UNIVERSITI TEKNIKAL MALAYSIA MELAKA

DESIGN PARAMETERS FOR MILITARY TACTICAL SURVEILLANCE UNMANNED AERIAL VEHICLE IN TROPICAL COUNTRIES

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A thesis submitted
in fulfillment of the requirements for the degree of
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DECLARATION

I declare that this thesis entitled "Design Parameters for Military Tactical Surveillance Unmanned Aerial Vehicle in Tropical Countries" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature :..

Name : Mohd Suhaimi Bin Omar

Date : 26 September 2025

APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Doctor of Philosophy.

Signature :...

Supervisor Name :Prof. Madya Ts. Dr. Wan Hasrulzizzam Wan Mahmood

Date : 26 September 2025

DEDICATION

This thesis is lovingly dedicated to my cherished parents, my late father, Allahyarham Omar bin Salang, and my dear mother, Hajjah Norbaiti binti Pakih, whose lives and values have been my constant source of inspiration.

To my beloved wife, Hajjah Wan Rowena Mohamad Rosli, my daughter Wan Irene Izaty, and my son Wan Addean Luqman, your unwavering love, encouragement, and patience have been the foundation of my academic journey. I am deeply grateful for your steadfast belief in me and the countless sacrifices you have made throughout this endeavour.

I also extend my heartfelt appreciation to my friends, research participants, and everyone who has touched my life with their contributions, friendship, and inspiration.

"Education is the most powerful weapon which you can use to change the world."

— Nelson Mandela

ABSTRACT

Unmanned aerial vehicles (UAVs) can be defined as an aircraft that operates and controls without requiring human intervention. The development stage of UAVs, however, differs depending on their particular use in each respective industry and the environmental conditions. In tropical countries, many factors and critical design parameters must be taken into consideration, especially in relation to the challenges posed by high humidity, strong crosswinds and fluctuating temperatures to ensure UAVs operate effectively and meet flight requirements. There are multiple phases in developing a UAVs, which include the design, material selection, system and flight test. The objective of this study is to investigate the essential components of UAVs design parameter specifically for military applications, to analyse the technical requirements of UAVs components by applying analytical hierarchy process and quality function deployment and to verify the performance of UAVs system by conducting flight test with the defined technical requirements and design parameter. The method used was Analytical Hierarchy Process and Quality Function Deployment. Some other method such as focus group discussion, semi structured interview, field observation and document review contributed to this research activities. Opinions and suggestion by all experts in Company XYZ were taken into consideration when the selection process for the design, material, component and test was made. This research succeeded in fulfilling the objectives as the selection had been made to figure out the best development of a UAVs. From this study, the weight of components and structured were set at 120kg which made it a successful development to reduce the maximum take-off weight from 150kg to 120kg. By comparing the aerofoil in terms of its aerodynamic performance, structural integrity, payload capacity, environmental consideration and manufacturability, the selected aero foil was RONCZ1046 as it scored higher than SD7062 and NACA0012.In addition, carbon fibre for wing structure and propellor, fiberglass composite for tail and body of UAVs were selected as the structures' material after its aerodynamic efficiency, lightweight, strength and fatigue resistance had been analysed. Meanwhile engine selected was Engine LMN compared to other engines such as Engine ABC and Engine PQR as it offered the most powerful performance, efficiency, reliability and affordable cost. The battery selected was Li-Ion while the RC test that was selected were used to verify the integration and development of the new UAVs as it analysed how the system works, the communication between UAVs and operators and the smoothness of flight. This study allowed future development of UAVs in tropical countries to be done easily with this research on design, material, engine and flight test as its benchmark.

PARAMETER REKABENTUK PESAWAT UDARA TANPA PEMANDU UNTUK APLIKASI KETENTERAAN DI NEGARA TROPIKA

ABSTRAK

Pesawat udara tanpa pemandu atau dalam bahasa inggerisnya, unmanned aerial vehicle (disingkatkan kepada UAVs) boleh ditakrifkan sebagai pesawat yang beroperasi dan dikawal tanpa memerlukan campur tangan manusia. Dalam peringkat pembangunan UAVs, bagaimanapun adalah berbeza bergantung kepada penggunaan khusus mereka dalam setiap industri khusus. Di negara tropika, banyak faktor dan parameter reka bentuk kritikal perlu diambil kira, terutamanya berkaitan dengan cabaran berkaitan kelembapan tinggi, angin yang kuat dan suhu yang berubah-ubah bagi memastikan UAVs dapat beroperasi dan memenuhi keperluan penerbangan.Terdapat beberapa fasa dalam pembangunan sebuah UAVs termasuk reka bentuk, pemilihan bahan, sistem dan ujian penerbangan. Objektif kajian ini adalah untuk menyiasat bahagian dan komponen penting reka bentuk dan pembangunan UAVs yang dikhususkan untuk kegunaan ketenteraan, untuk mengesahkan keperluan teknikal UAVs menggunakan pendekatan hibrid seperti proses hierarki analisis dan pembahagian fungsi kualiti dan untuk mengesahkan pendekatan teknikal melalui fabrikasi dan pembuatan UAVs melalui ujian penerbangan. Kaedah yang digunakan adalah melalui proses hierarki analisis dan pembahagian fungsi kualiti. Kaedah lain adalah seperti perbincangan berkumpulan secara berfokus, temu bual separa struktur, pemerhatian lapangan dan semakan dokumen telah menyumbang dalam aktiviti kajian ini. Pendapat dan cadangan oleh pihak professional dari Syarikat XYZ telah diambil kira semasa proses pemilihan reka bentuk, bahan, komponen dan ujian dibuat. Penyelidikan ini berjaya memenuhi objektif memandangkan pemilihan telah dibuat untuk mengetahui pembangunan terbaik sesebuah UAVs. Daripada kajian ini, berat komponen dan struktur ditetapkan kepada 120kg dan berat lepas landas maksimum berjaya dikurangkan daripada 150kg kepada 120kg. Dengan membandingkan sayap aerodinamik dari aspek prestasi aerodinamik, integriti struktur, kapasiti muatan, pertimbangan alam sekitar dan kebolehan pembuatan, sayap aerodynamik yang dipilih adalah RONCZ1046 kerana ia mendapat skor lebih tinggi berbanding SD7062 dan NACA0012. Selain itu, gentian karbon untuk struktur sayap, kipas, komposit gentian kaca untuk ekor dan badan UAVs telah dipilih sebagai bahan struktur setelah kecekapan aerodinamik, keringanan, kekuatan dan rintangan keletihan telah dianalisis. Manakala, enjin yang dipilih adalah Enjin LMN berbanding Enjin ABC dan Enjin PQR kerana ia menawarkan prestasi paling baik dalam kuasa, kecekapan, kebolehpercayaan dan kos yang berpatutan. Bateri yang dipilih ialah Li-Ion manakala ujian RC dipilih untuk mengesahkan penyepaduan dan pembangunan UAVs baharu kerana ia menganalisa cara sistem berfungsi, komunikasi antara UAVs dan pengendali serta kelancaran penerbangan. Kajian ini membolehkan pembangunan UAVs pada masa hadapan dilakukan dengan mudah dengan penyelidikan reka bentuk, bahan, enjin dan ujian penerbangan sebagai penanda arasnya.

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LIST OF ABBREVIATIONS

AFC	-	Alkaline Fuel Cells
AFCS	-	Automated Flight Control System
AHP	-	Analytic Hierarchy Process
CFD	-	Computational Fluid Dynamics
CI	-	Consistency Index
CPU	-	Central Processing Unit
CR	-	Consistency Ratio
FRIDA	-	Framework for Innovation Design in Aeronautics
GCS	-	Ground Control Station
GPS	-	Global Placement System
GSM	-	Global System for Mobile Communication
HOQ	-	House of Quality
IMU	-	Inertial Measurement Unit
ISTAR	-	Intelligence, Surveillance, Target Acquisition and Reconnaissance
LCO	-	Lithium Cobaltite
LFP	-	Lithium Iron Phosphate
Li-Ion	-	Lithium Ion
Li-Po	-	Lithium Polymer
MCFC	-	Molten Carbonate Fuel Cells
MRO	-	Maintenance, Repair and Overhaul
MTOW	-	Maximum Take-off Weight

NMC	-	Nickel-Manganese-Cobalt
OEM	-	Original Equipment Manufacturer
PAFC	-	Phosphate Fuel Cells
PEMFC	-	Proton Exchange Membrane Fuel Cells
PID	-	Proportional-Integral-Derivative
PWM	-	Pulse Width Modulation
QFD	-	Quality Function Deployment
RC	-	Remote controlled
RI	-	Mean Random Consistency
SOFC	-	Solid Oxide Fuel Cells
UAS	-	Unmanned Aerial System
UAVs	-	Unmanned Aerial Vehicles
VOC	-	Voice of Customer

LIST OF SYMBOLS

$W_{Takeoff}$	-	Take off weight
W_{Empty}	-	Empty Weight of UAVs
$W_{Payload}$	-	Payload Weight
W_{Fuel}	-	Fuel Weight
R	-	Range
v	-	Cruising speed
Ct	-	Engine's specific fuel consumption
L	-	Aerodynamic Lift
D	-	Drag forces
V	-	Global Alternatives Scores
S	-	Matrix of Alternatives
W	-	Weight Vector

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LIST OF PUBLICATIONS

Mohd Suhaimi Omar, Wan Hasrulnizzam Wan Mahmood, Noor Irinah Omar, Nur Diyanah Faizal, Nur Azmina Muhammad Haris Ong and Abdurrahman Faris Indriya Himawan. 2025. Multi-Criteria Decision Analysis for Optimal Material Selection in Unmanned Aerial Vehicle Manufacturing. *Malaysian Journal on Composites Science and Manufacturing,* 16 (1), pp. 85-99.
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