UNMANNED AERIAL VEHICLES AND THE FUTURE OF AIRPOWER: A TECHNOLOGICAL PERSPECTIVE

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Abstract:

Since the invention of the aeroplane by the Wright Brothers in 1903, developments in aerial space, particularly in airpower, have moved at a rapid pace. For countries whose militaries have developed a competent air force, airpower gives them a myriad of capabilities to protect their country's air space and security, such as the ability of airpower to access targets beyond the capabilities of the army and navy and to effectively destroy key infrastructure or high value targets with its penetration and range. Yet, with the advancement of weaponry such as Surface-to-Air missiles and Integrated Air Defence Systems, a more precise theorisation of airpower may be required to ensure the safety of a country's defence. This essay aims to give a technological perspective of the future of airpower, as well as a detailed analysis of unmanned aerial vehicles' role in operations today and its potential advantages and disadvantages.

Keywords: Unmanned Aerial Vehicles; Airpower; Technology; Integrated Air Defence System; Future

INTRODUCTION

TRADITIONAL AIRPOWER THEORY

Airpower comprises the use of flying vehicles to support a nation's security interests. There are myriad definitions of airpower. In this essay, the author will be considering two salient features of airpower that have been relevant for the majority of the 20th century and will remain relevant, albeit in different forms, in the future. The first feature, access, is the ability of airpower to access targets beyond the capabilities of land and maritime forces due to geographical limitations or static enemy defence. The penetration and range of airpower make the dynamics of its employment tactically and strategically effective in destroying key infrastructure and other high value targets. The second feature, speed, is the ability of airpower to amass quickly at a selected time and place, bringing to bear a concentrated amount of destructive force before appropriate evasive or defensive measures can be taken. These features mark the traditional notions of airpower as the ability of an air force to achieve air superiority, conduct strike operations and support other services.

REVIEW OF AIRPOWER THEORY FOR THE FUTURE

There is an urgent and fundamental need to revisit the concept of airpower for future threats and operating environments. With the advent of advanced Surface-to-Air Missiles, Integrated Air Defence System (IADS), and the introduction of Airborne Early Warning and stealth capabilities in our region, it may become increasingly impractical to depend on expensive and sophisticated manned platforms to achieve both strategic and tactical objectives.[1] The author will address the previous two features mentioned in traditional Airpower theory and propose the inclusion of strategic strike in a theorisation of future airpower.

ACCESS

The advanced surveillance and reconnaissance capabilities of the Republic of Singapore Air Force's (RSAF) Heron 1 UAV will prove to be important components in the complex battle environment of the future.

With the advancement of radar and sensors in addition to on-going developments of counter-stealth technology, only systems at the micro, near-silent and ultra-low energy levels will have any chance of operating undetected. Small Unmanned Aerial Vehicles (UAVs) that are extremely difficult to track and target, yet highly capable of both Intelligence, Surveillance and Reconnaissance (ISR) and offensive capabilities, have a higher chance of penetrating the network of sensors.[2] Another aspect of penetration could be achieved via sheer numbers, which would require autonomous UAVs which could be pre-programmed and execute their missions either with co-operative control (better known as 'swarm' technology) for maximum effect or for covert operations. Autonomous capability is a critical advantage for any military as it allows the system to react to threats faster with faster iterations within the decision-making loop. In addition, it should be noted that access is no longer restricted to geography, but should also be expanded to include communications and electronic networks as they play a greater role in warfare today and in the future.

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SPEED

Aircraft speed was an important measure of capability as the speed envelope directly impacts manoeuvring in a tactical dogfight. It is also a key component of strategic bombers which could enter the Area of Operations (AO) at high altitude and speed, drop their payloads and escape before it can be detected and brought down by enemy air defences. However, modern detection and targeting capabilities render aircraft speed to be practically irrelevant. The traditional notion that a tactical advantage is achieved by physical speed should be revised to the speed of information gathering and more importantly, processing of the information into usable intelligence. The military force which can collect, exploit and disseminate these information faster will hold the tactical advantage and allow better decision-making in force employments, especially for time-critical targets. In other words, the speed at which the military force completes the ISR cycle will determine its ability to secure air superiority regardless of whether the eventual attack is carried out by aircraft, ground forces, and naval missiles or even through cyber attacks.

STRATEGIC STRIKE

The third feature to be introduced is the increasing importance of an effective strategic strike capability. With the steadily growing economy of developing countries in the region and their emphasis on force modernisation, it is a matter of time before other countries in the region will be able to afford more advanced assets in greater numbers, such as stealth fighters and IADS.[3] The wars waged by the United States (US) and Israel in the Middle East also highlighted the political costs of collateral damage and perceived imbalance of military force application. Hence, it is critical for air forces to develop the capability to conduct precise strike operations to achieve strategic effects with minimal collateral damage. Attacks on key targets in civilian areas may even require the use of non-kinetic weapons to minimise harm to infrastructure and humans. Persistent presence for target monitoring, recognition and opportune engagement becomes more important than purely payload size and accuracy.[4]

UAVS' ROLE IN OPERATIONS TODAY

Remotely piloted aircraft were used more than fifty years ago, however, the increasing usage of armed UAVs in recent years have evolved UAV roles beyond the traditional ISR functions.[5] Extensive use of armed UAVs began with Operation Enduring Freedom and Operation Iraqi Freedom.[6] The armed UAVs provided direct support of military operations and were mostly utilised to detect and kill al-Qaeda and Taliban leadership in Afghanistan and Iraq.

The use of UAVs in contested airspace is still premature as many of the Predators in Iraq were shot down by Iraqi MiGs due to its low speed and vulnerability. However, once air superiority was achieved, the use of UAVs for close air support proved to be effective. This was primarily due to its ability to loiter over the Area of Operations (AO), provide intelligence to ground commanders and accurately neutralise key threats with extended time over target. The use of UAVs had also reduced the sensor-shooter loop as the UAV pilot was able to seamlessly complete the Fix, Find, Track, Target, Engage, Assess (F2T2EA) loop for time critical targeting. Persistent tracking of key enemy movements also provided key intelligence and bought time for decision-making and strike packages to be prepared.

It is also observed that the acquisition and development of UAVs, both armed and unarmed, are on an upward trend for most military forces in the world. It is projected that spending on procurement and development will grow from US$6.6 billion in 2013 to US$11.4 billion in 2022.[7] However, only 23 out of 70 UAV users have developed or are developing armed UAVs.[8] Self-imposed export control by the American government and the alignment of most friendly nations are some of the main reasons why proliferation of armed UAVs is not widespread yet. However, other countries actively markets their armed UAVs, with China announcing publicly that it would be exporting its armed UAV, *Wing Loong*, to Saudi Arabia and other

China's Wing Loong UAV.

unspecified countries.[9] Similarly, weaponising a UAV does not require extensive research. Less-developed countries such as Iran had created UAVs which could be used as 'suicide' weapons.[10] Faced with these realities, governments might have to review their export controls to friendly nations to counter these proliferation threats.

UAVS' AIRPOWER ROLE IN THE FUTURE

ENHANCED SPEED AND STRATEGIC STRIKE CAPABILITIES THROUGH PLATFORM AND PAYLOAD DEVELOPMENTS

Most militaries in the world are investing heavily in UAV technologies, and drone warfare will be the next bound in the evolution of airpower. The US, China and other developed nations are currently developing Unmanned Combat Aerial Vehicles (UCAVs) such as the Boeing X-45 and Sharp Sword. UCAVs can perform similar tasks as modern manned fighter aircraft with similar performance and self-defence features. Future UCAVs are likely to come with built-in autonomy, as demonstrated by the Northrop Grumman X-47B's capability of landing on an aircraft carrier, a challenging task even for aviation pilots.[11]

In terms of weapons, there are multiple trajectories in developments including micro-munitions, electromagnetic bombs, self-protection weapons and Directed Energy Weapons (DEWs). Electromagnetic bombs could be used to deliver a sharp burst of electromagnetic pulse which has the potential to destroy electronic targets without causing harm to infrastructure and humans. DEWs such as high-power microwave and high-energy laser are currently under development to exploit the long endurance of UAVs as they are effective for as long as the UAVs are in flight. This movement away from traditional munition-based weaponry will further increase the attractiveness of UAVs as a persistent ISR and strike asset which could achieve strategic strike effects with minimal collateral damage. Instead of employing speed to transit to the mission area quickly, UAVs are able to loiter over potential targets and strike on opportunity, leaving the targets with little reaction time.

In efforts to enable UAVs to match and even surpass current manned platforms, future UAVs such as the Northrop Grumman RQ-180 will incorporate stealth technologies to further reduce their radar cross-section, which are already small compared to manned platforms.[12] UAVs are also moving towards the use of turbofan engines, or in special cases, ramjets to attain speeds far greater than the turboprop or rotary power plants used in most UAVs today.[13] In the future, designers will have to trade speed and power performances with the traditional long endurance capability of UAVs today with consideration of an expansion of roles.

ENHANCED ACCESS AND STRATEGIC STRIKE CAPABILITIES THROUGH ELECTRONIC WARFARE

One of the upcoming capabilities for future UAVs that will enable Airpower to penetrate modern IADS is Electronic Warfare (EW). For example, the US Marine Corps tested the viability of UAVs to conduct EW missions against enemy air defences using MQ-9 Reapers carrying the Northrop Pandora EW System to carry out wideband, multifunctional jamming attacks on radar and targeting systems in support of tactical strike missions. UAVs are ideal EW systems due to the high-risk nature of close-in jamming or decoy operations and the ability to loiter over the area of operations for extended coverage. Systems such as the ADM-160 Miniature Air-Launched Decoy and the Northrop Grumman Bat come equipped with EW payloads to add on to their spectrum of missions, and are especially effective against Anti-Access/Area Denial (A2AD) strategies. As payloads get miniaturised in the future, as demonstrated by the Pandora system which was able to screen a fighter group in an attack package and was small enough to be integrated in a small tactical UAV, it will become increasingly easy and cheap for tactical ground commanders to employ EW capabilities. The low cost (asset and operating costs) of UAVs also enables the deployment of more assets in a single mission, allowing networked UAVs to operate as a swarm to provide suppression over large areas for specified times opening corridors for operations.

ENHANCED SPEED AND ACCESS THROUGH ACCURATE AND TIMELY INTELLIGENCE

To achieve accurate and timely intelligence, UAVs employ a suite of ISR payloads that includes Imagery Intelligence (IMINT), Communications Intelligence (COMINT) and Electronic Intelligence (ELINT). IMINT is critical in accomplishing Find, Fix, Track as part of the F2T2EA loop and commonly comprises fusion of multiple sensors such as Synthetic Aperture Radar (SAR) and Long Range Electro-Optics/Infra-Red (EO/IR) sensors. For EO/IR, one of the technologies being developed is the Wide Area Persistent Surveillance (WAPS) system, with an example being the Gorgon Stare system which was used in Afghanistan as a MQ-9 Reaper payload.[14] The WAPS system provides city-size images to provide a full field of view instead of a 'straw' view associated with traditional EO/IR sensors. WAPS aids in exploitation of pattern-of-life and is used to monitor and track multiple events of interest within a large area of operations, greatly enhancing the situational awareness of ground commanders.

The use of radars in UAVs for ISR is becoming commonplace, with the employment of SAR technology to deliver long-range and very high-resolution images and Ground Moving Target Indicator (GMTI) radars to detect moving targets against clutter. Developments are currently on-going for Foliage Penetration (FOPEN) technology, with an example being Lockheed Martin's Tactical Reconnaissance and Counter-Concealment system, which utilises a low-frequency dual band SAR to peer through foliage, rain and darkness and detect both moving and stationary targets. Multi-sensor fusion of FOPEN SAR, GMTI and ELINT enhances target identification in adverse conditions and aid in the targeting and engagement of high value assets. One of the challenging aspects of ISR is the need for substantial manpower and time to exploit the data that are collected, future developments of visual intelligence such as the Defense Advanced Research Projects Agency (DARPA)'s Mind's Eyewill enable automated analysis and detection of operationally significant activities.[15]

These MUAVs could potentially operate undetected for weeks and track targets through complicated terrain in urban areas. They could also be deployed for covert strike operations to disrupt key enemy installations or remote tagging or targeting for their larger counterparts to employ precision weapons.

In the future, with higher computing density and performance, more powerful COMINT and ELINT payloads will be able to be integrated within smaller UAV platforms. COMINT and ELINT sensors detect, geo-locate and classify Radio-Frequency transmissions and allow forces to access or disrupt enemy communications, these capabilities are key to enhancing the survivability of friendly forces whilst destroying/disrupting the enemy's military capabilities. Taiwan, for example, actively uses unmanned SIGINT aircraft to patrol the East China Sea to intercept the use of long range radars of China's A2AD systems.[16] In terms of ELINT, current payloads include Specific Emitter Identification and Automatic Identification System which greatly enhances situational awareness of the battle space in air, land and sea. The combination of these payloads and the UAV's ability to loiter and project these capabilities directly over the AO allow commanders to harness the tactical advantage derived from the speed of intelligence cycle and access to enemy networks.

GAME CHANGERS

Multi-UAV Control

There have been increasing interest and research into networked UAVs to perform complex tasks autonomously. The networking of multiple UAVs opens up a multitude of opportunities for mass operations that would have been otherwise too expensive or impractical to carry out with manned platforms. For example, there have been studies conducted into using UAVs which co-operate and explore a wide area quickly through datalink relay and dynamic task re-allocation. This can be controlled by a single pilot, allowing the military force to have a wider picture of the overall battle space with minimal human intervention. The co-operative control of these UAVs may even extend to the optimisation of targeting flight plans and perform co-ordination of multiple targets. The idea of using swarms of UAVs also potentially allows UAVs to overwhelm enemy air defences either by launching electronic attacks or by saturating the radar returns of detection systems. One other potential application is the creation of a mobile wireless mesh network which permits a group of UAVs to deploy large communication networks allowing ground forces to tap on images captured by any member of the swarm or utilise the network for ground communications.

Micro-UAVs

The most revolutionary aspect of UAVs in future warfare is the use of Micro-UAVs (MUAVs) in swarm operations. Currently, the United States Air Force (USAF) Research Laboratory is developing swarms of MUAVs based on biological fliers, such as birds and insects that could be mass-deployed via a larger aircraft. These could be used for extended surveillance in plain sight of the enemy and could extract key intelligence at extremely close ranges. Their endurance could also be extended through solar power or even the extraction of power from vibrating machinery or power lines. These MUAVs could potentially operate undetected for weeks and track targets through complicated terrain in urban areas. They could also be deployed for covert strike operations to disrupt key enemy installations or remote tagging or targeting for their larger counterparts to employ precision weapons. The ability of an MUAV to remain indefinitely in an AO while executing its missions autonomously could herald a new age in military technology.

POTENTIAL CHALLENGES FOR UAV AIRPOWER

Situational Awareness, Speed and Manoeuvrability

Lack of situational awareness is often quoted as a severe disadvantage of UAVs in air-to-air scenarios. UAV Pilots do not have the same field of vision as compared to pilots in a bubble canopy of modern tactical fighters; they can only rely on a suite of sensors to monitor the UAV's surroundings. UAV pilots are subjected to latency issues which could be significant for Within Visual Range (WVR) dogfights, which requires instantaneous decisions.[17] In the same vein, UAVs also perform worse off in terms of manoeuvrability and speed as compared to fighter aircraft. However, it can be argued that visual

The Sky Archer Counter Micro-UAV System is a locally developed solution to neutralise hostile and illegal drones within a 1km radius.

situational awareness may no longer be relevant with the proliferation of Beyond Visual Range (BVR) weapons today. In fact, situational awareness should be viewed as the ability to detect threats even before the threat becomes imminent through more advanced sensors and networked capabilities. Manoeuvrability and speed no longer remains relevant as the payload can be released or evasive actions can be taken way before the enemy detects the UAV. This will necessarily entail the miniaturisation of sensors or the use of overwhelming numerical advantage to match or overcome the more advanced electronic systems on board manned platforms or radar stations.

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Payload Capacity

UAVs are currently disadvantaged in terms of payload capacity when compared to their manned counterparts. For example, the MQ-9 Reaper can carry a payload of 1,724 kg while the lightweight Northrop F-5 can carry a maximum payload of 3,175kg. This is mainly due to the nature of UAV design, which values endurance more than physical performance. The current UAV payload capacity limits their ability to dispense firepower or carry bulky EW systems. However, it must be clarified that the limitation was a result of the modality of current UAV operations which influenced its design. It is not farfetched to envisage UAVs that can carry as much payloads as modern fighters or even bombers. For example, Russia had stated that they are considering introducing an unmanned strategic bomber after 2040 whilst the USAF had explored optionally manned bombers in the Long-Range Strike Bomber programme.[18] Tactical fighters such as the F-16 had also been converted to unmanned versions as high-speed manoeuvrable target drones while the unmanned K-MAX helicopters demonstrated UAVs' versatility by taking up the cargo lift role in Afghanistan.[19] These examples prove the viability of UAVs in carrying similar payload as manned platforms.

Losses Due to Enemy Fire and Poor Reliability

UAVs are vulnerable to enemy fighters and air defence systems as they are usually not equipped with Electronic Countermeasures such as Chaff/Flare/Radar Warning Receivers that can be found on most tactical fighters. As such, UAVs have mostly been used in relatively benign airspace. Most of the UAV losses in the Afghanistan and Iraq wars were due to poor reliability and resulted in significant financial losses for countries such as the United Kingdom.[20] For USAF, the RQ-4 Global Hawk, MQ-1 Predator and MQ-9 Reaper had a combined 9.31 accidents for every 100,000 hours of flying; more than triple the USAF fleet-wide average of 3.03.[21] UAVs are currently not subjected to internationally-recognised aviation standards and are often designed with greater tolerance of risk, which directly impacts the reliability of the system. The International Civil Aviation Organisation had indicated that the first set of UAV airworthiness standards will only be in place in 2018, and they will include air traffic management and 'sense and avoid' requirements in 2020, paving the way for manned/unmanned airspace integration.[22] Until then, UAV design standards will continue to lag behind the mature standards developed over years of manned operations.

Vulnerability to Electronic and Cyber Attacks

Any assessment of a UAV's vulnerability will be incomplete without a discussion on the impact of an EW environment on its datalinks and Global Positioning System (GPS). UAVs are subjected to potential unauthorised access to their video feeds as exemplified by the leakage of unencrypted UAV footage to Iraqi insurgents in 2009.[23] Other common threats to UAVs are GPS spoofing and jamming attacks. Spoofing fools GPS receivers into tracking counterfeit GPS signals and allow the enemy to take control of the UAV while jamming disrupts the GPS signals on the receiver end and results in loss of control of the aircraft. In 2012, Raytheon UK claimed that North Korea performed GPS jamming operations on a Schiebel S-100 Camcopter UAV in South Korea, which resulted in an aircraft crash.[24] Ground Control Stations are also vulnerable to cyber attacks due to software security vulnerabilities, which led to DARPA's research into High-Assurance Cyber Military Systems.[25] While countermeasures such as anti-jamming devices, more advanced encryption and software 'hardening' are being developed to reduce susceptibility to these attacks, it is envisaged that counter-UAV technology developments such as control datalink jamming will ramp up in the future as more military forces recognise the potential threats posed by UAVs.

Political Considerations

Despite the proliferation of UAVs in both military and civil sectors, there is still a growing stigma among the public of their usage, with their role in the CIA's hunter-killer missions leaving the deepest impression. Till date, only the US has openly admitted to the use of armed UAVs, with most countries either steering away from deployment of armed UAVs or choosing not to declare their usage due to political sensitivities. These sensitivities are illustrated by the limitations imposed by the Missile Technology Control Regime, the disarming of UAVs before they can be exported, and general public discourse.[26] As of now, most ASEAN military forces possess only Tactical UAVs which fulfil ISR roles. Notably, a number of nations in the region have embarked on indigenous UAV programmes such as Composites Technology Research Malaysia (CTRM) Aludra and Eagle and Indonesia's Wulung UAVs. Whilst the RSAF continues to acquire new UAV systems with more advanced electronics and capabilities, it should be aware of the potential of an UAV arms race in the region, as rapid UAV developments in China, Russia, and Israel will likely result in aggressive marketing to Association of Southeast Asian Nations (ASEAN) military forces, which are increasingly looking outward for technology transfer opportunities and advanced systems for force modernisation efforts. Singapore should also continue to develop indigenous UAV technologies through Defence Science Organisation (DSO) to maintain a technological edge over potential adversaries and nurture our local industries for future growth.

CONCLUSION

UAVs will definitely play an increasing role in the projection of airpower in the coming years. The advantages associated with UAVs, such as persistence, autonomy, low unit cost, flexible design and the removal of human lives from danger will continue to position UAVs as the go-to solutions for many future airpower challenges. However, civil airspace integration, frequency spectrum management, reliability, political sensitivities, integration challenges and vulnerability to electronic attacks continue to restrict the widespread use of UAVs across the entire spectrum of air operations. In the near future, manned platforms will continue to play an important role in airpower while UAVs will continue to take up 'dull, dirty and dangerous' tasks such as ISR over enemy airspace. However, it is envisaged that UAVs will eventually take over manned platforms in the second half of this century when the technologies for UCAVs, unmanned strategic bombers and even unmanned helicopters and tanker/transport are expected to mature. It is also projected that the corresponding network infrastructure and regulatory civil and military framework will eventually be as established and well-maintained as that of manned platforms. This future is dependent on the willingness of military forces and political governments to expand the roles of UAVs which will in turn drive their research and development, leading to UAVs which will eventually match, and even surpass manned platforms in performance and efficiency.

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4. Non-kinetic weapons, as defined by the USAF Doctrine Document 2, refers to logical, electromagnetic, or behavioural actions, such as a computer network attack on an enemy system or a psychological operation aimed at enemy troops. The effects they impose are mainly indirect.

5. The first remotely piloted drone used as a weapon was the German FX-1400, which consisted of a 2,300 pound bomb, dropped from an airplane and steered by a pilot in the main aircraft. It was deployed during World War II.

6. Initial testing of missile-equipped drones was completed in 2001, soon after the September 11 attacks the weaponised Predator UAVs, armed with Hellfire missiles, were flying over Afghanistan for the US invasion. In OEF alone, there were a total of 1,160 weapons released from armed UAVs, out of a total of 3,600 weapons released, showing the increasing role of UAVs for close air support missions.

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