# Emerging Technology is Changing the Character of Warfare

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Abstract

*Emerging technology is changing the charater of warfare. The combination of pervasive surveillance with cheap, long-range, autonomous precision weapons means the defense is becoming tactically dominant again. This offers great opporutnities for the ROK to increase the effectiveness of its defenses while spending less money.*

***Keywords:*** *Warfare, Technology, Advanced Manufacturing, Drones, Missiles, IEDs*

The convergence of 21st Century technologies is fundamentally changing the character of modern warfare. While the nature of war, what it is, will always include the tensions of Clausewitz's primary trinity – passion, chance, and reason – as well as fog and friction, the character of warfare, how it is fought, is changing rapidly. Since the Germans developed *Sturmtruppen* tactics near the end of World War I, offense has been the dominant form of war.[1] However, today the balance is shifting back to what Clausewitz termed the stronger form of war – the defense. This is not a unique occurrence but part of a continuing pattern of shifts between offensive and defensive dominance of the tactical battlefield.

While this paper will discuss emerging technology as a primary driver of this shift, it is very important that the reader understand that major changes in the character of warfare also require changes across the political, social, and economic fields. Technology alone does not force a shift in the character of war, nor is it even essential for one to occur. For instance, prior to the French Revolution, European warfare was a matter for kings and fought by small armies of full time professional soldiers. The French Revolution, both a political and social revolution, changed all that. It made war a matter that mobilized the entire population. As a result, the French could put armies numbering hundreds of thousands in the field. And yet there was little technological change during over 20 years of war. *HMS Victory*, Lord Nelson's flagship, was 40 years old at Trafalgar. The Land Pattern, or Brown Bess, Musket remained the standard weapon of the British Army throughout the war. In fact, it was in service from 1722 until 1838.[2] Yet, even without accompanying technological change on the battlefield, the Wars of the French Revolution and the Napoleonic Wars represented a true Military Revolution. For the first time in the modern era, whole societies mobilized and major nations all supported armies with hundreds of thousands of men.

At other times, technology has been essential to change. World War I's Western Front stalemate saw all the armies employing the advantages that flowed out of the French Revolution. The mass mobilization of their populations was supported by the mass production enabled by the Industrial Revolution. Yet the *Sturmtruppen* tactics of 1918 could not have evolved without the light automatic weapons and mortars that made the offensive work again at the tactical level. And only the interwar development of aircraft, armor, motor transport, and radio communications enabled the Germans to transform *Sturmtruppen* tactics into *Blitzkreig* to restore the offense at the operational level. It also illustrates that simply having access to new technologies does not mean a nation can use them effectively. The British, French,

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1) Bruce M. Gudmunsson, *Stormtroop Tactics: Innovation in the German Army, 1914-1918,* Praeger Books, 1995.

2) Mark Miller, "The Musket that Changed the World: The Land Pattern 'Brown Bess'," *American Gun Digest,* September 27, 2020, https://www.gunsamerica.com/digest/the-musket-that-changed-the-world-the-land-pattern-brown-bess/, accessed November 7, 2021.

Russians, and Americans did not employ *Blitzkreig-like* tactics until after the Germans demonstrated them decisively by conquering France in May 1940.

Today, rapid and far-ranging advances based on economic and technological changes are fundamentally changing the character of war again. They are creating a world in which pervasive surveillance will enable massed, long-range precision fires based on civilian technologies but only for those who, like the Germans, can anticipate how these technologies will change warfare. Cameras, accelerometers, GPS receivers, Synthetic Aperture radars (SAR), infrared sensors, and system electronics have all been miniaturized to facilitate better cell phones and autonomous commercial vehicles. These same systems, as well as emerging ones like non-GPS navigation, are enabling cheap guidance systems for a wide variety of weapons.

Advanced manufacturing – robotics, 3D printing, task-specific artificial intelligence, and other advances – are making it possible to produce drones and missiles at dramatically less cost than traditional manufacturing. As always, the Korean battlefield will be one of massed forces. But this time, the mass can be augmented by precision. As the technologies essential to precision weapons have become orders of magnitude cheaper, it has become possible to produce precision weapons systems in large numbers and integrate them into land, sea, and air systems. In 1989, a commercial GPS receiver cost over $100,000 and weighed 53 pounds. Today, they are available on Amazon for under $100 and weigh ounces. Synthetic aperture radars are available for $250 and have much greater resolution and reliability than their very expensive predecessors. LIDAR (light detection and ranging) costs have also come down by a factor of over 100. The cost of computing power has dropped even more dramatically. In 1980, a gigabyte of memory cost over $6 million, today it costs 16 cents.

The widespread commercial availability of these technologies is leading us to a battlespace where persistent surveillance will guide masses of precision weapons in attacking any exposed targets.

## Persistent Surveillance

The effective employment of extended range precision weapons requires highly capable, intelligence, surveillance, reconnaissance (ISR) and command and control (C2) systems. Ongoing massive global commercial investments in two fields – commercial space and commercial drones – are making this exquisite ISR available to all nations. Commercial investment in space means that constant surveillance of the planet by visual, infra-red, multi-spectral, radar, and electromagnetic sensors will be here very soon. Led by Planet Lab, a number of commercial companies already image the entire planet daily with resolution down to three meters. As part of their business models, these companies also provide interpretation of the fused visual,

radar, and electronic emissions imagery they sell.[3] Several companies have even moved beyond the optical frequencies. HawkEye360, a private company, developed a satellite that uses radio frequency (X-band, S-band, and VHF) monitoring and analysis to provide locations of specific ships and units to within 3 kilometers. The company plans to place a constellation of 18 in orbit.[4] This constellation will allow revisit times of less than an hour.[5] By 2022, Capella Space will have its own 36 satellite constellation that will provide SAR imagery of anywhere on the planet every hour.[6] SAR's ability to see through clouds and even heavy vegetation means it provides a massive increase in the value of commercial satellite imagery to military forces. Other firms and scientific researchers are already employing LIDAR satellites to survey the earth. LIDAR's ability to see through heavy vegetation has recently led to the discovery of thousands of ancient Mayan structure in the jungles of Central America. This effort was led and funded by a U.S. university which equipped a single small aircraft with LIDAR and in two days conducted a detailed aerial survey of 237 square kilometers. LIDAR penetrated the thick jungle canopy to detect the hard stone ruins in enough detail the researchers could identify 7,900 two to three room dwellings in numerous communities as well as the roads and water infrastructure that supported the communities.[7]

As noted, these companies sell not only raw data but finished, integrated intelligence products that can localize a target on land or sea. Progress in this field is being driven by commercial demand from non-technical users. To process the high volume of images requested, commercial firms are rapidly improving automated analysis tools.[8] In particular, there is a high commercial demand for change detection that compares images collected over time and notes any changes. This intelligence is of great commercial value. For instance, multi-spectral imagery allows futures traders to analyze grain production in real time and anticipate the quantity of the harvest. Oil futures traders can see how rapidly shale oil drilling rigs

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3) "Imagery and Insights, Delivered Where You Want to Work," Planet, https://www.planet.com/products/, accessed November 7, 2021.

4) "HawkEye 360 Pathfinder Cluster Mission to identify RFI locations," *eo,* June 11, 2021, https://directory.eoportal.org/web/eoportal/satellite-missions/h/hawkeye, accessed November 7, 2021.

5) Ibid.

6) Gavin Haines, "'No place to hide' for illegal fishing fleets as surveillance satellites prepare for lift-off," *Mongabay,* August 30, 2019, https://news.mongabay.com/2019/08/no-place-to-hide-for-illegal-fishing-fleets-as-surveillance-satellites-prepare-for-lift-off/, accessed October 30, 2021.

7) Laura Geggel, "Details of stunning Maya acropolises and sophisticated civilization revealed by laser scans," *Live Science,* April 30, 2021, https://www.livescience.com/lidar-maya-yucatan.html, accessed November 7, 2021.

8) Edward Lempinen, "A machine learning breakthrough uses satellite images to improve lives," *Berkeley News,* July 20, 2021, https://news.berkeley.edu/2021/07/20/a-machine-learning-breakthrough-using-satellite-images-to-improve-human-lives/, accessed October 30, 2021.

are being constructed or the volume of oil/gas in storage tanks and tankers. Clearly, the same software can be very valuable to military intelligence. In the long-term, it can allow intelligence analysts to track changes to facilities, transportation networks, industrial output, and thousands of other changes that are simply too numerous for human photo interpreters to track. In a crisis, it will allow intelligence officers to observe enemy movements/buildups in near real time even in bad weather.

Commercial firms are investing heavily in drone technologies to provide everything from surveillance to package delivery. To be commercially viable, delivery drones must be able to fly to a specified point with one meter of accuracy, take off and land vertically, navigate in GPS denied environments, be electronically shielded from radiation bursts, carry significant payloads, and fly to increasing ranges. Finally, they must be inexpensive enough for a company to own and operate thousands of these drones – and lose some for a variety of reasons. In short, commercial firms are investing heavily in developing drones that will be ideal for military use too.

The heavy investment has resulted in rapidly increasing range, precision, endurance, and autonomy for commercial drones. Volansi (previously Volans-i) has autonomous, VTOL drones capable of delivering packages out to 550 kilometers at speeds up to 110 kilometers per hour.[9] The company has used these drones to support delivery of emergency supplies during natural disasters.[10] In 2019, Drone Delivery Canada presented its largest and longest. range Cargo Delivery Drone. The company nicknamed it Condor and states it can deliver a cargo capacity of 180 kilograms out to 200 kilometers.[11] Aurora Flight Sciences has developed sensor and control packages that can be installed in any existing aircraft to turn it into a remotely controlled drone.[12] It is clear that commercial competition will continue to drive improved performance in both fixed wing and helicopter drones.

Clearly commercial drones can be converted for use as both ISR and strike platforms. This paper will deal with drones as strike weapons later. For now, it will focus on how drones can improve both ISR and C2. Once again commercial firms are leading the way. Aerovel is producing the Flexrotor. This man-sized drone has already been used for a wide variety of commercial missions – fishery management, guiding ships through sea ice, monitoring traffic in the Chesapeake Bay, and

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9) Brian Heater, "Long-range delivery drone maker Volansi raises $50M," *TechCrunch,* September 15, 2020, https://techcrunch.com/2020/09/15/long-range-delivery-drone-maker-volansi-raises-50m/, accessed November 15, 2021.

10) "The Future of Aerial Logistics Starts Now," https://volansi.com/, accessed November 15, 2021.

11) "Drone Delivery Canada Unveils 'Condor'," Drone Delivery Canada," February 21, 2019, https://www.helis.com/database/news/cargo-drone-delivery-condor/, accessed November 15, 2021.

12) Warren Duffie, Jr., "Special Delivery: New Autonomous Flight Technology Means Rapid Resupply for Marines," Office of Naval Research, December 13, 2017, https://www.onr.navy.mil/en/Media-Center/Press-Releases/2017/2017-AACUS, accessed November 15, 2021.

catching poachers in the Pacific Ocean. During the sea ice mission, fog closed in. The operators later noted

> Low visibility would have put a typical manned aircraft's crew in danger, but Flexrotor simply returned to the fog-shrouded ship, landed automatically, and waited for the skies to clear. The whole reconnaissance operation was much safer and more practical than any manned-aircraft option, and less costly.[13]

Given winter weather conditions in Korea, the inclement weather capability of modern drones is vital. In addition, Flexrotor drones are particularly useful due to their small size, vertical take-off and landing capability, autonomous, long-endurance (over 30 hours), and versatile sensor package of multi-spectral imagers or synthetic aperture radars (SAR).[14] Thus they not only can fly in inclement weather, they can continue to provide ISR through the weather and foliage. These systems can also be equipped with a communications relay package to allow them to relay information from other Flexrotors at a greater distance. The VTOL capability means they have been flown from parking lots, fields, research vessels, ice breakers, U.S. Coast Guard, and U.S. Navy vessels. Their relatively low cost (reported as $200,000 in 2015) and minimal manning requirements mean they can be fielded in sufficient numbers to provide tactical commanders with organic, responsive ISR.[15] And of course, Aerovel is only one of dozens of companies competing to improve drone capabilities and usefulness.

The rapid advances in commercial drone technology are influencing military drones too. The U.S. Navy and Marine Corps are fielding the V-BAT as a rugged, vertical take-off and landing (VTOL) drone to provide commanders a highly responsive, medium-endurance (8 hours) ISR platform.[16]

Aurora Flight Sciences has really pushed the performance envelope with its Orion UAV. It operates from any small airfield but can fly autonomously for five days with a 450 kilogram payload. The payload can include multi-spectral, synthetic aperture radars, LIDAR, communications packages, or a combination of these

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13) Andy Nickerson, "Aerovel Flexrotor Unmanned Aerial System," *Sea Technology,* https://sea-technology.com/aerovel-flexrotor-unmanned-aerial-system, accessed November 12, 2021.

14) "Flexrotor Small Tactical Unmanned Aerial System," Air Force Technology, https://www.airforce-technology.com/projects/flexrotor-small-tactical-unmanned-aerial-system/, accessed October 29, 2021.

15) M. Moon, "Drone can stay in the air for two days to spot fish poachers," *Engadget,* August 6, 2015, https://www.engadget.com/2015-08-06-aerovel-flexrotor-fisheries.html, accessed November 12, 2021.

16) "US Navy selects Marti UAV's V-BAT for VTOL UAS prototyping effort," *Naval Technology,* April 29, 2021, https://www.naval-technology.com/news/us-navy-selects-v-bat-for-vtol-uas-prototyping/, accessed October 29, 2021.

sensors. On shorter missions, it can carry a payload of up to 1,600 kilograms.[17)]

Drones can also provide communications nodes for command and control systems. With the ability to sustain hundreds of pounds of communications gear aloft for hours and even days, large drones can provide long-endurance communications networks to provide alternative communications pathways in time of war. Even smaller drones can be linked together into low-probability of intercept, local networks to provide temporary C2 for tactical units.

As with satellite services, it is commercial demand that is driving the very rapid improvements in range, precision, and payloads across the range of drones from small hobby systems to large, long-range delivery and surveillance systems. Thus we can expect continued remarkable advancements in all aspects of drone performance.

## Cheaper Autonomous Precision Weapons

The second major technological advance driving rapid changes in the character of war are autonomous weapons. These weapons require both on board navigation (to get to the desired battlespace) and sensors (to determine which targets to attack in that battlespace.) Navigating to the target area has been mastered. Today, every smart phone has a GPS receiver so cheap GPS navigation for weapons has clearly been mastered. At the same time, numerous researchers are examining alternatives to provide for location in GPS denied areas.

University's and commercial firms are producing drone navigation systems today that do not require and external signal to determine the location of the drone. Massachusetts Institute of Technology created an autonomous drone fleet that used LIDAR, onboard communications, and wireless communication to map the floor of a canopied forest.[18)] IEEE published a paper on using optical flow navigation, based on how animals navigate, to create a very low power, non-GPS onboard navigation system.

> The use of hardware and power consumption in the optical flow navigation is very much less when compared to other navigational aids and thus it is being developed for micro air vehicles enabling to fly in cluttered environments with high maneuverability fast mapping and very little overall system weight.[19)]

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17) "Revolutionary Endurance in a Flexible ISR and Communications Platform," Aurora Flight Sciences, https://www.aurora.aero/medium-altitude-long-endurance-uas/, accessed November 15, 2021.

18) Alan Cameron, "In MIT project, drones map without GPS," *GPS World,* January 9, 2019, https://www.gpsworld.com/in-mit-project-drones-map-without-gps/, accessed November 12, 2021.

19) C. Aasish, et. al., "Navigation of UAV without GPS," *IEEE Explore,* https://ieeexplore.ieee.org/document/7097260, accessed November 12, 2021.

Military organizations are also employing Inertial Navigation to operate in GPS-denied areas.

The second half of the targeting problem – determining what to attack in the battlespace – requires a combination of sensors and limited or task-specific artificial intelligence (AI). Once again commercial developments aimed at creating autonomous vehicles have resulted in massive drops in the costs of lightweight, low-power electro-optical and radar sensors. Systems like the Israeli produced Harop autonomous drone/loitering munition have proven that limited or task-specific AI can merge the inputs from optical, radar, and electronic signals to allow it to be an effective autonomous suicide system. Harops and other drones/loitering munitions dramatically demonstrated their effectiveness in the recent Nagorno-Karabahk Conflict.[20] The Harop also has a psychological effect on the battlefield. When this loitering munition enters its terminal dive and accelerates to 400 kilometers per hour, the engine creates an unnerving wail much like the German Stuka dive bomber in World War II. It can be heard in the video embedded in the article titled 'The Sound Of This Nighttime Suicide Drone Strike Is Absolutely Terrifying.[21]

## Operational implications

Electro-optical and electronic warfare sensors can provide a great deal of information that, combined with external sensors such as satellites and drones, can allow the defenders to visualize the battlefield using passive sensors. And the increasing range of a variety of smart weapons systems mean they will have the advantage of fighting from very widely dispersed, prepared positions. While most current systems must be manned to operate, autonomous and remote control systems are being developed worldwide. As these systems mature, defenders can be located at a distance from their weapons and thus not be at risk even after firing.

The evolution of massed, long-range, precision weapons and persistent surveillance can provide major advantages to the defense if the ROK builds a force structure that optimizes their use. It may also finally provide a viable counter to the north's artillery massed along the DMZ.

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20) John Antal, "The First War Won Primarily with Unmanned Systems," https://higherlogicdownload.s3.amazonaws.com/AUVSI/7bc57aaa-ae26-4c7a-93f9-512dc4a1bca0/UploadedImages/Ten_Lessons_from_the_2d_Nagorno-Karabakh_War_by_John_Antal_2021-03-08F.pdf, accessed November 14, 2021.

21) Thomas Newdick, "The Sound Of This Nighttime Suicide Drone Strike Is Absolutely Terrifying," *The Drive,* April 21, 2021, https://www.thedrive.com/the-war-zone/40265/the-sound-of-this-nighttime-suicide-drone-strike-is-absolutely-terrifying, accessed November 14, 2021.

However, like all major force transitions, it will be difficult and time consuming to overcome institutional and political resistance to the necessary changes. The transition can be eased by the relatively inexpensive concept of marrying new to old technology as a path to the new force structure.

For instance, long-range missiles can be mounted on existing military or even commercial vehicles eliminating the requirement to develop and field yet another expensive military vehicle. For over a decade, the Russian firm, Kontsern-Morinformsistema-Agat, has promoted its Club-K or Kalibr-class family of missiles mounted in standard shipping containers.[22] Rosobonorexport, which specializes in Russian defense equipment, provided promotional material showing the containers mounted on commercial trailers, merchant ships, and rail cars. As part of the sales pitch, Rosobonorexport offered to containerize the entire family of Kalibr missiles as well as drones. The company claims their current containerized missiles have ranges out to 1,500 miles.[23] By taking a modern missile system and mounting it in a standard shipping container, the Russians provided at least two key advantages. First, it vastly increased the number of vehicles that could carry these weapons. Any commercial truck, rail car, ship, or barge capable of carrying a standard 20 or 40 foot container is now a potential weapons carrier. So there is no cost involved in developing and maintaining a military platform to deploy the weapon. Second, until the missiles are raised to the firing position, it is virtually impossible to tell these containers from the tens of thousands of containers located in advance countries. These containers are ubiquitous even in underdeveloped countries.

The balance of this paper will consider how the Republic of Korea and exploit these new battlespace conditions and technologies to deter and, if necessary, defeat north Korean aggression.

## Defense Dominance

By employing cover, concealment, and passive or distributed sensors, defenders can observe and track the attacker without generating targetable signatures themselves. This combined with long-range, precision weapons in large numbers is recreating the 1914-1917 battlefields of Western Europe where a defender could identify, engage, and destroy any target within range on the surface. Except today defenders are not limited to line of sight and the short-range artillery of World War I. Today's defender can have near constant surveillance over and engagement ranges

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22) Michael Stott, "Deadly new Russian weapon hides in shipping container," *Reuters,* April 26, 2010, https://www.reuters.com/article/us-russia-weapon/deadly-new-russian-weapon-hides-in-shipping-container-idUSTRE63P2XB20100426, accessed November 14, 2021.

23) "Club K Missile System," Rosobornoexport, Russian Defence Export, http://roe.ru/esp/catalog/marina-de-guerra/armas-de-la-nave/klab-k/, accessed November 14, 2021.

to 500 miles. Thus any fixed facility can be easily targeted by a variety of long-range, precision weapons. Even mobile systems will be at risk to autonomous, active hunting drones.

Recent developments in advanced manufacturing have made it possible to produce small drones in the tens of thousands. In 2014, University of Virginia Professor David Sheffield 3D printed the Razor, a small autonomous drone. He attached a small jet engine and two batteries to provide power. Flight control/autonomy was provided by a cell phone. His team could print and assemble the drone in 28 hours. It was hand-launched and had a range of 50 kilometers.[24]

In 2015, Carbon 3D released a printer that was over 100 times faster than the one used by Sheffield.[25] This means he could have printed 100 of these autonomous drones in a day in 2015. Printing speeds have increased considerably since then. In addition, United Parcel Service projects that 3D printing will dramatically reduce the need for package shipping. It has started work on a 1,000 printer plant at its shipping hub in Louisville, KY, a 100 printer regional plant in Singapore and another in Germany, and is offering retail 3D printing in an increasing number of stores worldwide.[26]

The implications are staggering. Using only the 2015 3D printer speeds, a 100 printer plant (the size of those planned in Singapore and Germany) could produce 10,000 drones a day. A 1,000 printer plant could produce 100,000 drones per day. While these will be small drones, an explosively formed warhead that weighs only 100 grams can penetrate 1.25 centimeters of steel. If it impacts on the hood of a vehicle, it will be sufficient to cause a mobility kill. If it strikes the rockets on a Multiple Rocket Launcher, it will cause catastrophic secondary explosions.

## Implications for ground forces

Given the restrictive and harsh terrain of Korea, ground forces will benefit most from the growing family of missiles and drones. Each of the five traditional invasion

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24) "3D Printing Drones on Demand," *Fabricating and Metalworking,* May 3, 2016, https://www.fabricatingandmetalworking.com/2016/05/3d-printing-drones-demand/, accessed November 14, 2021.

25) Daniel O'Conner, "Introducing Carbon3D the fastest 3D printer ever?," *tctmagazine,* March 17, 2015, https://www.tctmagazine.com/additive-manufacturing-3d-printing-news/introducing-carbon-3d-the-fastest-3d-printer-ever/, accessed November 14, 2021 and "UPS to open 3D printing factory in Singapore with Fast Radius," *tctmagazine*, September 20, 2016, https://www.tctmagazine.com/additive-manufacturing-3d-printing-news/ups-on-demand-3d-printing-singapore/, accessed November 14, 2021.

26) "CloudDDM — Factory With 100 (Eventually 1,000) 3D Printers & Just 3 Employees Opens at UPS's Worldwide Hub," *3DPrint.com,* May 4, 2015, https://3dprint.com/62642/cloudddm-ups/, accessed November 14, 2021.

routes into the Republic of Korea forces an attacker into choke points. The increasing range and autonomy of drones means defending units can be widely dispersed but still concentrate their fires. The fact that even small, inexpensive drones can cause mobility kills on wheeled vehicles will reduce invader mobility to the pace of dismounted infantry.

Recent events have clearly demonstrated ground forces will be subject to attack by the emerging families of swarming drones.[27] While the Nagorno-Karabahk Conflict highlighted the utility of high-end, long-endurance drones like the Harop and Bayrakter TB2, inexpensive autonomous drones are flying now and can be mass produced using advanced manufacturing techniques. Both the United States and China are experimenting with launching drone swarms from vehicles and containers. China has launched 48-small drones from a single, imitation H1 Hummer truck.[28] The U.S. Defense Advanced Research Projects Agency is developing OFFSET – a software package that will allow small-unit infantry to control up to 250 drones at once.[29] The challenges of manufacturing, launching, and controlling large drones swarms have been mastered. Therefore, it is not unreasonable to expect a suitably organized defender to be able to launch hundreds or even thousands of loitering munitions against each brigade-size attack.

Even without drone launchers, dismounted infantry units can vastly increase their range and firepower by marrying new systems to old. The U.S. Marine Corps is testing the Drone 40 (already in use by UK forces). This small drone can be launched by hand or fired from a M203 40mm grenade launcher. With a flight time of 30-60 minutes and a range of 20 kilometers, it can carry a variety of packages – to include small anti-armor warheads.[30] Currently priced around $1,000 each, the producer hopes to cut costs to $500.[31] The low cost and autonomous operation means large swarms of active hunters can be generated by a single rifle company.

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27) Shaan Shaikh and Wes Rumbaugh, "The Air and Missile War in Nagorno-Karabakh: Lessons for the Future of Strike and Defense," Center for Strategic and International Studies, December 8, 2020, https://www.csis.org/analysis/air-and-missile-war-nagorno-karabakh-lessons-future-strike-and-defense, accessed November 1, 2021.

28) Dave Hambling, "China Releases Video Of New Barrage Swarm Drone Launcher," *Forbes,* October 14, 2020, https://www.forbes.com/sites/davidhambling/2020/10/14/china-releases-video-of-new-barrage-swarm-drone-launcher/?sh=4dbd7932ad7f, accessed November 14, 2021.

29) Dr. Timothy Chung, "OFFensive Swarm-Enabled Tactics (OFFSET)," Defense Advanced Research Projects Agency, https://www.darpa.mil/program/offensive-swarm-enabled-tactics, accessed November 14, 2021.

30) Brett Tingley, "Marines Train With Handheld Swarming Drones That Can Also Be Fired From 40mm Grenade Launchers," *The Drive,* July 9, 2021, https://www.thedrive.com/the-war-zone/41479/marines-train-with-handheld-swarming-drones-that-can-be-fired-from-40mm-grenade-launchers, accessed November 1, 2021.

31) Kelsey Atherton, "A drone with a can-doom attitude," *C4ISRNET*, June 5, 2021, https://www.c4isrnet.com/unmanned/2019/06/05/a-drone-with-a-can-doom-attitude/, accessed November 1, 2021.

On a slightly larger scale, the Polish Army has contracted for thousands of units of the Warmate family of small drones. These weapons are small enough a two-man team can transport and employ them on foot. The initial tests done in 2016 apparently mated RPG warheads (high explosive, high explosive anti-tank (HEAT), and thermobaric) to a new but inexpensive drone. The result was a man-portable anti-tank drone with a range of 15 kilometers. Since then, the manufacturer has continually upgraded the system to include limited autonomy. Poland pays about $7,500 per armed drone that with a top-down attack using an anti-armor warhead permits the operator to destroy wheeled and light armored vehicles as well as crew-served dismounted weapons on the battlefield.[32] The prices is a dramatic reduction from the $70,000 the U.S. military paid for similar Switchblade drone that was used extensively in Afghanistan.[33]

Moving up the scale to more capable systems, the Hero family of loitering munitions produced by Israel provides a wide range of options for deployment.[34] Because they can be canister or rail launched, they can be married to a variety of vehicles. They range in size from a few up to 40 kilograms and can range from 10 to 150 kilometers. In the rugged terrain of Korea, even the short range version would allow ROK soldiers to put a couple of ridgelines or many buildings between their launching positions and the targets.

Vehicle mounted weapons systems can provide further reinforcement for the ground forces. Several nations have mounted the containerized Israeli Spike missiles in existing vehicles. M-113 Armored Personnel Carriers, BMP Infantry Fighting Vehicles, BDM Airborne Fighting Vehicles have all been upgraded with these long-range anti-tank systems. Spike missiles can also be launched from light vehicles and helicopters. A package of 8 Spike Missiles can be mounted in military vehicles, commercial vehicles, or simply emplaced on the ground. The ROK has purchased a number of the largest missile in the family, the Spike NLOS (Non-Line of Sight). These weapons are capable of precision attacks at over 25 kilometers. And, at $210,000 per unit, these missiles cost less than the U.S. Javelin but have over 6 times the range. Nor do they require the gunner to initially have line of sight to the target.

The bottom line for ground combat is that infantrymen can have the ability to kill any enemy vehicle or weapons system from a distance. They not only don't have to

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32) Joseph Trevithick, "The Polish Military Is Now Officially Armed With The Warmate Suicide Drone," *The Drive,* February 19, 2021, https://www.thedrive.com/the-war-zone/39353/the-polish-military-is-now-officially-armed-with-the-warmate-suicide-drone, accessed November 1, 2021.

33) Rich Smith, "AeroVironment Will Upgrade the Switchblade," *Motley Fool,* May 11, 2016, https://www.fool.com/investing/general/2016/05/11/aerovironment-will-upgrade-the-switch blade.aspxa, accessed November 15, 2021

34) "UVision: Smart Loitering Systems," https://uvisionuav.com/main-products/accessed November 1, 2021.

expose themselves to the enemy, they don't even have to be within visual range.

## Counter-battery concept

One of the most difficult challenges facing the ROK is eliminating northern artillery before it can cause massive damage to the environs of Seoul. The combination of pervasive surveillance and massed drones provide a potential solution. Constant surveillance using multi-spectral and SAR systems will allow ROK commanders to immediately locate enemy artillery when it moves out of its shelters. As always, ROK counterbattery fire can then engage. Unfortunately, the time consumed by acquiring, targeting, assigning, and successfully engaging the targets, combined with the very large number of northern artillery pieces means Seoul and its environs will still suffer considerable damage. Even the professionalism of ROK artillery cannot prevent this.

But augmenting the artillery with relatively inexpensive suicide drones orbiting over likely enemy artillery locations means these drones can attack autonomously as soon as the artillery pieces expose themselves. Unlike tube and rocket artillery, the drones cannot be subjected to counter-battery fire from the north's artillery. Further, the precision of suicide drones mean the attacks can focus on particular vulnerabilities like the rocket pods and ammunition vehicles. While current sensors and software will not be 100% accurate, they will identify and destroy many artillery pieces.

There may be concern expressed about the ability of drones to discriminate between friend and foe but in the early hours of the fight, enemy artillery will still be north of the DMZ. Since drones can be programmed to limit their attacks to north of that line, target discrimination becomes less critical. They can also be programmed to destroy any trucks or light armored vehicles north of the DMZ to disrupt the north's maneuver units.

## Upgraded IEDs

In addition to high technology solutions, the Army can adopt simpler systems. The ROK already has an elaborate and effective program for mining and obstacle creation but recent events have shown yet another way to complicate an attacker's movement. For almost 20 years, IEDs (Improvised Explosive Devices) defied extensive U.S. efforts to neutralize them. Pairing legacy IEDs with modern surveillance and triggering devices could allow minimally trained reserves to observe and engage enemy formations from a great distance. Just as important, modern systems could allow one team or even an individual to monitor and trigger numerous IEDs. Depending on the anticipated countermeasures, a team could use

cheap video cameras located on buildings, telephones poles, trees, etc. to observe the target area. The camera feed could be delivered to the operator by wire or radio connection. The operator could then be connected to the explosive device by the same methods. When the sensors reveal an enemy in the target area, the operator can detonate the IED from a safe distance and out of sight of the target. Local forces or reserves would be best qualified to place these devices and supervise the evacuation of civilians to protect them.

To augment the defensive barriers, ammonium nitrate fertilizer could be used to provide relatively cheap, but very large devices. A standard 20-foot container can carry 25,000 kilograms of fertilizer – effectively a 25 ton bomb. These large devices could be prepositioned for rapid employment by reserve forces at key choke points. Many businesses have equipment for handling standard shipping containers. Thus reserves can move the containers to designated wartime locations and insert the detonators. These containers can be hidden inside buildings that are adjacent to key chokepoints. While enemy engineers can clear mines and breach obstacles, massive detonations will immobilize an advancing column for a significant period of time. Further, the extensive number of shipping containers found in almost all towns and even farms would force the attacker's to constantly pause until engineers checked the container. They will also be forced to check each building large enough to conceal a container.

In effect, local reserve forces could create smart minefields based on local knowledge of terrain trafficability by season. The only action required on mobilization would be installing fuzes, placing the devices, and connecting the observation and firing systems. Since these systems could make use of civilian vehicles for deployment, they will be very difficult to track or preempt. Of particular importance, it is not necessary to train reserve forces to the level they can engage heavy armor in close combat. Instead, they will be trained to remain at a distance, activate the IEDs, and withdraw to their next position.

## Implications for air forces

A key question today is whether ROK and U.S. forces can defend their base facilities against swarms of missiles and rockets. After years of neglecting airbase defense, U.S. forces are working hard to fill the gap. The United States is betting heavily on directed energy – lasers and microwave (electromagnetic pulse) – weapons to defeat swarm attacks. The U.S. Department of Defense doubled its budget for directed energy weapons from FY-17 to FY-19, upping it to $1.1 billion. These systems show great promise but still face numerous challenges.

Unfortunately, lasers are still subject to atmospheric conditions. Lasers also require a great deal of power that tends to limit the capability of mobile systems.

Fortunately, lasers favor the defense of fixed facilities since the systems can tap into base or national power systems or, if needed, large field generators. The United States has not yet fielded any lasers to protect fixed facilities. However, the U.S. Army will field its first four laser equipped Stryker tactical vehicles in FY-22.[35] The system is designed to engage aircraft, rockets, artillery, mortars, and drones. This first platoon of prototypes will be used to refine the technology, tactics, and logistics for future organizations. Obviously, they could be assigned to air base defense but there will be a very limited number of systems for the foreseeable future.

While laser research continues to absorb the majority of defense spending on direct energy weapons, microwave weapons offer even greater potential for dealing with swarms of drones or aircraft. Rather than having to acquire each target individually and direct the laser for sufficient time to destroy that target, a microwave system can generate a pulse to sweep across and area and disable many targets at a time. The key question is the ability of these systems to overcome electronic hardening and shielding to disable the targets. And of course, unlike lasers, microwave weapons are not effective against ballistic weapons like artillery, mortars, and rockets.

Until many more air defense weapons are fielded, fixed air bases remain vulnerable to massed attacks. This vulnerability will limit the effectiveness of allied air forces in a conflict. However, if the air forces adopt VTOL, long-endurance ISR and strike drones, they can reduce their dependence on air bases. In addition to not requiring an air base to operate, modern drones have vastly longer on-station time than manned aircraft. While a modern strike fighter requires repeated visits to a tanker to loiter over a target area, a V-BAT drone has over 8 hours endurance, a Harop over 30 hours, aTB2 over 25 hours, and a Flexrotor over 30 hours. Thus these relatively low cost, unmanned systems could loiter over the DMZ to immediately identify and engage artillery as it moves out of hardened positions to fire. For the lifetime cost of one F-35, the ROK could field hundreds of these autonomous and semi-autonomous drones. This would also free up manned aircraft to respond to the Combined Force Commander's immediate needs.

Long-range rocket and missile systems will also provide an alternative to aviation for strike missions. Given the ranges involved in an inter-Korean conflict, one has to ask if the U.S. Army's Precision Strike Missile (PrSM) cannot take over most of the strike missions assigned to manned aviation. Currently under development, the Army projects the PrSM will have a range of 500 kilometers by 2023 and 800 kilometers by 2025. Since they are compatible with the Multiple Launch Rocket System (MLRS) there is no need to develop a new platform to use these missiles.

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35) Devon L. Suites, "Army to field laser-equipped Stryker prototypes in FY 2022," *Army News Service,* August, 20, 2021, https://www.army.mil/article/249549/army_to_field_laser_equipped_stryker_prototypes_in_fy_2022, accessed November 1, 2021.

Another possibility is the Kongsberg Naval Strike Missile. The U.S. Marine Corps is fielding this missile mounted on the Joint Light Tactical Vehicle (JLTV). This autonomous cruise missile has a range of 180 kilometers but is small enough two can be mounted on the JTLV.[36]

To provide truly massed attacks, the U.S. Navy and Marine Corps conducted an experiment that launched 1,000 small, autonomous, armed drones from a single C-130. The U.S. Navy has even launched over 100 of these small drones from a flight of F-18s.[37]

In short, these weapons can provide resilience for long-range strike that, to date, has required manned aircraft operating from fixed facilities. The unfortunately reality is that allied forces cannot provide adequate defense of their airbases against drone and missile attack. While Allied Air Forces have the ability to operate manned aircraft from highways, their sortie rates will obviously be seriously degraded. And the major maintenance facilities that are part of every airbase will no longer be available.

Given the increasing lethality and availability of drones and missiles, it is prudent to consider what other weapons could be purchased in place of a manned aircraft. While Lockheed and the U.S. Air Force have announced the cost of Lot 14 F-35s will be down to $78 million each, that price does not include the equipment necessary to make the combat ready.

> According to the Air Force's aircraft procurement justification book for fiscal year 2021, the $77.9 million sticker price for the 2020 model F-35A jumps to $110.3 million per aircraft when all aspects of the program are added together.[38]

While it is impossible to find a definitive cost of a Harop in open source material, the estimates range from $100,000 to $500,000. Using the highest estimate, the ROKAF could purchase 220 Harops for the purchase cost of an F-35A.

But the real cost of manned aircraft comes in operating them. The F-35A has an estimated lifetime of 8,000 flight hours.[39] Each flight hour currently costs $36,000.

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36) "Naval Strike Missile," Kongsberg.com, https://www.kongsberg.com/kda/products/defence-and-security/missile-systems/nsm-naval-strike-missile-nsm/, accessed November 1, 2021.

37) Joseph Travithick, "The Navy Plans To Launch Swarms Of Aerial Drones From Unmanned Submarines And Ships," *The Drive,* March 1, 2021, https://www.thedrive.com/the-war-zone/39535/navy-contract-exposes-plans-to-launch-swarms-of-drones-from-unmanned-boats-and-submarines, accessed November 1, 2021.

38) Dan Grazier, "Selective Arithmetic to Hide the F-35's True Costs," *POGO,* October 21, 2020, https://www.pogo.org/analysis/2020/10/selective-arithmetic-to-hide-the-f-35s-true-costs/, accessed November 14, 2021.

39) "F-35 Joint Strike Fighter (JSF)," Department of Defense, https://www.dote.osd.mil/Portals/97/pub/reports/FY2017/dod/2017f35jsf.pdf?ver=2019-08-19-113748-273, accessed November

Lockheed is promising to reduce the cost to $30,000 per hour. (Although Lockheed has consistently exceeded their own cost estimates throughout the life of the F-35 program.) Using the Lockheed low-cost estimate, the lifetime flight hours cost is an additional $240 million per aircraft for a total of $350,000,000 per fighter. Based on these numbers, the ROK could purchase 700 Harops for the lifetime cost of one F-35.

Unfortunately despite focused efforts to improve readiness, the F-35 readiness rate is 69 percent so one has to buy three F-35s to have two available to fight. In addition, the $350 million covers only the purchase cost and operations and maintenance funds. It does not cover the training pipeline for pilots or maintenance personnel. Nor does it cover the cost of running the airfields required for operations. It does not cover the lifetime costs for the personnel necessary to operate and support the aircraft -- or the extensive and expensive support equipment. It is not improbable to estimate the ROK could have 1,000 Harops for the full lifetime support cost of one F-35A. With 6 Harops per truck, the enemy would have to eliminate 166 vehicles to pre-empt a strike. In contrast, the F-35 is very vulnerable when on the ground and only needs to be hit once.

This paper is not suggesting that the ROK necessarily buy Harops in place of F-35s. However, the ROKAF needs to carefully study the cost/benefit tradeoff of using unmanned platforms in place of increasingly expensive, increasingly vulnerable, and decreasingly ready manned aircraft.

## Implications for naval forces

Planned and delivered modern ships have already increased the effectiveness and lethality of the ROK Navy. However, purchasing modern missiles and drones would be a relatively inexpensive way to increase the lethality and range of the Navy's older and small vessels.

The U.S. Navy has demonstrate the use of deck mounted launchers to fire the Naval Strike Missile from Littoral Combat Ships. This missile can also be modified to be fired from helicopters. Other nations have also developed deck mounted launchers that could provide modern missiles for older ships. While it has a Long-Range Artillery Weapon (LORA) quad-pack launcher designed for shipboard use, Israel has also launched LORAs from a commercial ship by simply loading the truck mounted version on the deck, putting to sea, and testing the weapon. They achieved hits at ranges of 90 and 400 kilometers.[40] The LORA carries either a 600 kilogram unitary or sub-munition warhead.[41] Clearly, systems like these can

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40) "Ballistic Missile Firing Trial Completed Successfully," IAI Press Release, June 2, 2020, https://www.iai.co.il/lora-ballistic-missile-firing-trial-completed-successfully, ccessed November 14, 2021.

provide significant range and firepower to the ROK Navy older vessels.

The U.S. Navy has also used deck mounted launchers to deploy very large drone swarms. As noted earlier, even small autonomous drones can have considerable range and are effective anti-vehicle weapons. Drones and missiles employing both unitary and sub-munition warheads could provide the ROK Navy with increased capability not only against enemy naval forces but also provide supporting fires to ROK forces ashore.

## Conclusion

For a variety of reasons, ROK forces are project to be reduced in size over the next decade.[42] Fortunately, a new generation of small, relatively cheap, and increasingly autonomous weapons can provide major upgrades to combat capabilities of ground and naval forces. Just as important, they can provide an alternative for air forces if they can no longer operate from fixed bases.

[Received: November 27, 2021; Revised: December 10, 2021; Accepted: December 20, 2021]

41) "LORA," Missile Threat, CSIS Missile Defense Project, https://missilethreat.csis.org/missile/lora/, accessed November 14, 2021.

42) Benjamin Brinelow, "South Korea's military has big problems that are much closer to home than North Korea," *Insider,* February 3, 2021, https://www.businessinsider.com/south-koreas-military-modernization-bigger-problem-than-north-korea-2021-2, accessed November 1, 2021.