WEBINAR AVIATION, AEROSPACE, AND SPACE AWARENESS

KELAB RAKAN UDARA MALAYSIA (KRUM)

PEMBANGUNAN TEKNOLOGI AEROANGKASA BAGI PERTAHANAN NASIONAL

Lt Ts. Dr. Nur Azam bin Abdullah PSSTUDM

Pensyarah Kanan
Jabatan Kejuruteraan Mekanikal
Universiti Islam Antarabangsa Malaysia (UIAM)
Kuala Lumpur, Malaysia

Penasihat MAFJD 3-17 UAS
Angkatan Tentera Malaysia (ATM)

3 JUL 2021 (SAT)

OVERVIEW

- ❑ Strategic Directions
- ❑ Introduction on UAV
- ❑ Technical Issues
- ❑ Regulations
- ❑ Way Forward for UAV Research
- ❑ Conclusion

STRATEGIC DIRECTION

National Threats

WHY???

STRATEGIC DIRECTION

National Threats : Piracy Issues

STRATEGIC DIRECTION

National Threats : Smuggling Activities/ Penyeludupan Haram

Kesan penyeludup guna dron

Oleh Zuliaty Zulkiffli - Disember 16, 2020 @ 12:14pm
bhnews@bh.com.my

Anggota Pasukan Gerakan Am (PGA) mengawal pagar keselamatan sempadan Malaysia-Thailand selain dibantu Unit Dron bagi menangani penyeludupan. -Foto NST/Amran Hamid

Seludup dadah dari Malaysia guna dron, dua lelaki rakyat Singapura diberkas

Bernama
Jun 20, 2020 21:33 MYT

Dua lelaki, masing-masing berusia 29 dan 34 tahun, yang dipercayai pengendali dron ditahan pihak berkuasa. - Facebook / CNB Drug Free SG

National Threats : Militants & Terrorist Issues

Sebahagian daripada Ops Subuh: Pengepungan Tentera Di Sauk

Tarikh: 5 Julai, 2000
Lokasi: Bukit Jenalik, Sauk, Perak
Tamat: Al Ma'unah tumbang

National Threats : Militants & Terrorist Issues

Ops Daulat: Krisis Pencerobohan Lahad Datu 2013

Tarikh: 9 Februari 2013 – 22 Mac 2013

Lokasi: Kg. Tanduo, Daerah Lahad Datu, Semporna, Kunak dan Tawau di pantai timur Sabah

Punca: Kawasan timur Sabah yang tidak dimasukkan (dahulunya dikenali sebagai Borneo Utara) ke dalam Perjanjian Rangka Kerja mengenai Bangsamoro

Tamat: Kemenangan kepada pihak Malaysia

STRATEGIC DIRECTION

National Threats : Current Issues (Op Benteng)

STRATEGIC DIRECTION

National Threats : Current Issues (Op Penawar)

> KHAS > COVID-19 > Dron pantau pergerakan rakyat hingga ke malam

Dron pantau pergerakan rakyat hingga ke malam

ERNAMA | | 29 Mac 2020

COVID-19: Dron turut digunakan sebelah malam pantau PKP

Mac 29, 2020 @ 8:55am

INTRODUCTION

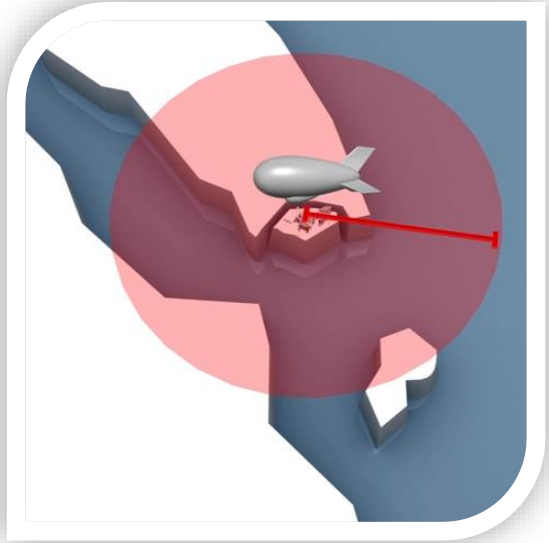
Which one? **UAS?** **UAV?** **UCAV?** **DRONE?**

UA Unmanned Aircraft

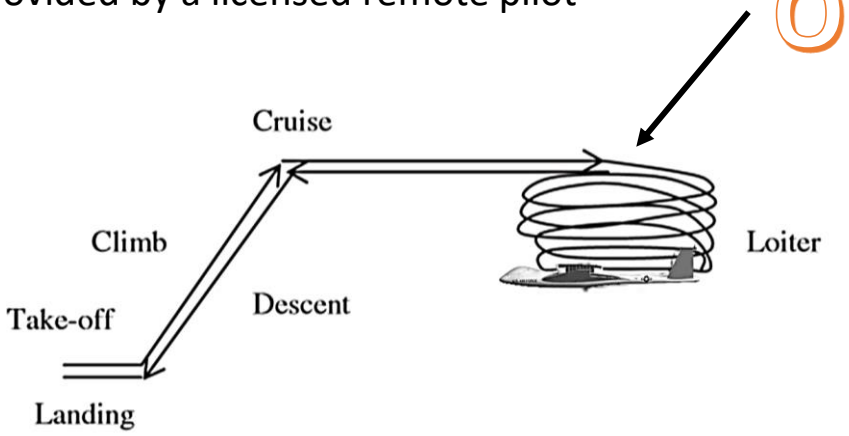
- Free balloons
- Fully automatic and/or autonomous aircraft
- Drones

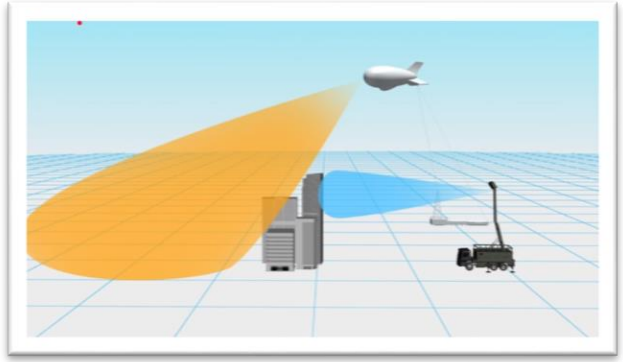
RPA Remotely Piloted Aircraft

- Airspace/ aerodrome integration
- Requires control
- Control, in real time provided by a licensed remote pilot



Operation!



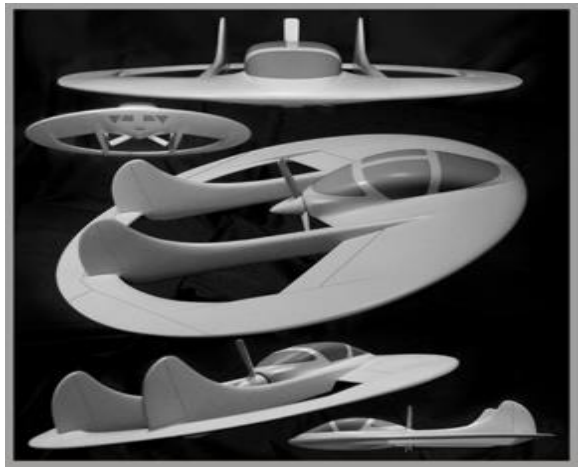


INTRODUCTION

Fix Wing UAV (Blended Wing)

Prototype of KLM Royal Dutch Airlines' futuristic-looking flying-wing aircraft

Pipistrel unveils blended-wing body eVTOL



GeoBat flying saucer

INTRODUCTION

Fix Wing UAV (Conventional Fuselage)

IAI Harop – Kamikaze UAV

Northrop Grumman RQ-4
Global Hawk – HALE

Russian Orion UAV – MALE

Stealth!

INTRODUCTION

ROTORBLADES DRONES: Vertical Take-off and Landing (VTOL)

DJI – Mavic Pro Quadcopter

Yuneec TORNADO H920 Hexacopter Drone

The name is derived directly from the atomic number of the element using the following Latin numerical roots:

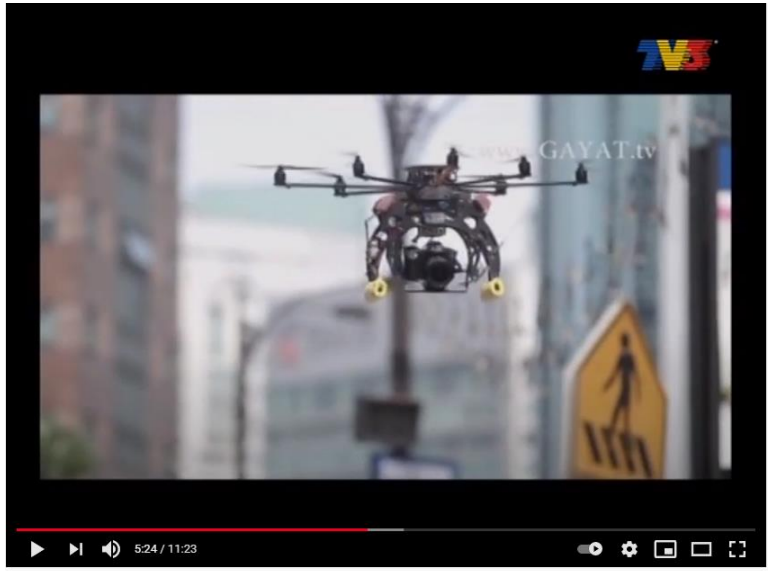
number	prefix
0	nil
1	un
2	bi
3	tri
4	quad
5	pent
6	hex
7	sept
8	oct
9	enn

Octacopter

Gayat Helicam live at MHI TV3

5,092 views • Feb 5, 2012

26 0 SHARE SAVE



Gayat Helicam live at MHI TV3

5,092 views • Feb 5, 2012

26 0 SHARE SAVE

TECHNICAL ISSUES

Perolehan terkini: MALE- Medium-altitude long-endurane

No.	Class	Mass	Size	Normal Operating Altitude	Range	Endurance
1	Micro	< 0.2 lb	< 10 cm	< 50 ft	0.1-0.5 km	< 1 hr
2	Mini	0.2-1 lb	10-30 cm	< 100 ft	0.5-1 km	< 1 hr
3	Very small	2-5 lb	30-50 cm	< 1000 ft	1-5 km	1-3 hr
4	Small	5-20 lb	0.5-2 m	1,000-5,000 ft	10-100 km	0.5-2 hr
5	Medium	100-1,000 lb	5-10 m	10,000-15,000 ft	500-2,000 km	3-10 hr
6	Large	10,000-30,000 lb	20-50 m	20,000-40,000 ft	1,000-5,000 km	10-20 hr
7	Tactical/ combat	1,000-20,000 lb	10-30 m	10,000-30,000 ft	500-2,000 km	5-12 hr
8	MALE	1,000-10,000 lb	15-40 m	15,000-30,000 ft	20,000-40,000 km	20-40 hr
9	HALE	> 5,000 lb	20-50 m	50,000-70,000 ft	20,000-40,000 km	30-50 hr

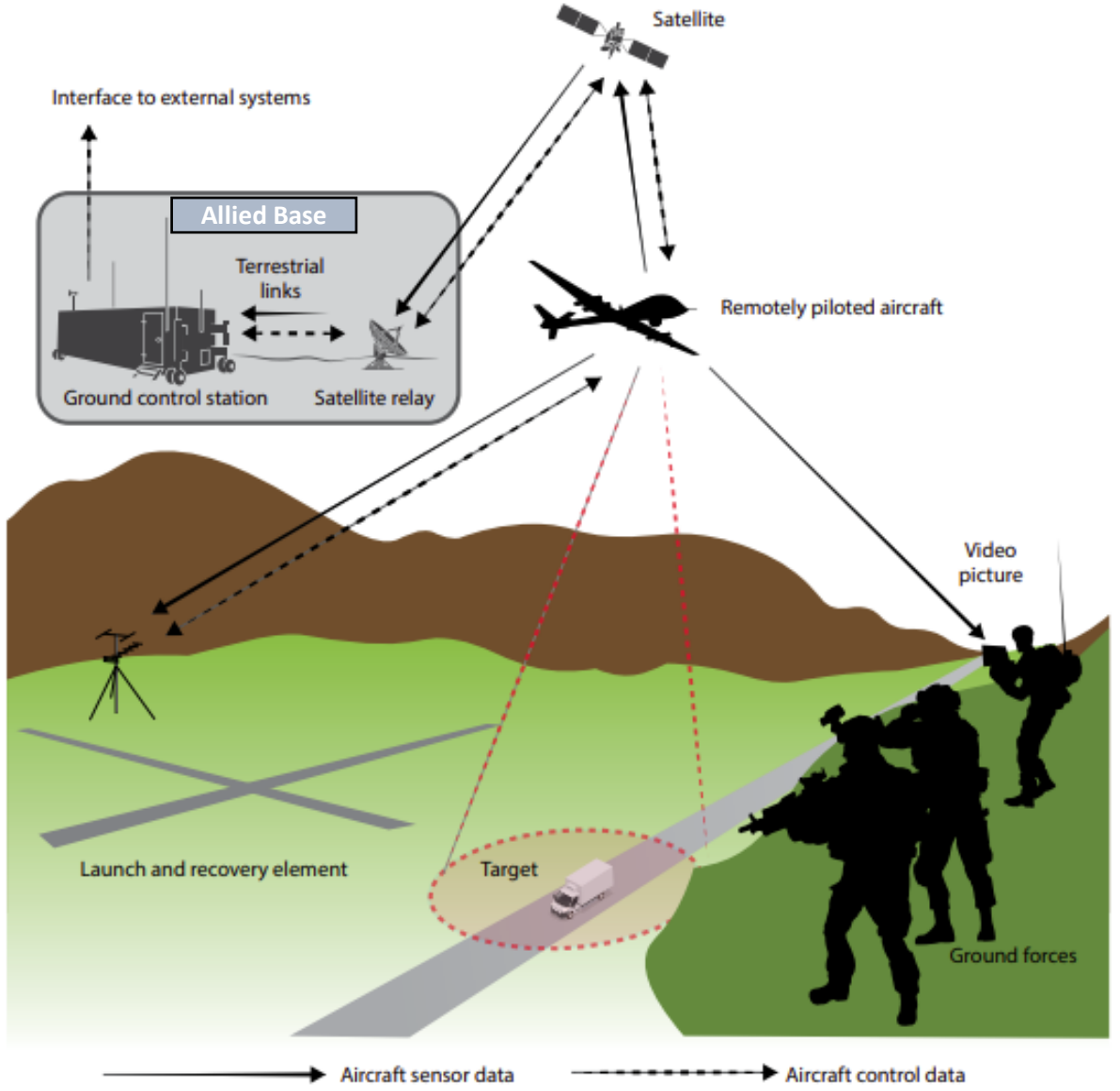
(1) manufacturing technology
(2) required accuracy
(3) mission
(4) weather
(5) reliability
(6) life-cycle cost
(7) UAV configuration
(8) human factors
(9) maintainability
(10) endurance
(11) communication system
(12) weight
(13) level of control

Sadraey, Mohammad. 2017. *Unmanned Aircraft Design: A Review of Fundamentals*. *Synthesis Lectures on Mechanical Engineering*. Vol. 1. https://doi.org/10.2200/s00789ed1v01y201707mec004.

TECHNICAL ISSUES

Remote-split operations illustrate the complexity of the command and data links required for some remotely piloted aircraft system operations

- Joint Doctrine Publication 0-30.2 Unmanned Aircraft Systems, Ministry of Defence Shrivenham SWINDON, Wiltshire, SN6 8RF



REGULATIONS

Joint Authorities for Rulemaking on Unmanned Systems (JARUS)

JARUS publishes regulatory categories for UAS operations

September 4, 2019 Civil/military integration, Commentary, Emerging regulations, UAS traffic management news

The Joint Authorities for Rulemaking on Unmanned Systems (JARUS) has published the *JARUS UAS Operational Categorisation* document on the RPAS website to define the level of regulatory involvement for different types of UAS. The document is available at http://jarus-rpas.org/publications.

WAY FORWARD FOR UAV RESEARCH

LIMA Langkawi 2011

WAY FORWARD FOR UAV RESEARCH

12 RABU, 11 NOVEMBER 2020

Rencana

Penggunaan dron strategi peperangan alaf baharu

Kawasan perebutan wilayah Nagorno-Karabakh yang menjadi punca peperangan etnik ini bukan isu baharu. Ia bermula sejak 1980-an sehingga 1944.

Lanjutan itu, kedua-dua Armenia dan Azerbaijan saling menuding jari bahawa pihak lawan gagal menatuhi arahan pelan damai gencatan senjata bagi tujuan kelestarian kemanusiaan serta memaksa peperangan terbaru berlanjutan sejak sebulan lalu sehingga kini.

Leftenan Dr Nur Azam Abdullah

Azerbaijan dan Armenia sebenarnya bekas wilayah dalam Republik Soviet, terbabit dalam peperangan di kawasan pergunungan Karabakh ketika Azerbaijan berusaha untuk mengekang gerakan pemisah di Nagorno-Karabakh.

Namun, konflik perebutan kawasan yang semakin parah membawa kepada persengketaan amat dahsyat, bahkan perang ini disebut menjadi tumpuan dunia pada masa kini.

Boleh dikatakan, taktik peperangan yang digunakan dalam perang ini sebenarnya doktrin peperangan luar biasa yang penggunaan teknologi seperti peralatan robotik, pesawat tanpa pemandu pertama kali diadaptasikan secara maksimum.

Ahli falsafah Yunani, Plato pernah mengatakan keperluan adalah ibu kepada penciptaan. Konsep ini dapat dilihat dalam siri peperangan kali ini.

Jika dilihat dari sudut aset persenjataan aerorangkasa Azerbaijan, ia tidak secanggih seperti negara maju lain.

Namun, akibat keperluan mendesak dalam peperangan ini, maka timbul pemikiran kreatif dan inovatif bagi merealisasikan strategi dalam usaha memenangi perang.

Azerbaijan kini dilihat lebih berinovasi dalam melaksanakan taktik peperangan moden apabila banyak mengaplikasikan penggunaan dron dalam siri peperangan terbaru ini.

Sebagai contoh, pihak tentera Azerbaijan yang turut dikenali sebagai Pasukan Azeri didakwa mengubah suai pesawat lama era Soviet Union AN-2 yang sebelum ini diguna pakai sebagai pesawat pengangkut tentera sejak 1946, menjadi 'dron umpan' bagi mengenal pasti lokasi sistem pertahanan udara pihak Armenia.

Pada 2020 ini, ia muncul sebagai senjata terbaru diadaptasikan tentera udara Azerbaijan; ia mudah ditembak jatuh oleh sistem pertahanan udara Armenia, sebaliknya dengan pelaksanaan strategi ini, posisi sistem pertahanan udara dan artileri berkenaan terdedah.

Menariknya, pada awal peperangan ini berlangsung, sering diberitakan pihak Armenia berjaya menembak jatuh pesawat AN-2 milik Azerbaijan, tetapi juruterbangnya tidak dijumpai setiap kali terhempas.

> *Menariknya, pada awal peperangan ini berlangsung, sering diberitakan pihak Armenia berjaya menembak jatuh pesawat AN-2 milik Azerbaijan, tetapi juruterbangnya tidak dijumpai setiap kali terhempas.*

Oleh itu, timbul perasaan curiga oleh pihak Armenia terhadap penggunaan AN-2 yang uzur, bahkan sangat 'lembab' ketika penerbangan, sedangkan ia digunakan dalam pertempuran.

Bertitik tolak daripada hal ini, keterlibatan dron kamikaze Harop buatan Industri Aeroangkasa Israel (dahulunya dikenali sebagai industri pesawat Israel) yang diklasifikasikan sebagai 'peluru berlegar-legar' (loitering munition) di ruang angkasa turut digunakan pihak tentera Azerbaijan.

Dron Harop yang juga dikenali sebagai Harpy 2 menjadi dron anti-radiasi yang boleh dikawal secara jauh melalui peranti radio kebanyakannya digunakan secara optimum bagi memusnahkan sistem pertahanan udara pihak Armenia.

Strategi serangan ini amat mudah, alihkan tumpuan pihak musuh dengan memancing menggunakan dron umpan ini, sekali gus pihak musuh (Armenia) mengaktifkan tembakan.

Dron Harop kemudian disasarkan bagi memusnahkan sistem pertahanan udara Armenia. Kerugian pihak Azerbaijan dilihat tidak sebesar mana jika hendak dibandingkan dengan potensi pulangan AN-2 sebagai dron umpan.

Hal ini kerana sistem pertahanan udara Armenia yang nilainya bernilai jutaan dolar dapat dimusnahkan selepas dikesan menggunakan dron Harop atau bom pintar yang dijatuhkan oleh pesawat tanpa pemandu (UAS).

Ini disebabkan kebolehan dari perspektif reka bentuk dron Harop yang mampu terbang tanpa dapat dikesan membuatkan pengesanan dan pemintasan oleh sistem pertahanan udara menjadi sukar.

Pada masa sama, pengeluaran kesan haba yang rendah menyebabkan senjata pengesan inframerah tidak mampu mengesan Harop secara efektif ditambah pula dengan reka bentuk badan pesawat yang halus dan licin, pengesanan lokasi secara visual semakin mencabar.

Dron Harop dilengkapi bahan peledak seberat 16 kilogram mampu beroperasi sejauh hampir 998 kilometer selama 6 jam. Dron ini akan berpatah balik ke pangkalan jika tiada sasaran dikenakan.

Bukan itu sahaja, malah bom pintar daripada pesawat MALE UAS TB2 Bayraktar buatan Baykar Defence dari Turki turut dilepaskan menggunakan taktik sama bagi situasi berbeza.

Sememangnya, pesawat tanpa pemandu TB2 Bayraktar berkenaan menjadi dron berpotensi besar apabila kejayaannya dapat dilihat ketika pihak tentera Turki mengoperasikannya dalam Operasi Spring Shield di Syria pada Februari lalu dan ketika menentang pasukan Khalifa Haftar di Libya.

Kesimpulannya, kita dapat melihat aplikasi dron atau pesawat tanpa pemandu ini memainkan peranan yang penting dalam konflik perebutan wilayah yang berlaku di Nagorno-Karabakh di antara Armenia dengan Azerbaijan.

Secara halusnya, kita juga dapat melihat peranan kuasa pengeluar aset ketenteraan seperti Turki, Russia dan Israel dalam membekalkan dron atau pesawat tanpa pemandu dalam siri pertempuran Armenia-Azerbaijan ini.

Maka, kecanggihan senjata oleh negara pengeluar yang terbabit dalam peperangan ini menjadi kayu ukur prestasi keupayaan ketenteraan mereka dan seterusnya menjadikan mereka lebih agresif dalam melaksanakan penyelidikan dan pembangunan pertahanan pada masa akan datang.

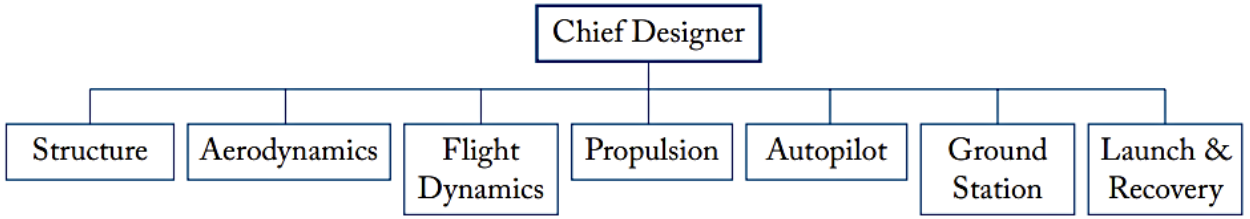
Dengan berkembangnya teknologi terkini seperti digariskan dalam Revolusi Industri 4.0 (IR4.0), internet benda (IoT), sistem berautonomi dan aspek lain semenangnya menjadi faktor utama perubahan 'wajah' peperangan pada alaf ini.

Tidak dinafikan, inilah punca siri peperangan berkenaan menjadi tumpuan dunia, bahkan dilihat sebenarnya menjadi medium negara besar menguji sistem senjata yang dibangunkan.

Penulis adalah *Pensyarah Kanan (Kejuruteraan Aeroangkasa), Jabatan Kejuruteraan Mekanikal, Universiti Islam Antarabangsa Malaysia (UIAM)*

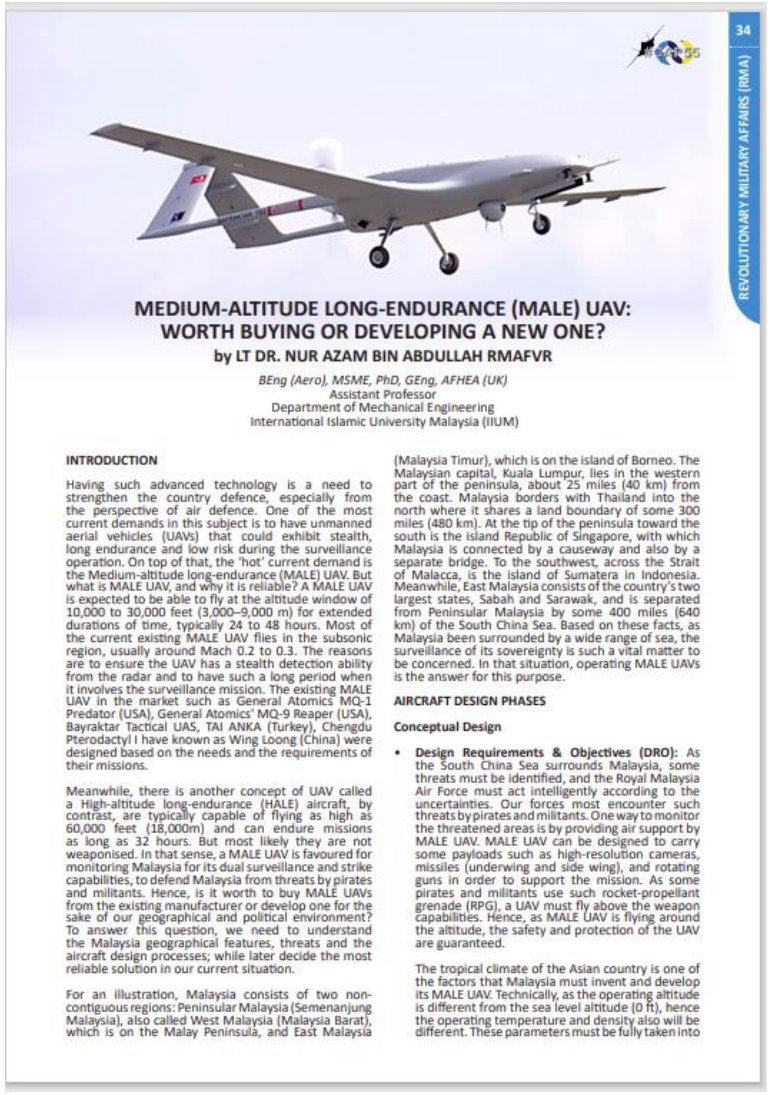
Group of UAV Designers

(1) military UAV designers
(2) civil UAV designers
(3) homebuilt UAV designers.



UAV main design group organisation chart

WAY FORWARD FOR UAV RESEARCH



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REVOLUTIONARY MILITARY AFFAIRS (RMA)

MEDIUM-ALTITUDE LONG-ENDURANCE (MALE) UAV: WORTH BUYING OR DEVELOPING A NEW ONE?

by LT DR. NUR AZAM BIN ABDULLAH RMAFVR

BEng (Aero), MSME, PhD, GEng, AFHEA (UK)
Assistant Professor
Department of Mechanical Engineering
International Islamic University Malaysia (IIUM)

INTRODUCTION

Having such advanced technology is a need to strengthen the country defence, especially from the perspective of air defence. One of the most current demands in this subject is to have unmanned aerial vehicles (UAVs) that could exhibit stealth, long endurance and low risk during the surveillance operation. On top of that, the 'hot' current demand is the Medium-altitude long-endurance (MALE) UAV. But what is MALE UAV, and why it is reliable? A MALE UAV is expected to be able to fly at the altitude window of 10,000 to 30,000 feet (3,000–9,000 m) for extended durations of time, typically 24 to 48 hours. Most of the current existing MALE UAV flies in the subsonic region, usually around Mach 0.2 to 0.3. The reasons are to ensure the UAV has a stealth detection ability from the radar and to have such a long period when it involves the surveillance mission. The existing MALE UAV in the market such as General Atomics MQ-1 Predator (USA), General Atomics' MQ-9 Reaper (USA), Bayraktar Tactical UAS, TAI ANKA (Turkey), Chengdu Pterodactyl I have known as Wing Loong (China) were designed based on the needs and the requirements of their missions.

Meanwhile, there is another concept of UAV called a High-altitude long-endurance (HALE) aircraft, by contrast, are typically capable of flying as high as 60,000 feet (18,000m) and can endure missions as long as 32 hours. But most likely they are not weaponised. In that sense, a MALE UAV is favoured for monitoring Malaysia for its dual surveillance and strike capabilities, to defend Malaysia from threats by pirates and militants. Hence, is it worth to buy MALE UAVs from the existing manufacturer or develop one for the sake of our geographical and political environment? To answer this question, we need to understand the Malaysia geographical features, threats and the aircraft design processes; while later decide the most reliable solution in our current situation.

For an illustration, Malaysia consists of two non-contiguous regions: Peninsular Malaysia (Semenanjung Malaysia), also called West Malaysia (Malaysia Barat), which is on the Malay Peninsula, and East Malaysia (Malaysia Timur), which is on the island of Borneo. The Malaysian capital, Kuala Lumpur, lies in the western part of the peninsula, about 25 miles (40 km) from the coast. Malaysia borders with Thailand into the north where it shares a land boundary of some 300 miles (480 km). At the tip of the peninsula toward the south is the island Republic of Singapore, with which Malaysia is connected by a causeway and also by a separate bridge. To the southwest, across the Strait of Malacca, is the island of Sumatera in Indonesia. Meanwhile, East Malaysia consists of the country's two largest states, Sabah and Sarawak, and is separated from Peninsular Malaysia by some 400 miles (640 km) of the South China Sea. Based on these facts, as Malaysia been surrounded by a wide range of sea, the surveillance of its sovereignty is such a vital matter to be concerned. In that situation, operating MALE UAVs is the answer for this purpose.

AIRCRAFT DESIGN PHASES

Conceptual Design

- **Design Requirements & Objectives (DRO):** As the South China Sea surrounds Malaysia, some threats must be identified, and the Royal Malaysia Air Force must act intelligently according to the uncertainties. Our forces most encounter such threats by pirates and militants. One way to monitor the threatened areas is by providing air support by MALE UAV. MALE UAV can be designed to carry some payloads such as high-resolution cameras, missiles (underwing and side wing), and rotating guns in order to support the mission. As some pirates and militants use such rocket-propellant grenade (RPG), a UAV must fly above the weapon capabilities. Hence, as MALE UAV is flying around the altitude, the safety and protection of the UAV are guaranteed.

The tropical climate of the Asian country is one of the factors that Malaysia must invent and develop its MALE UAV. Technically, as the operating altitude is different from the sea level altitude (0 ft), hence the operating temperature and density also will be different. These parameters must be fully taken into

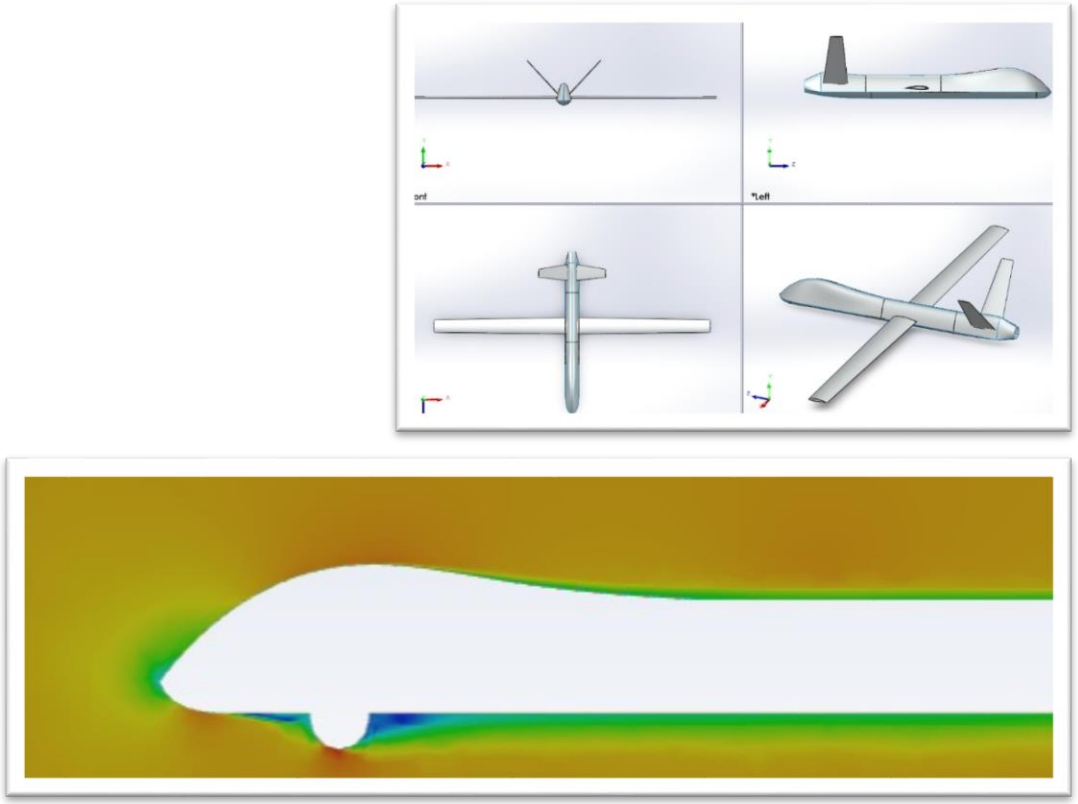
These three groups of designers have different interests, priorities, and design criteria. There are ten main figures of merit for every UAV configuration designer.

(1) production cost
(2) UAV performance
(3) flying qualities
(4) design period
(5) beauty (for civil UAV) or scariness (for military UAV)
(6) maintainability
(7) producibility
(8) UAV weight
(9) disposability
(10) stealth requirement

WAY FORWARD FOR UAV RESEARCH

AERODYNAMICS/ PERFORMANCE ASSESSMENT

Wind tunnel test of a wing model in the IIUM low speed wind tunnel

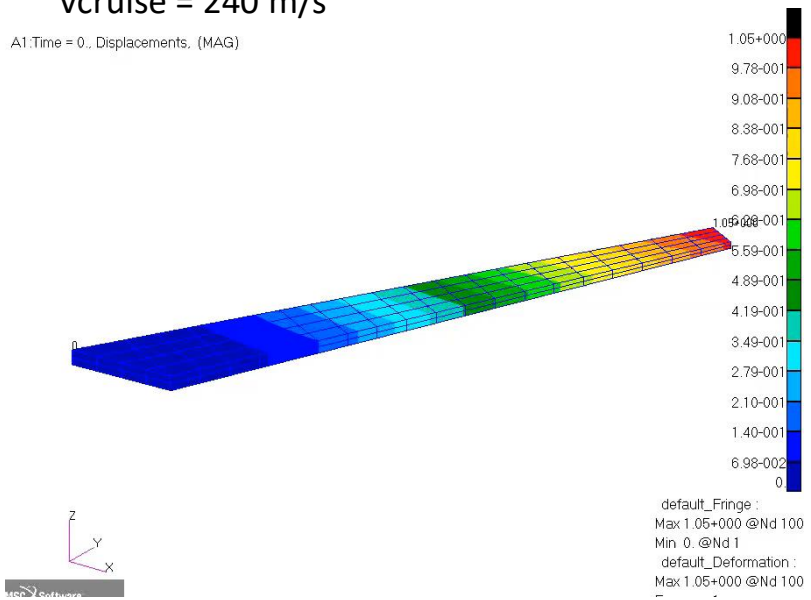


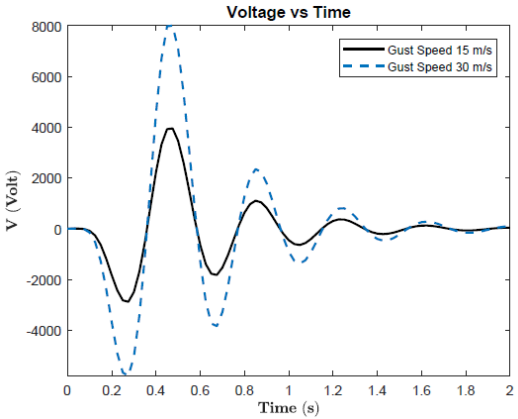
Computational fluid dynamics

WAY FORWARD FOR UAV RESEARCH

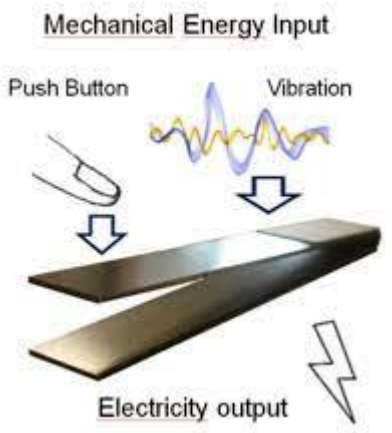
PIEZOAEROELASTIC

PZT-5A at upper wingbox
Vcruise = 240 m/s





Ref: **Akbar & Curiel-Sosa, 2019**



Be creative and innovative!

WAY FORWARD FOR UAV RESEARCH

GROUND CONTROL STATION (GCS)

RQ-7A Shadow 200 and its GCS

Global Hawk Operations Center
at NASA Armstrong

UAV+ GCS = UAS

UAS: Unmanned Aircraft System

WAY FORWARD FOR UAV RESEARCH

UAV / UCAV DEVELOPMENT

No	Component	Configuration Alternatives
1	Fuselage	- Geometry: lofting, cross section - Internal arrangement - What to accommodate (e.g., fuel, engine, and landing gear)?
2	Wing	- Type: swept, tapered, dihedral; - Location: low-wing, mid-wing, high wing, parasol - High lift device: flap, slot, slat - Attachment: cantilever, strut-braced
3	Horizontal tail	- Type: conventional, T-tail, H-tail, V-tail, inverted V - Installation: fixed, moving, adjustable - Location: aft tail, canard, three surfaces
4	Vertical tail	Single, twin, three VT, V-tail
5	Engine	- Type: turbofan, turbojet, turboprop, piston-prop, rocket - Location: (e.g., under fuselage, under wing, beside fuselage) - Number of engines
6	Landing gear	- Type: fixed, retractable, partially retractable - Location: (e.g., nose, tail, multi)
7	Control surfaces	Separate vs. all moving tail, reversible vs. irreversible, conventional vs. non-conventional (e.g., elevon, ruddervator)
8	Autopilot	- UAV: Linear model, nonlinear model - Control subsystem: PID, gain scheduling, optimal, QFT, robust, adaptive, intelligent - Guidance subsystem: Proportional Navigation Guidance, Line Of Sight, Command Guidance, three point, Lead - Navigation subsystem: Inertial navigation (Strap down, stable platform), GPS
9	Launch and recovery	HTOL, ground launcher, net recovery, belly landing

Boeing's QF-16 Makes its First Unmanned Flight

709,090 views • Sep 26, 2013

LIKE DISLIKE SHARE SAVE ...

A soldier from the Royal Artillery prepares a Desert Hawk III for flight

WAY FORWARD FOR UAV RESEARCH

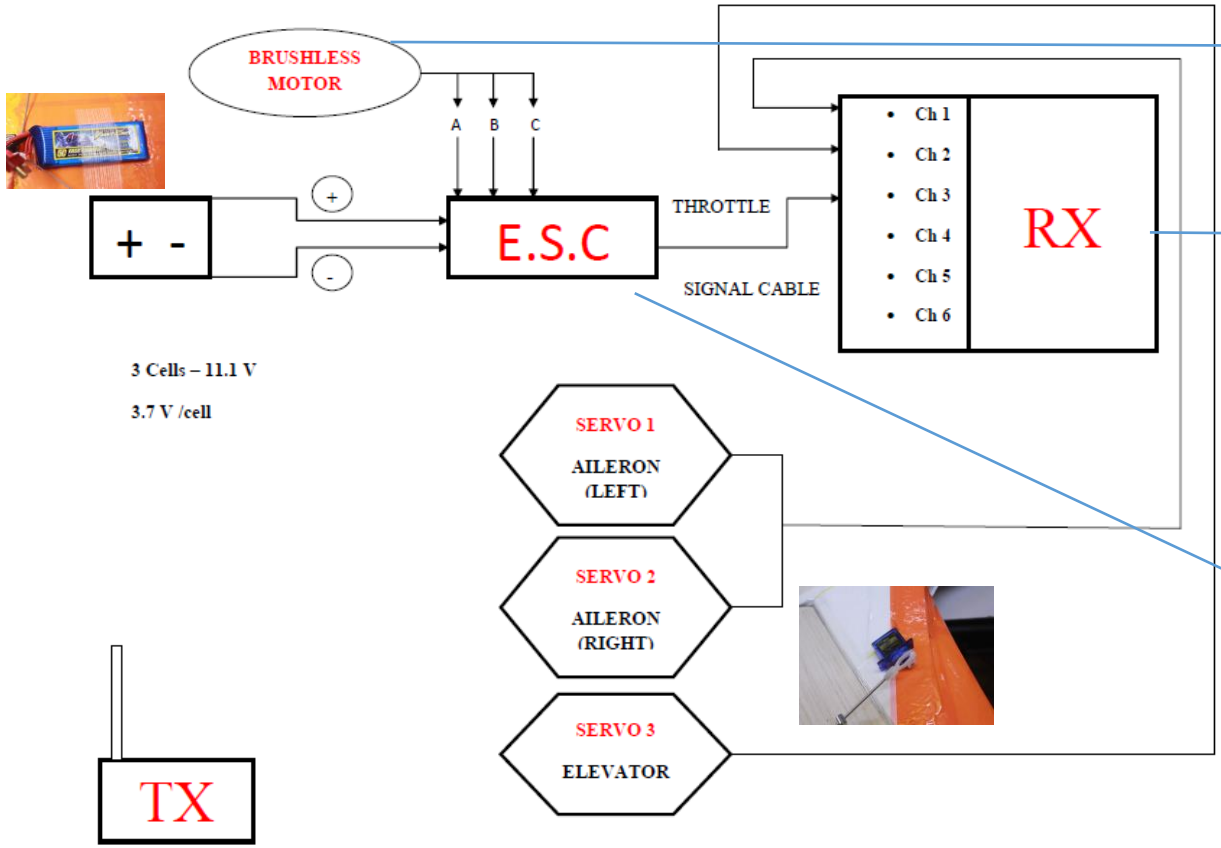
SWARM ALGORITHM/OPTIMISATION

Swarm bees formation

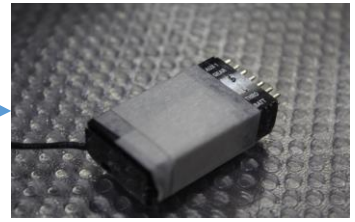
Swarm bees algorithm for drones' operation

WAY FORWARD FOR UAV RESEARCH

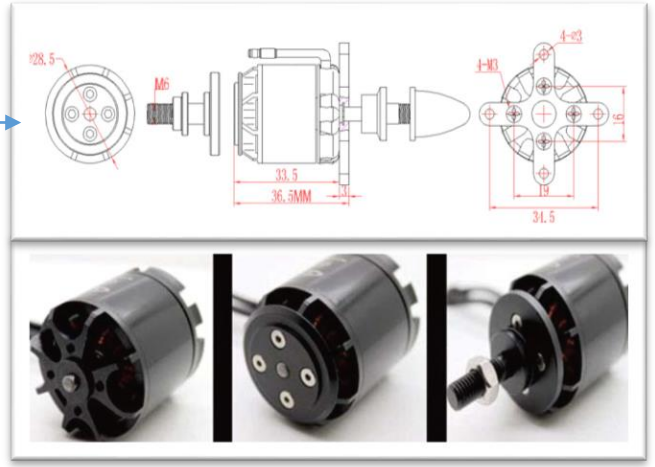
GROUND CONTROL STATION (GCS)



Electronic mechanism of Remote Controlled Aircraft



Receiver



Brushless motors

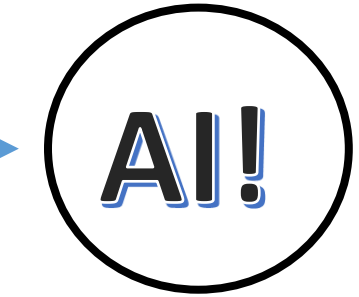
Electronic speed controller

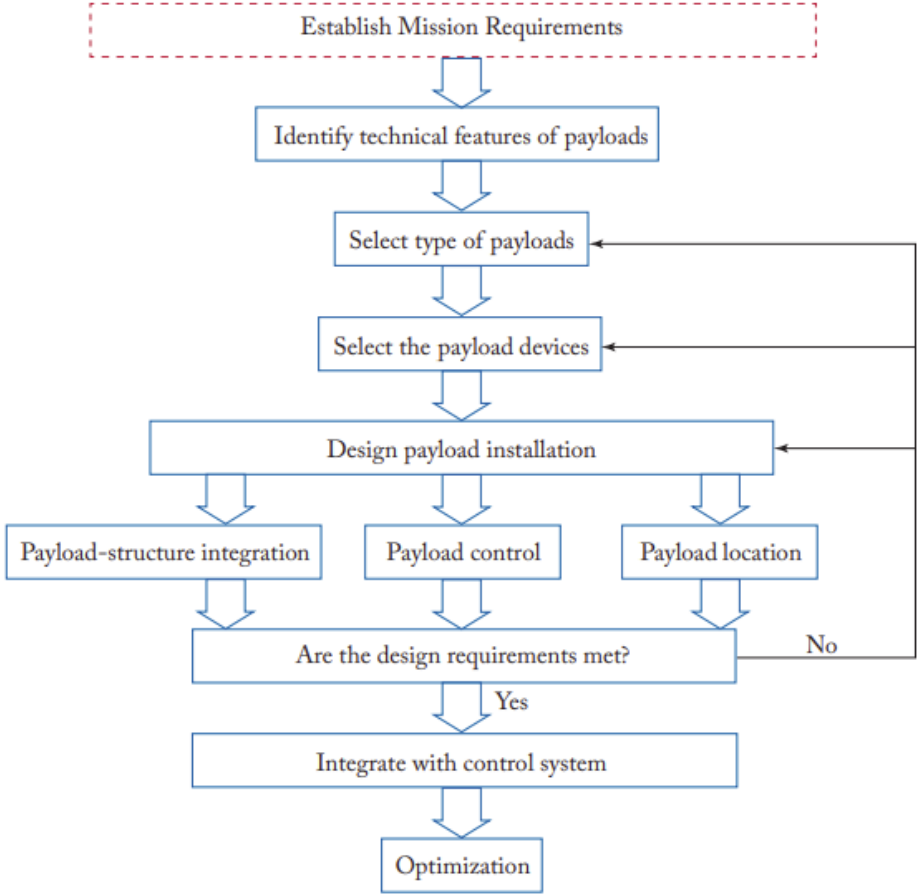
WAY FORWARD FOR UAV RESEARCH

PAYLOADS

- Structural integrity of the UAV must be maintained such as the various flight loads (e.g., gust, aerodynamic, and weight) and stresses (e.g., normal, shear, bending) are handled safely by the structure
- Two basic types- dispensable and non-dispensable
- Example: Radar, camera, scientific payload (*spectrometer, radiation detector, environmental sensor, atmospheric sensor*), military payload (weapon: missile, installed gun)

CONTROP's medium range stabilized EO/IR Cameras (EO/IR Gyro-stabilized payloads by CONTROP Precision Technologies Ltdcamera.).





CONCLUSION

Three scenarios of priorities (in percent) for a military UAV designer

No	Figure of Merit	Priority	Designer # 1	Designer # 2	Designer # 3
1	Cost	4	8	9	9
2	Performance	1	50	40	30
3	Autonomy	2	10	15	20
4	Period of design	5	7	7	8
5	Scariness	10	1	1	2
6	Maintainability	7	4	5	5
7	Producibility	6	6	6	7
8	Weight	8	3	4	4
9	Disposability	9	2	2	3
10	Stealth	3	9	11	12
		Total	100%	100%	100%

Sadraey, Mohammad. 2017. *Unmanned Aircraft Design: A Review of Fundamentals*. *Synthesis Lectures on Mechanical Engineering*. Vol. 1. https://doi.org/10.2200/s00789ed1v01y201707mec004.

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Adaptasi teknologi, persekitaran tingkat keberkesanan produk

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Dalam merencanakan strategi pertahanan dan peperangan, faktor mengadaptasikan teknologi dengan persekitaran amat penting untuk memiliki kelebihan demi memperoleh kemenangan.

Ini dapat dilihat apabila tiga kapal selam berkuasa nuklear milik Russia melaksanakan formasi surfacing secara serentak ketika latihan pertahanan di Laut Artik, Mac lalu.

Latihan ketenteraan itu dilakukan berhampiran Franz Josef Land, sekitar

Daya hentaman itu memberi kejutan atau hentakan tinggi dalam jangka singkat apabila dua entiti bertembung.

Dalam hal ini, struktur permukaan terdedah kepada daya impak itu perlu mempunyai sifat serapan impak dan membolehkan kapal terus beroperasi seperti biasa. Tambahan pula kapal selam ini menggunakan kuasa nuklear pastinya akan memberi risiko tinggi sekiranya gagal dalam proses pengujian.

Jika dilihat sejarah, peristiwa letupan berlaku semasa proses pengisian minyak kapal selam buatan

kekuatan lenturan dan integriti struktur kapal selam dikekalkan walaupun beroperasi di bawah suhu ekstrem sangat rendah.

Bidang penyelidikan dan pembangunan bahan dapat dihasilkan melalui eksperimentasi dan pengujian logam aloi atau keluli dengan teknologi nano bagi meningkatkan keupayaan bahan tersebut di bawah pengaruh beban impak.

Dalam hal berkaitan, Kementerian Sains, Teknologi dan Inovasi (MOSTI) agensi di bawah kendalian-nya seperti NanoMalaysia perlu bekerjasama

Institut Penyelidikan Sains & Teknologi Per

di bawah Kementerian Pertahanan untuk m

kinkan kemajuan dalam bidang kejuruterae

termaju, nanobioteknologi termasuk kecerdasan

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