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NATIONAL DEFENSE UNIVERSITY

JOINT FORCES STAFF COLLEGE

JOINT ADVANCED WARFIGHTING SCHOOL



FUTURE AUTONOMOUS ROBOTIC SYSTEMS IN THE PACIFIC THEATER

by

Seth Thornhill

LCDR, US Navy

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Seth Thornhill

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A paper submitted to the Faculty of the Joint Advanced Warfighting School in partial satisfaction of the requirements of a Master of Science Degree in Joint Campaign Planning and Strategy. The contents of this paper reflect my own personal views and are not necessarily endorsed by the Joint Forces Staff College or the Department of Defense.

This paper is entirely my own work except as documented in footnotes.

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ABSTRACT

On nearly every list of emerging technology expected to change the world are autonomous robotic systems (ARS). Over the next five to ten years, ARS will develop greater functionality and assume more roles that are performed by humans today. The number of ARS employed by the Department of Defense (DoD) will also grow and become an integral part of the US military. However, private industry and other countries are also heavily investing in this field of technology, and the advantages and innovations of ARS will not be held solely within the DoD. The US Pacific Command (PACOM) will be at the forefront of the challenges facing the United States with the development of this technology as it contends with technological savvy allies (South Korea and Japan), competitors (China), and adversaries (North Korea and violent non-state actors). PACOM must advocate that research and development funding be allocated to ARS acquisition programs. ARS technology will enable PACOM to find solutions to the challenges it faces and enhance a host of its military missions to include surveillance and how to counter adversary's efforts to deny US power projection.

DEDICATION

I dedicate this thesis to the service men and women of the US Pacific Command in the hopes it provides useful insight and understanding of an emerging technology that I believe will transform our military in the next five to ten years.

ACKNOWLEDGEMENT

Thank you to my thesis advisors for their patience, advice, and constant encouragement in my research and writing for this thesis. Much gratitude has to be expressed to Dr. Phillip Saunders for providing outstanding guidance and resources that were of great benefit. I also need to thank my fellow classmates for helping me stay focused, avoid the bitterness, and not lose sight of the big picture.

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Table of Contents

ABSTRACT.....	i
DEDICATION.....	ii
ACKNOWLEDGEMENT.....	iii
Introduction.....	1
Chapter 1 – Current Trends in Technology.....	1
A. Robotics.....	3
1. Unmanned Aerial Systems.....	4
2. Sentry Robots.....	5
B. Miniaturization.....	7
C. Autonomy.....	9
Chapter Two - Technology Convergence.....	14
A. Non-Lethal Systems.....	15
1. Aerial Surveillance.....	15
2. Maritime Operations.....	20
3. Land Systems.....	21
B. Lethal Systems.....	23
Chapter Three – Future Challenges and Recommended Solutions.....	25
A. Anti-Access / Area Denial.....	25
B. The Battle for the Strategic Narrative.....	26
C. The Tyranny of Distance.....	28
D. Killbots.....	29
E. The Way Ahead.....	31
Conclusion.....	34
Bibliography.....	35

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Introduction

Four years ago, the United States federal government began to shift focus and resources towards Asia and the Pacific nations. Representing over half of the world's population with two of the three largest economies, the region is a growing vital force in the global economy. Conversely, nationalist movements and deep-rooted animosity born from centuries of violent conflict and present struggles threaten the delicate order. The US Pacific Command (PACOM) strives to maintain stability and international law in the most militarized part of the world. It relies heavily on building partnerships and alliances based on common interests with other nations, but PACOM "is first and foremost a war fighting command, committed to maintaining superiority across the range of military operations in all domains."¹ The technological advantages and capabilities of its armed forces give PACOM the means to sustain its superiority in military operations. PACOM must contend with countries ranging from openly hostile (North Korea) to uncertain (China) to friendly (Japan), all of which possess high technological capabilities. In essence, PACOM must maintain its military technological superiority in all domains while overcoming the vast distances within its area of responsibility in the most technological, militarized region in the world.

As PACOM wrestles with the significant challenges of the Asia-Pacific-Indo region of the world, three areas of technology are converging to create new opportunities to assist PACOM with its mission, but this convergence will also present dire threats such as robots that employ lethal force without human consent. Robotics, autonomy, and miniaturization have existed for

¹ US Pacific Command, "USPACOM Strategy," <http://www.pacom.mil/AboutUSPACOM/USPACOMStrategy.aspx> [accessed December 3, 2014].

decades, but now they have advanced to the point where they will combine to create robotic systems that can perform highly complicated functions without human operators in extremely mobile and durable platforms. The signs of this convergence are seen today in the rapid rise of the number of unmanned systems (but still human-operated) used by the world's militaries. Within the next five to ten years, these unmanned systems will become increasingly autonomous. At the same time, China's aggressive posture towards its neighbors jeopardizes the partnerships that PACOM has labored to maintain. South Korea, Japan, India, and Vietnam all feel threatened by China's growing power. Its technological advancement poses potential problems to US power projection in the East and South China Sea through its improvements in anti-access / area denial (AA/AD) capabilities. Autonomous robotics designed to kill humans are becoming more capable, and more entities are striving to acquire them. PACOM can find solutions to its strategic challenges in emerging autonomous robotic systems (ARS) technology and acquire new methods to accomplishing a host of missions.

Chapter 1 – Current Trends in Technology

Overall, technology is advancing at an increasing rate. One principle driver of this trend is the microprocessor transistor count over the last forty years (Figure 1).

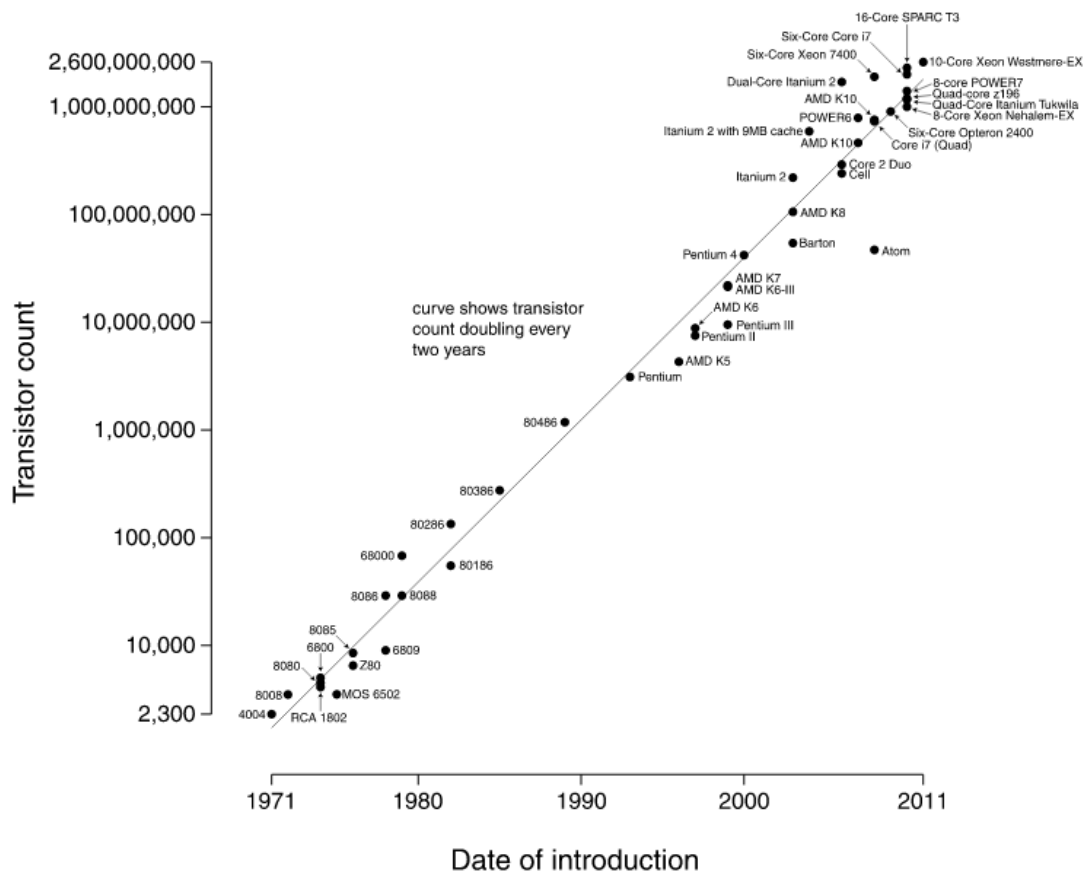


Figure 1 – Microprocessor Transistor Count 1971-2011 on a logarithmic scale¹

Like the power of compound interest, the processing power of computers is growing exponentially as the number of microprocessor transistors doubles approximately every two years (also known as Moore's Law). It took forty years for processing power to reach 1 billion,

¹ Brad Chacos. "Breaking Moore's Law: How chipmakers are pushing PCs to blistering new levels." *PC World*. April 11, 2013. <http://www.pcworld.com/article/2033671/breaking-moores-law-how-chipmakers-are-pushing-pcs-to-blistering-new-levels.html> [accessed December 3, 2014].

and now each two year iteration increases the transistor count by billions. Continuing this trend into 2015, the transistor count will be 9.6 billion. In other words, the microprocessors in 2015 will be over three times as powerful as the ones in 2011 when IBM's Watson supercomputer defeated two human players on the show Jeopardy. Both robotics and autonomy rely on the computing power of microprocessors, and its exponential growth in turn directly correlates to the growth of these technological fields.

A more troubling trend is the multitude of businesses and countries investing heavily in robotics, miniaturization, and autonomy. In the past, the US military-industrial complex led the way in technological advancement such as guided munitions, computer networking, satellites, and global positioning. The US military has long maintained a technological advantage over its adversaries such that many of its defense strategies rely on having this edge over its adversaries. Today, the global demand for advances in robotics, miniaturization, and autonomy have encouraged other countries and private enterprise to devote large efforts to research and market new innovations. Teal Group estimates just for the Unmanned Aerial Vehicle (UAV) market, spending will "almost double over the next decade from current worldwide UAV expenditures of \$6.6 billion annually to \$11.4 billion."² At the present moment, the UAV market is dominated by the US military, but its market share declines each year. With spending estimated at \$4-5 billion annually for the next four years, DoD will lose the majority of the UAV market share within three years as other militaries and corporations in the world rapidly enter the UAV market.³ Between 75 and 87 countries have unmanned aircraft (including Australia, China, India, Japan,

² Tim Storey, "Teal Group Predicts Worldwide UAV Market Will Total \$89 Billion in Its 2012 UAV Market Profile and Forecast," *Press Release Newswire*, November 11, 2012.

³ Department of Defense, *Unmanned Systems Roadmap: FY2013-2038*, Washington D.C.: Department of Defense, December 2013, pg 3.

Philippines, and South Korea), of which 26 countries utilize armed drones like DoD's MQ-1 Predator.⁴ Unlike past technological advances that were utilized primarily by DoD, robotics and autonomy will be available and employed by entities other than the US military. PACOM faces the challenge of having to adapt these technologies faster than its adversaries to stay ahead.

Revolutionary innovations in many areas of technology are currently under development, but this thesis will focus on robotics, miniaturization, and autonomy. Cyber warfare will continue to evolve and be a part of future warfare, but DoD has already established Cyber Command as a clear signal that it recognizes the important role of how cyber will alter future warfare. Breakthroughs in biology and energy will also be significant for PACOM, but the timeline and cost of these innovations are unclear. However, advances in the fields of robotics, miniaturization, and autonomy are in the near future, and the convergence of these three technologies will create new opportunities and challenges for PACOM. The following sections outline what is available today in order to establish a baseline for what is to come in the next five to ten years.

A. Robotics

The field of robotics has existed for decades, and the DoD fully expects their use will grow since “unmanned systems have proven they can enhance situational awareness, reduce human workload, improve mission performance, and minimize overall risk to both civilian and military personnel, and all at a reduced cost.”⁵ Currently, the vast majority of robotic systems in DoD have not replaced humans, but work in conjunction with them to augment their missions.

⁴ P.W. Singer, “The Global Swarm: Drones are not only spreading to other countries, they’re becoming smaller and smarter,” *Foreign Policy* (March 13, 2013), http://foreignpolicy.com/2013/03/11/the-global-swarm/?wp_login_redirect=0 [accessed December 7, 2014].

⁵ Department of Defense, *Unmanned Systems Roadmap: FY2013-2038*, Washington D.C.: Department of Defense, December 2013, pg 20.

Having proven their utility in combat operations, robotic systems will continue to be funded and developed at an increasing rate.

1. Unmanned Aerial Systems

The DoD maintains an inventory of over 10,000 unmanned aerial systems (UAS). These platforms range in size from small drones the size of a backpack designed for intelligence gathering and surveillance (RQ-16 T-Hawk) to the size of a biplane (MQ-9 Reaper) that carries ordnance to deploy against enemy forces.

While the vast majority of UASs in use today are used for military applications, this trend will shift towards private use as UASs become more marketable and usable for commercial profit. Corporations will develop future innovations in this market and sell them to customers throughout the world, making it harder for the US military to maintain its edge of having the most advanced UASs in the world. Each year the private sector incorporates more UASs into its business functions. Countries including Japan, Australia, Canada, and the United Kingdom allow commercial enterprises to operate aerial drones. Japan uses them to apply fertilizer and pesticide to their agriculture fields, and Australia has issued over 180 permits for businesses to use drones in photography, surveying, and other lines of work.⁶ American corporations have submitted applications to use drones for activities such as electric power line monitoring and precision agriculture, but their global competitors are already employing this technology. The Federal

⁶ United States Government Accountability Office, “Unmanned Aerial Systems: Efforts Made Toward Integration into the National Airspace Continue, but Many Actions Still Required,” Report# GAO-15-254T, (Washington D.C.: GAO, December 10, 2014), 14.

Aviation Administration heavily restricts the use of drones in American airspace, and it has not yet reached a conclusion for how to integrate UASs into the national airspace framework.⁷

Demand for aerial drones is also high among private citizens. They are easily purchased from Amazon and other web-based retailers. Websites like www.diydrones.com sell the materials to build custom drones of various sizes and provide auto-pilot software. Privacy is a growing concern as many people have equipped drones with cameras, while other enthusiasts have equipped them with paintball guns.⁸ This has law enforcement agencies very concerned since it is a small step away from citizens arming aerial drones with actual firearms. The video game company Activision already built a quad-rotor prototype armed with a submachine and plastic explosives for \$2,000 as a marketing ploy for the release of its game “Call of Duty: Black Ops II.”⁹

2. Sentry Robots

Other countries have turned to sentry robots to augment defense perimeters. Along the 160 mile de-militarized zone (DMZ), South Korea installed SGR-1 stationary robotic guards, armed with a 5.5mm machine gun and a 40mm grenade launcher.¹⁰ Using motion and heat sensors, the mechanized sentries scan for human-sized targets at a maximum distance of two miles (the DMZ is 2.5 miles wide) and alert the command center when a potential target has been found. South Korean officers then make the decision whether the target is a threat and have the

⁷ Federal Aviation Administration, “DOT and FAA Propose New Rules for Small Unmanned Aircraft Systems,” February 15, 2015, http://www.faa.gov/news/press_releases/news_story.cfm?newsId=18295 [accessed March 21, 2015].

⁸ <http://www.youtube.com/watch?v=rbpL3UwAYjo> [accessed December 10, 2014].

⁹ Brendan McGarry, “MQ-27: Infantry Drone of the Future?” *Defense Tech*, September 16, 2013, <http://defensetech.org/2013/09/16/mq-27-infantry-drone-of-the-future/> [accessed December 10, 2014].

¹⁰ Mark Prigg, “Who goes there? Samsung unveils robot sentry that can kill from two miles away,” *Daily Mail* [UK], September 15, 2014, <http://www.dailymail.co.uk/sciencetech/article-2756847/Who-goes-Samsung-reveals-robot-sentry-set-eye-North-Korea.html> [accessed February 4, 2015].

option of authorizing the SGR-1 to use its internal targeting protocol to fire on the target. Russia employs similar robotic sentries on five ballistic missile installations, except these are mobile and do not seek human authorization to engage lethal force.¹¹ Using a laser rangefinder and radar sensors, the Russian “mobile robotic complex” can patrol the installation perimeter at 45 kilometers per hour with a 12.7-millimetre heavy machine gun for 10 hours at a time.

Much like the computer, the major developments within robotics evolved from military research. However, once the technology became profitable for commercialization, private enterprise drove future innovations and made the technology globally available. Today computers are widespread and an integral part of society, but the US grapples with cyber warfare to secure its information systems. The same evolution will occur for robotics. The demand for this technology is profitable, and more companies are developing robotic systems to sell. However, the US will struggle to maintain an edge in a world where an individual operating alone can buy a drone for the sole purpose of arming it with explosives to attack government institutions.¹²

¹¹ David Hambling, “Armed Russian Robocops to Defend Missile Bases,” *New Scientist*, April 23, 2014, http://www.newscientist.com/article/mg22229664.400-armed-russian-robocops-to-defend-missile-bases.htm#.VM_-8GjF-XI [accessed February 4, 2015].

¹² Kevin Johnson, “Man accused of plotting drone attacks on Pentagon, Capitol,” *USA Today*, September 29, 2011, <http://usatoday30.usatoday.com/news/washington/story/2011-09-28/DC-terrorist-plot-drone/50593792/1> [accessed December 7, 2014].

B. Miniaturization



Figure 2 – The size of cell phones over time.¹³

Miniaturization refers to the trend of electronic systems becoming smaller over time. Cell phones and personal computers are two prime examples. For computers, not only are microprocessors becoming exponentially more powerful over time as shown in Figure 1, they are becoming smaller and lighter. In 2011, IBM's Watson supercomputer was the size of a master bedroom. Today, the same computer is the size of a bathroom. By 2020, IBM predicts Watson will be the size of a smartphone.¹⁴

If the world's most powerful computers of today will be handheld in five years, then it is necessary to understand what supercomputers are capable of doing today to gain a better understanding of what a smartphone computer will be able to do in 2020. These smartphone-

¹³ Kyle Bean, "Mobile Evolution," <http://www.kylebean.co.uk/portfolio/mobileevolution> [accessed December 11, 2014].

¹⁴ Lucas Mearian, "IBM: Watson Will Eventually Fit on a Smartphone, Diagnose Illness," *Computer World*, March 5, 2013, <http://www.computerworld.com/article/2495890/high-performance-computing/ibm--watson-will-eventually-fit-on-a-smartphone--diagnose-illness.html> [accessed November 23, 2014].

sized supercomputers will become the primary processing power (the “brains”) of the future autonomous robotic systems (ARS).

Today’s supercomputers possess an incredible ability to process vast amounts of data to find desired information. IBM currently runs a trial program in which doctors use Watson to give medical advice. A doctor asks Watson in plain language a question about a patient’s medical problem, and it accesses tens of thousands of medical records and research, compares them against the current patient’s medical history, and makes a diagnosis that has been proven to be accurate 90 percent of the time.¹⁵ “E-discovery” scans millions of legal documents for attorneys at greater accuracy, but far less cost than a human lawyer.¹⁶ Computers are also becoming more sophisticated at interpreting the environment. Facial recognition software being developed by Facebook can compare two facial images regardless of angle or lighting to determine with 97.25% accuracy whether the images are the same face.¹⁷ The future smartphones will thus be able to store astounding volumes of data, but also possess the capability of sifting through the data to find patterns and specific information to fulfill more advanced functions.

Microprocessors are not the only commodity that are decreasing in size as time progresses. Using carbon nanotube fabric, business suits can be made that are bulletproof and 50 percent lighter than Kevlar. A polo shirt that is capable of withstanding a 9mm bullet can be

¹⁵ Bruce Upbin, “IBM’s Watson gets its First Piece of Business in Healthcare,” *Forbes*, February 8, 2013, <http://www.forbes.com/sites/bruceupbin/2013/02/08/ibms-watson-gets-its-first-piece-of-business-in-healthcare/> [accessed December 20, 2014].

¹⁶ Sharon D. Nelson & John W. Simek, “BIG DATA: Big Pain or Big Gain for Lawyers?” *American Bar Association*, July/August 2013, http://www.americanbar.org/publications/law_practice_magazine/2013/july-august/hot-buttons.html [accessed February 4, 2015].

¹⁷ Amit Chowdhry, “Facebook’s DeepFace Software Can Match Faces With 97.25% Accuracy” *Forbes*, March 18, 2014, <http://www.forbes.com/sites/amitchowdhry/2014/03/18/facebooks-deepface-software-can-match-faces-with-97-25-accuracy/> [accessed December 20, 2014].

purchased for \$7,500.¹⁸ Car engines and battery sizes are also becoming smaller as advances in miniaturization create new materials that can fulfill the same function better than their predecessors. This trend leads to future robotic systems becoming smaller, consuming less energy, but capable of performing more advanced functions than those today. Some of these higher functions will include navigating through the environment, interpreting the environment to find specific search criteria, and tracking multiple objects – man or machine.

C. Autonomy

Autonomy refers to robotic systems operating on their own under a pre-programmed set of instructions without human operators or supervision. When the system encounters variables that are not defined in the instructions, human intervention is needed to prevent the system from locking up or performing erratically. Autonomy is not to be confused with artificial intelligence, where robotic systems operate independently and self-correct without human operators.

From warehouse distribution to aerial flight, the trend of automation replacing humans continues to rise. Amazon.com utilizes a system of autonomous robots to meet its high volume order-fulfillment within the 48 hours promised by Amazon Prime. Within a massive warehouse of materials, Amazon uses automated robots to bring goods to a central location where people pack and process the orders, saving the human staff from having to walk through the warehouse themselves to search for each individual ordered item. Over the course of 24 hours, each robot retriever travels twelve miles per day, taking five minute breaks per hour to return to a recharge

¹⁸ William Lee Adams, “Dressed Not To Be Killed,” *Time*, July 24, 2008, <http://content.time.com/time/magazine/article/0,9171,1826292,00.html> [accessed December 20, 2014].

station.¹⁹ The system has significantly reduced the time between when an order has been placed to when it is shipped.

The DoD has a long history of using ARS. It defines an autonomous weapon system as “a weapon system that, once activated, can select and engage targets without further intervention by a human operator.”²⁰ The Tomahawk missile was developed in the 1970s, and once fired, it operates under a pre-programmed flight path to travel to its target and detonate. With each progressive year, DoD adds more unmanned autonomous systems to its inventory. The Northrop Grumman’s X-47B UAV successfully launched and recovered autonomously from a US Navy aircraft carrier in 2013.²¹ During the testing, the X-47B detected an anomaly in its navigation computer and diverted itself to a previously assigned shore installation. The X-47B shows autonomy has advanced to where unmanned robotic systems can perform highly complex maneuvers such as landing on an aircraft carrier, but also detect errors within themselves and take corrective action. Troubled by Iranian speedboats harassing US aircraft carriers in the Straits of Hormuz, the Navy has developed its own autonomous speedboats designed to intercept incoming surface threats and block their approach to the US surface combatant.²²

Using robotic systems to follow or track an object continues to advance today as researchers push forward to develop ARS for tracking human targets. Since 1981, the Navy has

¹⁹ Rob Walker, “Amazon’s Warehouse Robots at Work and Play,” *Yahoo News*, November 20, 2014, <https://www.yahoo.com/tech/amazons-warehouse-robots-at-work-and-play-103129789109.html> [accessed November 22, 2014].

²⁰ Department of Defense, “Autonomy in Weapon Systems,” DoD Directive 3000.09 (Washington D.C.: DoD, November 21, 2012) <http://www.dtic.mil/whs/directives/corres/pdf/300009p.pdf>, pg 13.

²¹ US Navy, “X-47B Makes First Arrested Landing at Sea,” July 10, 2013, http://www.navy.mil/submit/display.asp?story_id=75298 [accessed December 22, 2014].

²² David Smalley, “The Future Is Now: Navy’s Autonomous Swarmboats Can Overwhelm Adversaries,” Office of Naval Research, October 5, 2014, <http://www.onr.navy.mil/Media-Center/Press-Releases/2014/autonomous-swarm-boat-unmanned-caracas.aspx> [accessed February 3, 2015].

utilized the SPY-1 high-powered transmitter to acquire and track multiple targets such as planes and missiles. DARPA has made significant strides towards this goal with the Legged Squad Support System. Built like a mechanized pack mule, this ARS will follow a human leader over any type of terrain while carrying 400 pounds.²³ Private industry is also working to develop this capability in the hopes of constructing service robots that will assist people in daily life.

Other countries are also investing in autonomous robotic systems. Britain's Taranis UAV autonomously searches and identifies targets, then seeks authorization from human controllers. Designed to fly faster than the speed of sound, the Taranis has a single wing stealth design to evade enemy radar.²⁴ China, PACOM's most significant competitor in technological advancement, is investing heavily in modernizing its military, prompting the Defense Science Board to speculate the possibility of China out-spending the US on unmanned systems in the future. In the past year "China unveiled details of four UAVs under development, three of which are designed to carry weapons."²⁵ China has armed UASs and considered using one to kill a drug trafficker in Myanmar in February 2013, but used a task force to capture the target alive instead.²⁶ A number of Chinese defense industries are researching UAVs to cover a broad spectrum of missions including strike, reconnaissance, stealth, ISR, and A2/D2.

²³Defense Advanced Research Projects Agency, "Legged Squad Support System," [http://www.darpa.mil/Our_Work/TTO/Programs/Legged_Squad_Support_System_\(LS3\).aspx](http://www.darpa.mil/Our_Work/TTO/Programs/Legged_Squad_Support_System_(LS3).aspx) [accessed January 31, 2015].

²⁴ Sarah Griffiths, "Britain's Deadly Superdrone Makes First Test Flight: Taranis Unmanned Military Vehicle 'Surpassed All Expectations' in the Air," *Daily Mail* [UK], February 5, 2014, <http://www.dailymail.co.uk/sciencetech/article-2552361/Britains-deadly-superdrone-makes-test-flight-Taranis-unmanned-military-vehicle-surpassed-expectations-air.html> [accessed November 23, 2014].

²⁵ U.S. Department of Defense, "Military and Security Developments Involving the People's Republic of China, 2014," Office of the Secretary of Defense, April 24, 2014, p. 33.

²⁶ Ernest Kau, "China Considered Using Drone in Myanmar to Kill Wanted Drug Lord," *South China Morning Post*, February 20, 2013, <http://www.scmp.com/news/china/article/1154217/china-considered-using-drone-myanmar-kill-wanted-drug-lord> [accessed January 7, 2015].

On a smaller scale, the general public has also demonstrated the capability of using personal robotic systems to navigate a closed course with obstacles and perform maneuvers. Sparkfun hosts an annual autonomous vehicle competition in which participants enter ground and air vehicles to navigate a course for cash prizes.²⁷ In the 2014 contest, Sparkfun required contestants in the UAV bracket to autonomously take-off, stay within the fly-zone, and hit two navigation points with bonus points awarded if they succeeded in dropping a tennis ball into a target area. DoD spent millions developing the software for an unmanned weapon system to fly and hit a marked target. Today the general public practices this capability to win a cash prize of \$1,000. In other words, autonomy is not solely being developed by state militaries or even large corporations, but also by the general public. The high level of interest and potential for profit in this field implies this technology will not be restricted to solely the military, for market forces will make this technology available to everyone.

Already world leaders sense the dangers of autonomous robotic systems, specifically ones designed to kill. Fearing the moral and legal implications of weapons that decide on their own whom to kill, United Nations Special Rapporteur Christof Heyns presented the controversial subject to the UN, calling for a moratorium on all development and use of lethal autonomous robots.²⁸ To date, no robotic systems have purposely killed without human operator's permission. However, this is primarily because the national leadership of the countries using the

²⁷ Sparkfun, "Autonomous Vehicle Competition," June, 2014 <https://avc.sparkfun.com/2014> [accessed December 22, 2014].

²⁸ United Nations, "A Call for a Moratorium on the Development and Use of Lethal Autonomous Robots," Office of the High Commissioner for Human Rights, May 31, 2013, <http://www.ohchr.org/EN/NewsEvents/Pages/ACallforamoratoriumonthedevelopmentrobots.aspx> [accessed November 20, 2014].

technology has chosen against using it, not because the capability is not there. Both the United States and Britain possess robotic systems that can kill autonomously, but their leadership demand human authorization before engaging lethal force.

Robotic systems have become more complex, automated, smaller, and cheaper to produce. At the same time, global demand, both military and private, increases each year while the US military's market share declines as corporations invest in these technologies for profit and countries pursue ARS to further national interests. Private citizens and extremist organizations are also observing the advancing trends in these technologies and seeking to utilize ARS for their own purposes. PACOM must not allow the current budget crises to prevent it from surrendering the opportunities of ARS to foreign competitors that will use them against US forces in the Pacific.

Chapter Two - Technology Convergence

The previous chapter covered technology in its current form and will be used to analyze how the convergence of robotics, miniaturization, and autonomy will create new challenges for PACOM, but also opportunities if it pursues them. In a time of budget reduction coupled with increasing manpower costs, PACOM can find solutions to its strategic challenges in emerging technology. With military personnel-related costs reaching 34 percent of the base budget in 2012, the cost of personnel and crew combat platforms continues to increase and force the Department of Defense (DoD) to siphon scarce resources from investment and procurement.¹ The vast size of the Pacific region presents obstacles to PACOM's capability of monitoring its area of responsibility (AOR) and quickly responding to crises. A military drawdown stands to worsen this problem. Not since the Soviet Union has the US military had to address the threat of anti-access/area denial (A2/AD) technology that would deny the US ability to project power into a region. China is developing and implementing this technology. DoD understands the rising costs and threat of A2/AD, resulting in a significant increase in the number of unmanned systems employed throughout the military and funding being allocated to research and develop further unmanned systems. Much of this research is specifically tailored to PACOM given the shift in strategic focus to the Asia-Pacific theater and the rising threat of operating in an environment where freedom of access is contested.²

¹ Robert O. Work and Shawn Brimley, *20YY: Preparing for War in the Robotic Age*, (Washington DC: Center for New American Security, January 2014), 21.

² Department of Defense, *Unmanned Systems Roadmap: FY2013-2038*, Washington D.C.: Department of Defense, December 2013, pg v.

A salient advantage a person has over an ARS is situational awareness. A human can see an object and interpret what it is far greater than an ARS (whether an object is a cat or a dog or if a man is holding a pistol or a power tool). This advantage is not likely to change over the next ten years. On the other hand, in seconds an ARS will be able to receive vast amounts of input from thermal or infrared imaging and compare with a stored database to find an approximate match for what it senses. For entities abiding by international norms, this approximation will only be accurate enough for surveillance and detection. For rogue organizations and states, the approximation will be close enough for lethal force.

A. Non-Lethal Systems

Research in integrating ARS with current ISR platforms and designing more maneuverable airframes will allow PACOM to monitor the vast distances within its area of responsibility as well as take over tasks that pose significant risk to human operators.

1. Aerial Surveillance

Today, surveillance UAVs can operate for extended periods of time. As sensors and autonomy improve and the cost of building them decreases, these missions can be turned over to ARS, especially in contested, non-combat areas such as borders between rival nations and controversial territories such as the Senkaku/Diaoyu Islands and the South China Sea. China claims sovereignty over both areas, but their claims are disputed by Japan, Vietnam, and the Philippines (Figure 3).

China's use of UAVs has also increased tensions in the region. In September 2013, Japan detected a Chinese unarmed BZK-005 UAV operating over the Senkaku/Diaoyu Islands, prompting the Japanese Prime Minister to approve plans to destroy foreign drones operating in

Japanese airspace including those operating over the disputed islands.³ China responded that such action would constitute an act of war.

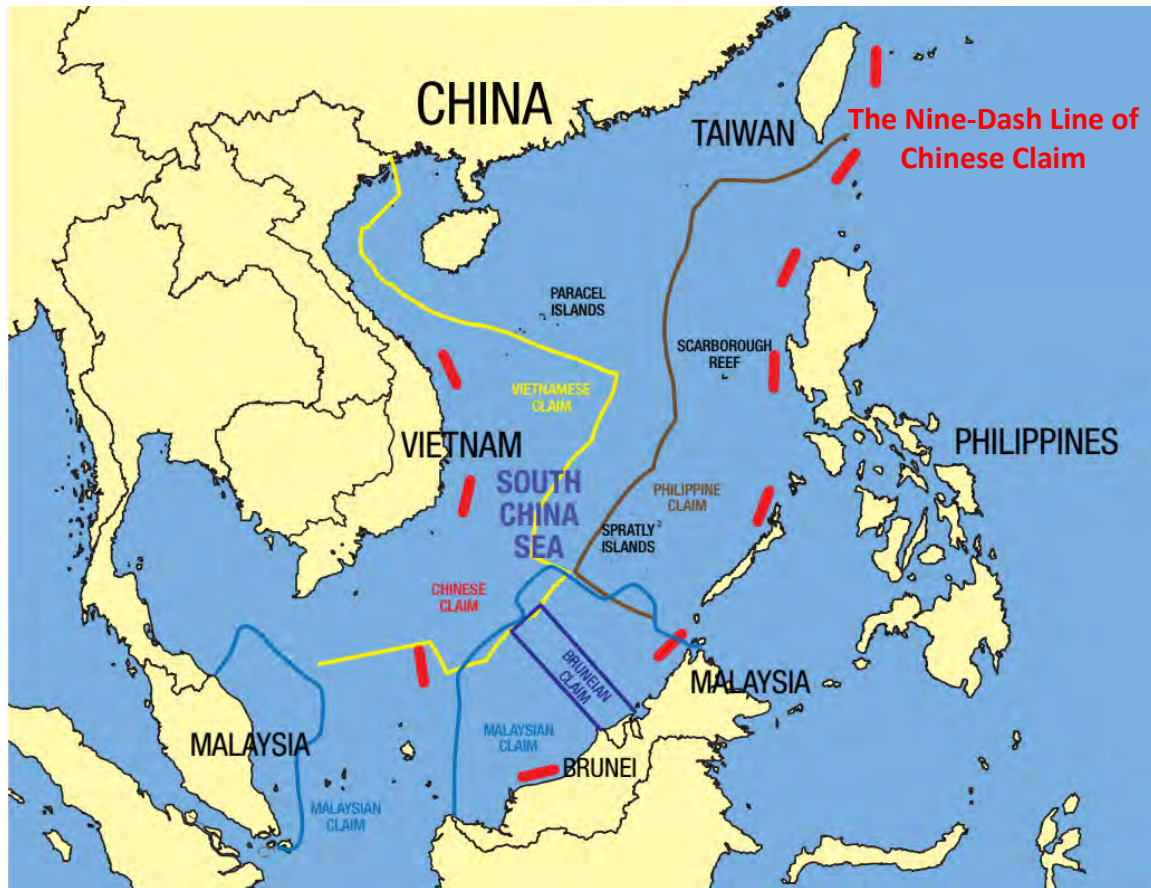


Figure 3 -- South China Sea Territorial Claims⁴

Annually, China imposes a ban on all fishing in the South China Sea from mid-May to August, increasing tensions within the region. Vietnam and the Philippines in particular have vocalized their opposition to China's right to impose regulations on territory that both countries view as outside of Chinese sovereignty. China, however, remains dedicated to enforcing its claims on these waters. In May 2014, a Chinese vessel rammed and sunk a Vietnamese fishing

³ Ankit Panda, "Japan to Shoot Down Foreign Drones" *The Diplomat*, October 22, 2013, <http://thediplomat.com/2013/10/japan-to-shoot-down-foreign-drones/> [accessed January 7, 2014].

⁴ U.S.-China Economic and Security Review Commission, "2014 Report to Congress," November 20, 2014, http://www.uscc.gov/Annual_Reports/2014-annual-report-congress [accessed January 31, 2015], p. 16.

vessel off the coast of Vietnam when it approached a Chinese oil rig that was constructed within Vietnam's claimed section of the South China Sea.⁵ At this time, China lacks the capability of monitoring every vessel operating in the region, but aerial ARS can help China further establish its hold on the South China Sea.

Using aerial ARS will be one method of acquiring continuous real-time data over a large area like the South China Sea or the Northern Limit Line (NLL) between North and South Korea. An ARS will be programmed to launch from its home station and return periodically to recharge. Its mission will be to monitor a designated zone to detect entities that either match or do not match a programmed target criteria. For example, China may deploy ARS to find surface vessels containing trawling nets for fishing, or South Korea may use ARS to locate and report on vessels near the NLL that do not match the known energy signatures and dimensions of Republic of Korea naval ships. Once a potential target has been found, the ARS relays footage and information of it to human operators and waits for a response to continue monitoring the target or search for others. This technology will enable countries to gain a greater operational picture over a vast area, and in this way, China will potentially increase its ability to govern the South China Sea.

ARS can operate from smaller, more austere locations than humans and extend the operational reach of a country. China is in the midst of constructing artificial islands in the South China Sea, near the Spratly Islands.⁶ On the Fiery Crossing Reef, China is reclaiming land just large enough to fit a 3,000 meter runway. Eight hundred miles from the mainland of China, this

⁵ Jane Perlez, "China and Vietnam Point Fingers After Clash in South China Sea," *New York Times*, May 27, 2014, http://www.nytimes.com/2014/05/28/world/asia/vietnam.html?_r=0 [accessed January 4, 2015].

⁶ James Hardy and Sean O'Connor, "China building airstrip-capable island on Fiery Cross Reef," *IHS Jane's Defence Weekly*, November 20, 2014, <http://www.janes.com/article/46083/china-building-airstrip-capable-island-on-fiery-cross-reef> [accessed January 28, 2014].

forward airbase will be an ideal location to employ surveillance ARS operating continuously as well as armed UAVs if lethal force is desired. Not only will ARS require less space to operate, but their reaction time will be considerably less than manned aircraft. Today when long range sensors detect an anomaly, manned aircraft scramble from a nearby airbase to investigate. The time from the moment the anomaly is detected to an aircraft on station to investigate can be greatly shortened if an aerial ARS is programmed to launch the moment the anomaly is detected at a significant cost-savings over using manned aircraft. This response time is even further decreased if the investigating aircraft operate from such forward locations as the artificial islands being created in the South China Sea.

Large cargo planes will provide an alternative to deploying aerial drones from land based stations. In 2014, DARPA initiated the research initiative to use planes as aircraft carriers in the sky for unmanned drones.⁷ In the *Mayaguez* incident in 1975, P-3 Orion aircraft based in the Philippines flew to the Indian Ocean off the coast of Cambodia to locate the *SS Mayaguez* after it had been seized by Khmer Rouge naval forces. Using the available intelligence of the time, President Ford ordered a Marine assault of the Koh Tang Island to rescue the crew of the *Mayaguez*, not knowing for certain whether the crew had been moved off the island or the composition of enemy forces. The US suffered eighteen casualties and three downed CH-53 helicopters in the assault, but the *Mayaguez* crew was rescued. Projecting this incident into the next 5-10 years, P-8 aircraft will carry multiple ARS that launch upon reaching the search area. Specifically programmed with the characteristics and signatures of the missing ship, each ARS within the aircraft scans its designated search zone, returning to the carrier to refuel or recharge

⁷ Defense Advanced Research Projects Agency, "Wanted: Ideas for Transforming Planes into Aircraft Carriers in the Sky," <http://www.darpa.mil/NewsEvents/Releases/2014/11/09.aspx> [accessed November 20, 2014].

as required. Once the *Mayaguez* has been found and identified, the ARS can switch immediately to reconnaissance of the surrounding environment, focusing on the areas that correlate with significant human presence and military hardware. Like today's security cameras that monitor sensitive areas, the constant surveillance provided by aerial ARS will provide real-time data about the conditions of its targeted area. More importantly, the intelligence gathering of enemy force numbers and position would have prevented the US *Mayaguez* rescue effort from being caught off guard by the larger than expected opposition force.

Two significant disadvantages of aerial ARS will be mitigated in the upcoming years, though a third will continue to limit their use in military settings. Today's low-flying UAVs are susceptible to small arms fire, making their utility in combat areas less effective since the enemy can more easily shoot them down. Constructing an ARS out of similar material used in bulletproof clothing discussed in Chapter One will protect this asset, allowing it to operate and provide intelligence on the battlefield. The battery life also limits the operational time of small UAVs to approximately an hour, but trends in miniaturization will continue to decrease the size of batteries and improve their capacity. Future ARS will hold multiple batteries, extending their flight time significantly. On the other hand, aerial ARS will still be easily detectable through visual sightings and radar technology. Incidents such as the Japanese response to China's UAV operating over the disputed Senkaku/Diaoyu Islands will occur more often as more countries employ this technology to patrol potential hotspots. Nations do not hold the same reservations over shooting down ARS versus a manned aircraft and will do so. Losing an ARS, though not as serious as the loss of a human operator, will still heighten tensions between rival nations and increase the chances for open conflict.

2. Maritime Operations

Maritime surveillance ARS will have several advantages over aerial ones that will compensate for their speed disadvantages. Their endurance is measured in days, possibly weeks as energy sources improve, versus hours. Operating below the water surface, these ARS will be harder to detect, making them ideal for reconnaissance as well as surveillance. Onboard sensors can be programmed to search for ships, submarines, or mines. After finding a match, the ARS can shadow the target and record its activities or relay coordinates of its location and move on to find others.

Maritime ARS can also be designed to accompany surface combatants to provide anti-submarine warfare. Considerably less cost than a manned submarine, these ARS can actively search for enemy underwater threats to prevent a similar occurrence to the one in 2007 when a Chinese submarine surfaced in the heart of the USS KITTY HAWK battlegroup.⁸ If the ARS detects an incoming torpedo, their quick reaction programming will act as a decoy or intercept the weapon itself to save the surface combatant.

Mine detection and removal will become a predominant mission for maritime ARS. Using today's mine detection technology to create automated programming can be combined with robotic systems that will carry out the task of locating the hazards and then neutralize them. One possibility is for a mine hunting ARS to search for metal objects within a designated depth range that are chained to the ocean floor or floating on the surface or just below the surface that also match the components and consistency of mines. Upon detection, the ARS attaches an

⁸ Matthew Hickley, "The uninvited guest: Chinese sub pops up in middle of U.S. Navy exercise, leaving military chiefs red-faced," *Daily Mail [UK]*, November 10, 2007, <http://www.dailymail.co.uk/news/article-492804/The-uninvited-guest-Chinese-sub-pops-middle-U-S-Navy-exercise-leaving-military-chiefs-red-faced.html> [accessed February 3, 2015].

explosive device, moves to a safe range, and detonates the mine. Several of these ARS platforms can operate in a designated area with a single manned minesweeper in the area to ensure the area remains clear of friendly and neutral vessels.

On the flip side, ARS become the mine created to hunt known signatures of enemy units. Once deployed within an area, the ARS remain mobile and actively seek their targets. The characteristics of US surface ships such as size, shape, and displacement are public knowledge, and ARS can use this knowledge to narrow its search to find only surface units that match this criteria. Objects that are rapidly approaching a ship in a straight line will immediately raise the alarm on the surface unit to deploy countermeasures, but if the ARS mimic the movement of sea life, they can close the gap and switch to strike mode when it will be too late for the target to react.

3. Land Systems

The advantages of ARS to utilize infrared and detection technology will greatly augment human sentries. A stationary ARS inside a guard post will scan continuously the environment for search criteria such as approaching military vehicles, UAVs, or human beings. The sentry ARS will not replace human guards, for they will still be needed for their situational awareness and ability to distinguish between threats and non-threats. The ARS capabilities, however, that can go beyond the abilities of human sight and sound will alert human sentries to the presence of potential problems and threats.

The capability of ARS to scan large areas to find targets that match a specific search criteria can assist PACOM in protecting its soldiers by locating hazardous material. Throughout the war in Iraq and Afghanistan, explosive devices posed a serious threat to US servicemen. ARS

programmed to locate explosive material can lead patrols or conveys in order to find the threat before the soldiers enter its kill radius. The ARS can scan for chemical or radiological hazards in addition to explosives, further providing a protective service to human soldiers. Should the regime of North Korea fall from power, this capability will be especially useful in locating their stockpiles of chemical and nuclear weapon. The size of the ARS can be very small and designed to move quickly and only detect threats, or it can be the size of a bulldozer, designed to not only find, but also neutralize explosives devices.

The search criteria on the ARS should include thermal imaging that matches human targets as well as scanning the environment to detect gunpowder or oils and solvents used to clean or lubricate firearms. This will allow the ARS to detect enemy troops before US soldiers are exposed to a possible ambush. Aerial ARS will not be sufficient to perform this mission as underground shelters or urban rooftops can block the view from above. Ground ARS can scout these danger areas to inform the friendly units behind of what potential threats lurk within.

Once secure supply routes are established, driverless vehicles can perform logistic conveys between bases. An ideal configuration for this convey is a lead vehicle equipped with sensors to detect and neutralize explosive devices. Following the lead ARS is a manned vehicle to provide situational awareness and carry a homing beacon. The remaining vehicles in the convey are ARS, programmed to follow the vehicle with the homing beacon. These ARS could utilize GPS instead to navigate to a destination, but in areas of the world where satellite communication is unreliable or sporadic, following a homing beacon provides an alternative to this challenge and a secure linkage that is more resistant to jamming signals.

B. Lethal Systems

The moral and ethical debate of allowing ARS to kill human targets is ongoing. The fear of Terminator-like machines and giving the responsibility (and liability) of taking human life to a robotic system has led to international condemnation in pursuing this technology. Human rights groups and think tanks such as University of Cambridge's Centre for the Study of Existential Risk believe this is a direct threat to all humanity.⁹ In the near future, the controversy will persuade countries that abide by international norms to avoid development of killer ARS, but rogue nations and violent non-state actors will pursue them nonetheless.

To construct a killer robot (killbot), one needs to combine the robot with lethal armament and a set of instructions on how to actively use it. Both robots and armament are widely available in the world today, and a Youtube search for "Paintball drones" will reveal the general public already possesses the knowledge of how to attach armament to an aerial drone and remotely operate it. The missing critical piece is the programming that automates the entire system. A specialist has to design the code that will instruct a robotic system to scan its environment to find an object that matches its desired target. Once found, the ARS will then utilize a targeting program to fire its armament. Such programming is too complex and enormous to fit on today's smartphone, but not for those that will exist in five years. "There's an app for that" will take on a more ominous meaning when the supercomputer smartphones in 2020 have the capacity of executing such programs. Black hat hacking groups write and sell malicious code today to attack networks and commit cyber crimes. These same nefarious, enterprising individuals or groups will develop the programs for killbots to sell on the black market. Another possibility is the same

⁹ Centre for the Study of Existential Risk, "Artificial Intelligence," University of Cambridge, <http://cser.org/emerging-risks-from-technology/artificial-intelligence/> [accessed January 25, 2015].

groups may steal the code from nations like Russia or South Korea who have already developed the code for their defense sentry ARS and adapt it for other systems. Rogue nations, such as North Korea who has already demonstrated its cyber capabilities in the recent network attack on Sony, will most likely research and develop the programs as well.

A multitude of “killer” applications are possible for the 2020 supercomputer smartphones. Using programs similar to Facebook’s facial recognition software, the ARS can be instructed to find a specific human target and open fire. More broadly, adversaries may design an application to search for people wearing clothing with a particular pattern, such as the camouflage uniforms worn by US soldiers, and then execute a suicide maneuver to explode at the center of the group. The killbot does not have to be an aerial drone. It can be a stationary device placed in an area where soldiers are known to patrol that detonates when they enter its kill radius. Like the applications of today’s smartphones, it requires only one imaginative individual to design the code that integrates the search protocol for a single individual or a particular vehicle class with the sensors. Once completed, the application can be sold to interested parties, who download it onto their smartphones along with an execution program that instructs the killbot what to do once its target has been found.

The quality of the sensors and coding will not be high enough for killbots to guarantee high success rates at executing lethal force against their intended targets. Moral arguments aside, the margin of error will be too great in the near future for countries concerned about collateral damage or killing the wrong targets. For organizations that have no inhibitions about using suicide bombers or killing innocents, they will accept the margin of error and use killbots. They provide a cost-effective means to kill the enemy and achieve the effect of striking fear into a population while not exposing the human perpetrators to enemy fire.

Chapter Three – Future Challenges and Recommended Solutions

Adversaries, allies, and competitors are just as interested in the opportunities presented by ARS technology and seek to acquire it. To maintain its technological advantage, PACOM must pursue developing and procuring ARS. If hostilities erupt, US forces may have to deploy to an environment where freedom to operate is contested, and the enemy's anti-area/area denial capabilities will spur PACOM to use ARS to prevent human loss of life. Lethal ARS will become a widespread reality in the near future when rogue organizations and nation-states acquire killer robots for use in pursuit of their goals. PACOM can meet these strategic challenges through developing its own ARS technology.

A. Anti-Access / Area Denial

A growing concern for PACOM is the increasing capability of China to impede US power projection into the Western Pacific. "China maintains the largest and most lethal short-range ballistic missile force in the world; fielded the world's first antiship ballistic missile in 2010..."¹ It now maintains a constant military presence in the South China Sea through its fleet of submarines and surface ships. With a defense budget that increases each year by double digits and estimated at \$145 billion in 2014, the Chinese are researching stealth UAVs and hypersonic missiles to further fulfill its goal to become the reigning power in the Asia-Pacific theater.

The increased threat of A2/AD escalates the possibility of US casualties in the event of an armed conflict between China and the US, but ARS will decrease the loss of human life. As stealth technology and advanced autonomy becomes even more integrated into ARS, they will

¹ U.S.-China Economic and Security Review Commission, "2014 Report to Congress," November 20, 2014, http://www.uscc.gov/Annual_Reports/2014-annual-report-congress [accessed January 31, 2015], p. 290.

become more capable of performing the highly dangerous missions of entering A2/AD environments for purpose of destroying the enemy's capacity to deny US power projection. Waves of ARS specifically designed to act as decoys and emit false signals will be sent in first to reveal enemy missile sites. Aerial ARS decoys will be able to perform maneuvers that exceed the capability of a manned aircraft, but can track multiple targets and evade enemy fire. Behind the initial wave, ARS armed with anti-radar missiles fly in to destroy the enemy sites, followed by manned aircraft to provide the situational awareness and assessment. Similar concepts for maritime platforms will play out as stealth underwater ARS enter the A2/AD environment and destroy targets revealed by decoys. Surface combatants will have guardian ARS that detect and intercept enemy torpedoes and missiles.

B. The Battle for the Strategic Narrative

Just as security cameras are rapidly becoming part of everyday life as they proliferate throughout malls, intersections, and major public areas, the world's hot spots will be under constant surveillance as countries compete to ensure their national interests are secured. Tensions between rival nations have the potential to increase for cases in which countries are willing to risk international criticism to achieve national goals. China's ambition to enforce its claim on the South and East China Seas violates the freedom of navigation under the UN Convention on the Law of the Sea, making conflict inevitable with the United States and its Pacific allies. The surveillance capability of ARS will enable China to gain increased knowledge of ships operating in the disputed waters, including during its annual fishing ban, and escalate conflict when it moves to enforce its ban. Similar potential for clashes between nations exist in the Northern Limit Line between North and South Korea or in the Kashmir region between India and Pakistan. The long animosity existing in these regions guarantees that each side will push for surveillance

ARS to ensure it is not being taken advantage of by the other. Possibly, tensions will not rise between rival nations since each side will understand the constant monitoring by ARS will inform all parties of the actions being taken in the conflict regions, leading the groups involved to make greater efforts to be above reproach in how they interact with the other. However, a country cannot be perfect all the time. When ARS do capture an incident, the offended government will most likely release the footage to the world in order to galvanize the population and gain political capital. Through the power of visual imagery, the raw footage of a perceived wrong from a rival country can arouse compelling sentiments of nationalism that in turn leads populations to increase pressure on their leadership to retaliate against the offender.

To protect itself and its allies, PACOM must have the visual imagery to win the battle for the strategic narrative. In a world in which spin, sensationalism, and false reporting pervades society, a sense of distrust permeates the general public's attitude towards the message coming from politicians, the media, and subject matter experts. What makes people believe and demand action, however, is raw footage on a Youtube channel. A school system can expel a boy for fighting, but the public will rally behind the boy if they see a video of him stopping a bully from humiliating and hurting smaller children. Before 1991, Americans doubted whether police brutality was a nationwide issue in the US, but the imagery of Los Angeles police beating Rodney King pushed the issue to the forefront of national concern. Visual images galvanize public response. In December 2013, a Chinese amphibious ship sailing alongside the USS COWPENS in the international waters of the South China Sea suddenly veered into the path of the US ship at a distance of 200 yards and came to a full stop.² The COWPENS avoided a

² Jane Perlez, "American and Chinese Navy Ships Nearly Collided in South China Sea," *New York Times*, December 14, 2013, http://www.nytimes.com/2013/12/15/world/asia/chinese-and-american-ships-nearly-collide-in-south-china-sea.html?_r=0 [accessed January 29, 2015].

collision with the Chinese vessel, but had the two ships collided, the battle for the strategic narrative over who was to blame would have been fought. Without the hard evidence provided by a visual recording of the event, the Chinese claimed the American ship almost collided with their ship instead. Having the raw footage of the entire incident would have greatly improved PACOM's case against Chinese unprofessional and dangerous actions.

Capturing the strategic narrative will be critical for US allies who desire to counter Chinese aggression. Throughout the South China Sea, Vietnam and the Philippines have populated islands with families to assert claims on their respective areas within the region. As China becomes more resolved to establish its rule on the South China Sea, it may decide to remove these villages. Visual imagery of Chinese soldiers using blunt force to evict women and children from their homes will have a far greater impact on world opinion than a printed new story, but capturing this imagery will only occur if Vietnam and the Philippines invest and procure the technology. They have no hope of fighting the Chinese conventionally, but they can defeat Chinese aggression by capturing raw footage of Chinese bullying and intimidation to galvanize world opinion in their favor. In turn, China will also use visual imagery obtained by its aerial ARS to craft its own message for building domestic support for its actions. Future incidents like the sinking of Vietnamese fishing boats or preventing Filipino vessels from resupplying their outposts in the Spratly Islands must be recorded and broadcasted to the world to deter aggression in the Pacific theater.

C. The Tyranny of Distance

The vastness of the Pacific Ocean places a severe handicap on PACOM's ability to deploy forces due to the time it requires to travel from a PACOM base to the destination of interest. Aircraft designed to carry multiple types of ARS will mitigate this handicap by being

able to deploy rapidly with capabilities that range from reconnaissance and surveillance to armed UAVs that are controlled by human operators remotely. The time required for a quick response force to be on-station will be reduced to the flight time of the ARS carrier. Today, the average flight time for a commercial airline flying from Hawaii to Japan is nine hours. The ARS carrier will not replace the missions of today's aircraft carriers and destroyer squadrons as these assets possess far greater power projection and capabilities, but it does provide PACOM the means to acquire constant aerial surveillance and limited firepower at any point in its AOR within a day's time.

D. Killbots

This thesis relies heavily on one assumption – China will make rational decisions and abide by international norms in the choices it makes regarding ARS. If China decides instead to open Pandora's box and fully develop armies of ARS that remove human decision making from the choice of when to employ lethal force on the battlefield, war becomes inevitable. The current fear of robots killing humans without discretion that exists in today's society will not permit a country to utilize this technology. The moment the world learns of a Chinese ARS killing a human target without seeking authorization first, the international community will demand action against China. Sanctions will follow and force China to either bow to international pressure and abandon its investment in ARS technology or defy the sanctions and continue to develop and use the technology. At this time, China is well aware of the world perceptions regarding ARS killing humans, and it is highly unlikely that it will risk all of its plans to become a world superpower by researching and using lethal ARS technology when it can achieve the same result through conventional means without the international controversy. If China does push ahead with using killbots, it does so knowing it will face a hostile reaction from the rest of the world and is

prepared to confront it. Sanctions will not deter China in this scenario, and the international community will either have to accept lethal ARS as a legitimate tool of warfare on the battlefield (and thus begin developing their own) or forcibly stop China from employing the technology. Given the two choices, the international community will choose war.

Violent extremists will add killbots to their list of deadly tools to promote their agenda. Terrorism continues to plague Pacific nations such as Indonesia, Malaysia, and the Philippines, where 250 members of the Moro National Liberation Front conducted a violent three-week siege of Zamboanga City in 2013 that killed dozens of Philippine Security Force members and displaced thousands.³ Uninhibited by the international condemnation of robots autonomously killing humans, extremists will deploy ARS against civilian populations and military targets for the cost of a drone, a smartphone, light weapons or heavy explosives, and the programming application to link them all together.

PACOM can use several methods to countering the killbots used by rogue nations and violent non-state actors. First, PACOM must help define the requirement and necessity for USCYBERCOM to attack the internet sources that seek to sell the killbot smartphone applications to potential buyers. Inevitably, the programming code will fall into the hands of adversaries who will then integrate the components to make lethal ARS. The next step is to apply the same countermeasures used against UAVs – disrupt their incoming signals. The vast majority of aerial ARS will rely on GPS signals to determine current location and how to reach a destination. A University of Texas at Austin research team successfully proved these signals can be spoofed, allowing the UAV to be hijacked and directed elsewhere. Although unproven, the

³ US Department of State, “Country Reports on Terrorism 2013: East Asia and Pacific Overview,” Department of State, April 2014, <http://www.state.gov/j/ct/rls/crt/2013/224821.htm> [accessed January 31, 2015].

research team believes an Iranian cyber team utilized this method to commandeer a US RQ-170 UAV while it was flying in Iranian airspace in December, 2011.⁴ Strong encryption can remove this vulnerability, but if US forces can gain access to the GPS signals, they can redirect a potential threat away from friendly units.

Lethal ARS will still be a threat to society, even if China decides not to use it. Non-rational actors will still desire to wage violence and create chaos, but they will lack the vast resources of a world superpower to develop killbots into a legitimate threat to world order. The irony is that violent extremists will provide the impetus for the international community to make the stand that dissuades world powers from developing the advanced killbots that would threaten world order. In the next five years, extremists will utilize killbots to murder and create chaos, but the international community will react with such condemnation that world powers will refrain from creating the battlefield armies of lethal ARS. However, the possibility exists that the gradual introduction of using killbots as defense sentries will convince society the danger of them running amok is overstated.

E. The Way Ahead

The possibilities of what ARS will be able to do appear limited only by the imagination of the developers. Ten years ago, the thought of killer robots and autonomous submarines performing the same missions of reconnaissance and protecting the battlegroup seemed a far away idea, but they will become reality in the next ten years. The number of options for how to employ ARS in the future far exceed the amount funding required to fully develop them all.

⁴ “Todd Humphreys' Research Team Demonstrates First Successful GPS Spoofing of UAV,” Department of Aerospace Engineering and Engineering Mechanics Cockrell School of Engineering, The University of Texas at Austin, 2012, <http://www.ae.utexas.edu/news/features/todd-humphreys-research-team-demonstrates-first-successful-gps-spoofing-of-uav> [accessed January 30, 2015].

PACOM must prioritize what missions and capabilities are the most important to advocate for research.

Surveillance ARS should be the highest priority for development for its key role in deterring conflict. China's aggressive posture in the East and South China Sea will continue to challenge the interests of PACOM and its allies in the region. To counter this aggression, the US could sell weapons to arm the Vietnamese and Filipinos. Naturally, China will condemn this action, and the international community will understand Chinese objections to the selling of lethal weapons intended to harm Chinese soldiers. On the other hand, the international community will not see an issue with the US selling surveillance ARS to Vietnam for monitoring Chinese naval ships operating inside the disputed waters of the South China Sea. Knowing the interactions between China and its neighbors will be recorded and publicized to the world will raise the risks of international condemnation and criticism that China faces if it continues its aggressive posture against its neighbors and in enforcing its claim on the East and South China Sea. China will find great difficulty in spinning a confrontation with the US in its favor, as it did in the USS COWPENS incident in 2013, if the world sees the raw footage and can judge for itself that a ship suddenly veering into the path of another at 200 yards is reckless and unprofessional. Just as individuals act more responsibly when they understand a live camera is recording everything they do, countries will also be more mindful of their actions.

PACOM should also promote not using limited research funding for further development of lethal ARS. Doing so will force other countries to do the same, beginning a global arms race to create more advanced killbots that removes human decision making from the use of lethal force. This effort will be met with condemnation from many sectors of the world that already perceive this occurrence as the beginning of a doomsday scenario that ultimately results in

machines eradicating all human life. Plausible or not, the controversy will be great enough to lead political leaders to doubt whether the benefits are worth the cost. If the United Nations does approve a moratorium on developing this technology, the political leadership of the United States will have to decide whether to abide by the UN decision or not. Instead, funding should be diverted to countering killbots. If violent extremists succeed in using killbots to commit a terrorist act, the demand for this technology will dramatically increase, leading to an incentive for developers to create better, more capable lethal ARS. By preventing terrorist killbots from succeeding while the technology is still early in development and by advocating for the international community to discourage nation-states from developing killbots, the feared crisis can be pushed farther into the future.

After surveillance and countering killbots, PACOM should focus on counter A2/AD and anti-mine ARS. The latter two capabilities will only be required in the event of armed conflict with another nation-state such as China, whereas surveillance ARS can be utilized regardless of hostilities and killbots will become a reality in the next ten years, though extremists are more likely to use them than a nation-state.

Conclusion

The convergence of the three technologies of robotics, autonomy, and miniaturization will accelerate the ongoing transformation of utilizing machines to perform functions previously done by humans. From guarding the DMZ between the two Koreas to creating robotic pack mules to move supplies across rough terrain, militaries around the world are integrating ARS into their arsenals. Private industry is also pouring billions of dollars into developing new ARS, from driverless vehicles to handheld medical devices that dispense personal diagnoses, tailored to that individual's medical history. Overall, the rate of technological advancement is also climbing, fueled by the processing power of computers. Ten years ago, it was increasing by the millions, but is now expanding by the billions every two years.

With the exception of lethal force, nations and corporations will develop ARS to perform both military and civilian functions. Their innovations will further drive the development and advancement of future ARS to perform even higher advanced functions. Surveillance, reconnaissance, electronic warfare, and logistics are only a few of the near-term possibilities. Private industry and military research will continue to drive future innovation in ARS like they have done for computers and aviation. In order to stay on top of the future changes coming in the years to come, PACOM must continue to press for the needed research and development funding required and adapt the technology faster than the competition.

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