Technologies Converge and Power Diffuses

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Abstract:

The convergence of dramatic improvements in the fields of robotics, artificial intelligence, materials, additive manufacturing and nano-energetics is dramatically changing the character of conflict in all domains. These developments will provide smaller powers—and even some individuals—with capabilities that used to be the preserve of major powers. This diffusion of power has major implications on the conduct of warfare and national strategy. This is because while massive investment in mature technology leads to only incremental improvement in capabilities, the proliferation of many small and smart weapons may simply overwhelm a few exceptionally capable and complex systems. Strategically, small nations will be able to afford effective anti-access/area denial (A2/AD) defences that can defend not only their territories, but also reach out to strike an invader's intermediate and home bases. They can generate many of the capabilities of the most expensive current systems at a fraction of the cost, which will drastically change the calculus of intervention. However, the critical military functions will remain—but how they will be accomplished will change. Rather than investing everything in few, exquisite and very expensive systems, it makes more sense to explore augmenting them and, in time, replacing them with systems that conform to small, smart, and many.

Keywords: Additive Manufacturing; Nano-energetics; Changing Character of Conflict; Investment in Mature Technology; Small and Smart Weapons.

HISTORICAL CASE

Fortunately, this level of technological change and convergence is not unprecedented. From 1914 to 1939, there were breakthroughs in the fields of metallurgy, explosives, steam turbines, internal combustion engines, radio, radar, and weapons. In 1914, at the beginning of World War I (WWI), battleships were considered the decisive weapon for fleet engagements, and the size of the battle fleet was seen as a reasonable proxy for a navy's strength. The war's single major fleet action, the Battle of Jutland, seemed to prove these ideas correct. Accordingly, during the interwar period, battleships received the lion's share of naval investments. Navies took advantage of rapid technological gains to dramatically improve the capabilities of the battleship. Displacement of capital ships almost tripled, from the 27,000 tons of the pre-WWI United States (US) *New York* class to the 71,660 tons of Japan's *Yamato* class. The largest main batteries grew from 14-inch to 18-inch guns with double the range. Secondary batteries were improved, radar was installed, speed increased from 21 to 33 knots for US fast battleships, cruising range more than doubled, and armor improved. Yet, none of these advances changed the fundamental capabilities of the battleship—they simply provided incremental improvement on existing strengths. This is typical of mature technology, even massive investment leads to only incremental improvement(s).

In contrast, naval aviation was in its infancy in 1914. Aircrafts were slow, short-legged, lightly armed, and used primarily for reconnaissance. Air combat was primitive—one early attempt at this endeavour involved a grappling hook! Military aviation made great strides in tactics, technology, and operational concepts during the war. Yet, after the war, aviation—particularly naval aviation—remained an auxiliary and was funded accordingly. The US and United Kingdom (UK) governments focused most of even this limited investment on heavy bombers. Despite this neglect, by 1941, carrier aviation in the form of fighters, dive bombers, and torpedo bombers dominated Pacific naval warfare. Most of the advances in aircraft design and production that applied to naval aviation were developed for civilian uses. Aircraft production was a wide-ranging and highly-competitive business that led to these rapid technological advances. Relatively modest investment in these new technologies resulted in massive increases in aircraft capability. As a result, in World War II (WWII), aircrafts—the small, smart, and many weapons of WWII naval force—could swarm and destroy the few and exquisite battleships. By mid-1942, the battleships were reduced to expensive anti-aircraft and naval gunfire platforms.

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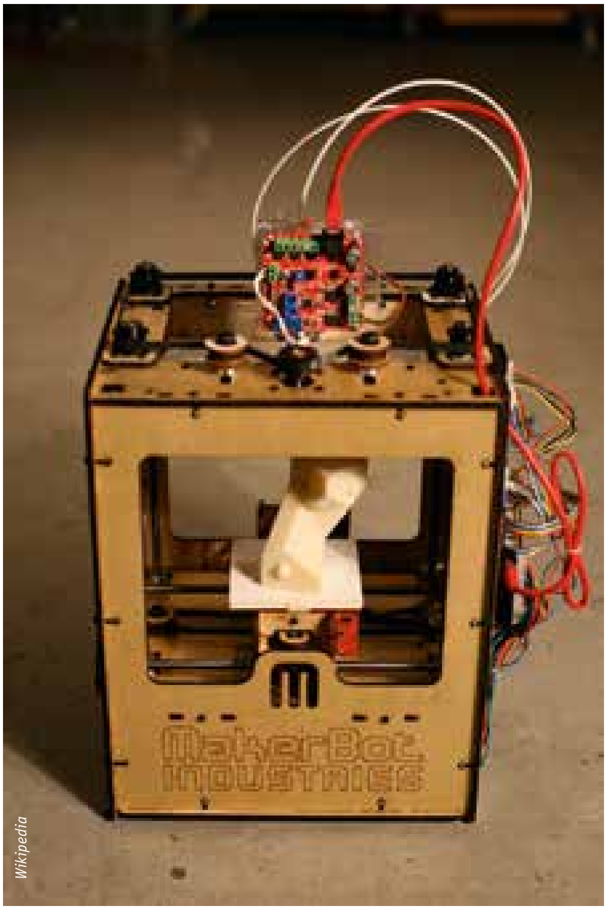
However, it is important to note that the transition took almost 20 years. Thus, the early investment in battleships was correct. The failure lies in not understanding when the character of naval warfare changed and naval aviation capabilities exceeded those of the battle line. Interestingly, there was also relatively little investment in submarines, the other powerful newcomer to the naval battle. Submarines progressed from a fragile but deadly weapon system in WWI to one that almost defeated Britain and destroyed the Japanese industry in WWII. It is essential to remember that institutional biases can keep investment focused on the dominant technology even as multiple emergent technologies clearly challenge it.

EVOLVING TECHNOLOGIES

As noted in the introduction, we are currently in an area of rapidly evolving technologies that, when combined, may well radically alter the way we fight. This paper is too short to even begin to explore the explosion of new technologies that are changing our daily lives. However, it will take a look at a few that will have short-term impact on how wars are fought—additive manufacturing, nano-materials and energetics, space-like capabilities, artificial intelligence, and drones. This paper will also consider how they may come together to change conflict.

Additive Manufacturing

In the last few years, additive manufacturing (AM), also known as 3D printing, has gone from an interesting hobby to an industry producing a wide range of products from an ever growing list of materials. The global explosion of AM means it is virtually impossible to provide an up-to-date list of materials that can be printed, but a recent top ten list includes metals such as stainless, bronze, steel, gold, nickel steel, aluminum, and titanium; carbon fibre and nano-tubes; stem cells; ceramics; and food.[1] In addition to a wide range of materials, AM is progressing from a niche capability that produces prototypes to a manufacturing industry capable of producing products in large quantities. United Parcel Service (UPS) has created a factory with 100 printers.[2] The current plant requires one operator per



Wikipedia

A MakerBot three-dimensional printer.

eight-hour shift and works around the clock. It accepts orders, prices them, prints them and ships them on the same day from its adjacent shipping facility. With 100 printers, UPS can print production runs of a number of products, and the firm has plans to increase the plant to 1,000 printers to support major production runs.

At the same time, AM is dramatically increasing the complexity of objects it can produce while simultaneously improving speed and precision. Recent technological developments indicate that the industry will be able to increase 3D printing speeds up to 100 times with a goal of 1,000 times, all while providing higher quality than current methods.[3] In January 2015, Voxel8 revealed a new printer ($8,999) that printed a complete, operational drone with electronics and engine included.[4] In February 2015, Australian researchers printed a jet engine.[5] Furthermore, the very nature of additive manufacturing reduces the price of parts since there is little or no waste. With subtractive (or traditional) machining, one starts with a block of metal and cuts it to the correct form, wasting a great deal of material. With AM, material wastage is near zero, thus making it cheaper to make a part from titanium using AM than from steel using traditional machining. Although only two decades old, AM is already starting to encroach on a wide range of traditional manufacturing.

Nano-Technology

Nano-technology is another field that is advancing rapidly in many areas, two of which are of particular interest to us. The first is nano-energetics or explosives. As early as 2002, nano-explosives generated twice the power of conventional explosives.[6] Since research in this field is close hold, it is difficult to say what progress, if any, has been made since that point. Obviously, it would be unusual if greater efficiencies have not been achieved in over a decade. But, even if two times is as good as it gets, a 100 percent increase in destructive power for the same size weapon is a massive increase. Much smaller platforms will carry greater destructive power. The second area is nano-materials. Although this field has not advanced as far as nano-energetics, the potential for nano-carbon tubes to dramatically reduce the weight needed for structural strength will have significant implications for an increasing range of drones. In a related field, numerous firms are applying nano-materials to batteries and increasing their storage capacity.[7] In fact, a recent accidental discovery may triple battery power storage and increase battery life by a factor of four.[8] Researchers are also applying nano-technology to develop capacitors that can function as batteries.[9] These improvements in energy storage, materials, and explosives will lead to increases in range and payload for a wide variety of vehicles.

Space-Like Capabilities

The addition of cheap persistent space-based and air-breathing surveillance will provide the information necessary to employ these new technologies. In space, several companies are deploying cube satellites (CubeSats) in order to include SkyBox Imaging which was recently purchased by Google. Their goal is to sell half-metre resolution imagery with a revisit rate of several times a day—to include an interpretation of what the buyer is seeing.[10] A buyer could literally track port, airfield, road, rail system activity in near real time. Initially, SkyBox and other CubeSats companies achieved low-cost launch by serving as ballast on larger rockets. Today, New Zealand's Rocket Lab is proposing to conduct weekly launches specifically for CubeSats to allow rapid, cheap launch of CubeSats. Although Rocket Lab has not yet opened its space port, numerous firms have signed up for its launch services.[11]

Other firms are working on systems that can duplicate the communications and surveillance functions provided by satellites. Google's Project Loon is attempting to provide reliable, cost-effective internet services for much of the southern hemisphere by deploying a constellation of balloons that will drift in the stratosphere.[12] High-altitude long-endurance drones are another avenue to satellite capabilities without the satellite. The US Air Force has successfully tested Global Observer to conduct surveillance and intelligence operations.[13] For long endurance operations, several organisations are pursuing solar-powered drones.[14]

Artificial Intelligence

Artificial intelligence (AI) is yet another exploding field, but two areas are of particular importance in the evolution of small, smart, and cheap weapons—navigation and target identification. Global Positioning System (GPS) has proven satisfactory for basic autonomous drone applications such as the Marine Corps K-MAX logistics helo-drone in Afghanistan.[15] However, GPS will be insufficient for operations in narrow outdoor or indoor environments, dense urban areas, and areas where the GPS signal is jammed. Academic and commercial institutions are working hard to overcome the limitations of GPS to provide truly autonomous navigation for drones.[16] Inertial and visual navigation are advancing rapidly and are already cheap enough to use in small agricultural drones.[17] Clearly, the commercial applications for navigating in agricultural areas and inspecting buildings in urban areas can be adapted for military uses. While such a system would serve to get a drone to the target area, it would not ensure that a specific target could be hit. For that, optical recognition is essential. And in fact, there have been major advances in surveillance and tracking software that are more than sufficient for an autonomous drone to attack specific classes of targets and perhaps even specific targets.[18] Today, artificial intelligence can identify a distinct object—such as an aircraft or fuel truck—using on board multi-spectral imaging.[19] In short, the AI necessary for many types of autonomous drone operations currently exists—and is operating aboard small, commercial drones.

AI is the development that makes the convergence of material, energetics, drones and additive manufacturing such a dangerous threat. It is advancing at such a rapid rate that over 1,000 distinguished researchers signed an open letter seeking to ban autonomous weapons. They stated that "the deployment of such systems is, practically if not legally, feasible within years, not decades..."[20] It is exactly that autonomy that makes the technological convergence a threat today. Because such drones will

Cyberpioneer

The future of the Singapore Armed Forces (SAF) will utilise more unmanned systems and drones, as shown during the Future of Us exhibition.

require no external input other than the signatures of the designated target, they will not be vulnerable to jamming. Not requiring human intervention, they will be able to operate in very large numbers. They can be programmed to wait patiently prior to launch or even proceed to the area of the target, but hide until a specified time or a specified target is identified.

Drones

Clearly, drone capabilities have increased dramatically in the last five years and, perhaps most significantly, usage has spread widely. Still, small drones can only carry a limited payload. This limitation can be overcome with two separate approaches, one of which is the use of Explosively Formed Penetrators (EFPs). The other less technically challenging approach would be to think in terms of 'bringing the detonator'.

For harder targets, EFPs will allow even small drones to damage or destroy armoured targets. Weighing as little as a few pounds, these penetrators can destroy even well-armoured vehicles. In Iraq, Coalition forces found EFPs in a wide variety of sizes—some powerful enough to destroy an Abrams tank. Others were small enough to fit in the hand—or on a small drone.[22] And of course, nano-explosives at least double the destructive power of the weapons.

The primary limitation on production in Iraq was the need for high-quality shaped copper plates that form the projectile when the charge is detonated. Up until recently, this was a significant challenge that required a skilled machinist with high quality machine tools. However, in the last few years, additive manufacturing has advanced to the point that it can be used to print a wide variety of materials to include copper.[23] The US space agency, National Aeronautics and Space Administration (NASA), has printed a copper combustion chamber liner for a rocket motor.[24] Thus, we can expect small and medium-sized drones to pack a significant punch against protected targets.

The second approach entails bringing the detonator, and it applies to aircraft, vehicles, fuel, and ammo dump targets. In each case, the objective is to simply detonate the large stock of explosive material already provided by the target. Against these targets, even a few ounces of explosives delivered directly to the target can initiate the secondary explosion that will destroy the target.

The convergence of new technologies discussed above may allow these small, smart, and cheap drones to dominate combat in the land, air and sea domains. Anyone with a television or access to YouTube during the last decade will be very familiar with the US' use of drones to both hunt enemies and protect friendly forces. Although the numbers stand in the tens of thousands worldwide, these drones represent only the first wave. Like many technologies, early versions were expensive and difficult to operate, thus only the wealthy employed them. But over time, technology has become cheaper, more reliable and is more widely employed. We are seeing this with the explosive growth in commercial drones. Indeed, additive manufacturing will soon make them cheap enough for small companies and even individuals to own a large swarm of simple, autonomous drones.

In fact, the US Air Force is actively exploring the use of swarms, with most of its focus on smart swarms that communicate and interact with each other and other platforms.[25] The US Navy is also pursuing swarming technology with the Low-Cost Unmanned Aerial Vehicle Swarming Technology (LOCUST) as well as small craft.[26] While these programmes are vague about how many drones will be involved, they envision being able to employ large numbers as recent, dramatic cost reductions in each of the needed technologies will increase the number by a sizeable magnitude. Researchers in England have prototyped a simple drone body that costs roughly US$9 a copy.[27] Researchers at the University of Virginia are 3D printing much more complex drones in a single day, then adding an Android phone to produce a US$2,500 autonomous drone.[28] Thus, a small factory with only 100 3D printers using the new printing technology noted above could produce 10,000 drones a day. The limitation is no longer the printing, but the assembly and shipping of products. However, both processes can be automated with industrial robots. Then, the limitation becomes preparing and launching thousands of drones at a time when they arrive in theatre, which will require refined organisation, planning, and equipment.

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Nor will cheap drones be limited to the air. In 2010, Rutgers University launched an underwater 'glider' drone that crossed the Atlantic Ocean unrefueled.[29] Such drones are being used globally and cost about US$100,000.[30] This year, the US Navy launched its own underwater glider that harvests energy from the ocean thermocline and they are planning to operate it without refueling for five years.[31] Based on the commercially produced Slocum Glider—a five-foot long autonomous underwater research vehicle—it can patrol for weeks following initial instructions, then surface periodically to report and receive new instructions. In short, small sea platforms have demonstrated the capability of achieving intercontinental range while producing very little in the way of signatures.

Ashore, mobile land mines/autonomous anti-vehicle weapons are also under development.[32] The natural marriage of Improvised Explosive Devices (IEDs) to inexpensive, autonomous drones is virtually inevitable. However, truly autonomous land drones—those that actually move on the ground—will remain the most difficult challenge simply because land is the most complex combat environment. Thus, AI and maneuvering for land drones require an order of magnitude for far more capability than for air or sea. In the interim, cheap fixed and rotary wing drones will provide an inexpensive way to strike ground targets. Non-state and state actors alike can rapidly transition to drones that can hunt mobile targets.[33]

IS IT EVEN POSSIBLE TO LAUNCH THOUSANDS OF DRONES?

It is one thing to have access to thousands of drones, it is quite another to have the logistics and manpower available to effectively employ them. One method that demonstrates it can be done is the Chinese system that mounts 18 Harpy Unmanned Combat Air Vehicles (UCAVs) on a single five-ton truck using a system similar to a Multiple Launch Rocket System (MLRS).[34] The Chinese can transport, erect, and fire these fairly large drones with a single vehicle and a one or two-person crew. Initially developed in the 1990s by Israel as an anti-radar system, the Chinese version has a range of 500 km and a warhead of 32kg with multiple types of seeker heads. Both China and

The British M270 Multiple Launch Rocket System (MLRS) firing a rocket during an exercise. The M270 is the original version of the MLRS, which features a weapon load of 12 rockets in two six-pack launch pod containers.

Israel have displayed these weapons at trade shows in an effort to sell them to other nations. The system is currently operational with the Turkish, Korean, Chinese, and Indian armies. Today, the Israeli version, the Harop or Harpy 2, has an electro-optical sensor to attack non-emitting targets and an extended range of 1,000 km.[35] One can assume that China has made similar improvements to its systems. Thus, even with old technology, the capability to launch swarms of drones already exists. Further, the Harpy is not a small weapons system. A similar-sized vehicle could be configured to carry over 100 Switchblade size drones or perhaps a thousand mini-drones.[36]

IMPLICATIONS FOR THE MODERN BATTLEFIELD

Irregular War

Unfortunately for nation states, autonomous drones will initially favor the less technologically advanced actor because their targeting problem is simpler. For instance, a non-state actor may not own armoured vehicles or aircrafts, so their autonomous drones only have to find and attack any armoured vehicle or parked aircraft. It does not have to discriminate but simply fly a pre-programmed route to a suspected target area. Target areas for many locations in the world—to include most airfield flight lines—can be determined using Google Maps or Google Earth. Cheap optical recognition hardware and software that provide effective target discrimination are also becoming widely available. Thus, once in the target area, the drone can scan for an easily identifiable target, say a large cargo aircraft, and then simply crash into it. Limited standoff is also currently available. If the software of a farmer's autonomous drone can point and shoot a camera, it can point and shoot a projectile as well.

Soon, Skybox Imaging or similar firms will provide near real-time imagery to anyone with a credit card and a laptop. Terrorists and insurgents will be able to conduct initial target studies without leaving their houses. Using Tor and the current version of the Silk Road dark website, they will be able to purchase the systems too.

Clearly, today's commercial products have demonstrated the ability for autonomous drones to reach a target area, but what weapon could it use? Against the thin skin of an aircraft, a simple point-detonating three-ounce warhead would be sufficient. Thus, even very small commercial quadcopters can destroy an aircraft on the ground. Against armour, the drone designer may choose the heavier and more complex, explosively formed penetrator. This will obviously require larger quadcopters/drones, but they will also help provide standoff distance. Like most commercial products, for more money, you can purchase more capability in terms of payload, range and discrimination. Advances in additive manufacturing, composite materials, energy densities in gel fuels, and nano-explosives indicate that we will be able to build longer range, more powerful and stealthier drones in the immediate future. Unfortunately, almost all of our anti-terror physical defenses are based on blocking observation and ground access to targets. Drones will simply fly over existing defences. Defending against this threat is a possibility but expensive, particularly when the cost of defending against these weapons is compared to the cost of employing them.

In theatre, top-down attack drones will negate the gains that the West has made in survivability against ground IEDs. Even Mine Resistant Ambush Protected (MRAP) and light armoured vehicles will no longer protect our people or supplies. The fact that fuel and water trucks are distinctive and vulnerable creates more trouble. A smart enemy may well ignore your combat forces and literally fly over them to attack your logistical forces. Operationally, how do you protect ports of debarkation and logistics nodes? How do we defend intermediate supply depots? Overhead cover will work, but also dramatically increase the time, resources and effort that must be dedicated to logistics support. And, of course, the supply vehicles remain vulnerable while loading and transporting those supplies.

And, for the first time in history, insurgent groups may well be able to purchase weapons that can project forces well outside the area of conflict. Very long-range drone aircraft and submersibles give an insurgent the capability to strike air and sea ports of debarkation, and perhaps even embarkation. This will create major political problems in sustaining a US effort. For instance, a great deal of our support into Iraq flows through Kuwait. Suppose the Islamic State of Iraq and Syria (ISIS) demonstrates to Kuwait that it can deploy drones that can hit an airliner sitting at Kuwait International Airport. They state they will not do so as long as Kuwait withdraws landing rights for those nations supporting Iraq. Similar threats can also be made against sea ports. When the time comes, is the West prepared to provide the level of air defence required to protect key targets across those nations providing interim bases and facilities?

Conventional War

While these systems pose a genuine threat to all nation states, they and their descendants will provide a significant boost to the ability of small and medium states to defend themselves. This may lead to a period similar to that between 1863 and 1917 where any person or animal moving above the surface of the ground could be cheaply targeted and killed. Thus, defence has become the dominant form of ground warfare. Drone swarms may make defence the dominant form of warfare in ground, air, sea, and space domains. Drone swarms will also be able to attack the physical elements of the cyber domain. The advantage will come to those who can exploit the domains while operating from a heavily-defended and fortified position.

Ground Domain

The performance of American and British armoured forces in Operations Desert Storm and Iraqi Freedom shows how well-trained crews with advanced gunnery systems could make short work of poorly trained crews in less capable tanks. It seemed that the combined arms team in the offensive was dominant on the battlefield. Then, the 2006 Israeli-Hizbollah war indicated that well-trained, determined irregulars armed with advanced anti-tank weapons, particularly guided missiles, could make defence dominant again in ground warfare. Since then, conventional ground warfare has become both deadlier and cheaper. Direct fire gunnery systems have improved, wire-guided and fire-and-forget missiles systems are proliferating, but both are very expensive. In contrast, artillery can now provide much cheaper precision fire. While each Excalibur 155mm round costs about US$100,000, the US Army signed a contract in 2015 for a new 155mm fuze that makes any 155mm artillery round a precision weapon.[37] Each fuze costs only about US$10,000.[38]

The next great leap will be inexpensive drones. For much less that the price of a precision fuze, commercially available autonomous drones will provide greater range than artillery without the latter's large logistics and training tail. Deployed in large numbers, these drones will provide a particularly nasty challenge for ground forces. Autonomous drones which have already demonstrated the ability to use multi-spectral imagery to identify specific objects, will hunt on their own.

Today, even relatively light forces are dependent on vehicles and helicopters for support. For over a decade, western forces have struggled with hunting

IEDs to ensure the ability to move about the battlespace. Now, the IEDs will start actively hunting our forces in the field, our vehicles, our helicopters and our fuel and ammo dumps.[39] When one combines simple drones with additive manufacturing, ground forces face the real possibility of thousands of drones in wave attacks.

Autonomous drones will be the most difficult to defeat, but remote control drones will most likely appear first. Yet even remote-controlled drones no longer require the operator to have line of sight to his target. Today, even hobbyists are using immersion goggles to control high speed, maneuvering drones.[40] As mentioned earlier, autonomous drones that operate on the ground will be the most difficult to defeat, but they will arrive, and early versions may simply be self-deploying mines/IEDs. Later versions may be advances on the Fire Ant and will be capable of actively hunting ground targets.[41] This has major implications on everything from force structure to equipment purchases to operational and tactical concepts. Tactically, how does a force protect itself against swarms of thousands of small, smart, cheap drones?

Sea Domain

Obviously, swarms of autonomous drones provide a challenge to any naval force trying to project power ashore. The drones need not attempt to sink a ship, but only achieve a mission kill. For instance, a drone detonating against an aircraft on the deck of a carrier or firing a fragmentation charge against an Aegis platform's phased-array radar will degrade its capabilities. While the self-defence systems and speed of most warships make them difficult targets, amphibious or cargo ships have to slow down or stop to operate and thus will be easier targets. And, of course, with drones achieving trans-Atlantic range already, home ports must now be defended.

Undersea weapons will provide a much greater challenge to navies. There is clearly a movement by middle powers in Asia to establish effective submarine forces. However, a submarine force is expensive, complex and difficult to operate. Unmanned underwater vehicles may provide a much cheaper alternative for a middle power. This year, the US Navy has launched an autonomous underwater glider with plans for it to operate for five years without refueling.[42] Similar drones are being purchased globally for about US$100,000 each but commercial firms are striving to reduce the cost by 90 percent.[43] If developed as a weapons system, they could dramatically change the face of naval combat. Offensively, they can become self-deploying torpedoes or mines with trans-oceanic range. Defensively, they can be used to establish smart minefields in maritime choke points. They can be launched from various surface and subsurface platforms or even remain ashore in friendly territory until needed, during which they will be launched from a port or even the beach. Imaginatively, they could be a relatively inexpensive substitute for a submarine force. Clearly, such drones can be modified to be long-range autonomous torpedoes or even to position smart mines. For the cost of one Virginia-class submarine, a nation could purchase 17,500 of such drones at current prices.[44] If additive manufacturing can reduce the cost of these systems roughly by 40 percent that is predicted for satellites, one could buy almost 30,000 such drones for the current cost of a Virginia-class submarine.[45] What is more important is that the skills and organisation needed to build and employ a glider are orders of magnitude less than those needed for a nuclear sub.

Sea mines should be a particular concern to trading nations. They have the distinction of being the only weapon that has denied the US Navy freedom of the seas since WWII. First, mines defeated a US amphibious assault: the landing at Wonson in 1950.

While lanes were eventually cleared through the primitive minefields, forces attacking up the east coast of Korea had already seized the amphibious objectives before the first amphibious forces got ashore. After Wonson, the commander of US Naval Forces noted that the most powerful navy in the world was stopped by weapons designed 100 years ago and delivered by ships designed 2,000 years ago. However, not much has changed. In February 1991, the US Navy had its operations in the northern Arabian Gulf jeopardised by the over 1,300 simple, moored mines that were sown by Iraqi forces.[46]

Since 1950, mines have become progressively smarter, more discriminating and more difficult to find. They have sensors which can use acoustic, magnetic and other signals to attack a specific kind of ship.[47] As early as 1979, the United States fielded encapsulated tornado (CAPTOR) mines. These are basically encapsulated torpedoes anchored to the ocean floor. When they detect the designated target, they launch the enclosed torpedo to destroy it up to a range of eight kilometres.[48] Today, China possesses 'self-navigating mines' and even rocket-propelled mines.[49] We are seeing early efforts to use unmanned underwater vehicles to deliver mines. Since

A Polish contact mine. When deployed, the protuberances near the top of the mine will trigger the mine's detonation upon contact with any ships out at sea.

commercially-available drones are already crossing the ocean autonomously, pairing drones with mines will most certainly make it possible to mine sea ports of debarkation and perhaps even sea ports of embarkation as well as sea lines of communication.

And, of course, these gliders can also be used against commerce. Launched from shore bases, these systems will allow any nation bordering the South China Sea and its critical straits to interdict trade. While they cannot stop trade, damaging a few ships will cause dramatic increases in maritime insurance rates. To date, no nation has developed a minehunting force capable of clearly smart, self-deploying mines with a high degree of confidence.

Air Warfare

For air warfare, the key problem will be protecting aircraft on the ground. An opponent does not have to fight modern fighters or bombers in the skies. Instead, he can send hundreds or even thousands of small drones after each aircraft at its home station. Tanking, airborne early warning, transport and other support aircraft are even more difficult to protect on the ground. Even if aircrafts are protected by shelters and radars, fuel systems and ammunition dumps are still highly vulnerable. Currently, range is a problem for printed drones, but an Aerovel commercial drone first crossed the Atlantic in 1998 and the company now sells an extremely long-endurance drone.[50] The exceptionally rapid increases in commercial drone capabilities indicate range problems will soon be solved, even for markedly smaller drones.

While manned aircraft will become vulnerable due to basing issues, cruise missiles will become both more capable and cheaper. According to the

A Tomahawk Land Attack Missle (TLAM) detonating above its test target.

Naval Air Systems Command, the older Tomahawk Land Attack Missile (TLAMs) cost US$607,000 in FY-99 dollars.[51] Today, that cost stands at $785,000 in FY-2013 dollars.[52] As noted earlier in this article, Lockheed expects to be able to cut the cost of two new satellites by 40 percent using AM. This has some very interesting implications for reducing cost of complex systems. If we assume we can obtain production savings similar to those projected for the satellites, TLAMs will cost about US$470,000 each. These missiles carry a 1,000-pound warhead for a distance of up to 1,500 miles (Block II variant).[53] While somewhat expensive, missiles such as these can provide long-range heavy strike—particularly if the warhead uses nano-explosives. Since they can be fired from a variety of land and sea launchers, they can either be dispersed or hidden in underground facilities (to include commercial parking garages) until minutes before launching. Thus, missiles will remain immune to most pre-emptive strikes and still cost less than ballistic missiles.

The key question is whether we will invest in the equivalent of battleships or aircrafts. Will our investments prove to be exquisite and irrelevant or change the face of conflict?

The previously mentioned US Air Force experiments that uses cargo aircraft to launch dozens of drones also has some very interesting implications for the future of airpower. The combination of cheap drones and much more capable cruise missiles may offer small and medium-sized states A2/AD, precision-strike and long-range strike capabilities in the air domain.

Ncube-2, a Norwegian CubeSat.

Space Warfare

In space, the advent of micro and cube satellites paired with commercial launch platforms will allow a middle power to develop an effective space programme for surveillance, communications, navigation and even attack of other space assets. In addition to Skybox Imaging and Rocket Lab, Japan's Axelspace is also launching CubeSats. In Axelspace's case, it has launched a US$1.9M satellite to provide navigation assistance in the Arctic. It plans to launch a constellation of CubeSats similar to Skybox Imaging's that will provide hourly satellite imagery of Tokyo's traffic.[54] As such, surveillance and navigation satellites are already within reach of a small or medium power or, it can buy the service from a commercial company.

In addition, high-altitude, long-endurance (able to stay in the air for months) drones and even balloons are being tested by a number of commercial firms as alternatives for providing internet connectivity and surveillance. The British Ministry of Defence is studying the Zephyr 8, a solar power drone that can fly at altitudes up to 70,000 feet and provide surveillance and communications at a fraction of the cost of current satellites.[55]

Cyber Warfare

While one would not normally think of drones as part of conflict in cyber space, it is important to remember that all networks have nodes in the real world. Furthermore, some of these nodes such as key fibre-optic network lines and switches are quite exposed. For instance, satellite downlinks and point where fibre-optic networks come ashore are both exposed and vulnerable. Smart drones provide a way to attack these nodes from a distance.

Offering more potential for precision effects, Boeing successfully tested its Counter-electronics High-Powered Advanced Missile Project (CHAMP) in 2012. CHAMP is a drone mounted Electro-magnetic Pulse (EMP) system that successfully knocked out all electronic targets during its test.[56] Such a system can target specific nodes of an enemy's network while not damaging friendly nodes.

STRATEGIC IMPLICATIONS

Since Operation Desert Storm, there has been a belief that information superiority tied to precision weapons will defeat mass. It has certainly allowed numerically smaller Allied forces to defeat Iraq's much larger Army (twice) as well as drive Al Qaeda and the Taliban out of Afghanistan using a very small ground force. However, the convergence of several new technologies seems to be pointing to the revival of mass (in terms of numbers) as a key combat multiplier. The small, smart, and many revolutions will provide all nations and some non-state groups with capabilities previously reserved for great powers simply because they cost so much.

Western forces have had the luxury of unopposed access to the theatre of operations outside Europe for decades. This monopoly is changing as US access will be contested in several domains. We have to ask the question 'Does the strategic cost/benefit calculation change as a result?' When almost any enemy can cause severe damage throughout a major power's supply, deployment and employment chains—perhaps even to the ports and airfields of embarkation in its homeland—does the cost of intervention expand nearly exponentially? On top of that, the mechanics of moving forces from home bases to the combat zone will become much more difficult. Will other nations provide transit or port rights if it means that their homeland will be subjected to significant attacks? Power-projection nations will find their options limited and will be required to rethink how they project power.

In contrast to the ever more expensive and extremely high technological systems, small, smart, and relatively cheaper drones are creating entirely new challenges across the battlefield. While current Western high technology programmes produce fewer and fewer bespoke weapons systems, the convergence of technological advances is resulting in the proliferation of tens of thousands of cheap, smart systems.

CONCLUSION

The world has entered an era of rapid and converging technological advances in many fields similar to that following WWI. This creates the potential for disruptive shifts by creative applications, especially by combinations of these advances. The key question is whether we will invest in the equivalent of battleships or aircrafts. Will our investments prove to be exquisite and irrelevant or change the face of conflict? Unfortunately, many militaries today are mirroring the navies between the wars. They are applying new technologies in an effort to squeeze another five percent of performance out of older weapons, while under-investing in the evolving technologies that are changing the character of contemporary and future conflicts.

In contrast to the ever more expensive and extremely high technological systems, small, smart, and relatively cheaper drones are creating entirely new challenges across the battlefield. While current Western high technology programmes produce fewer and fewer bespoke weapons systems, the convergence of technological advances is resulting in the proliferation of tens of thousands of cheap, smart systems. Western nations are struggling to find answers to this challenge, and none of them look like the few and bespoke programmes currently consuming the bulk of major procurement programmes.[57]

For small and medium nations, the 'small, smart, and many' represents a great opportunity for their investment programmes. They can generate many of the capabilities of the most expensive current systems at a fraction of the cost. They may also be shifting the balance to the tactical defensive side, which would allow a smaller power to employ effective, affordable A2/AD strategies against a much larger power. They may simply raise the cost of conflict until it is too high for any possible gain.

The critical military functions will remain, but how they will be accomplished will change. Rather than investing everything in few, exquisite and very expensive systems, it makes more sense to explore augmenting them and, in time, replacing them with systems that conform to small, smart, and many.

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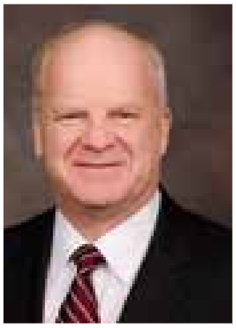

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