Drones

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Brief preface to Drones: My goal for this paper is to provide a “Drones: 101” overview of drones with emphasis on miliary uses because the greatest impact in dollars and on military doctrine is in warfare. I’ll list civilian uses, and on the way, I will identify some bits of trivia that I hope will add to one’s appreciation of drone development. Power Point will provide only pictures of various drones in different environments. Slide #s refer to the Power Point attached.

The digital copy will contain two topics that I culled from drone research in order to meet time limits--- one addresses what might be victory and the other the lack of drone laws and regulations. And, so to begin:

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Warfare ranks first in dollar impact, causing an immediate $100 billions of world defense

realignment. We will quickly go down the list with illustrations and then return to drone warfare.

Slide Number two: Emergency response, delivering medical supplies to inaccessible places, reducing time, saving lives and at lower cost. Drones are not ubiquitous as of yet, but an early study shows them arriving nearly 5 minutes sooner than an ambulance.

Number three: Disaster monitoring: floods and fires. Early detection and locating victims are common. While not standard for fires, yet, drones have become standard in flood response for both rescue and to provide food and water.

Number four: Precision agriculture. Remote sensing and monitoring of crop health; Less wasted fertilizer and pesticides. USDA estimates drone market value at $560 million and globally at $6 billion with annual growth of nearly 25%.

Number five: Logistics and delivery of goods. Enormous growth in supply chain management: Cameras on goods, Remote Delivery, Pandemic Isolation. Growth is at 75% per year with growth from $1.5 billion to $18 billion by 2030.

Number six: Infrastructure inspection and maintenance: Great for hard-to-reach places, lowering human risk. Growing rapidly into the $ billions to inspect power lines and sewers.

Number seven: Surveillance and Intelligence. Heat signals are detected from high above; people easily located and filmed in remote locations. This is one of the most mature and versatile uses of drones for police, search and rescue and disaster response.

Number eight: Democratized aerial filmmaking: aerial perspectives more intimate than helicopters. Far cheaper than helicopters. Slide shows a student narrating a drone-video of a high school football game.

Number nine: Urban Planning. City mapping. Currently a niche use but growing.

Number ten: Wildlife Conservation and Anti-poaching: Growth is projected $ 3 billion in US by 2034.

Picture Eleven: The results will be job creation and new industry: Gamers become military drone pilots

and high school students can create video special effects.

From that list, we see the huge span of effects, some of which were previously available by helicopter or satellite but importantly, now cheaper and more widely available.

STOP PICTURES AT #11

How did this happen? This is a typical story of invention. What are said to be new inventions are most often a mashup of the old. The typewriter and printer plus the telegraph made the FAX machine. The carriage plus a motor, the car. The smart phone added the computer, GPS, camera, memory and the Internet. With drones, we will see a similar path with cameras, satellites, Internet, radio, and explosives. And even more with A.I. Drones will make decisions in the air.

Timeout for Trivia: Insect drones buzz over to the Queen Bee, mate and then conveniently die. That duplicates the sound, the name and also the fate for Unmanned Airborne Vehicles (UAV.) The British Royal Navy's biplane---the WW1 Queen Bee--- used

for target practice---is credited as the first drone. Such drones led to flying bombs.

But World War 1 was not the first modern drone. The trivia fact is that the first drone was invented by Jacques and Louis Breguet, a quadcopter in 1907. It flew for a few seconds. In 1924 Etienne Oehmichen, also in France, completed a one-kilometer closed circuit flight, however despite military efforts in the 1950s by Curtiss-Wright, it took the invention of gyroscopes and microcontrollers before stable quadcopter drones were practical, like the Parrot using MEMS sensors to create a drone market, about 2010.

PICTURE #12. Left is 1907 Quadcopter Drone: Right toy Parrott

The history of warfare is one of change and brutality. After plodding along familiar tracks, abrupt changes topple empires. Persia (about 500 BCE) exploited long-range composite bows, but then Alexander the Great defeated Darius of Persia (about 330 BCE) by

ruthlessly fusing cavalry, phalanx discipline, and short swords. Rome added logistics, building roads and creating new professionalized formations for its armies, creating an empire that fell to the Huns on horseback. Emperor Consantine moved the Roman Capital to Turkey where the Byzantine empire of a thousand years survived until 1453. About 1206, the Mongols surrounded the Byzantines and the empires overlapped until about 1360. The Mongols had invented new bows with a range of 400 yards fired from mobile horseback, and with unequaled brutality, they created the largest contiguous empire in history. And so, for 2000 years, war depended on tactics with swords, spears and the mobility of horsemen. Although Constantinople fell from within in 1453, it was gunpowder that ended the long era of walled castles, and gunpowder with airpower and a global navy allowed Great Britain to build an even larger non-contiguous empire. These empires trace war-history technology for nearly 3000 years wherein mobility and firepower from air and sea were the forces for change. We speed you through this abbreviated history to make the point that drone

warfare as a force for change is quite equal to previous innovations, and for largely the same reasons.

The conflict in Ukraine has served as a live laboratory in which drones—once considered mere surveillance tools—have redefined the tempo, visibility, and lethality of modern combat. What has emerged is more than an evolution in technology, but instead the abandonment of long-held military doctrinal assumptions. Ukraine was the trigger.

The initial shock of Ukraine's defense against Russia's 2022 invasion reverberated far beyond Eastern Europe. The capacity of small, inexpensive drones to detect, track, and help destroy large concentrations of armor and artillery stunned observers who had expected the conflict to be dominated by conventional massed formations. It surprised everyone when Turkish Bayraktar TB-2 drones and a host of small reconnaissance, unmanned airborne vehicles (UAVs), all linked to precision artillery, destroyed Russian armored columns outside of Kyiv.

Russian generals had relied, as their doctrine had for generations, on waves of troops protected by columns of tanks supported by artillery and aircraft.

The loss of a thousand tanks and thousands of human casualties brought the world's financial cost accountants into the conversation. Drones radically change the cost ratio between killer and killed. A nation's survival may depend on calculations made by CPAs who assist Generals. We still need $20 million drones that can destroy a $billion ship, but it is the $200 drone that halts a $10 million tank, destroys a $50 million in oil tanks or forces ships to flee their ports that brings a tiny nation to parity with the Great Powers

Thus, the old calculus of war is obsolete, and drones linked to A.I. are unavoidable. The Pentagon and European counterparts have unveiled studies acknowledging that the new drone-sensor battlefield has "collapsed" (their word) the concept of operational depth. TRADOC, the U.S. Army Training and Doctrine Command, founded in 1973 as the group responsible for all technologies, tactics and procedures, quickly addressed new ways to detect, track, identify and defeat hostile drones.

RUSI, the British Royal United Services Institute for Defense, called the transformation "a revolution in reconnaissance and strike," Drones eliminated operational sanctuaries.

In China, The People's Liberation Army immediately changed tactics, warning in 2022 that "integrating drones with artillery created a new paradigm of transparent battlefields."

States already invested in UAV development—Israel, Turkey, and Iran—accelerated production and marketing to increase sales and export, treating Ukraine's battlefield as a marketing proof of concept. The Turkish Bayraktar TB-2 became a symbol of inexpensive, semi-autonomous lethality, an advertisement for the democratization of tactical airpower.

SHOW PICTURE #13 OF BAKTAR TB@ Stop at #24

I will break here to scroll, rapidly, through some pictures of Six Large, Expensive drones and four small drones then return to my text.

Even Russia by late 2022 changed military doctrine, adopting domestic and imported drones—the Lancet, Orlan, and Shahed systems.

To quickly review the new rules: Drones target troop concentrations; local air dominance costs a fraction of fixed-wing air cover; drones strike deep behind lines; and tanks must be dispersed and protected from above where their armor is light. As important,

the battlefield has become constantly visible forcing dispersion, concealment and digital control.

Institutional adaptations testify that the shift is systemic, not episodic. This has caused:

A. Rapid Funding for Counter-UAS Systems: Nations have poured resources into jammers, lasers, and kinetic interception weapons.

B. European militaries, from Poland to Finland, rushed to procure modular anti-drone shields for their borders.

C. Research now focuses on autonomous swarm-on-swarm engagements and AI-assisted early-warning systems that can detect UAVs faster than human operators.

D. U.S. Army's 2022 revision of Field Manual

3-0 and NATO's 2023 Allied Joint Doctrine both enshrine drone swarms, and demand constant and persistent Intelligence.

E. Training Transformations: Sergeants from platoon to battalion now train using GPS-jamming, as standard scenarios. U.S. General Mark Milley, as Chairman of the Joint Chiefs of Staff, observed that *"we are witnessing a fundamental shift in the character of war."*

The change is deeply philosophical, affecting even the psychology of combat leadership. No one likes being constantly watched. Drones are the Big Brother of the battlefield.

But, in many respects, the past is prologue.

As trench warfare gave way to tank mobility, drones have reintroduced the stalemate. Static lines-drone warfare allows for use of both very high technology and very low. Simple fish nets are used over roads and machines. Wire cages are placed over tanks. Deception is encouraged involving decoys and false targets. In Ukraine, cardboard tanks were used to lure drones. Inflatable mock weapons have been used. False heat signals can be scattered to confuse detection of warm engines or human body heat. Guerilla sized skirmishes that avoid concentration of manpower reward small team tactics from the past.

We will move on, from offense to drone defense. How drones are controlled and programmed, is intertwined with how they may be defeated. The current status is that drones use a small set of low-cost sensors that may be visual, Infrared, Radio Frequency, Satellite-Geo-Positional or from Inertial Angular measurements; those sensors must be protected by the drone but targeted for attack by the defense. Monitoring of sensor and communications systems provides opportunity for early warning and perhaps for “soft kill” solutions that distort the drone’s orientation and down it quietly. Soft kills include radio frequency jamming, GPS “spoofing,” dazzlers that blind optical sensors, and networked no-drone airspace.

Often, in a swarm, a mixture of control modes exists: It is common in the front lines for a soldier to control one or more drones by line of sight (LOS) for which the controller sees the target as if he is inside the drone

3) Show actual drone here $1500 3-mile range with camera and TV screen

Other drones in a swarm are longer range, beyond visual line of sight (BVLOS) are programmed and integrated. Autonomous behaviors include collision avoidance, task allocation and primitive cooperation,

and a human may be engaged for some mission-friendly decisions. The trend is for “human friendly” controls that allow one operator to supervise many systems.

Hard kill technology applies to small numbers of drones and also to take out expensive drones of extended range ---the drones that cost millions but that can destroy targets of hundreds of millions of dollars. We know this to be the job for radar, expensive rockets, lasers and systems like “the iron dome” of Israel. These are the defenses that bankrupt the attacked.

SLIDE #24 Anti-Drone Guns for Soldiers

Hard kill solutions may involve special “shotguns” that target drones with sprays of buckshot. High Energy Lasers (HEL) are good against single or small numbers of drones in clear conditions; Israel and several other countries have demonstrated successful single-target or small-group intercepts. Lasers are attractive because cost per shot (electricity) is low relative to missiles. And, as well, rockets, actual airplanes and swarms of our drones (versus their drones) provide a hybrid mix of drone defense.

But swarms are the problem.

The greatest challenge comes with autonomous swarms of cheap drones. What is a swarm in numbers? It is less a fixed number and more a *tactical concept* of many low-cost drones, that are coordinated to do reconnaissance, decoy and strike a target. https://www.gao.gov/assets/gao-23-106930.pdf Programming of these attacks uses biological patters of "swarm intelligence" as seen in groups of bees or birds, where decentralized rules create complex collective behavior, or murmuration. https://sdi.ai/blog/military-drone-swarm-intelligence-explained/ The rules of murmuration are based on each bird being aware of 7 birds and watching separation (do not collide) and direction (go with the flow) and position/velocity (stay with the group) and goal following. Leadership is distributed but "on the wings of" only a few birds, not "a leader," a natural example of emergent intelligence.

This Artificial Intelligence murmuration of drones to be autonomous allows them to enact programmed activity, even when some drones, even leading drones, are 'killed'. Swarms challenge every defense.

Purposes of swarms also vary. A saturation attack may be to overwhelm defenses, or a distributed

swarm may blend sensors in overlapping areas to build a composite intelligence picture. Other swarms may be to use cheap dollars to cause the enemy to waste money on expensive interceptors. Counter measures depend on swarm numbers, but include attacks by one's own swarm of drones, and wide area microwave, called high-power microwave (HPM,)the latest and best current solution to swarms.

#25 HPM Camp Atterbury & #28

Here we encounter a test done at Camp Atterbury, Indiana. On August 28, 2025, Epirus company demonstrated its high-power microwave counter-UAS system by neutralizing a swarm of 49 drones **in** a single pulse. According to Epirus' press release, the system in the event disabled 61 out of 61 drones (100 %) across five flight scenarios, culminating in the 49-drone swarm. The system is described as delivering "weaponized electromagnetic interference" designed to disable drone electronics across a volume/area rather than targeting individually. The event included observers from the U.S. Department of Defense and foreign allied nations. This is milestone event that signals a shift from interceptors toward an area effect.

The Swedish Armed Forces unveiled a new drone-swarming program, developed by defense giant Saab. This cutting-edge software empowers soldiers to control up to 100 uncrewed aircraft systems (UAS) simultaneously. Defense systems program their assets to allow for ten to fifty per operator per system. Research is aimed at coordinating defense of thousands. We'll mention quickly that the United States has the MIT Perdix system as well as the August 2025 Replicator program, with $500 million allocated to study drone swarms. All major nations have such programs, and in each, the bottom line is that of cost imbalance.

We have discussed Ukraine vs Russia. What might be the next event? It seems Russian policy regularly to test enemy defenses using flyovers. This map of Europe is instructive as are the news reports of airport closings in Europe related to anonymous drone overflights.

SLIDE #26 EUROPE

And to finish on a low note, here is the Asian Times, musing about China and the Taiwan strait. The article began with what we know to be the common sentiment---that is that the author expected a short war. Now he states: "Russia seeks no genuine peace. The Ukrainian stalemate will continue."

Elsewhere, “the core Asian question remains China’s claim to Taiwan, and the wealth of Taiwan’s chip foundries. Beijing’s calculus is constrained. Taiwan’s semiconductor industry is the prize it covets yet cannot replicate. A kinetic assault could destroy the foundries it needs intact, forcing years of reconstruction.” Drones allow for targeted, partial destruction of hard assets.

Last SLIDE #27

“Beijing calls reunification historical justice. Taipei sees resistance as survival. It is not China’s capacity to invade but Washington’s will to intervene. In most US–China war games, America loses unless it rewrites its playbook.” The author’s conclusion: The United States “must relearn how to produce weapons at scale, fast and without foreign dependencies.” The only question is whether the US will rearm its industries before Beijing tests the strait —or whether Ukraine’s slow grind will replay itself in Taiwan.

Words: 2650

LAST SLIDE DRONE ORGANIZATION

This ends the verbal presentation. Removed from research documents were these thoughts:

What constitutes victory? Military doctrine states that the victor must occupy, control and govern the conquered territory, but this has not always been necessary. A no-go zone can be established as has been done on the 38th parallel in Korea. Another option is to make a territory unlivable, or scorched earth. Yet another is enforced servitude and penury as the Mongols (and to a degree the Vikings) enforced on Russia. After the Mongol Army was successful in defeating the enemy, governance and total occupation was not contemplated. By returning each year with a renewed threat of destruction, the winner extracts tribute when it regularly returns. This became known as "The Mongol Yoke," and was an intelligence gathering, administrative success for 240 years. Conquered officials became local "princes" who were in fact Mongol tax collectors. And so, there are different ways "occupy" territory.

Also removed from the presentation copy was this reference to the legal status of drones in civilian life and one's right to privacy.

We've examined military changes and dangers, but we should address another conflict before we leave the topic of drones. Outer space is regulated by the ITU of the United Nations with an ill-defined border of 100 km, the

so-called Kaman line. The Federal Aviation Agency (FAA) controls our airspace above 500 feet—1000 feet above cities. But the huge problem for now that airspace below 500 feet---and despite claims, since 2015, by FAA that they control that also, this is disputed by States, Cities, Homeowners and Farmers. We can divide that 500 feet into increments: 0 to 83 feet; 83 feet to 500 feet or 200 feet to 500 feet.

The *U.S. Supreme Court case United States v. Causby (1946)* established that landowners have **exclusive use of the "immediate reaches" of the airspace** necessary for the enjoyment of their land.

- In *Causby*, low-flying military aircraft (~83 ft) were held to constitute a **taking**, because they destroyed the use of the farm.
- The Court deliberately **did not define a precise altitude boundary**, leaving the "immediate reaches" open to interpretation.
- Some City and State laws have regulations that apply to 200 feet and below, but the area between 200 and 500 feet is least defined and least regulated.
- This creates problems for damage caused by drones, legal rights to destroy a drone that impairs personal privacy or creates unwanted noise, and basic control of homeowners' airspace.
- *The Economist* magazine headlined October 25, 2025, that "The Trump administration has a chance to write sensible rules for drones, and he issued an

executive order in June ordering FAA to speed up rules allowing drones to operate beyond visual sight.

- Those rules need be clear, uniform and feasible. It is likely that flights will be forbidden over outdoor public gatherings and above 400 feet.
- Everyone from hot air balloonists to drone hobbyists have complained about FAA plans.
- Pilots say drones should always give way to manned vehicles, saying that a drone carrying a burrito" is more nimble than a balloon or plane. All drones should broadcast a location signal, they say.
- For this Indiana audience, this argument amounts to a review of Indiana University Nobel Prize winner, Lyn Ostrom's publication: "Governance of the Commons." Commons, she said, delighting conservatives, can best be governed by rules agreed upon by those who use the fishery, the forest, the condominium and enforced by adequate punishments. If not, she said, delighting those who favor more government, the government must step in and provide rules and punishments.

But, for now, drone warfare and civil use of drones is the Wild West. Until Congress takes the opportunity to enact necessary and useful legislation to address civil conflicts involving privacy and regulation of space, drones are guaranteed to bring chaos, both civilian and military.

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