UTM

NUR AIZAT NAZIHAH BINTI AZMI

DEVELOPMENT OF THE VERTICAL TAKE-OFF LANDING (VTOL) AIRCRAFT

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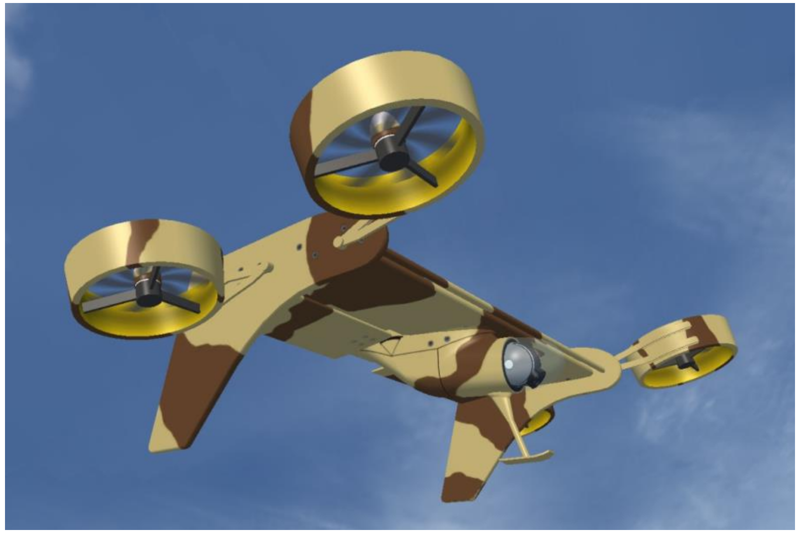
CO-SUPERVISOR : PROF IR. DR. SHUHAIMI MANSOR

VTOL



Capable to take-off, hover and land vertically

PROBLEM IDENTIFICATION

- Extra aerodynamic drag results in additional burden to the pushers
- Extra unnecessary weight coming from the VTOL motors itself
- The overlapped thrust during the transition flight mode

OBJECTIVES

- Conduct wing deflection test to find effect of VTOL motors on wing vertical deflection during take-off
- Carry out flight test to determine the highest power consumption
- Carry out flight test to determine the suitable PID controller

SCOPES

- A total weight not more than 4kg (including payload)
- 4 VTOL motors and 1 pusher motor
- Consists of 2 sets of propulsion system with battery as power source
- Analysis cover from structural, propulsion and control system

CATEGORIES

ROTORCRAFT

AS332

ORNITHOPTER

James DeLaurier Jet-assisted Ornithopter

FIXED WING

- Single System
- Dual System

SINGLE SYSTEM

TAILSITTER

Lockheed XFV2.

TILTROTOR

Bell XV

TILTWING

Vertol 76

ROTOR FIXED-WING UAV

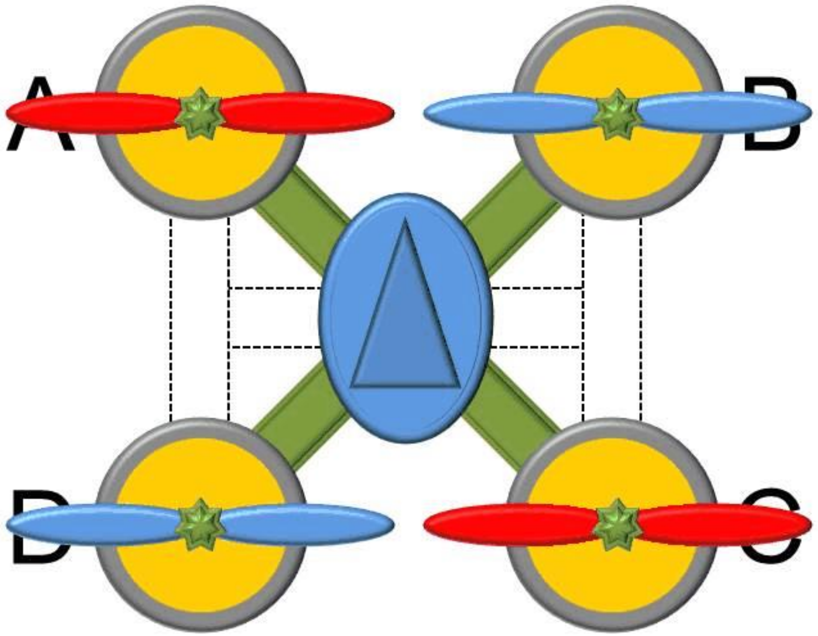
- Combine fixed wing and rotor type of UAV. (Gunarathna & Munasinghe, 2018)

Quadcruiser by Airbus Group

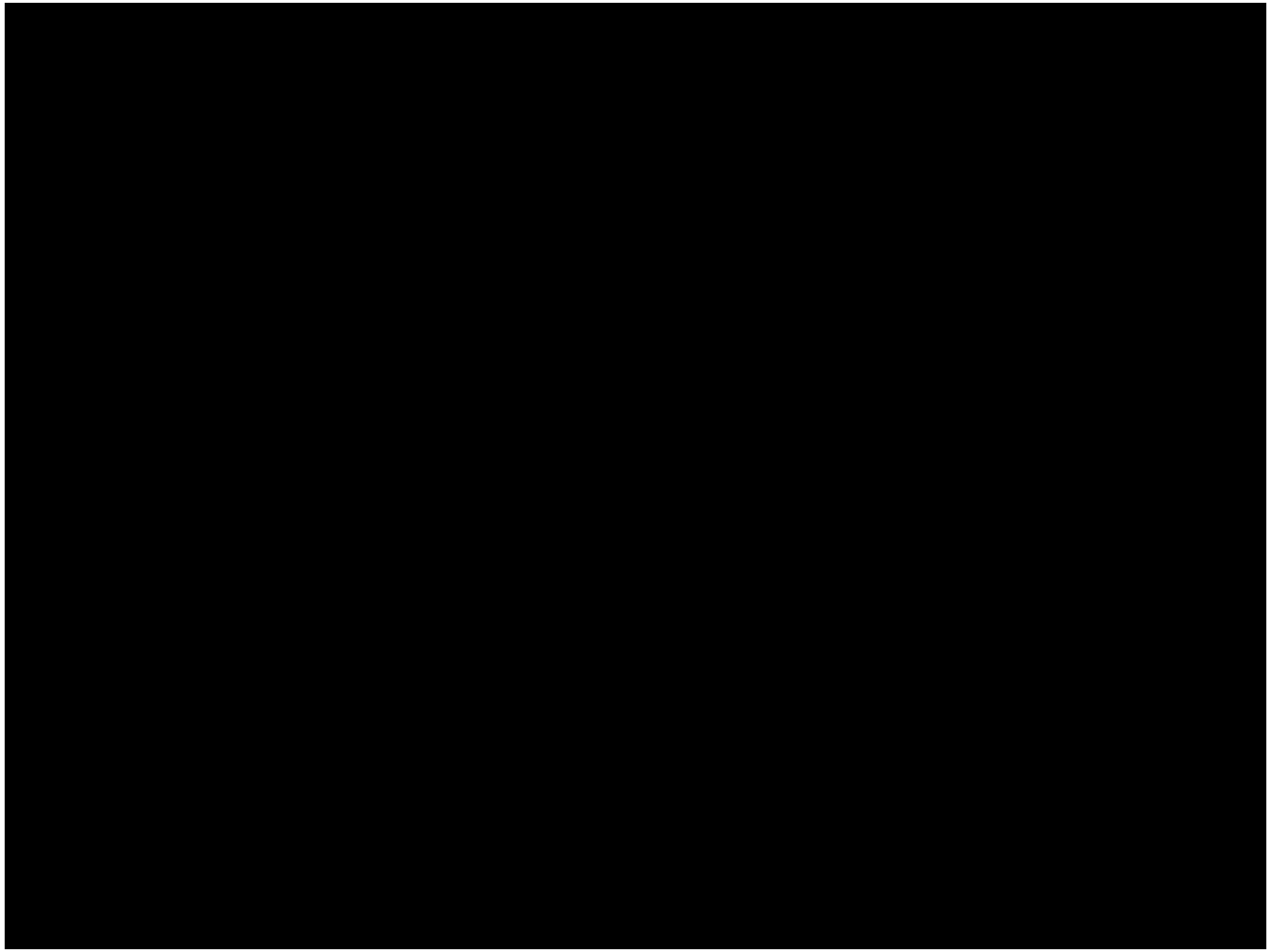
The Arcturus UAV JUMP by Arcturus UAV

HQ-60 Hybrid Quadrotor by Latitude Engineering

QUAD-ROTOR CONFIGURATION



MECHANISM



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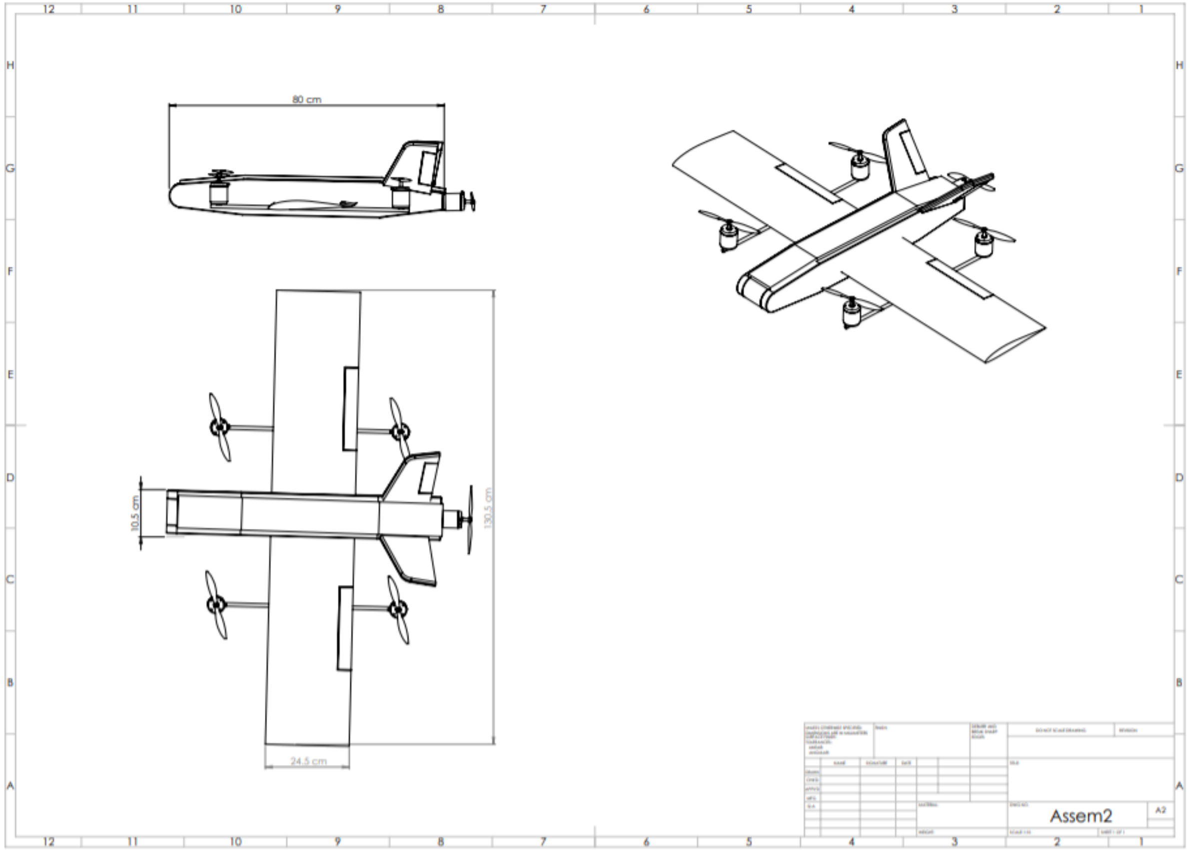
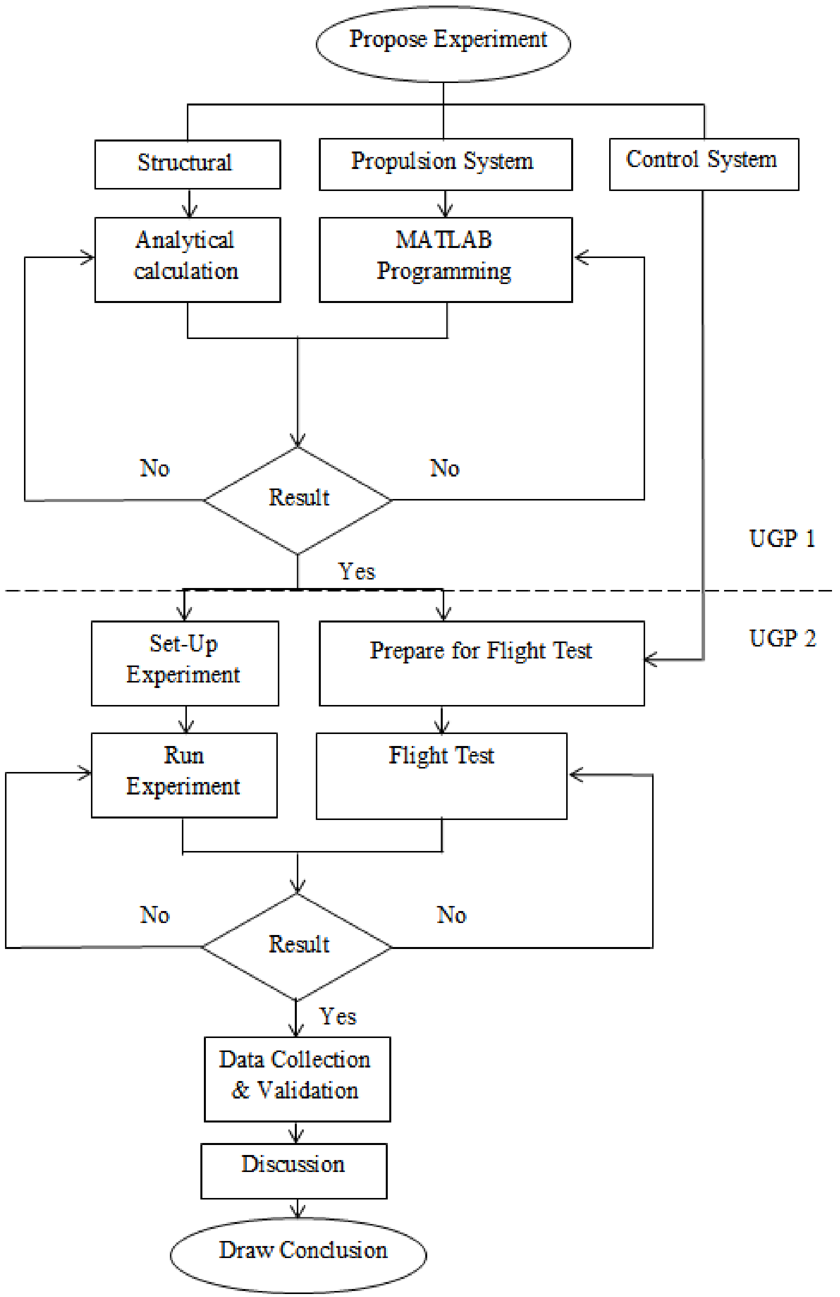
REFERENCE UAV



UAV WEIGHT

No.	Components/Parts	Unit	Weight per unit (kg)	Total Weight (kg)	Weight Distribution (%)
1	Motor and propeller				
	Front VTOL	2	0.183	0.366	9.53
	Rear VTOL	2	0.183	0.366	9.53
	Pusher	1	0.183	0.183	4.77
2	Metal bar	2	0.057	0.114	2.97
3	Servo	2	0.014	0.028	0.73
4	Battery	1	0.452	0.452	11.77
5	Fuselage	1	0.800	0.800	20.83
6	Wing with spar	2	0.287	0.574	14.95
7	V-Tail	1	0.300	0.300	7.81
8	Arduino	1	0.046	0.046	1.19
9	ESC	1	0.097	0.097	2.53
10	Telemetry	1	0.021	0.021	0.55
11	GPS Module	1	0.033	0.033	0.86
12	Receiver	1	0.034	0.034	0.89
13	Others (wires, glue, etc)	-	-	0.300	7.81
TOTAL WEIGHT				3.84	100

METHODOLOGY



STRUCTURAL ANALYSIS

Objective: To find the effect of VTOL motors on wing vertical deflection

VTOL motors added to the wing

↓

During taking off, a point force exists

↓

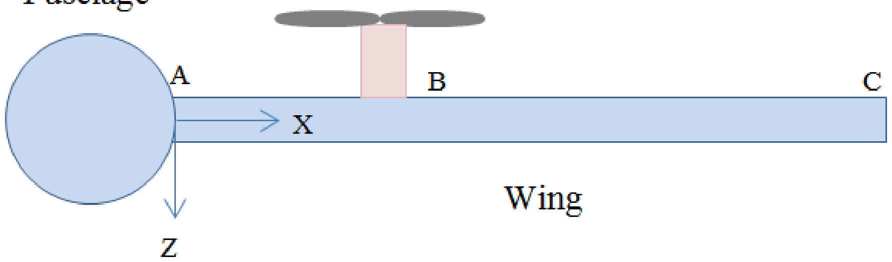
4L = W, assume lift needs to be 1.5>W to lift the UAV

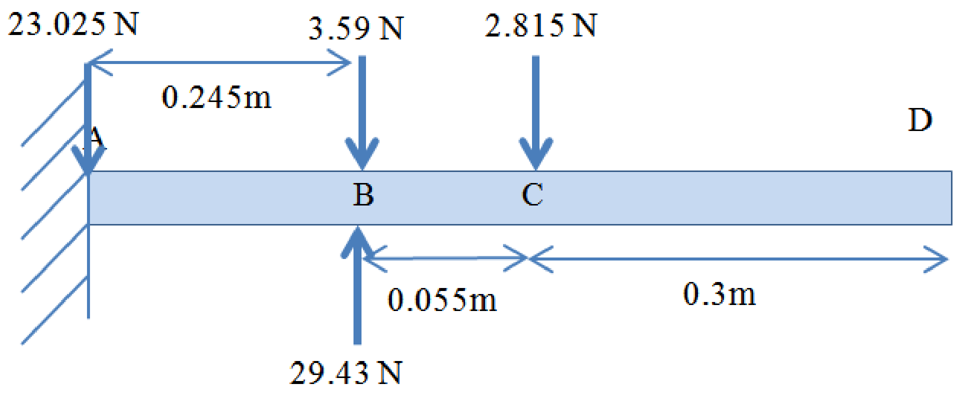
↓

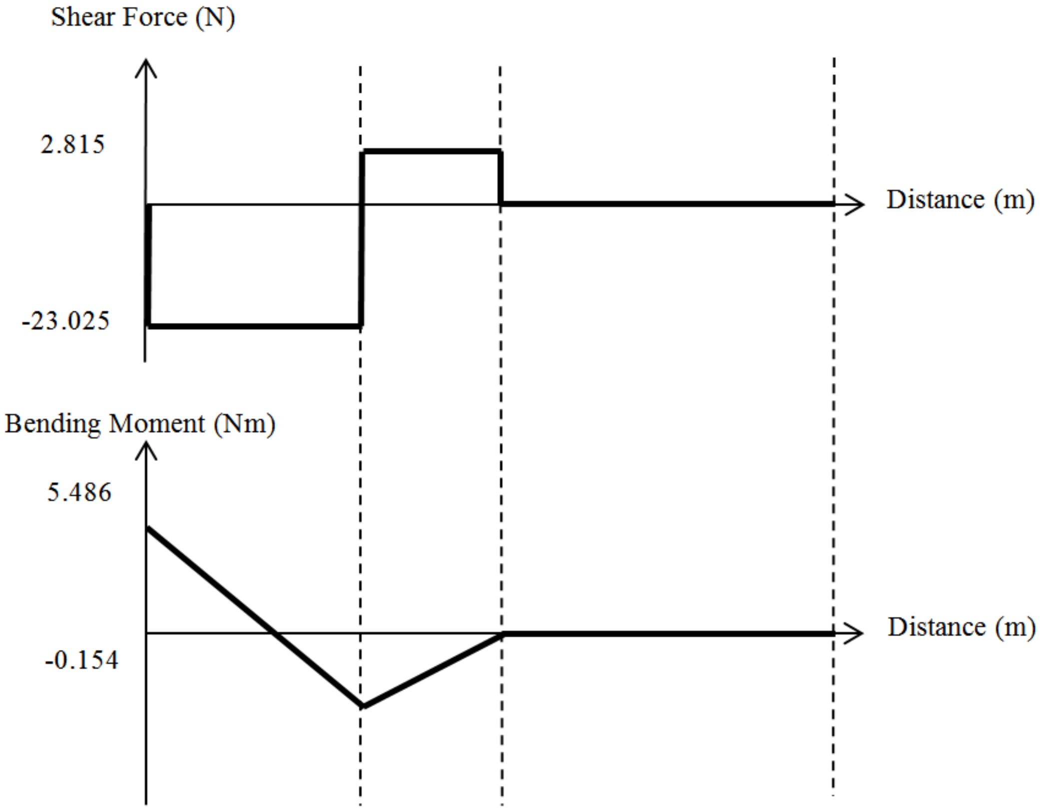
State/solve analytically to find SFD and BMD

↓

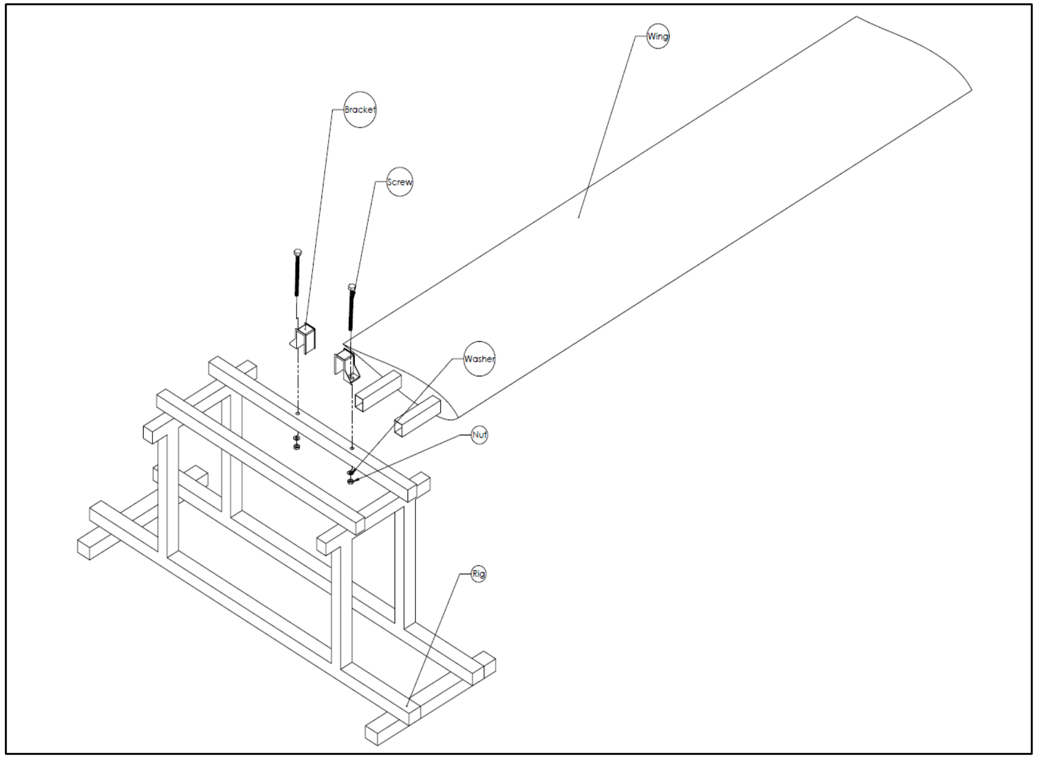
Wing deflection test


Fuselage
A
B
C
X
Z
Wing


23.025 N
3.59 N
2.815 N
0.245m
A
D
B
C
0.055m
0.3m
29.43 N


Shear Force (N)
2.815
-23.025
Distance (m)
Bending Moment (Nm)
5.486
-0.154
Distance (m)

DEFLECTION TEST



Attach wing upside down to bracket

Fix the bracket to the rig by using screws

Place dial gauge at four different locations

Slowly increase the amount of weight placed on the wing

Read the dial gauge for deflection data

No	Velocity (m/s)	Force (N)	Weight (kg)	Deflection at wing			
				Root	Motor	Middle	Tip
1.	0	0	0				
2.	0.5	1.458	0.15				
3.	1.0	5.832	0.60				
4.	1.5	13.121	1.35				
5.	2	23.328	2.40				
6.	2.5	36.449	3.70				
7.	3.0	52.488	5.35				

$$T_{TO} = \frac{\left(W_{TO} + \frac{1}{2}\rho V_{TO}^2 S_{ref} C_{D,O,axial}\right)}{\eta_{motor}}$$

PROPULSION SYSTEM

Objective: To determine the highest power consumption among all flying modes

VTOL motors are added

↓

Weight increases

↓

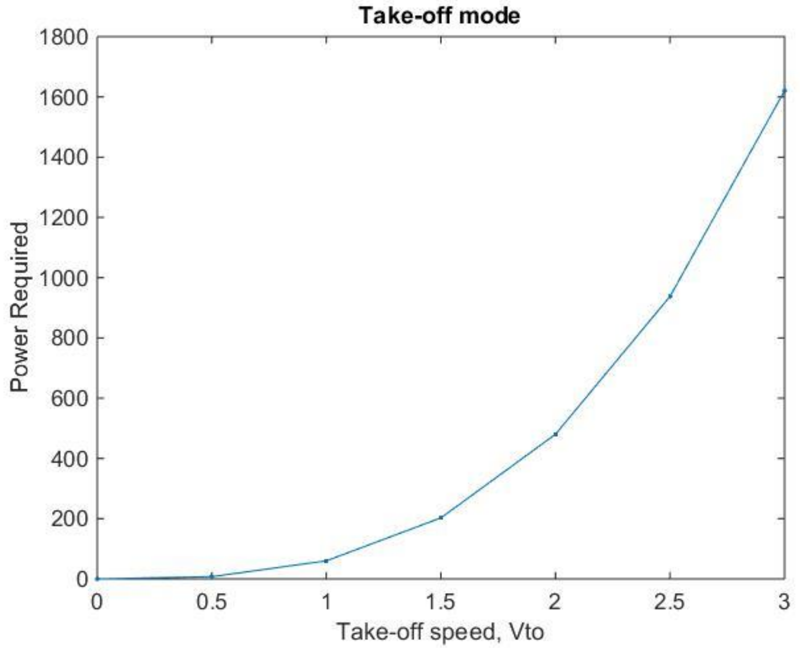
1. Structural Approach
2. Aerodynamic Approach

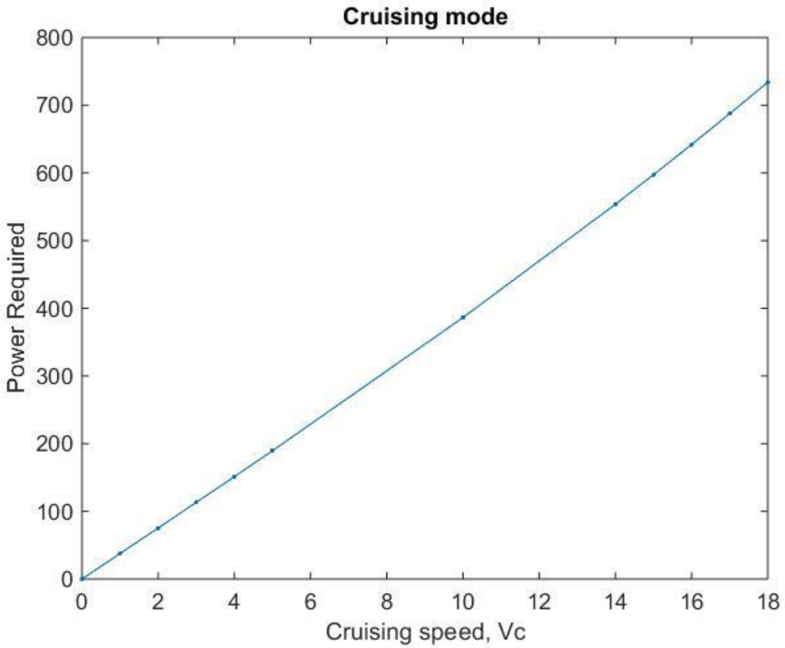
↓

MATLAB Modelling

↓

Flight Test





Multi-rotor

$$T_{TO} = \frac{\left(W_{TO} + \frac{1}{2}\rho V_{TO}^2 S_{ref} C_{D,O,axial}\right)}{\eta_{motor}}$$

$$P_{TO} = \frac{T_{TO} V_{T0}}{2(\eta_{propMR})}\left[2 + \sqrt{1 + \left(\frac{2T_{TO}}{\rho A_{prop} V_{TO}^2}\right)}\right]$$

$$P_H = \frac{\left(\frac{W_{TO}}{\eta_{motor} \times N}\right)^{3/2}}{\eta_{propMR}\sqrt{2\rho \times A_{prop}}}$$

Cruising

$$T_R = D = \frac{1}{2}\rho v^2 S C_{D/0} + \frac{1}{2}\rho v^2 S \frac{C_L^2}{\pi e AR}$$

$$P_R = T_R \times V$$

FLIGHT TEST

1. Idle mode: Switch on power source for 30 seconds
2. Take-off mode: Turn on VTOL motors and take off
3. Hovering mode: Hover the UAV at same altitude for 30 seconds
4. Cruising mode: Turn off VTOL motors and switch on pusher motor
5. Landing mode: Land the UAV slowly until it touches the ground
6. Repeat experiment with different altitude
7. Retrieve data from Mission Planner software

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CONTROL SYSTEM

Objective: To develop a simple PID controller

During transition, overlapping thrust (perturbation)

↓

Cause the aircraft to become unstable.

↓

Problem: How long does it take for the aircraft to back to the original horizontal position?

↓

Tuning test to find value of P, I and D gain

↓

Develop PID controller

Tuning Test (Multicopter & Fixed-wing)

↓

Retrieve data from Mission Planner

↓

Plot suitable graph

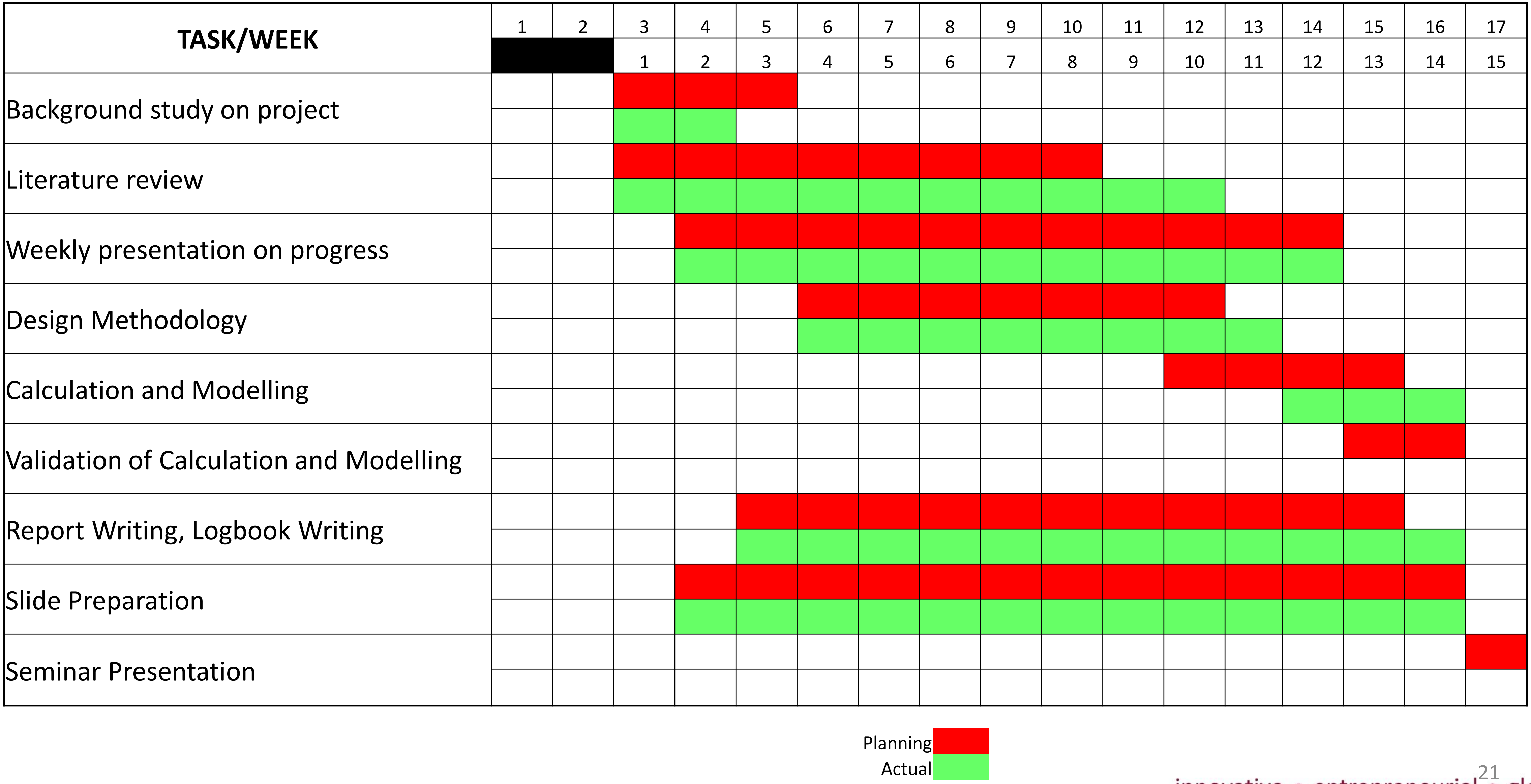
↓

Develop transfer function from input and output obtained

↓

Develop PID controller

GANTT CHART


TASK/WEEK
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
1
2
3
4
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15
Background study on project
Literature review
Weekly presentation on progress
Design Methodology
Calculation and Modelling
Validation of Calculation and Modelling
Report Writing, Logbook Writing
Slide Preparation
Seminar Presentation
Planning
Actual

CHAPTER 2: LITERATURE REVIEW

No	Author	Title	Knowledge
1.	L.Kohlman	Introduction to V/STOL Airplanes	Definition VTOL
2.	Intwala & Parikh	A Review on VTOL Vehicles	Definition VTOL
	L.Kohlman	Introduction to V/STOL Airplanes	VTOL advantages and disadvantages
3.	Saeed, Younes, Cai & Cai	A Survey of Hybrid Unmanned Aerial Vehicle	VTOL Category
4.	McCornick	Aerodynamics of V/STOL Flight	Tiltwing aircraft
5.	Gerdes & Gupta	A Review of Bird -Inspired Flapping Wing Miniature Air Vehicle Designs	Ornithopter

6.	Reg Austin	Unmanned Aircraft Systems UAVs Desugn, development and Deployment	Definition UAS
7.	Gunarathna and Munasinghe	Development of a Quad-rotor Fixed-wing Hybrid Unmanned Aerial Vehicle	Type of UAV
8.	Abd Rahman, Hajibeigy, Al-Obaidi & Cheah	Design and Fabrication of Small VTOL UAV	
9.	Md. Shamim, Tariq & Kazi	Development Of A Multi-purpose Hybrid & Portable Surveillance Drone For Security and Disaster Management	Usage of UAV
10.	Tielin, Chuanguang, Wenbiao, Zihan, Qinling and Xiaoou	Analysis of Technical Characterisitics of Fixed-Wing VTOL UAV	Category of hybrid UAV

No	Author	Title	Knowledge
	Gunarathna & Munasinghe	Development of a Quad-rotor Fixed-wing Hybrid Unmanned Aerial Vehicle	Advantages of Quad-rotor Fixed-wing
	Abd Rahman, Hajibeigy, Al-Obaidi & Cheah	Design and Fabrication of Small VTOL UAV	
	Abd Rahman, Hajibeigy, Al-Obaidi & Cheah	Design and Fabrication of Small VTOL UAV	Quadcopter mechanism
	Abd Rahman, Hajibeigy, Al-Obaidi & Cheah	Design and Fabrication of Small VTOL UAV	VTOL flying mode
11.	Resnick & Halliday	Fundamental of Physics	Newton's Law

No	Author	Title	Knowledge
12.	Gunasegaran Kanesan	Validation of UAV Wing Structural Model for Finite Element Analysis	Experimental Set-Up for Structure Analysis
13.	Dr. S. P. Tayal	Engineering Design Process	Definition, steps
14.	Cynthia J. Atman, Robin S. Adams, Monica E. Cardella, Jennifer Turns, Susan Mosborg and Jason Saleem	Engineering Design Processes: A Comparison of Students and Expert Practitioners	Steps

No	Author	Title	Knowledge
15.	Ali Gharibi , Hamid Reza Ovesy, Reza Khaki	Development of Wing Deflection Assessment Methods Through Experimental Ground Tests and Finite Element Analysis	The development of wing deflection prediction methods
16.	Bo Wang, Zhongxi Hou, Zhaowei Liu, Qingyang Chen, and Xiongfeng Zhu	Preliminary Design of a Small Unmanned Battery Powered Tailsitter	Thrust, Power and Energy formula
17.	Muhammad Fadhil Bin Jamaludina	Design and Analysis Performance of Fixed Wing VTOL UAV	

No	Author	Title	Knowledge
18.	Natassya Barlate, Roberto Santos, Kalinka Castelo, JolJoao Vitorior vIlto	Development of a fixed-wing vertical take-off and landing aircraft as an autonomous vehicle	Structure of horizontal and vertical controller autopilot
19.	D. Felix, Cees Bil and Carsten Braun	A Review of Configuration Design for Distributed Propulsion Transitioning VTOL Aircraft	Single system and Dual system
20.	Hasini Viranga, Beeshanga Abewardana , Ying He, Eryk Dutkiewicz	Empirical Power Consumption Model for UAVs	Comparison graph of power consumption

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