tests

Materials and Production

Key parameters:

- ✓Lightweight structure to be able to get a high score in the contest
- ✓Strong structure so that the aircraft can withstand flight and landing loads.
- ✓Easiness of production so that production can be performed in limited amount of time

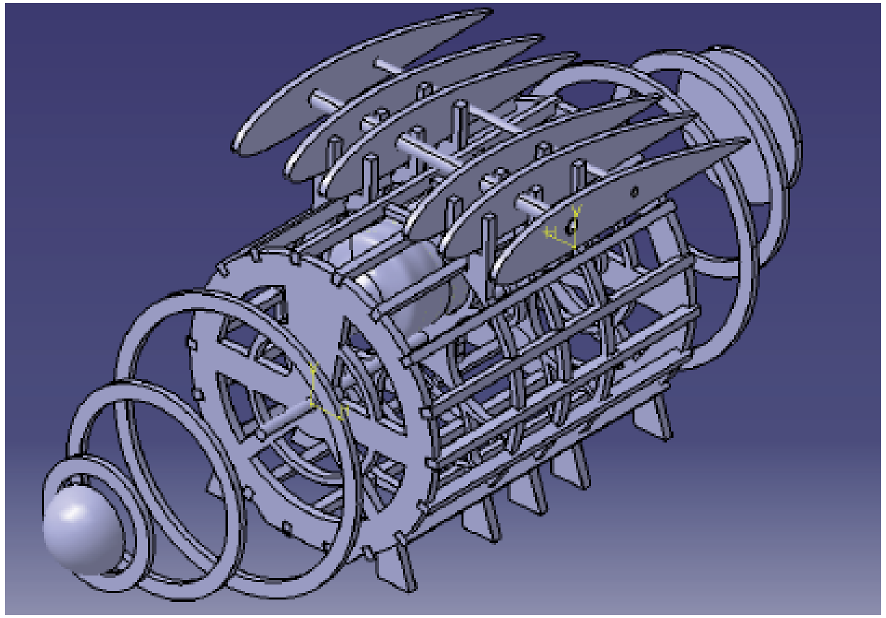


Figure 9: MODEUS Fuselage Structure CAD Drawing

Materials and Production
Fuselage and Tail

Balsa is used because;

- ✓It is very easy to manufacture. It can be shaped using just a handsaw and some quick adhesives.
- ✓It is very light

However;

- ✓It is not really a very strong material

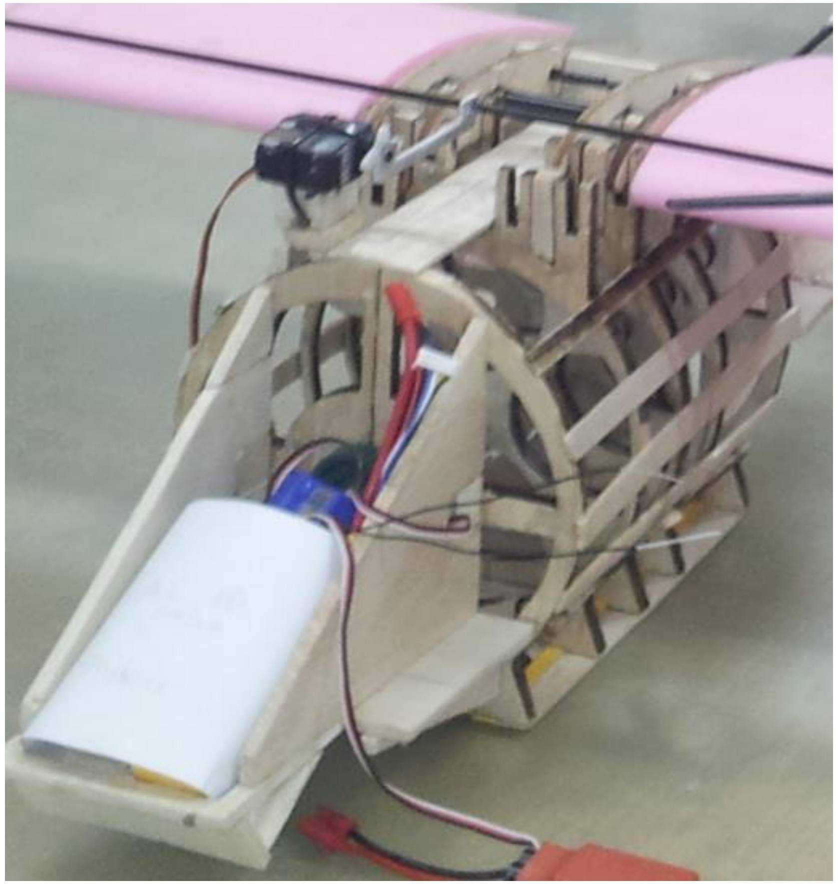


Figure 10: Fuselage Structure

Materials and Production
Wing

Figure 11: Wing Structure

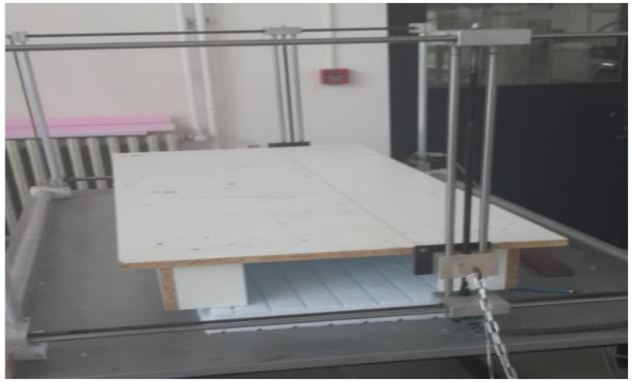


Figure 12: Hot Wire Cutter

Foam and carbon roads are used because;

- ✓It is easier and faster to manufacture the wing using foam than using balsa because of the curvature the airfoil possess
- ✓Carbon roads serve as spars which increase the overall strength of the structure

However;

- ✓Using foam instead of balsa for the wings brings weight penalty

Materials and Production
Motor Case and Connection to Wings

Aluminum is used because;

✓It is a very strong material compared to balsa and the team cannot risk any failure at these critical spots.

Two types of aluminum part are used,

1. Motor case as seen in Figure 13
2. Connection part which is used to connect the motor case to the wing as seen in Figure 14

Although it is not a light-weight material, very few amount of aluminum is used so it doesn't really increase the overall weight considerably.

Figure 13: Motor Case

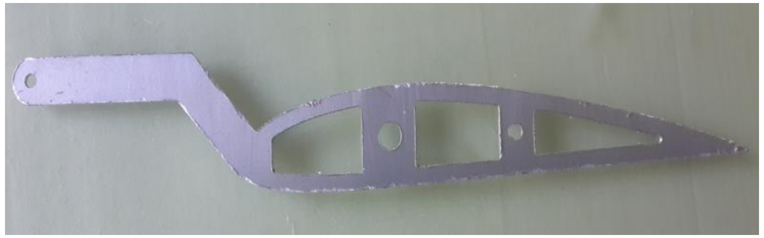


Figure 14: Airfoil Shape

Unique Systems on the Aircraft

Two unique system that makes MODEUS aircraft different than other aircrafts exist:

1. Tilting system to tilt the engines for VTOL missions
2. Payload releasing system to drop the water bottles in the 3rd mission with almost no shift in the center of gravity in the lateral direction

Unique Systems on the Aircraft
Tilting System

- ✓What the tilting system does is to tilt the two engines on the wings by the help of a servo and a rod which is connected to the motor case.
- ✓The third engine located between wings and tail stops after take-off.

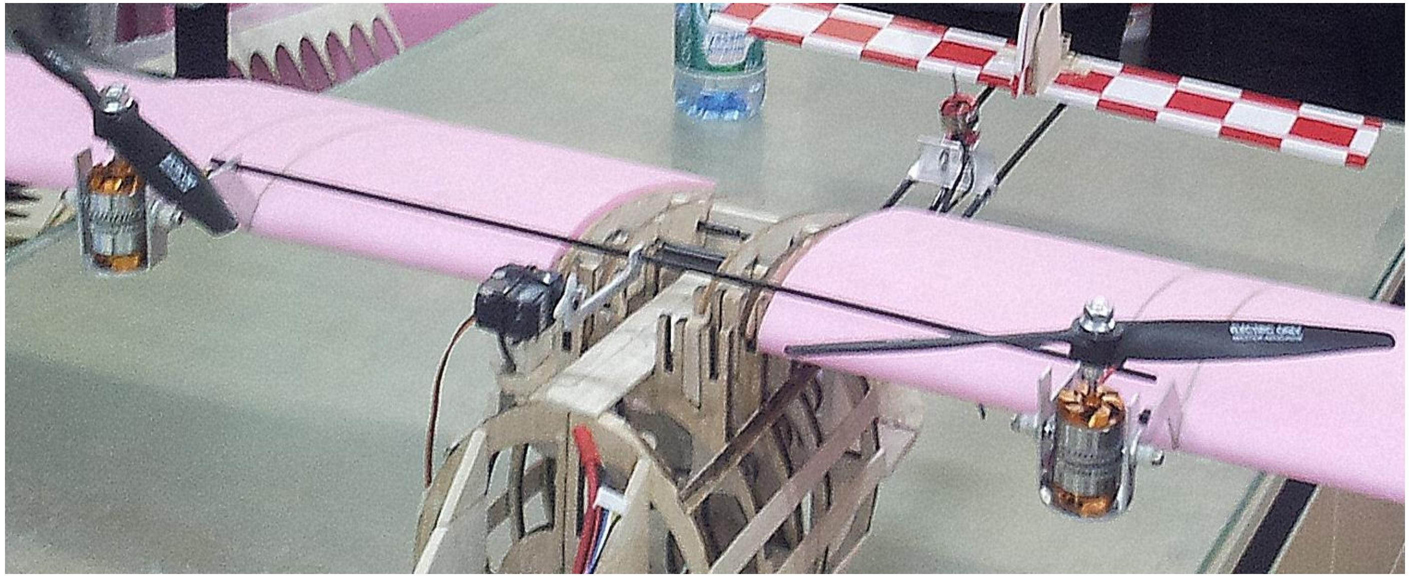
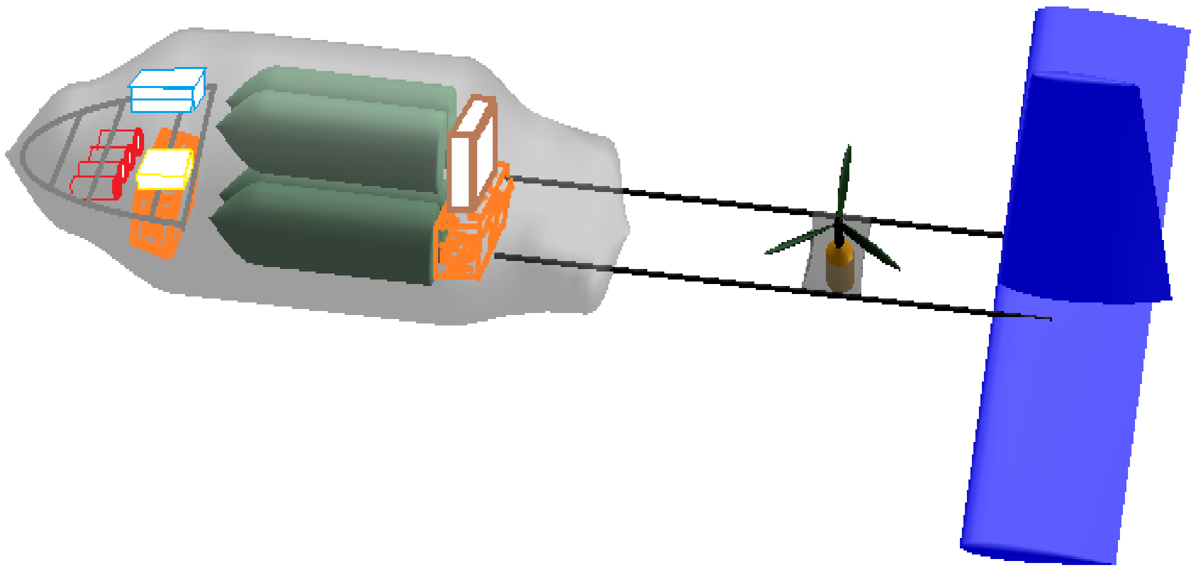


Figure 15: Tilting System

Unique Systems on the Aircraft
Payload Releasing System



a.

b.

Figure 16: Fuselage (a. CAD Drawing, b. Payload Arrangement)

Unique Systems on the Aircraft
Payload Releasing System

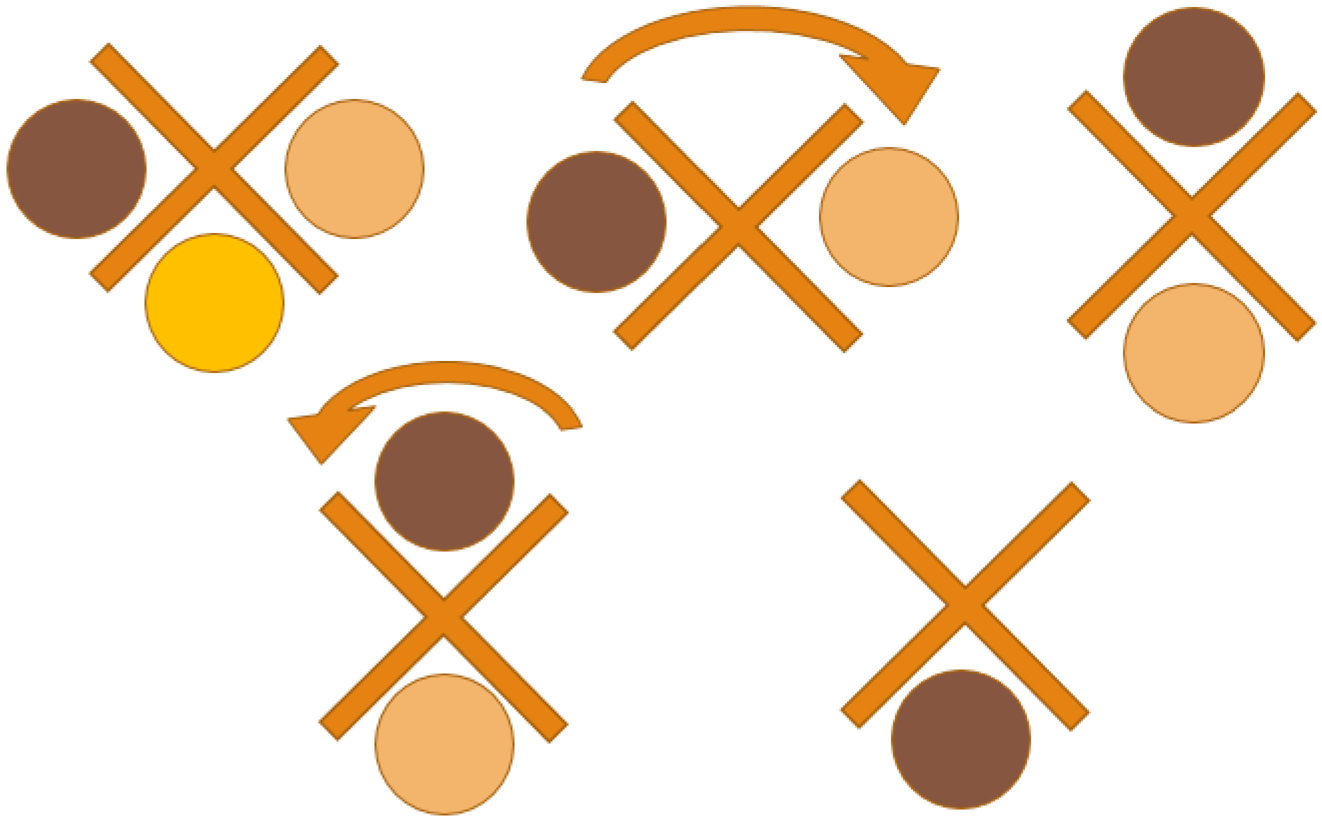


Figure 17: Payload Releasing System

- ✓ There is almost no change in the center of gravity of the aircraft
- ✓ Important to preserve the stability of the aircraft as the bottles are dropped.

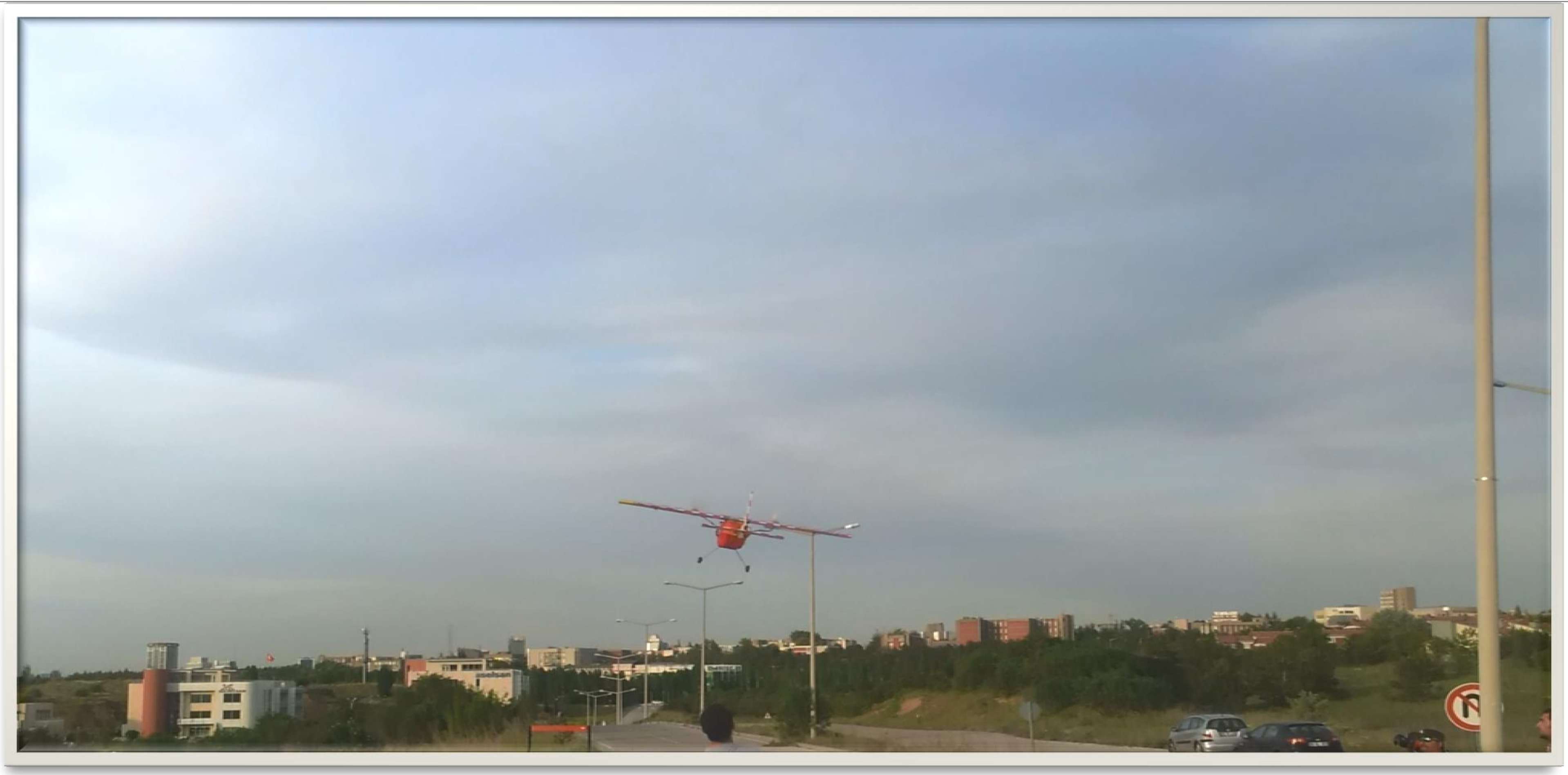
Results
Flight Test

Table 2: Flight Test Results

Middle East Technical University MODEUS Team Test Flight Checklist					
Flight	Second test				
Time	19.33				
Date	07.05.2013				
Place	Yalıncak				
Objective	General Test				
Temperature	21 ºC				
Wind	5-6 m/s				
Pilot	Saffet Gökuç				
Flight Periods					
Before Flight		**In Flight**		**After Flight**	
CG Control	✓	**Takeoff Speed (Vertical)**	0 m/s	**Batteries**	ND
Secure	✓	**Takeoff Speed (Horizontal)**	6 m/s	**Radio**	ND
Batteries	✓	**Stall Speed**	11 m/s	**Receiver**	ND
Propellers	✓	**Takeoff Controllability (Horiz.)**	✓	**ESC**	ND
ESC (Electronic Speed Controller)	✓	**Takeoff Controllability(Vert.)**	✓	**Propeller**	D
Rudder	✓	**Sink Rate**	3 m/s	**Payload Mechanisms**	D
Elevator	✓	**Thrust Characteristics**	T/W=1.5	**Structure**	D
Ailerons	✓	**Roll Stability and Control**	✓		
Engine Tilting Mechanisms	x	**Yaw Stability and Control**	✓		
Payload Mechanisms	x	**Pitch Stability and Control**	✓		
Engine Mechanisms	✓	**Cruise Speed**	17-18 m/s		
Radio Controller	✓	**Payload Releasing**	x		
Receiver	✓	**Landing Speed (Vertical)**	-3 m/s		
Fail Safe	✓	**Landing Speed (Horizontal)**	10 m/s		
Cables and Connections	✓	**Landing Controllability (Horiz.)**	✓		
Processor (Ardu)	x	**Landing Controllability(Vert.)**	x		
Comments		**Comments**		**Comments**	

ND: 'No damage'
D: 'Damage'
Due to high vertical landing speed, the aircraft crashes to the ground during landing. This can be due to high stall speed or pilot mistake. After this test, wing span is increased to be able to generate more lift at low velocities.

Results
Flight Test



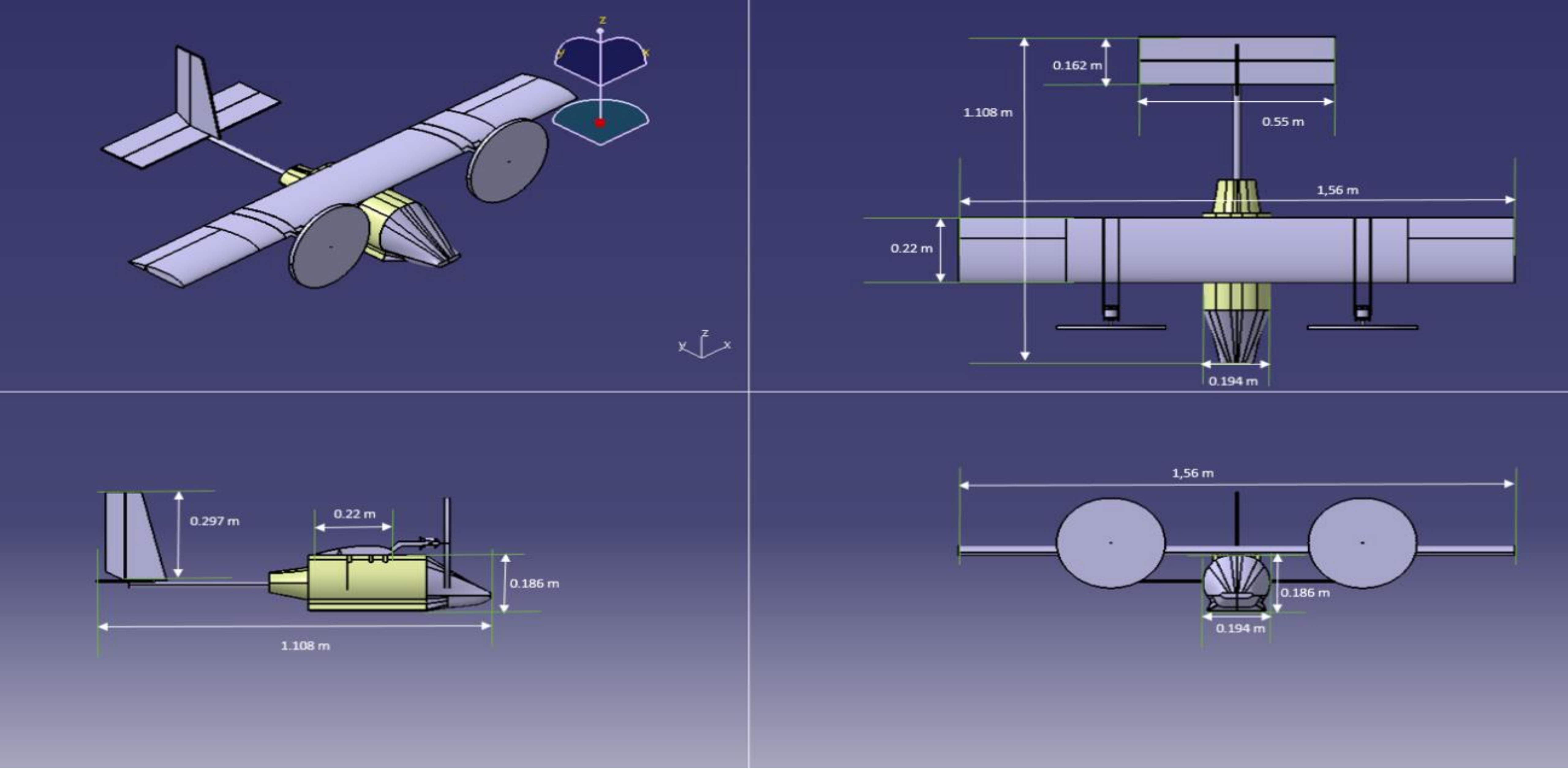


Figure 18: Final CAD Drawing of MODEUS Aircraft

Conclusions

- ✓After 3 months of work, MODEUS aircraft is designed and built.
- ✓However, it cannot be made as a VTOL aircraft because the team realizes that the amount of time before the FFD competition is not enough to make a VTOL aircraft.
- ✓Also, taking-off and landing vertically provide no advantage in the competition because of the format of the competition; on the contrary; it increases the flight time which decreases the overall flight score.
- ✓The reason why it is decided to attend the FFD competition is only to gain experience about designing and building an aircraft
- ✓Project is in progress

Reference;

[1] Raymer, D. (2006). *Aircraft design: A conceptual approach.* (4 Ed.). Blacksburg: AIAA.

Questions