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AIRFORCE Digest

RESILIENT, MOTIVATED, ADAPTABLE & FORMIDABLE

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in fulfilling all its roles and functions towards excellence


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through strategic military engagement and convergence programs




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FOREWORD

GEN DATO' SRI ACKBAL BIN HJ ABDUL SAMAD RMAF
CHIEF OF AIR FORCE

I would like to thank the Editorial Board for inviting me to pen a few words in this edition of Air Force Digest in conjunction with the 62nd Anniversary of the RMAF. We have come a long way to reach where we are today - a modest but modern air force operating in a wide range of spectrum of operations. On behalf of the RMAF, it is only be fitting for me to share this honour with all current and former fellow comrades, men and women of the RMAF. The success and achievements of the RMAF are built on the foundation of your dedications, perseverance and sacrifice. Thank you!

Six month ago, I succeeded General Tan Sri Affendi bin Buang RMAF to become the 19th Chief of Air Force. Just merely two months after that, the nation was hit by the Coronavirus pandemic known as COVID-19. The increasing spread of the COVID-19 across the country has prompted the Malaysian government to adopt drastic and stringent containment measures that require the involvement of the MAF personnel as the front liners in the fight to flatten the curve. Around 635 personnel from all over the RMAF bases were involved in Op Penawar in assisting PDRM to enforce the Movement Control Order or MCO.

Consequently, the global supply chain has left almost paralysed due to the lockdown and movement control in most countries. Industries around the world were forced to shut down and it affects RMAF operations in some ways especially in sourcing spares and services. Despite these increasing challenges, the RMAF still managed to perform its roles and functions dutifully especially in the air operations. We are able to carry out many logistics support and humanitarian missions to assist government agencies and affected citizens along with our core business – safeguarding our sovereign sky.

As a proud RMAF people, we must continue to live up to the expectation and deliver our promise to the nation. Our motto for this 62nd anniversary - **'Berupaya Bersiaga Kedaulatan Terjaga'** should remind us to effectively raise, train and sustain our force to be able to generate the air power the country needed. While the COVID-19 pandemic is far from over, the RMAF must move forward and realize its vision and mission. To do this, we need to be adaptive and practice the new norms in our day-to-day activities. May Allah SWT bless the RMAF people with good health, strength and courage during this trying period.

Finally, I would like to congratulate the Editorial Board for another exceptional AFD edition that covers a broad range of issues and being able to get articles written by an officer from the RMAF Volunteer Force and a retired RMAF officer. Well done! Happy 62nd anniversary to all RMAF people.

Sentiasa Di Angkasa Raya

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CURRENT ISSUES

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

by LT DR. NUR AZAM BIN ABDULLAH RMAFVR

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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

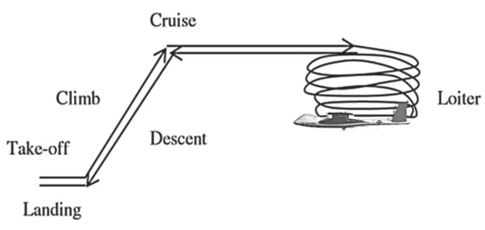
- **Design Requirements & Objectives (DRO):** As the South China Sea surrounds Malaysia, some threats must be identified, and the Royal Malaysia Air Force must act intelligently according to the uncertainties. Our forces most encounter such threats by pirates and militants. One way to monitor the threatened 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 consideration since the concept of flight depends on the lift produced by the wing airfoil section at a specified speed based on the Bernoulli's equation of lift. For illustration, if we buy a MALE UAV from the USA manufacturer that could operate at 20,000 ft with a designed speed limit, the speed limit must be revised to cater to the Asian region operating region due to the different value of air density at 20,000 ft [1].

In that case, the design requirements and objectives must reflect several factors such as operating altitude, payload (camera, missiles/stores), operating range, endurance (time of flight), operating speed (subsonic, transonic or supersonic) and take-off and landing mechanism. Hence, the maximum take-off weight (MTOW) can be evaluated via an aircraft design process using the iteration of the MTOW guessing weight build-up method.

- **Technology Advancement:** Many ground-breaking innovations, such as sensors and artificial intelligence (AI) applications, have been adopted for the multipurpose approach in upgrading the UAV capabilities. Face recognition device, shooting risk and assessment equipment, heat or motion detection sensor, high-performance computing in image processing camera might be installed in the UAV. For aerospace engineers, these devices or sensors will result in increasing the payloads weight segment. Still, their capabilities are essentials for developing an innovative MALE UAV that has some updated technologies for accomplishing the mission.

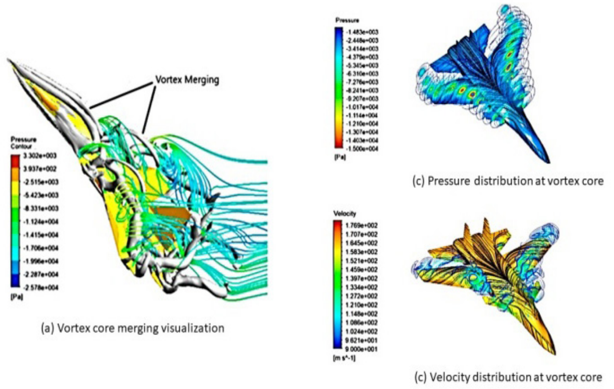
- **Mission Profile:** As mentioned in the design requirements & objectives section, a MALE UAV must be designed according to the requested by the user, in this case, RMAF. Design take-off gross weight can be separated into several weight segments; crew weight, payload weight, fuel weight and the remaining empty weight. The empty weight covers the structure, landing gear, fixed-equipment, avionics, and any other items that not considered as the crew, payload and fuel. For the designed MALE UAV, there will be no crew on this aircraft, but the need for having long-endurance, payload (camera, missiles and guns) is compulsory. Consequently, more fuel will be stored to carry such weight. A simple mission profile might be drafted from taking-off, climbing until reach required altitude, cruising for some range and long endurance, loitering for surveillance mission, low-level strike (missiles drop) and landing. The weight of fuel used for each segment must be calculated before the wing, tail, and fuselage sizing could be estimated. In that sense, some aircraft designers might come out with different designs according to their options such as wing aspect ratio, lift to drag calculation and thrust to weight ratio (for estimating the required propulsion-engine).



Typical mission profile for reconnaissance UAV (monitoring/surveillance) [2]

Preliminary Design

- **Aerodynamics Performance:** As more than one aircraft designers might come out with different designs, this phase will choose which model is the most suitable to be forwarded as the final design. The key in this phase is the aerodynamics performance. The selected design must have the best aerodynamics performance, such as a high lift to drag ratio. A drag force is the resistance force generated by the motion of a body through a fluid, such as water or air. For a MALE UAV, the drag force could be higher at the near nose of the fuselage due to the attachment of the camera at that location. Besides, such store attachment, missiles and guns also will increase the drag. All proposed designs will be assessed via simulation in computational fluid dynamics. Several existing CFD software, e.g., ANSYS Fluent, Star-CCM+ can be used for this purpose, where such fluid model will be selected based on the complexity of the design and the operating speed flow (laminar, transition or turbulent flow). To verify the simulations, the selected model will be experimentally tested in the wind tunnel test section at the sea level altitude. Hence, the aerodynamics performance will be the standard benchmark to choose the best design to be developed.



Vortex core visualisation in CFD models [3]

Detail Design

This phase is the state where the favourable design chosen from the previous stage will be divided into several segments, such as ribs, spars, and skins. These include all the aircraft parts, wing, fuselage and tail. All of this structured will be separately designed and analysed. In modern approaches, this period has been shortening with the help of technology advancement compared to conventional analytical methods. Such numerical software in finite element modelling (FEM) has assisted the aircraft design analysts in predicting the stress on each component under several loads. For example, an advanced approach called the Extended Finite Element Method (XFEM) might be applied to predict the crack propagations of a structure under certain types of load, static load [4], dynamics load [5]–[7]. As the MALE UAV is required to have long endurance, the structural designer must decide the best material for the construction of the major components (wing, fuselage and tail). The application of composite materials, for example, might contribute to the reduction of weight, but increase the strength due to its high strength to weight ratio compared to the metallic material.

The application of FEM might be used to optimise the design and assist the aerospace structural engineers in deciding the best material for each component. To summarise, the structural analyses part will look into several assessments which are weight and balance, stress and loads estimation, fatigue test (to predict the life cycle of the structure after several cyclic loads), and aeroelasticity (branch of physics and engineering that scrutinises the interactions between the inertial, elastic, and aerodynamic forces that occur when an elastic body is exposed to fluid flow). In the aeroelasticity test, the most critical flutter speed (a condition which is the uncontained vibration that can lead to the destruction of an aircraft) at each region of altitude. For that, the designed flight envelope will be plotted as the reference for the flight test later.

For the system, all the electrical devices (radar, sensors, avionics), selected type of engine and landing gear (hydraulic or pneumatic, retractable or non-retractable) must be decided. This element is essential since the ‘heart’ of a MALE UAV is depending on the advanced technologies inside its body. At last, the detail design phase ends with the manufacturing of the designed MALE UAV.

MANUFACTURING

The aerospace industry nature in Malaysia is currently the barrier that needs to be broken if Malaysia plans to develop its own MALE UAV. Most of the aerospace industries in Malaysia are working on maintenance, repair and overhaul (MRO) clusters. This nature of business has to be adjusted to extend out our capabilities as the aerospace manufacturer country. However, there are still some other aircraft manufacturers in Malaysia, e.g. CTRM Aero Composites Sdn. Bhd., Strand Aerospace Malaysia Sdn. Bhd., DEFTECH Aviation Sdn. Bhd. that could collaborate for our mission in developing our MALE UAV. The partnership is to the key to this element, where a consortium of aerospace clusters (design, manufacturing, MRO and training) could be established later.

TESTING & COMMISSIONING

Ground Test

Several types of tests must be conducted to prove its flying safety in terms of its structural strength and flight envelope before an aircraft is approved to fly. The first test to be conducted is a structural test where the structure will be assessed in terms of its strength to stand the loads. As we learn that the structure will undergo such vibrational motion during flying, this situation will trigger the cyclic load upon the structure, especially the wing. Hence, the second test is required to predict the life cycle under these cyclic loads, which is called a Fatigue test. Another significant test at this stage is called a Ground Vibration Test (GVT), where the structure will be excited at a certain frequency and will exhibit the vibrational mode shapes (bending, torsion). The results of GVT is really important since the data of excited frequency shows the natural frequency where the highest vibrational amplitude will occur. Also, an aeroelastic wind tunnel testing is required in this stage to evaluate the flutter speed at sea level as the benchmark before the flight test is conducted.

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

Flight Test

This is the final test where the design will be tested outdoor for the first time to its designed conditions (DRO) as requested by the users or customers. As mentioned in the conceptual design phase, the requirement includes the maximum speed at certain altitude requested. Hence, the aeroelasticity results (flutter speed) estimated in the design phase will be used as the reference to the regulations (example: Federal Airworthiness Regulation (FAR)) of the maximum cruise speed. For example, FAR 25 Guidelines mentioned that the flutter speed would be 1.15 times of the dive speed, and the dive speed is 1.25 times the cruise speed [8]. Mathematically, the designed cruise speed will be 1.4375 times the designed flutter speed. Another UAV authority such as Joint Authorities for Regulation of Unmanned System (JARUS) might be taken into consideration since Malaysia is also a member of this organisation. In that case, the aeroelastic engineer must always observe the designed maximum cruise speed is achievable during the flight test (wind tunnel test and real environmental test) without any structural failure. In the case of failure to achieve the designed cruise speed, the flight test must be ceased immediately, and the structure must be redesigned (reassess in terms of aerodynamics, structure and material).

Aeroelasticity problems can be solved by adjusting the mass, the stiffness or the aerodynamics of structures [9]–[11]. The obtained results can be determined and verified through the use of calculations, ground vibration tests and flight flutter trials. In the current aerospace industrial practice, the aeroelastic analysis can be assessed by using the fluid-structure interaction (FSI) modelling, either from the frequency domain or the time domain function. Subsequently, if the first time flight test is successful (in the event the maximum cruise speed is achieved without any structural failure), the designed aircraft will be commissioned for the operational purpose.

CONCLUSION

Operating MALE UAVs in our region is such an imperative necessity to protect Malaysia’s sovereignty from the intimidations by militants and pirates. Based on our current circumstance, buying MALE UAV from another manufacturer is a vital matter to provide better defence protection to our country. However, within another five years’ time, the MALE UAV will be ageing due to its fatigue lifetime and will require maintenance provided by the operator. Consequently, momentarily it will be the most desirable time for us to start our MALE UAV design and manufacturing centre that could render more immeasurable protection to our country based on our shortages. By the time the bought MALE UAV flight will be decommissioned following five years, our own designed MALE UAV will be a fit replacement.

In term of defence research investment, an example of Turkish Aerospace Industries (TAI) ANKA program has led them to spend more than US$200 Million for the entire program. From a more meaningful outlook, the program will be extended for mass productions (perhaps more than 100 units in the future). For instance, one unit of purchase might cost around US$9 Million, while the unit production cost might be around US$3.8 Million. In that judgment, the Turkish Aerospace Industries could increase their MALE UAV quantities more than comparing to acquire one unit from other manufacturers. For an additional illustration, the General Atomics Aeronautical Systems (USA) has spent US$2.38 billion for the General Atomics MQ-1 Predator development program, while the selling price is US$4.03 million per unit. Until now, the USA has produced more 360 units of this MALE UAV. In my opinion, our government would spend less amount of investment if this program is initiated since the manufacturing cost (materials, utilities and labours) in Asian is four to five times cheaper compared to European countries. Be reminded that we are not going to buy a single unit of MALE UAV, but most likely it would be more than ten units for a one-time purchase. Consequently, we could save millions of the taxpayers' funds for the annual defence budget since the production and maintenance will be conducted inside the country.

This vision will positively lead to a new era in Malaysian space capabilities. This investment will contribute to the advancement of Malaysian military technology, reduce the annual budget for military expenses, produce more local expertise and professional aerospace engineers. This type of research project will take Malaysia to another level of space production countries like Turkey, China and the USA. The government through Ministry of Defence (MINDEF), Ministry of Science, Technology and Innovation (MOSTI), and National Aerospace Industry Coordinating Office (NAICO) – a unit under Ministry of Trade and Industry (MITI) should put some efforts in the investment of the new aerospace consortium that consists of aerospace industries, academic institutions and government research institutions. If this matter works as its plan, I believe that more continuing military research projects, e.g. submarines, rocket launchers and attack helicopters could be easily produced within 10 to 20 years in the future.

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AIRCRAFT SILHOUETTE

Aircraft in flight signifies readiness to employ its air power capabilities. It also signifies the RMAF's aspiration to achieve multi-dimensional and multi-capability status through the CAP55. The yellow trails represent the RMAF's loyalty and oath of allegiance to His Majesty The Yang di-Pertuan Agong as the Supreme Commander of the Armed Forces.

DOUBLE ARROWS UPWARD IN BLUE

The arrows signifies the transition of AFNG to CAP55 and the colour Blue represents the Core Values of RMAF (Integrity, Courage, Esprit de Corps, Excellence and Service before Self). Blue is also the colour of the sky and it is associated with depth and stability.

RADAR SCOPE

The Radar Scope represents RMAF's 24/7 readiness to counter any threats and aggression towards the nation through undivided diligence and surveillance of the Malaysian Airspace.

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