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14. ABSTRACT

Limitations of Marine Corps aviation are exacerbated in a dense urban environment such as a Megacity. Many of the capabilities and tactics of manned rotary-wing and fixed-wing aircraft are not suited for operations within such an environment. Current capabilities provide great success in fighting what the operators can see on the ground and rooftops but leaves a vacuum of capability in the space between. By augmenting manned aircraft with unmanned systems, the Marine Corps can cover a wider area with better ISR capability than with manned systems alone. By developing a means by which to increase ISR capability to the ground commander through the use of small unmanned aerial vehicles, ISR limitations in a dense urban environment can be mitigated. Similarly, augmenting either medium or heavy-lift rotary wing assets with unmanned systems such as the K-MAXX increases the coverage area covered by distributed operations in a time of limited available assets.

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TITLE: Air Domain Dominance in a Megacity

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AUTHOR: Major Nathan J. Storm

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Mentor and Oral Defense Committee Member: Dr. Benjamin M. Jensen
Approved: _____
Date: 23 April 15

Oral Defense Committee Member: Evans, Russell A. CAPT USN
Approved: _____
Date: 23 Apr 15

Executive Summary

Title: Air Domain Dominance in a Megacity
Author: Major Nathan J. Storm, United States Marine Corps
Thesis: The vertical development of megacities provide a unique challenge to Marine Corps aviation thereby requiring a new method of developing combat power in the space between what can be influenced on the ground and at roof-top level.
Discussion: As George Hillary said when asked why he wanted to climb Mount Everest, the U.S. Marine Corps will fight in the dense urban environment of a megacity "because it's there." A major problem becomes the limitations of Marine Corps air power while fighting in a dense urban environment. Namely, many of the capabilities and tactics of manned rotary-wing and fixed-wing aircraft are not suited for operations within the megacity. Current capabilities provide great success in fighting what the operators can see on the ground and roof tops but leaves a vacuum of capability in the space between. The Japanese invasion of Singapore provides several findings that provide a means by which the Marine Corps can dominate the intermediate space. Namely, the Japanese dominated the British on the Malay Peninsula at the onset of WWII by substituting speed and maneuver for mass, maintaining multi-domain dominance, and control of key infrastructure. The Marine Corps can apply these lessons to develop a future operating concept using both existing and emergent technology including micro air vehicles, remotely piloted vehicles, and unmanned aircraft systems.
Conclusion: Continued development of small air vehicle technology provides added flexibility for the Aviation Combat Element (ACE) Commander. By providing the ACE Commander with added flexibility in the means by which he completes his mission effectively supports the Ground Combat Element (GCE) commander in his mission as he prosecutes targets that will no longer be able to find sanctuary in the previously invisible spaces between the ground and the roof.

DISCLAIMER

THE OPINIONS AND CONCLUSIONS EXPRESSED HEREIN ARE THOSE OF THE INDIVIDUAL STUDENT AUTHOR AND DO NOT NECESSARILY REPRESENT THE VIEWS OF EITHER THE MARINE CORPS COMMAND AND STAFF COLLEGE OR ANY OTHER GOVERNMENTAL AGENCY. REFERENCES TO THIS STUDY SHOULD INCLUDE THE FOREGOING STATEMENT.

Preface

The threat to aviation within a megacity may prove extreme. The distractions, reflections, and apparent invisibility of enemy actors create a large window of risk for any ACE Commander sending his aircraft into a dense urban environment. This paper does not seek to eradicate the risk to aviators and their customers but it does seek to provide an opportunity to feed discussion on possible means by which the risk to our sons and daughters may be reduced. The risk to aviators is always present, regardless of where they fly, but this risk is compounded in the urban environment and even more so within the dense urban environment of a megacity.

The creation of this thesis would not have been possible without the guidance and assistance from academics and professionals both inside and outside the Marine Corps University Command and Staff College. My thesis advisor and senior advisor for the Advanced Studies Program, Dr. Benjamin Jensen deserves special thanks in his energy, guidance, and academic acumen. I would not have finished without his assistance on this project.

I also want to thank my father, Allan D. Storm, who provided valuable information regarding the use and development of unmanned aircraft systems within the NATO community. I also thank Mark A. Hewitt for proofreading this paper as I it developed, changed, and grew. I appreciate the guidance and editing he provided this venture.

Lastly, I thank my wife of ten years, Thera F. Storm, for supporting me as I developed these thoughts and ideas while pregnant with our first child. Thank you ever so much for your love and support.

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Marine Corps Aviation Doctrine and Capabilities in a Megacity

The future of urban warfare is bleak. The possibility, or probability, of conducting any of the range of military operations inside a dense urban environment is incredibly high. A national security professor at the Naval War College, Richard Norton, certainly expects it, stating, "If three quarters of the world will live in cities, and we still fight wars, then wars are going to be fought in this environment."[1] With that concept in mind, the Marine Corps must research, develop, and practice new concepts for conduct of war in a dense urban environment. Current Marine Corps air doctrine and maneuver capabilities are poorly suited for operations within this dense urban environment. For purposes of this project, we'll describe the dense urban environment as a "megacity." In order to understand how to fight in a megacity, we must have a broad definition from which to work. We must also justify a reason for studying war in a megacity environment and determine if current doctrine and tactics suitably account for the vast human network the military will encounter while operating in a megacity.

The generally accepted size of a megacity is an urban area with a population greater than ten million people. The United Nations World Urbanization Prospects: 2014 Revision (WUP) reports 28 current megacities and predicts 41 by 2030.[2] The WUP continues:

> In 2007, for the first time in history, the global urban population exceeded the global rural population, and the world population has remained predominantly urban thereafter. The planet has gone through a process of rapid urbanization over the past six decades. In 1950, more than two-thirds (70 per cent) of people worldwide lived in rural settlements and less than one-third (30 per cent) in urban settlements. In 2014, 54 per cent of the world's population is urban. The urban population is expected to continue to grow, so that by 2050, the world will be one-third

[1] "Homemade Tank Powered by Game Boy Fights Wars of Future," Flavia Krause-Jackson, Nicole Gaouette, *Bloomberg*, last modified September 9, 2014, http://www.bloomberg.com/news/print/2014-09-09/home-made-tank-powered-by-game-boy-fights-wars-of-future.html.

[2] World Urbanization Prospects: 2014 Revision, *United Nations World Urbanization Prospects: 2014 Revision* (New York, NY: United Nations, 2014), 2.

> rural (34 per cent) and two-thirds urban (66 per cent), roughly the reverse of the global rural-urban population distribution of the mid-twentieth century.[3]

The World Health Organization (WHO) further explains annual increase in urban population. "The global urban population is expected to grow approximately 1.84% per year between 2015 and 2020, 1.63% per year between 2020 and 2025, and 1.44% per year between 2025 and 2030."[4] Expanding urban populations place more humans at closer proximity to each other than ever before. Close physical proximity coupled with increased electronic connectivity yields drastically increased global interconnectedness. Over the course of this study, the size of a megacity became irrelevant to our purposes. The key feature is population density over absolute size. Gaza is more densely populated than Los Angeles, even with a total population of about 1.8 million people. If our major concern is the interconnectedness of major urban centers, we need not worry about an arbitrarily defined population requirement but that there exists ample opportunity for connections to form within the population.

Mavens and Connectors or Programmers and Switches, no matter what you call them, the people who establish, recruit, train and man human networks are a major threat. The pool from which recruits are drawn continues to increase as the local, interconnected population size grows. In a networked megacity, the ability to control or regulate those human networks is key. In *The Tipping Point*, Malcolm Gladwell discusses two types of human network facilitators he calls "mavens" and "connectors." Mavens collect information; they have knowledge and want to distribute that knowledge to as wide an

[3] World Urbanization Prospects: 2014 Revision, *United Nations World Urbanization Prospects: 2014 Revision* (New York, NY: United Nations, 2014), 7.
[4] World Health Organization, "Urban Population Growth," accessed 17 December, 2014, http://www.who.int/gho/urban_health/situation_trends/urban_populatioin_growth_text/en/.

audience as possible. In order to distribute knowledge, mavens enlist help from connectors. According to Gladwell, connectors are important not only for the number of people with whom they're connected, but also the quality of those connections.[5] Noted sociologist Manuel Castells discusses a similar concept in his 2011 article "A Network Theory of Power." Castells' terms "programmers" and "switches" hold similar meaning to Gladwell's "mavens" and "connectors." Castells defines programmers as a person or group with "the ability to constitute network(s) and to program/reprogram the network(s) in terms of the goals assigned to the network" and connectors have "the ability to connect and ensure the cooperation of different networks by shaping common goals and combining resources while fending off competition from other networks by setting up strategic cooperation."[6] Mavens and Programmers control the knowledge base. They transfer their knowledge to a close group of followers but need another means to translate that knowledge to a wider audience. Connectors and Switches are that means, so during a future war in a megacity, the people or groups who facilitate these roles are a key to success in defeating any adversarial group.

Physical and electronic interconnectedness, increasing population density and size, and the power to form, program, and spread networks creates a distinct problem for the United States Marine Corps with regard to war in a megacity. From an aviation point of view, how does the Marine Corps respond to military operations within a megacity assuming control and regulation of physical and electronic network connections are key?

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[5] Malcolm Gladwell, *The Tipping Point* (New York: Little, Brown and Company, 2000), 30-86.

[6] Manuel Castells, "A Network Theory of Power," *International Journal of Communications, Vol. 5 (2011): 776.*

One current military doctrinal publication "recommends isolating and bypassing urban terrain when possible due to the costs involved."[7] Obviously when discussing the future of war in a megacity, bypass and isolation is neither possible nor the best means by which to prosecute the war. In order to effectively fight in a megacity, the U.S. Marine Corps must be capable of controlling individual networks. Current Marine Corps aviation doctrine seems ill equipped to function against the interconnected complexities of war in a megacity.

The U.S. Marine Corps maintains six aviation functions: Electronic Warfare (EW), Air Reconnaissance, Offensive Air Support (OAS), Assault Support, Command of Aircraft and Missiles, and Anti-Air Warfare (AAW).[8] Initial problem framing assessment within the megacity describes problem of aviation maneuver. Problem framing also leads to a cursory list of questions the U.S. Marine Corps must parse through. How does the U.S. Marine Corps adapt these six functions to operate within a dense urban environment? Similar to ground urban operations, aviation urban operations are fraught with myriad challenges. How does Marine Aviation maneuver safely and effectively within this type of environment? Will the megacity's concentration of electromagnetic radiation affect the capability and effectiveness of EW? How will urban canalization affect the Assault Support aircraft's mission of airborne movement of equipment and personnel? Will the vertical nature of most megacities interfere with OAS and Air Reconnaissance ability to locate, target and prosecute the enemy without high collateral damage risk? Without

[7] Headquarters U.S. Marine Corps, *MTTP for Aviation Urban Operations*, MCRP 3-35.3A (Quantico, VA: U.S. Marine Corps, 15 April, 2001), I-1.
[8] Headquarters U.S. Marine Corps, *MCWP Aviation Operations*, MCWP 3-2 (Quantico, VA: U.S. Marine Corps, 9 May 2000), 2-1 – 2-6.

adaptation of procedures and capabilities, limited line of sight affects positive command and control of aircraft within a megacity. How will the megacity affect the U.S. Marine Corps' ability to conduct AAW? The asymmetric nature of urban combat affects every aspect of Marine Aviation.

MCRP 3-35.3A Aviation Urban Operations (essentially a joint publications since all four services signed and maintain it) speaks in very broad terms about considerations for military aviation operations in an urban environment but notably does not discuss the interconnected nature of urban warfare. Joint Publication 3-06 Urban Operations more appropriately discuses the interconnectedness of a megacity "as a complex and dynamic system, with unique political, military, economic, social, information, and infrastructure (PMESII) and other components. Each element impacts, constrains, and influences military operations."[9] JP 3-06 continues to discuss "complex social and political interactions by compressing large numbers of people into a small geographic area. Critical infrastructures (physical, economic, governmental, social, etc.) are in such close proximity and, in most areas, so intertwined that even minor disruptions by military operations can cause significant repercussions."[10] JP 3-06 discusses aviation operations as well, stating "air operations must adapt to the unique urban environment…although [Command and Control] C2 does not change in the urban environment, tactics, techniques, and procedures (TTP) may be vastly different from those employed on the

[9] Chairman Joint Chiefs of Staff, *Joint Urban Operations*, JP 3-06 (Washington, DC: Joint Chiefs of Staff, 20 November, 2013), I-2.
[10] Chairman Joint Chiefs of Staff, *Joint Urban Operations*, JP 3-06 (Washington, DC: Joint Chiefs of Staff, 20 November, 2013), I-2 – I-3.

open battlefield."[11] The Marine Corps must cooperate with the joint community to research and deploy new techniques and technology suitable to a megacity.

One key to success in megacity warfare is creating and adapting TTPs to the megacity environment. The Marine Corps also must develop new means of conducting urban aviation operations to include airborne non-traditional ISR (NTISR), assault support and offensive air support (OAS). With regard to NTISR and OAS, the traditional "top-down" approach will likely not be as effective in an urban environment because of the vertical characteristics of a modern megacity. Assault support TTPs may also need to be adjusted especially in light of the probability of aircraft operating below the building horizon and limitations on current aircraft survivability equipment (ASE).

Additional aviation considerations are impacts to aircraft systems like forward-looking infrared radar (FLIR) and night vision devices (NVD). For example, thermal reflectivity precludes FLIR systems from being able to see through glass. Glass has high thermal reflectivity and will reflect the thermal energy of the background.[12] The *Marine Aviation Weapons and Tactics Squadron (MAWTS-1) Night Vision Device (NVD) Manual* continues: "Certain smooth, glossy surfaces, such as…windshields and glossy painted fenders can reflect [infrared] IR radiation images incident on them from other sources."[13] Glass fronted buildings dominate the modern cityscape thereby making them opaque to modern aviation thermal imaging devices.

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[11] Chairman Joint Chiefs of Staff, *Joint Urban Operations*, JP 3-06 (Washington, DC: Joint Chiefs of Staff, 20 November, 2013), I-9.
[12] Marine Aviation Weapons and Tactics Squadron One, *MAWTS-1 Night Vision Device (NVD) Manual, 9th Edition* (Yuma, AZ: U.S. Marine Corps, 14 January 2011), 26.
[13] Marine Aviation Weapons and Tactics Squadron One, *MAWTS-1 Night Vision Device (NVD) Manual, 9th Edition* (Yuma, AZ: U.S. Marine Corps, 14 January 2011), 28.

The nighttime urban environment has similarly negative effects on NVDs. Current advances to the Marine Corps night vision goggle device, the AN/AVS-9 with OMNI-VI image intensifier tubes, have reduced "halo" effect around non-NVD compatible lights (typical white, yellow, red city lights are non-NVD compatible).[14] Improved image intensifier tubes cannot account for the increased clutter and reflected light negatively affect the devices. Decreased visual acuity increases the risk associated with flying in the urban environment and creates significant difficulty with locating, tracking and operating against individuals who control urban networks.

In order to effectively operate in the megacity environment, the U.S. Marine Corps must research, study, and experiment with new and existing concepts in order to develop appropriate TTPs and equipment. Current capabilities are well suited to warfare in an open environment as seen in Iraq and Afghanistan. Current satellites and unmanned aircraft systems are poorly equipped to gather intelligence in the narrow streets of a megacity. To facilitate future success, the Marine Corps must recognize these limitations and develop new methods of locating, tracking and controlling megacity network programmers and switches.

Before developing a concept for the future of Marine Corps Aviation in a megacity, this paper seeks to develop a more thorough understanding of the problems related to megacity war. In order support that desire, the following case study of the Japanese

[14] LCDR Heath Clifford, "NVD Technology Update," (PowerPoint presentation, Marine Aviation Weapons and Tactics Squadron One, Yuma, AZ, Accessed 10 November 2014).

invasion of the Malay Peninsula and Singapore during WWII develops one perspective of apparent issues of megacity war.

Case Study: Japanese Invasion of Singapore during WWII

Japan's first offensive in the Pacific war against the West was not the attack on Pearl Harbor. About twenty hours before the Japanese attack on Oahu, Hawaii five Japanese Army fighters took off from Thailand to support a convoy in the Gulf of Siam. During their flight, the fighters happened upon a Royal Air Force (RAF) Consolidated PBY Catalina. The amphibious aircraft, based out of Singapore, was searching for the convoy those Japanese fighters were meant to support. The Japanese fighters vastly outmatched the sluggish boat-plane and destroyed the Catalina before it could radio back to its headquarters in Singapore.[15] So began the war in the Pacific and Japan's conquest of the Malay Peninsula and their eventual seizure of Singapore.

Initially, one might look to a 74-year old battle in the Pacific and think it of little significance to a discussion of 21st century war or, more specifically, to war in a megacity. The Marine Corps Doctrinal Publication (MCDP) *Warfighting* extolls the "two concepts of universal significance in generating combat power: speed and focus."[16] It is this speed and focus that led the Japanese to dominance during their multi-modal and multi-domain assault on the Malay Peninsula and Singapore. Japan's air and sea power dominated in the face of a numerically superior British occupation and established defense. Through the next few pages, we will briefly frame a discussion of the battle, the operational planning for both the Japanese and British. Finally, we'll discuss overall

[15] Stanley L. Falk, *Seventy Days to Singapore* (New York: G.P Putnam's Sons, 1975), 16.
[16] Headquarters U.S. Marine Corps, *Warfighting*, MCDP 1 (Washington, DC: U.S. Marine Corps, June 30, 1991), 40.

findings from the case study and how we can relate this operation to war in a megacity and the concept paper to come.

The method of research for this case study was through internet searches, online research databases, written histories, and theoretical works. The intent of this work is to develop a link between the military necessity of gaining and maintaining rapid domain dominance within an urban environment, such as Singapore in 1941, and the capacity to gain the same dominance in a modern megacity environment. To this end, the research for this paper was primarily concerned with the historical narrative regarding Japan's domination of the Malay Peninsula and follow-on seizure of the island and city of Singapore. The modern commander may find the best way to gain control of a megacity is through the valuable lesson of the rapid multi-modal dominance the Japanese achieved in Singapore.

Historical Background

In order to continue their offensive in China, the Japanese needed access to natural resources they could not otherwise procure in the open markets. The economic sanctions placed on Japan worked to strangle the nascent Japanese empire.[17] Forced to look for war materials elsewhere, Japan looked to the south for relief to "seize for herself the mineral-rich resources of South-east Asia."[18] At approximately 0215 on 8 December 1941, a little more than an hour before the attack on Pearl Harbor, the initial Japanese invasion force in Malaysia landed.[19] Over the next few hours, the Japanese brought three divisions ashore

[17] Stanley L. Falk, *Seventy Days to Singapore* (New York: G.P Putnam's Sons, 1975), 19.
[18] Ibid., 19.
[19] Yap Siang Yong, Romen Bose, Angeline Pang, *Fortress Singapore: The Battlefield Guide* (Singapore: Times Books International, 1992), 10.

in Thailand while holding another division in reserve.[20] Using what one must assume to be deceptive tactics, the Japanese leadership in Thailand "completed [formalities] allowing us to pass through Thailand."[21]

The British forces in Singapore and throughout the Malay Peninsula had accurate intelligence regarding the impending Japanese assault. However, the general understanding and analysis of that intelligence was that the Japanese Army was attacking Thailand and not the British in Singapore.[22] The British recognized also the difficulty of defending against a Japanese assault into neutral Thailand's sovereign borders. British forces crossing Thailand's border to defend Malaysia and Singapore against the Japanese offense would likely paint the British as the aggressor.[23]

In the introduction to Arthur Swinson's book *Defeat in Malaya, the Fall of Singapore,* Sir Basil Liddell Hart describes the defending British force as having "more than sufficient strength in the island to repel the invasion, particularly as it came in the sector where it was most expected."[24] Under Lieutenant General Arthur Percival, Malaya Command, the British command in Singapore, totaled approximately 88,600 troops. Troop breakdown in Malaya Command was 37,000 Indian troops, 19,600 British, 15,200 Australians, and 16,800 Malayan and Chinese troops. The Indians were broken down into two divisional command and the Australians had one. The British troops had no division command but

[20] Stanley L. Falk, *Seventy Days to Singapore* (New York: G.P Putnam's Sons, 1975), 31.
[21] Arthur Swinson, *Defeat in Malaya: The Fall of Singapore* (New York: Ballantine, 1970), 51.
[22] Ibid., 51.
[23] Brian P. Farrell, "High Command, Irregular Forces, and Defending Malaya, 1941-1942, *Global War Studies* Vol. 8, No. 2 (December 2011): 46-47, http://search.ebscohost.com/.
[24] Arthur Swinson, *Defeat in Malaya: The Fall of Singapore* (New York: Ballantine, 1970), 7.

were broken into six battalion commands. Percival commanded a weak air force of 158 operational aircraft made up of mostly obsolete types operated by underprepared pilots who had not seen combat. Finally, the Royal Navy in Singapore included aircraft carrier *Hermes,* the battle cruiser *Repulse,* battleship *Prince of Wales,* and a few of smaller ships.[25]

Approximate total Japanese force brought to bear against the Malay Peninsula and Singapore was roughly matched with the British forces in the area. Japanese forces included about 50,000 infantry, 80 medium and 100 light tanks, strong artillery presence, and various support elements (engineers to support bridging operations) totaling an additional 30,000 troops. The Japanese force totaled more than 450 aircraft and strong naval presence of cruisers, destroyers and submarines.[26]

Analysis

So how did a numerically inferior force (~80,000 Japanese to ~88,600 Allied) push one of the world's great powers south along the length of the Malay Peninsula and eventually rout them in Singapore? Herein lies the heart of what this paper looks to portray. The superior Japanese planning, strategy, and execution continuously kept the British forces off balance and in an almost constant state of withdrawal.

Similar to the numbered war plans the United States maintains, Japan built a specific war plan against the strategically important island of Singapore. To use the parlance of our times, the Operational Planning Team (OPT) leader was Lieutenant Colonel Masanobu

[25] Stanley L. Falk, *Seventy Days to Singapore* (New York: G.P Putnam's Sons, 1975), 53-57.
[26] Ibid., 28.

Tsuji.[27] Though not specifically trained in amphibious operations jungle warfare, the Japanese embarked on a crash course. The Japanese planners sought information regarding the tropics from any source they could imagine to include "pestering sea captains, mining engineers, bankers, university professors, diplomats, Buddhist priests – in short, anyone and everyone in Japan and Formosa who knew anything at all about the tropics."[28] In order for the Japanese troops to prepare for the assault through Malaysia, they conducted regional exercises throughout the spring of 1941 allowing the army and navy to build interoperability and amphibious experience.[29] Tsuji and his planners personally conducted ground and aerial reconnaissance of the Malay Peninsula and potential landing beaches.[30] Through detailed planning, reconnaissance, and multiple rehearsals, the OPT ensured every opportunity for Japanese success in Singapore. The Japanese leadership recognized the strategic importance of Singapore and the necessity for Japanese control over Singapore while conducting the Pacific campaign. With this recognition came long-term and deliberate planning that ultimately led to their success.

Political forces at home in London hampered British defenses in Singapore as much they were by poor local tactical decisions. In his book *Operation Matador*, Ong Chit Chung argues that much of the fault for Singapore's fall to the Japanese fell on Winston Churchill. That Churchill's attention was with the more immediate war on the European continent than with the much farther afield defense of Singapore (thinking in London was that Japan might invade Thailand, but certainly would not risk war with the Western

[27] Ibid., 24.
[28] Ibid., 25.
[29] Henry Frei, *Guns of February* (Singapore, Singapore University Press, 2004), 31.
[30] Stanley L. Falk, *Seventy Days to Singapore* (New York: G.P Putnam's Sons, 1975), 26-27.

powers).[31] Furthermore, Churchill generally believed that Japan was not on the verge of war with the West (with their preoccupation in China) and that the best defense of Singapore was through "strong *local* garrison and the general potentialities of sea-power. The idea of trying to defend the Malay Peninsula and of holding the whole of Malaya…cannot be entertained."[32] Churchill's views thusly the long delayed arrival of the capital ships *Repulse* and *Prince of Wales*'s (ill-fated as their arrival may have been). Theorists often quote Clausewitz's definition "that war is not merely an act of policy but a true political instrument, a continuation of political intercourse, carried on with other means."[33] However, in this case, the converse is true. The politics in Britain, far from pursuing war in Singapore, found a war in Southeast Asia at least partially because of their political inaction. British unwillingness to initiate Operation MATADOR because they feared being seen the aggressor in Thailand did not help the defense of Singapore.[34] Nor did the quick demise of the *Repulse* and *Prince of Wales* or the modest (at best) northern defense in Singapore assist in the ultimate success of the British.

The Japanese fought south quickly. Upon the initial assault, their priority was air supremacy. Japanese air forces destroyed British aviation units and upon seizure of British-held airfields, extend the range of Japanese aircraft further south. Once satisfied they had attained air supremacy, the Japanese would speed their southward advance

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[31] Ong Chit Chung, *Operation Matador: Britain's War Plans Against Japan, 1918-1941* (Singapore: Times Academic Press, 1997), 222-223.
[32] Winston Churchill, Prime Minister to General Ismay, September 10, 1940, *The Second World War* Vol. II, *Their Finest Hour* (Boston: Houghton Mifflin, 1949), 667-668
[33] Carl von Clausewitz, *On War*, ed. Michael Howard and Peter Paret, trans. Michael Howard and Peter Paret (Princeton, NJ: Princeton University Press, 1984), 87.
[34] Ong Chit Chung, *Operation Matador: Britain's War Plans Against Japan, 1918-1941* (Singapore: Times Academic Press, 1997), 232-233.

toward Singapore.[35] Speed was of the utmost importance to the Japanese. Dr. Brian P. Farrell, the head of the history department at the National University of Singapore, writes, "The British expected the Japanese to consolidate a beachhead, build up their strength, advance only when their main force was concentrated, then advance methodically."[36] Mr. Farrell continues:

> Within 100 hours they shattered all British defensive plans, seized the initiative, and advanced boldly into northern Malaya. Force Z sortied, but was caught at sea by Japanese land-based naval air forces and destroyed on the morning of 10 December. This, plus the Japanese success at Pearl Harbor, gave the IJN command of the sea. That al- lowed it to threaten the whole east coast. This forced Malaya Command to keep much of its strength in southern Malaya and on Singapore Island. RAF Far East gave battle, but was outmatched in every respect. Losing nearly half its strength in three days, the air force drew back to regroup and try to protect reinforcement convoys approaching Singapore; this left the army vulnerable.[37]

Contrary to British expectations, the majority of Japanese land forces flowed like water to the western coast of the Malay Peninsula then south to arrive at the Johor Strait by the first week of February 1942. Sun Tzu describes the necessity of speed as "the essence of war. Take advantage of the enemy's unpreparedness; travel by unexpected routes and strike him where he has taken no precautions."[38] Japanese forces succeeded in that paradigm. As mentioned above, the Japanese land-based naval air forces destroyed the British "Force Z" (the capital ships *Repulse* and *Prince of Wales*) leaving the peninsula unguarded at sea. Japanese air forces also destroyed virtually all of the British aviation capability on the Malay Peninsula and in Singapore. The rapidity in attack affected by the Japanese kept the British defense off balance negated the numerical superiority the

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[35] Stanley L. Falk, *Seventy Days to Singapore* (New York: G.P Putnam's Sons, 1975), 31.
[36] Brian P. Farrell, "High Command, Irregular Forces, and Defending Malaya, 1941-1942." *Global War Studies* Vol. 8 Issue 2 (December 2011): 47. http://search.ebscohost.com/.
[37] Ibid., 49.
[38] Sun Tzu, *The Art of War*, trans. Samuel B. Griffith (New York, NY: Oxford University Press, 1971), 134.

British enjoyed.

The battle raged the length of the peninsula and by the end of January, the British forces had retreated back across the causeway onto Singapore Island. On the morning of 31 January 1942 at approximately 0815, the British forces destroyed the causeway and prepared for the final defensive stand in Singapore.[39] On 8 February 1942 the Japanese arrived at the Johor Strait, began an amphibious assault on Singapore, and by the morning of 9 February had two divisions of infantry and portions of their heavy machinery across the Johor Strait. The Japanese continued to push the British forces back toward Singapore and by 12 February the Japanese controlled the reservoirs that fed water to the city. The British forces surrendered in the early afternoon of 15 February 1942.[40]

Inferences

The question now is how to correlate these lessons learned from Japans successful assault of the Malay Peninsula and Singapore to the future of warfare in a megacity. We'll condense the above pages to a few "findings" that provide a glance at a theory of victory. First we want to look at the importance of intelligence gathering, analysis, and planning processes then discuss the influence of speed, surprise, maneuver, and multi-domain dominance as these subjects relate to military operations in a megacity.

Military theorist Sun Tzu, second only to Carl von Clausewitz in the esteem of the Western military, describes the need to conduct planning so that one may "know the

[39] Louis Allen, *Singapore 1941-1942* (Oxford, Frank Cass, 2005), 160.
[40] Ibid., 169-174.

enemy and know yourself; in a hundred battles you will never be in peril."[41] The Japanese forces were well prepared for the operation to capture Singapore. They gathered intelligence, built their plan based solidly on intelligence estimates, and rehearsed their concept. To be victorious in a future megacity war, the United States military must be equally prepared. Preparation must entail detailed studies of how conflict in a megacity would present. War in an urban environment is exceedingly complex, even more so because each megacity has a unique character, culture and environment. A one-size-fits-all approach cannot work (at least not efficiently). In order to be successful, the U.S. military must fully understand the requirements, environment, and develop tactics, techniques, and procedures (TTPs) by which to gather operable intelligence in the networked environment of a megacity and subsequently attack targets that support those networks.

Carl von Clausewitz describes the value of speed and surprise in his treatise *On War* as "the means to gain superiority."[42] The Japanese did not have numerical superiority so they maximized their use of speed and surprise. Conversely, the British forces on the Malay Peninsula had neither surprise nor initiative. Though Operation MATADOR could have influenced the outcome of the 70 days between the invasion and the surrounding of Singapore, the authorization to initiate MATADOR didn't arrive until 5 December 1941.[43] The Japanese rapid ingress across the beach and south through the peninsula evidenced no sacrifice of speed and initiative. Without sacrificing speed and initiative,

[41] Sun Tzu, *The Art of War*, trans. Samuel B. Griffith (New York, NY: Oxford University Press, 1971), 84.
[42] Carl von Clausewitz, *On War*, ed. Michael Howard and Peter Paret, trans. Michael Howard and Peter Paret (Princeton, NJ: Princeton University Press, 1984), 198.
[43] Louis Allen, *Singapore 1941-1942* (Oxford: Frank Cass, 2005), 99.

the Japanese had little requirement to build up forces in the traditional sense. Similar to Corbett's theory, Japanese speed and surprise without loss of initiative created a sort of mass in being. This is not to say that they did not mass their forces, they certainly did. The speed with which the Japanese moved gave a semblance of mass that provided maneuver space while their forces continued to flow ashore.

The Japanese forces quickly captured and controlled critical infrastructure on the island of Singapore that contributed to the British surrender. As mentioned, on 12 February Japanese forces controlled the water reservoirs that supplied Singapore. Though the Japanese did not halt water service to the city, they certainly had the capability. Controlling this key infrastructure and service must have influenced the British surrender.

The most important finding of this case study is the speed with which Japan gained multi-domain dominance across the length of the peninsula and surrounding waters. Though the British ineffective defense was partially due to political decision making in London, the reality was that the Japanese quickly marched south along the peninsula and dominated nearly the entire way. Only a few hours after the initial amphibious landing in the north, Japanese bombers completed their first bombing raid on Singapore. Though there was little significant damage, the raid set the tone for the remainder of the Japanese push south.[44] Still on the 8th of December, the Japanese air forces reduced British air strength in the northern parts of the peninsula from 110 operational aircraft to 50.[45] Japanese air supremacy over the entirety of the peninsula and Singapore soon followed.

[44] Arthur Swinson, *Defeat in Malaya: The Fall of Singapore* (New York: Ballantine, 1970), 52.
[45] Ibid., 55.

Similarly, the Japanese attained domination of the seas surrounding the Malay Peninsula and Singapore almost as soon as the British capital ships arrived. By the afternoon of December 10, both British ships were lost and Japan had control of the sea lines of communication. On 14 February, the Japanese completed repairs to the destroyed causeway across the Johor Strait adding one more domain the Japanese dominated.[46] The Japanese now controlled air, sea, and ground access to Singapore. The British subsequently surrendered on 15 February 1942. One can surmise that multi-domain dominance allows the freedom of maneuver to be ultimately successful.

Conclusion

Though we didn't discuss the operation in intricate detail, the premise is easy to comprehend. Japan's thorough planning allowed the Japanese army and navy to entirely dominate the Malay Peninsula and Singapore. Nested within their theory of victory was the rapid multi-domain domination they enjoyed in both the skies above and the seas around Singapore. But we return to our earlier question, how does this case study affect our comprehension of future war in a megacity.

One way we can look to build and maintain speed and initiative in a megacity is through acquiring domain dominance. The air domain is of particular interest because current doctrine and capabilities does not lend itself to successful operations within a megacity's environment. Singapore was initially under total military control by the British making it easy for the Japanese to gather intelligence and select targets. It is unlikely that a modern megacity will be completely controlled by some group therefore intelligence gathering,

[46] Louis Allen, *Singapore 1941-1942* (Oxford: Frank Cass, 2005), 174.

targeting, and fires become infinitely more difficult. Indiscriminate bombing (or even precise targeting that ends in a destroyed building) will likely further the enemy's cause and enrage the local populace. The military must look to other means to create this domain dominance and one such possibility is the use of unmanned aerial systems, micro air vehicles, and systems and techniques that have yet to be developed.

Future Concept: How Unmanned Aircraft Systems Support Megacity War

GENERAL PURPOSE

The United States military will fight in a megacity. The question is not "if" but "when." Richard Norton, a professor of national security at the U.S. Naval War College states specifically that "if three quarters of the world will live in cities, and we still fight wars, wars are going to be fought in this [urban/city/megacity] environment."[47] The general purpose of this concept is to describe a paradigm shift for Marine Corps Aviation and implementation of airpower within a megacity environment. Siege warfare is neither feasible nor appropriate for combatting an adversary within a megacity. National resolve would likely not be such that the public would willingly ignore the plight of the millions of non-combatants within a besieged megacity. The U.S. Marine Corps must be able to capture the initiative through rapid multi-modal multi-domain dominance of specific areas within a megacity. Multi-modal and multi-domain dominance describes the ability of the operational force within a megacity to control the air, land, and potentially water

[47] "Homemade Tank Powered by Game Boy Fights Wars of Future," Flavia Krause-Jackson, Nicole Gaouette, *Bloomberg*, last modified September 9, 2014, http://www.bloomberg.com/news/print/2014-09-09/home-made-tank-powered-by-game-boy-fights-wars-of-future.html.

within an area via multiple means. The multiple modes of dominance include ground forces, air power, sea power, and cyber capabilities. Major Jonathan Frerichs writes of the need to "gain critical maneuver space for the commander."[48] In order to support the commander, Marine Corps Aviation should change its theory of victory to provide support within a megacity. In order to support the commander, Marine Corps Aviation should diversify its capabilities through greater use of unmanned aircraft systems. These systems should be able to operate independently as well as in concert with traditional manned aircraft. This concept hopes to describe specific means by which the Marine Corps can add capability within the Air Combat Element (ACE) to better support the ground combat element (GCE) commander.

Based on previous problem framing and case study analysis regarding the question of megacity war, the following concept is offered as one possible solution. The concept is a narrow view of the defined problems and case study findings. Earlier problem framing describes issues related to aviation doctrine, maneuver, and sensor technology. The concept references these problems in the discussion. The previous case study of the Japanese invasion of Singapore yielded several findings regarding speed, key terrain, and multi-domain dominance. The concept narrows multi-domain dominance looking at the air domain specifically and ways by which remote and autonomous technologies can assist Marine Corps aviation to become more flexible and efficient.

[48] Jonathan Frerichs, "Maneuvering in a Megacity: Case Study of Grozny and Medellin" (unpublished manuscript, November 17, 2014), Microsoft Word File.

TIME HORIZON AND RISKS

Imagine an increasingly bold and ambitious Boko Haram striking far to the southwest of their current territory in Borno State, Nigeria. Imagine this group rapidly moving through Nigeria and establishing a foothold within Lagos. Lagos, the largest city in Africa and 19th largest in the world, has an urban population of about 13 million people.[49] Irrespective of the likelihood, the time horizon for the requirement to be able to operate within a megacity environment is, for all intents and purposes, now.

By and large, the technology the Marine Corps needs to facilitate non-traditional intelligence, surveillance, and reconnaissance (NT-ISR), targeting, and fires within a megacity already exists. Micro Air Vehicles (MAVs), Unmanned Aircraft Systems (UASs), and Remotely Piloted Vehicles (RPVs)[50] already exist within the military's inventory. RPVs are what we generally think of as "drones." They are a subset of Unmanned Aircraft Systems. A true UAS does not require human interaction beyond the planning phase, the aircraft autonomously flies its mission. A pilot or controller "flies" an RPV through all stages of flight. British armed forces currently use similar small air vehicles in an unarmed role.[51] However, the Marine Corps should develop creative doctrine for their use. Swarming[52], pre-programed, or autonomous vehicles can add great

[49] World Urbanization Prospects: 2014 Revision, *United Nations World Urbanization Prospects: 2014 Revision* (New York, NY: United Nations, 2014), 26.
[50] For purposes of this paper, the term "small air vehicles" describes the multiple types of aircraft defined by the terms MAV, UAS, and RPV.
[51] "The UK's Unmanned Roadmap." *Military Technology* 37, no. 12 (December 2013): 76. *http://search.ebscohost.com* (accessed February 15, 2015).
[52] "The Drones of the Future Will Work in Flocks," Joe Pappalardo, *Popular Mechanics*, last modified January 23, 2015, http://www.popularmechanics.com/flight/drones/a13688/drone-teams-pentagon-darpa-code-17663303/?%3Fsrc=rss

flexibility with which the ACE can provide ISR and targeting capability that traditional rotorcraft and fixed-wing aviation cannot provide within a megacity.

MILITARY PROBLEM

In order to be successful in any military operation, a military force must gain and maintain the initiative and domain dominance through speed, surprise, and conducting operations rapidly. Marine Corps Aviation faces several problems within this concept of victory in a megacity or extremely dense urban environment. With current tactics, techniques, and procedures (TTP) and current capabilities, none of these problems are un-surmountable but future adaptations and creative solutions will make victory easier for the Marine Corps. An easier and faster victory with less collateral damage is an obvious benefit. If military operations in a megacity affect fewer non-combatant lives and property, non-combatants are less likely to be aggrieved and thus less likely to take up arms against friendly forces. Some major military problems facing Marine Corps aviation units fighting in a megacity are:

- Maneuverability in the confines of a megacity
    - Threat envelopes and reaction time. For instance, the RPG-75 has an approximate range of 200m against a moving target. The rocket fires at 189m/s (in excess of 400mph) and flies for somewhere between 3-6 seconds before self-destruction.[53] The SA-7B "Grail" has a 5km range,

[53] "RPG-75 Light Anti-Armor Weapon," Jane's Online, *Jane's Infantry Weapons,* accessed on March 4, 2015. https://janes-ihs-com.lomc.idm.oclc.org/CustomPages/Janes/DisplayPage.aspx?DocType=Reference&ItemId=+++1361259&Pubabbrev=JIW_

flying at nearly 385m/s (in excess of 800mph).[54] The ability to see and react to a system like either of these is limited within the urban environment due to the canalization if flying below the top of building or from reduced identification and reaction time because of the distractions created within the urban environment (sun reflecting off glass, lights, etc.).

- ISR capability
    - Specifically with respect to viewing angle of traditional ISR and NT-ISR platforms. For example, it is difficult to see into a building by using traditional ISR tools like a geo-synchronous satellite stationed 23,000 miles[55] above the battlespace. Other traditional ISR tools like fixed wing aircraft and drones have similar limitations. Unlike traditional and non-traditional ISR platforms, small air vehicles can fly level with the target upon which they are attempting to gather information.
- Optical sensor capability
    - Night Vision Devices (NVD) to include Infra-red cameras
- Ability to attack specific targets with little or no collateral damage to surrounding spaces

In the next few sections, this paper matches the above military problems with potential solutions, new technology, and recommended tactical employment changes. These

[54] "9M32 Strela-2 (SA-7 'Grail')," Jane's Online, *Jane's Air-Launched Weapons*, accessed March 4, 2015. https://janes-ihs-com.lomc.idm.oclc.org/CustomPages/Janes/DisplayPage.aspx?DocType=Reference&ItemId=+++1307230&Pubabbrev=JALW

[55] "U.S. Air Dominance in a Fiscally-Constrained Environment: Defining Paths to the Future – Intelligence, Surveillance and Reconnaisance," Loren B. Thompson, *The Lexington Institute*, last modified March, 2013, http://lexingtoninstitute.org/wp-content/uploads/2013/09/AirDominance-ISR.pdf.

solutions take into account the findings gleaned from a recent case study of the Japanese invasion of Singapore in 1941.

CONCEPT OVERVIEW

The Japanese invasion of Singapore case study provides several pertinent findings to this concept. The Japanese were able to overwhelm the massed British forces by creating the semblance of a mass of their own. The Japanese traded consolidated mass for the ability to maneuver quickly. The Japanese also maintained dominance in multiple domains, land, air, and sea. By dominating these domains and controlling key infrastructure, the Japanese were able to overwhelm the British defenses on Singapore and capture the island. This concept seeks to answer the question of how the Marine Corps can take those lessons of multiple domain dominance, speed, and mass to impact the future of warfare in the modern dense urban environment. The concept specifically focuses on the air domain in and above the city.

The Marine Corps set out a vision of distributed operations in the *Expeditionary Force 21 (EF21)* Capstone Concept.[56] To support the operational intent found therein, the Marine Corps should entertain creative conceptual solutions. The Marine Corps should similarly entertain creative solutions for operations within a megacity. This concept entails use of UAS, MAV, and RPV systems to augment traditionally piloted aircraft. This concept's operating theme is the coordinated operation of traditional aircraft and small air vehicles. To support this concept, small air vehicles can assist the commander in three distinct ways: 1) flying in concert/close proximity to traditional aircraft in support of the mission,

[56] Headquarters U.S. Marine Corps, Expeditionary Force 21 (Washington, DC: U.S. Marine Corps, March 4, 2014), 11.

2) providing real-time non-traditional intelligence, surveillance, and reconnaissance (NT-ISR) capability, and 3) supporting attack and assault support aircraft by providing close air support or NT-ISR support to close air support aircraft.

The Marine Corps creates opportunity for the ground commander by exploring the collection of capabilities created by development of modern technologies like small air vehicles. As explained below, small air vehicles provide an opportunity for the ground commander to increase his ISR collection, ability to expand assault support missions, and reduce collateral damage while destroying point targets.

APPLICATION AND INTEGRATION OF MILITARY FUNCTIONS

MANEUVERABILITY

As previously discussed, the dense urban terrain of a megacity restricts maneuverability for traditional UAS and aircraft systems. In order to maintain sufficient reaction time to enemy threat systems, aircraft must fly above the urban horizon. Ensuring traditional aircraft fly above the cityscape allows additional time for aircraft survivability systems (ASE) and aircrew to react to enemy weapons systems. The ubiquitous RPG supports this argument. With a 200-400m range, travelling at approximately 400mph, aircraft have about 2.1 seconds to react. Reaction time within an urban environment is complicated further by buildings (if flying in or near an urban center) and the ability to identify the threat against the background clutter. Though they likely would not have substantial ASE, smaller air vehicles are less expensive in both monetary and human capital, thus their loss is more easily accepted. Small air vehicles are not limited by ASE requirements therefore they can maneuver in an urban environment in unprecedented ways. The flexibility small air vehicles provide to aviation maneuver not only yield better

information to the commander and opportunities for manned aircraft to perform tasks to which they are better suited.

The Marine Corps describes both need and method for distributed operations using the F-35 Joint Strike Fighter and other elements of the Marine Air Ground Task Force (MAGTF). A presentation called "F-35 Joint Strike Fighter and Distributed STOVL (Short take-off, vertical land) Operations" defines distributed STOVL operations (DSO) as:

> A threat-based limited objective operation which occurs primarily when the entire MAGTF cannot be brought to bear against the enemy. DSO asymmetrically moves inside of the enemy targeting cycle by using multiple mobile forward arming and refueling points (M-FARPs). Using existing infrastructure (multi-lane roads, small airfields, damaged main bases), DSO provides strategic depth and operational resiliency to the joint force.[57]

Using small air vehicles in addition to current traditional platforms will allow the MAGTF greater flexibility in conducting DSO. Small air vehicles support DSO from a logistical perspective and a close air support perspective.

LOGISTICAL SUPPORT OF DSO

Platforms like the Lockheed-Martin / Kaman K-MAX could provide the MAGTF greater flexibility while reducing requirements for traditional aircraft conducting logistics missions. The Marine Corps used two K-MAX aircraft in Afghanistan starting in 2011 to great acclaim.[58] The K-MAX could increase ability to conduct DSO with fewer logistical

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[57] Headquarters Marine Corps, "F-35 Joint Strike Fighter and Distributed STOVL Operations," *Marine Corps Aviation Plan 2015*, 2.3.7, accessed February 10, 2015, https://marinecorpsconceptsandprograms.com/sites/default/files/files/2015%20Marine%20Aviation%20Plan.pdf.

[58] Mike McCarthy, "Post Afghanistan: What's Next For Marines' K-MAX And Unmanned Cargo Supply?," *Defense Daily* 258, no. 24 (May 2013): 10. http://search.ebscohost.com/.

requirements on other MAGTF aircraft that may be needed for more sensitive missions. As of July 2014 the K-MAX was not a program of record.[59] K-MAX, or a similar system, can easily conduct logistical support to DSO by ferrying fuel or armament to specified M-FARP locations. Using K-MAX in addition to CH-53E and MV-22B assault support aircraft supports greater flexibility by allowing aviation assets to spread-load across the battle-space without increasing manned mission requirements.

CAS SUPPORT OF DSO

A traditional Marine Expeditionary Unit (MEU) deploys with four AH-1W/Z Cobras, two UH-1N/Y Hueys, and six AV-8B Harrier IIs. The F-35B Joint Strike Fighter will replace the Harrier IIs within the next several years. Small air vehicles could provide additional CAS capability and flexibility in the conduct of DSO. By conducting the DSO mission with both manned and unmanned CAS systems, the MEU can spread its capabilities more widely.

INTEGRATION

Instead of these tools being separated by time, space, and altitude, they fly together to conduct their mission. Small air vehicles flying in close proximity to traditional aircraft creates problems. For instance, no helicopter pilot wants a small air vehicle (regardless of size) flying into the helicopter's rotor systems. A solution to this problem is a proximity signal that prohibits the small air vehicle from coming within a certain distance from the aircraft. If the small air vehicle is "slaved" to the traditional aircraft ("master") and mirrors its flight, all while maintaining a safe distance, the likelihood of a collision

[59] "K-MAX ends Afghanistan deployment, USMC studies data," Marina Malenic, *IHS Jane's 360*, last modified July 24, 2014, http:// http://www.janes.com/article/41190/k-max-ends-afghanistan-deployment-usmc-studies-data

should be reduced to nil. Without modifying existing airframes, small air vehicles can be used in the manner they are used today wherein the aircraft are programmed for the mission at a certain airspeed, altitude, and route. The traditional aircraft simply separate from the unmanned systems by time, space, or altitude. For logistical missions, the traditional means of separation supports the concept but the same method of separation would not realize the same results in conduct of a close air support (CAS) mission. For the CAS mission, a "slave – master" relationship between the traditional platform and the small air vehicle would likely provide the best support.

Small air vehicles capable of swarming benefit ground and air commanders. The additional requirement will be for additional analysts or information managers for the information swarming air vehicles produce. To translate information produced by swarming drones into actionable intelligence, the intelligence structure within the MAGTF will require modification. Swarming air vehicles also serve to overwhelm enemy defenses.[60] An ultimate goal might be individual maneuver units as small as squads or fire teams having the capability to deploy multiple small air vehicles in support of fire and maneuver.

In August 1997, the Marine Corps Warfighting Laboratory conducted a 12-day experiment at the Marine Corps Air Ground Combat Center in Twentynine Palms, California. The Hunter Warrior Advanced Warfighting Experiment "took a look at enhancing Marine units' effectiveness by utilizing a combination of experimental

[60] Joint Air Power Competence Center, *Remotely Piloted Aircraft Systems in Contested Environments* (Kalkar, Germany: Joint Air Power Competence Center, 2014), 101.

equipment and new warfighting tactics and techniques."[61] The experiment realized that mixing traditional capabilities with new technologies showed that a small Marine Corps unit could "provide a forward afloat force with the capability to have an operational effect on a larger, capable foe. Hunter Warrior proved that it can be done, but not by using new technology alone."[62]

ISR AND TARGETING

Flying above the city restricts viewing angle to a relatively vertical line of sight. Top-down angles create a dilemma within the megacity especially where high-rise buildings dominate the cityscape. Vertical look angles limit ISR, targeting, and fires to top down approaches. In a megacity, top-down ISR allows the analyst access only to what is un-obscured by various structures. Similarly, top-down angles limit targeting and fires to rooftops, entire buildings or open spaces. Destroying entire buildings is unacceptable in a megacity where limiting collateral damage should be a priority. Smaller air vehicles level the look angle allowing greater visual access to previously inaccessible places. Additionally, small air vehicles can augment current platforms in the megacity environment. Imagine the following scenario: attack helicopters conducting an escort mission deploy a number of swarming MAVs that provide the aircrew with ISR of

[61] U.S. Marine Corps, "Findings Released on Hunter Warrior Advanced Warfighting Experiment," news release August 22, 1997, http://fas.org/irp/news/1997/usmc_970822c.htm.
[62] U.S. Marine Corps, "Findings Released on Hunter Warrior Advanced Warfighting Experiment," news release August 22, 1997, http://fas.org/irp/news/1997/usmc_970822c.htm.

specific terrain, a route, or objective area. Those MAVs could increase the situational awareness of the escort helicopters by expanding the visual range of the aircrew.[63]

OPTICAL SENSOR CAPABILITY

As mentioned previously, operations in a dense urban environment have detrimental effects on optical sensors.[64] One possible solution is removing the limitations to these sensors by mounting them onto small air vehicles. By mounting a low-light video camera on a small air vehicle, limitations such as thermal reflectivity and detrimental affects of cultural lighting can be eliminated. Imagine a small air vehicle affixing itself to the outside of a building allowing a camera to be placed immediately against the outside surface of a window. This theory requires continued advancement of optical sensors and technology. This research does not address battery capacity but technology exists to allow small drones and MAVs to recharge via pre-staged inductive charging stations.[65] These technologies exist, the Marine Corps should be willing to creatively use them and develop operating concepts with these tools in mind.

MINIMIZING COLLATERAL DAMAGE

Minimizing collateral damage in a megacity is not only a moral obligation; it may also be a military imperative. Innocent civilian and non-combatant deaths may urge previously

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[63] Prox Dynamics developed and manufactured a production quality helicopter "nano air vehicle" called the PD-100 Black Hornet PRS. The entire system (including two air-vehicles) weighs 1.3kg for a system capable of 1.5km video datalink and 25 minutes of flight.
"PD-100 Black Hornet PRS," proxdynamics, http://www.proxdynamics.com/products/pd-100-black-hornet-prs.

[64] Nathan Storm, "Megacities I: Megacities vs. Aviation Doctrine'" (Unpublished manuscript, November 17, 2014) Microsoft Word File.

[65] "Skysense Charging Pad," Skysense, last modified 2014, skysense.de.

non-combatants to take up arms with enemy combatant forces. Therefore, reducing collateral damage may tend to reduce the strength of enemy combatants. One method by which to provide precise fires is through the use of small air vehicles instead of traditional weaponry. One such concept under development by the U.S. Air Force Research Laboratory (USAFRL) and General Dynamics are weaponized small air vehicles capable attacking a specific person with little or no additional collateral damage.[66] Another technology pursued by the USAFRL is biologically inspired small air vehicles capable of adaptive flight.[67] Using similar technology, local commanders can target or reconnoiter key infrastructure, named areas of interest (NAIs), or numbered targets. These small air vehicles have the ability to enter specific buildings and find specific rooms once inside. These small air vehicles can discretely prosecute targets without unnecessary destruction.

These advanced capabilities will not be without a certain level of risk and cost. Any small air vehicle that does not autonomously fly its mission would certainly be at risk of being hacked by an adversary. The informed public would likely not accept a completely autonomous version of a micro air vehicle capable of targeting specific people. Therefore these vehicles would require authorization from some responsible actor leaving open a window of opportunity in which those vehicles could be hijacked. Likewise, the financial cost of developing a product thus described is likely to be relatively high. In today's fiscally constrained reality, this kind of project is likely to end up on the chopping block. Militarized micro air vehicles also impart a moral and public relation cost on the country

[66] "US Air Force Flapping Wing Micro Air Vehicle," video, 4:32, posted by theworacle, July 16, 2009, https://www.youtube.com/watch?v=_5YkQ9w3PJ4

[67] "WOW Technologies, BIO Inspired Flight for Micro Air Vehicles," video, 1:38, posted by Team AFRL, February 28, 2013, https://www.youtube.com/watch?v=qiDLHBalq-0.

that uses such technology. It is difficult to distinguish between the controversial drone strikes seen in the Middle East over the last few years and the potential use of militarized MAVs.

NECESSARY CAPABILITIES

The capabilities required for these small air systems are as varied as the six functions of Marine Corps Aviation. The realization of this concept requires continued technological development and creative application of technologies already in existence. Small air vehicles promise flexibility in their use. Developers (civilian and military alike) must also be flexible in imagining a future of unmanned air vehicle use. Likewise, future leaders should see use of small, unmanned air vehicles as augmenting traditional manned aircraft. These systems should operate in concert, not independently of each other. The paradigm by which manned and unmanned vehicles do not mix should change; the future of Marine Corps aviation is maximized by teamwork between manned and unmanned systems. The Marine Corps should develop and exercise opportunities to test the operational feasibility of small air vehicles. These technologies, though they currently exist, require continued development, use, and testing.

CONCLUSION

This concept is a creative solution to an exceedingly difficult problem. One can only accept an attempt to distill warfare in a dense urban environment like a megacity to a short document like this for what it is. This is one person's offering to solve one perspective of war fighting within a megacity. Using small air vehicles to augment, support, and extend current aviation capabilities will take time, experimentation, and

patience. The majority of technologies mentioned in this concept already exist, though, and their potential uses are limited by our own ambitions. The British Army bought 160 Black Hornet MAVs for $20M.[68] Likewise, for a relatively small sum, the Marine Corps might invest in similar technology that could greatly expand Marine Corps Aviation capabilities.

This concept is not merely a collection of current and future capabilities but shows a possible future in which the Marine Corps can be better prepared for warfare in a dense urban environment like a megacity. Current Marine Corps capabilities prove the force as capable of dominating the ground and rooftops. The concept offers a means by which the Marine Corps can also dominate the space in between – in a megacity, this space is within the individual buildings. The capabilities offered herein create an opportunity for the ground combat element to better effect its mission.

[68] 'Spy Master' 2013, *Aviation Week & Space Technology*, 175, 7, p. DT20, Academic Search Premier, EBSCO*host*, viewed 15 February 2015.

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