DRONES

YESTERDAY, TODAY, AND TOMORROW

Technology changes the face of combat

BY **STEVE LLANSO**

EDITOR'S NOTE:
Drones are not, as is often assumed, a 21st-century development. Far from it. Their history goes back more than 100 years, but the rate at which they are changing our everyday life continues to accelerate. So we thought it is worth looking back and seeing where the concept came from, how it developed, and where it stands today. Given the current rate of change, it's obvious we're only seeing the tip of what is going to turn out to be a very big technological and cultural iceberg.

1. Kittering Bug, 1918. (Photo courtesy of Wikimedia Commons) 2. KDN-1 Target Drone, circa 1946, developed at NAMU Johnsville. (Photo courtesy of Stan Piet) 3. General Motors A-1 Drone, Muroc, 1941. (Photo courtesy of USAF) 4. Predator, currently active. (Photo courtesy of Wikimedia Commons) 5. The early Ryan Q-2A Firebee was operated by all three services in the mid-1950s. (Photo courtesy of Stan Piet) 6. Movie star Reginald Denny built models and drones for the U.S. Army. (Photo courtesy of USAF)

First-order change

Drones constitute a fundamental transformation in both military and civilian realms. In an unmanned air system (UAS), the miniaturization in technologies, accurate navigation, and the separation of the pilot from the vehicle form a combination that might be called a "first-order change." It is a fundamental shift in direction. Just as jet engines wrought a similar change in commercial and military aviation, it is the effect of the Big Change that matters more than the types or uses of aircraft that follow.

The drone's usefulness is expanding exponentially and runs the gamut from highly beneficial support of humanitarian operations to the frankly destructive mission of armed conflict. In short, a new day is upon us, but it didn't happen overnight. It was a long time coming.

Early Days: Trial, Error, and Indifference

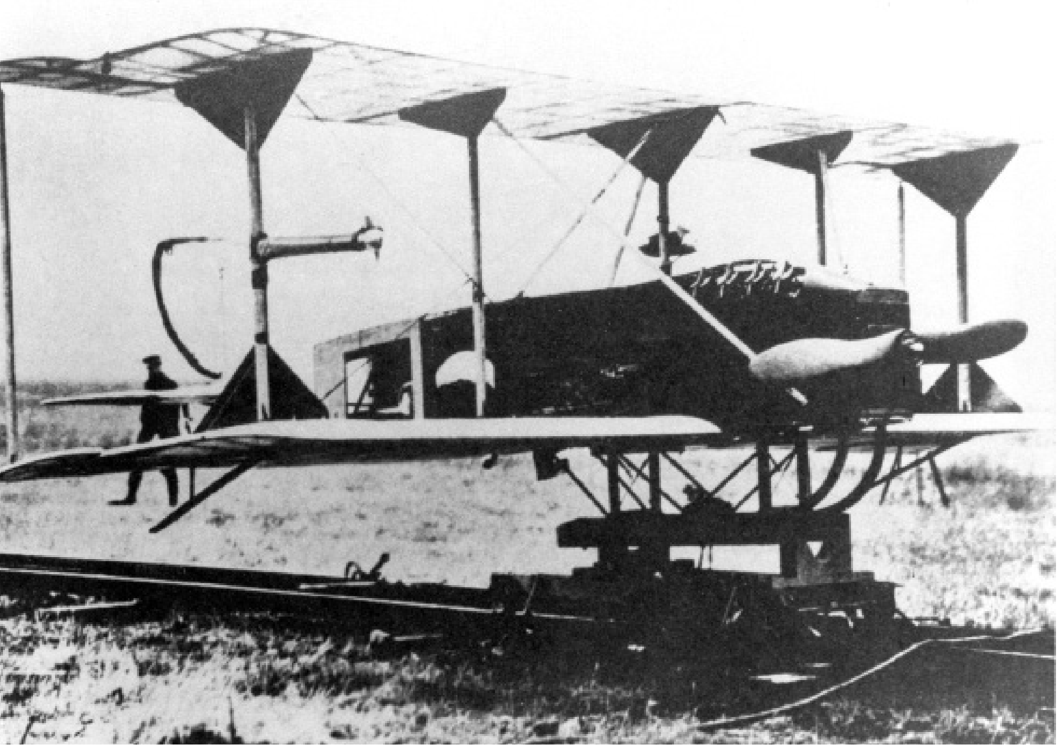
The first drones were developed along two different paths: an autonomous vehicle and one guided by a separate aircraft. In World War I, the Navy tested one kind of "aerial torpedo," the Army another. Each involved a collection of ingenious and experienced inventors.

The Navy program incorporated Elmer Sperry's three-axis gyroscopic flight-control system that was demonstrated in a successful flight down the Seine a month before the Great War began. Peter Cooper Hewitt's $3,000 and a partnership with Sperry in late 1916 led to the Hewitt-Sperry Automatic Airplane. Daring tests undertaken by Sperry's son Lawrence led to a contract for six Curtiss Speed Scout airframes, which were the "first purpose-built unmanned aircraft."

The Aerial Torpedo, fitted with the Sperry system, enjoyed its only success on March 6, 1918, when it guided itself over a 1,000-yard flight, then obeyed a preset command to dive on the target. Given that the target was the Long Island Sound, this may seem like a small success, but it has been noted by some that the Aerial Torpedo was the first unmanned aircraft vehicle (UAV) to be recovered and flown again.

Problems with the catapult and other systems crashed the Speed Scouts, but a converted N-9 trainer was successfully launched on October 17, 1918, and flew as planned for eight miles. At that point, drone aviation experienced its first uncommanded "fly away," when the trainer's flight continued until it disappeared over the horizon. The Navy's attention turned to an occasional interest in target drones and the Sperry-Hewitt program ended.

The Sperry-Curtiss "Pilotless Flying Bomb" was an attempt at a cruise missile in 1918 with a 40-mile range. The dive into the target was initiated after a given number of engine revolutions. It had limited success and was never produced but is still considered the first pilotless aircraft. (Photo courtesy of Wikimedia Commons)



Kettering's Bug

Meanwhile, Charles Franklin Kettering persuaded the Army to award a contract to the Dayton Wright Airplane Company for 25 Liberty Eagle aerial torpedoes. The Kettering Bug's design and construction set precedents in several areas of later drone design in its inexpensive construction. The specially designed 41hp engine propelled the aircraft at 120mph. The distinctive dihedral of the biplane wings came from Orville Wright, as did launch from a dolly. Sperry's gyro contributed controllability.

The Bug's flight tests proved mostly unsatisfactory, largely due to a flight-control system that mixed pneumatics with gears and electricity. The Bug never approached its promised reliability, however, primarily because of its late start: It first flew just a month before the armistice was signed, so the Bug was never "debugged" due to lack of interest. The last few flights in 1919 enjoyed some success, but by that time, no one cared.

The Navy continued testing the radio control of pilotless aircraft, reaching a milestone on September 15, 1924, when a control aircraft successfully flew a radio-controlled Curtiss F5L flying boat from takeoff through its flight and water landing. But development in remotely piloted aircraft then stalled and didn't resume for more than a decade.

Officially named the Kettering Aerial Torpedo during WW I but generally referred to as the "Kettering Bug," it was much more successful than the Curtiss Flying Bomb. Elmer Sperry, later known for gyro instruments, devised the guidance system, while the airframe was built by Curtiss-Wright, with Orville Wright as a consultant. The 40hp De Palma engine was produced by Ford. The fuselage was made out of wood and papier-mâché, while the wings were originally cardboard. It had a range of 40 miles. (Photo courtesy of Wikimedia Commons)

Sideshows and Desperate Measures

Navy Lt. Cmdr. Delmar S. Fahrney revived the aerial torpedo as an outgrowth of his development of drones (a usage he coined) beginning in 1936. Spurred by U.S. observers' reports on British target aircraft such as the Fairey "Queen Bee," Fahrney and RCA began development of television-guided weapons in which the bomb's camera transmitted target images to a controller in the launch aircraft.

The entry of the United States into WW II dramatically increased demand for target drones and spurred the search for useful offensive weapons. Encouraged by tests conducted in 1942 in which 47 of 50 flights were deemed successful, the Navy contracted for 500 assault drones and 170 mother ships.

Interstate TDR-1 drones would be the only WW II type to attack targets. An agreeably flyable airframe, the midwing monoplane was powered by two 220hp Lycoming engines, spanned 48 feet, and weighed 5,900 pounds. With 189 TDR-1s built, they could carry up to 2,000 pounds of explosive payload about 425 miles. The RCA Block-1 TV system developed by Vladimir Zworykin used a small camera and transmitter that weighed 97 pounds and fit in a box measuring only 8 x 8 x 26 inches. An austere pilot's position for tests and transportation would be faired over when the TDR-1 was sent on its primary mission.

Staging STAG-1: Drones Go to War

Special Task Air Group One (STAG-1) tested the combination of TDRs and TBM-1C Avenger mother ships in 1943 and early 1944. Low on the funding food chain, the crews adopted workable makeshifts including the use of a rotary phone dial to select drone altitude and weapons release options. STAG-1 was sent to the Solomon Islands in July 1944; the two squadrons of TDR-1s and TBM-1Cs performed capably with 21 of the 46 attacks considered successful. The system enjoyed little support, however, and was canceled. Both types of aircraft were pushed overboard on the way home.

The Interstate TDR-1 "Edna" saw moderate success in 1944 under Operation Option, where, carrying bombs, 50 were directed toward Japanese targets in the Solomon Islands utilizing an RCA TV camera guided by a TBM-1C drone controller. (Photo courtesy of Stan Piet)

Replacing the earlier F6F-3Ks, Grumman Panthers and later F9F-6K Cougars provided a more robust target platform for air-to-air missile testing at Point Mugu in the late 1950s. (Photo courtesy of Stan Piet)

Desperate Measures Redux

During WW II, the Army Air Forces (AAF) and the Navy modified war-weary bombers into massive flying bombs. The AAF's program was Operation Aphrodite: Its mission was to destroy Vengeance-weapon launch sites by crashing a B-17 (designated BQ-7) into them. Using TV imaging and a radio control system, laden with 18,000 pounds of Torpex explosive, the bombers required pilots onboard during takeoff and a short cruise-flight phase. Just before the plane reached the North Sea, the two-man crew armed the Torpex and bailed out. About 25 B-17Fs were converted for that purpose.

In tests and actual attacks from August to October 1944, crew fatalities were surprisingly low, but maintaining control of the aircraft proved to be nearly impossible. In attacks against German V-weapon sites and later against submarine pens, only a few BQ-7s exploded upon impact in Germany, Sweden, and England. Only one attack caused significant damage to the enemy.

The Navy's Project Anvil converted PB4Y Liberators into drone BQ-8s beginning in July 1944. Only two missions were flown to test the complicated control system. A director located in a PV-1 Ventura flew the pilotless BQ-8 after receiving course corrections from an accompanying PB-1 (Navy B-17), which received the television image from the BQ-8. In its first test flight, flown by Lt. Joseph P. Kennedy and Lt. Wilford John Willy, the onboard TV system apparently transmitted stray voltage to one of the Torpex detonators, and the plane suddenly exploded. Poor TV quality frustrated the only actual attack on a sub pen. After those two flights, the program was canceled.

For almost two decades after WW II, unmanned aircraft development in the United States focused on target drones. Only one other attack-drone system saw action during that time. In July 1952, Guided Missile Unit 90 (GMU-90) deployed six F6F-5K Hellcat drones, each carrying a 1,000-pound bomb. Flying from USS Boxer (CV 21), Douglas AD-4N control aircraft sent the drones against six North Korean targets in August and September 1952, with little success.

With wingtip-receiving antennae, surplus F6F-3K Hellcat drones served as target material for early Sidewinder and Sparrow I missile development at NAS Point, Mugu, the last in May 1961. (Photo courtesy of Stan Piet)

Eye in the Sky

The very nature of manned aerial reconnaissance aircraft at the time (slow and vulnerable to ground fire) put pressure on the designers of target drones to assign their creations' additional duties: The ability to see was deemed as important as the ability to destroy.

In 1955, the Army tested a reconnaissance variant of Northrop Ventura's RP-4 (OQ-19) target drone, named RP-71 Falconer (SD-1, later MQM-57). Falconer may have been the first U.S. drone to be designated part of a system (AN/USD-1) that included the air vehicle and control system.

Twelve feet long with a span of 12 feet and weighing 430 pounds, the RP-71 zero-launched using small rockets, reached 184mph, and had a range of about 100 miles at altitudes from a few hundred feet above sea level to four miles. Its control system used radar to track the aircraft's flight when it flew out of the controller's sight. A stick box provided direct control using pictures from an onboard camera, which was switched on when the Falconer reached an area of interest during its 30-minute flight. Images were captured by a still camera or an optional video camera.

The Army purchased 1,485 Falconers over several years, and although it had limited capability and never saw combat, drone expert John David Blom says that it "solved many of the traditional problems Army ground commanders had with aerial reconnaissance support. It was stationed with his forces, it could fly in weather that would ground other aircraft, and the intelligence it gathered could be processed by the unit's staff and be available for use in a timely manner."

Despite these contributions, the Falconer was the only battlefield UAV deployed by U.S. forces for some time.

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A DASH for Salts: Going After Submarines

Beginning in the mid-1950s, the Navy saw the potential for operating attack drones from destroyers against the enormous Soviet submarine fleet. A DASH (Drone Anti-Submarine Helicopter) extended the weapons reach of small anti-submarine warfare ships out to the limit of the powerful AN/SQS-26 sonar.

The flight vehicle was the compact Gyrodyne DSN-1 helicopter, which used coaxial main rotors and, as the definitive turboshaft-powered DSN-3 (redesignated QH-50C), was first deployed in January 1963. Possessing no sensors, the DASH relied on shipboard radars for command and control.

Naval affairs expert Norman Polmar observed that the DASH program was "both a success and a failure." More than any earlier remotely flown attack aircraft, DASH claimed a capability in its own right. According to many destroyer commanders, DASH, when flown within its limits, granted an unparalleled offensive reach to

The AQM-34L Firebee "Tom Cat" flew an amazing 68 missions before being lost. (Photo courtesy of USAF)

smaller combatants.

On the negative side, 411 of 746 QH-50C and QH-50Ds procured (55 percent) were lost in crashes due to electronic-systems failures in either the aircraft or the shipboard control units.

Significantly, when DASH ships independently flew QH-50s on "Snoopy" gunfire-support missions over Vietnam beginning in January 1965, the partnership fared far better due to the increased operational tempo, which enhanced proficiency of their operators, and the fitting of real-time video and film cameras. QH-50s also bombed river traffic and tested cargo transport into remote outposts.

The Navy ceased DASH operations in November 1970 and would not procure another shipboard drone for nearly two decades.

Lightning Bug

The first Q-2A (Ryan 134) Firebee jet-propelled target drone entered service in July 1957. At the same time, Ryan began touting its Ryan 136 reconnaissance variant with longer wings for higher-altitude flight and radar-return-reduction modifications to the fuselage and engine intake.

By 1963, the redesignated Ryan 147, now known as a "remotely piloted vehicle" (RPV), had entered service in the Strategic Air Command with its DC-130 Hercules drone-control aircraft. It solved the problem of risking pilots over China by placing the controller thousands of miles from the aircraft in hostile territory. Unquestionably, the Q-2C brought unmatched speed, range, and survivability to the remotely piloted reconnaissance mission, setting the standard for all long-range ISR (Intelligence, Surveillance, and Reconnaissance) drones to come.

After initial teething problems, the Lightning Bug found success in a variety of configurations and in high- and low-level operations, mostly over Vietnam between 1964 and 1973.

The 350th Reconnaissance Squadron flew 3,466 Lightning Bug sorties between August 1964 and June 1975, losing 578 drones (an average of one loss for every six sorties). The AQM-34Ls achieved a survivability rate of 87 percent, and one flew 68 missions before being lost.

Still, the complexity of the systems and a natural proclivity for commanders wanting human eyes and cameras over the target stopped further development of the system.

Pioneering RPV

Beginning in 1975, interest in RPVs led to several programs, including the Sky Eye and the potentially capable Aquila, but they remained limited for a variety of reasons. Meanwhile, a continuing Israeli search for a relatively inexpensive RPV led to their development of the Mastiff. The U.S. Navy and Marine Corps chose the Mastiff II in 1986 for manufacture in the United States as the aptly named Pioneer, an UAS that would demonstrate many technologies still central to battlefield UAVs.

MANY MILITARY ANALYSTS POINT TO THE INHERENT POTENTIAL LIABILITY OF DEPENDING ON A SATELLITE SYSTEM. KNOCK OUT GPS AND MANY ELECTRONIC NAVIGATORS MIGHT DRIFT AIMLESSLY.

Built by the Insitu subsidiary of Boeing Aircraft, the ScanEagle was originally designed for civilian fish spotting but has proven itself as a long-endurance observation drone. (Photo courtesy of Wikimedia Commons)

A small twin-boom aircraft (essentially an RC airplane) with a gimbaled TV and forward-looking infrared turret, 100nm data-link range, and eight-hour endurance, the RQ-2 Pioneer was rail-launched from Marine Corps trucks and zero-launched from two battleships. The 82nd Airborne Division took one system of five Pioneers to Kuwait in 1990. Pioneer's real-time targeting capability led to the well-known Iraqi soldiers' attempt to surrender to the USS *Wisconsin*'s RQ-1, while the design's endurance led to continuous tracking of a mobile Scud launcher until its destruction by other aircraft.

Changes in the types of conflicts involving U.S. and NATO forces after the Cold War's end ensured that both kinds of pilotless vehicles—lookers and shooters—would see service frequently. Over such battle zones as Kosovo, however, early Predators were vulnerable to ground fire and lacked the radar needed to fly in the frequently foul weather. It has been a learning process.

No Pilots in Cages, Please

The use of drones flown by U.S. military and intelligence organizations exploded in the late 1990s and really took off after the 9/11 attacks for many reasons.

A key reason for the growth certainly lies in U.S. revulsion over the treatment of downed pilots in the Korean and Vietnam Wars. This durable constraint, combined with the end of the Cold War in the early 1990s, influenced American actions in a succession of new conflicts in which the combatants deployed asymmetric (i.e., sometimes brutal and unacceptable) means and ends that often frustrated U.S. aims. But it's also clear that the United States has enjoyed a favorable asymmetry in many instances: The use of unmanned drones, as well as cruise missiles, forestalled any decision to put "boots on the ground," whose wearers could be captured and killed.

The Sky's the Limit?

The size, variety, and competence of the U.S. drone fleet compared to just a decade ago is difficult to summarize. Current or imagined drone design envisages enhancements using more computer power, sharper and more discriminating sensors, or greater independence from continuous remote control while ensuring more precise responsiveness. Overall capability per pound of airframe keeps rising and is unlikely to level off soon.

Small hand-launched drones, like the electrically powered RQ-11B Raven, weigh less than 5 pounds yet carry EO/IR cameras and IR markers, and cruise noiselessly at 1,000 feet for up to 90 minutes. The Navy's widely used ScanEagle weighs less than 50 pounds and offers persistent ISR. Its origins in commercial fish finding demonstrate the ubiquity of many drone capabilities. Well-known Predator-family systems use runway-launched aircraft (RQ-1/MQ-1/MQ-9) for both ISR and armed attack. At the top of the weight and cost scale is Global Hawk (RQ-4), which combines high operating altitudes, subsonic cruise, and a multitude of sensors.

The X-47B test aircraft successfully took off and landed from aircraft carriers in 2013 and conducted autonomous refueling trials in April 2015. The Aurora Orion completed an 80-hour endurance flight in December 2015. Thus, the drone horizon continues expanding—in both directions.

Top: The Raven is a squad-deployable, short-range, low-cost UAV that instantly gives infantry units eyes in the sky. (Photo courtesy of Wikimedia Commons) **Above:** With a wingspan of 130 feet, the Northrop Grumman RQ-4 Global Hawk is a true airplane-size unmanned aerial vehicle. It has become the "Swiss Army knife" of the government drone program as it is used for everything. All-up unit cost, including R & D, is reported to be $222.7 million. (Photo courtesy of Wikimedia Commons)

Infallibility Is for Popes

Despite the improvements, drone design reveals persistent shortcomings in several key areas, chief among them being completely accurate positioning. The Global Positioning System (GPS) has solved much of that problem but has introduced other vulnerabilities.

The Vietnam-era AQM-34's Doppler navigation system had a nominal drift error of 3 percent, which often led to a failure of capturing the target on film in many low-level flights.

The end of the Cold War in the early 1990s accelerated the open use of the GPS satellite network by civilians as well as organizations, and the impact of increased accuracy has been dramatic.

Weak points still exist. Many military analysts point to the inherent potential liability of depending on a satellite system. Knock out GPS and many electronic navigators might drift aimlessly. Indeed, a stealthy RQ-170 jet-powered drone was reportedly brought down in Iran in 2014 through GPS jamming. Several companies are working on navigation systems that do not rely on GPS.

Available Manpower Limits Unmanned Flight

Weight and cost growth are inevitable companions to mission creep and requirement expansion. Perhaps the greatest constraint on drone operation, however, comes from the very remoteness and limited supply of its operators. Far from being a one-to-one-scale video game, drone operations require unique skills. In 2014, Captain "Joe" described the two-person Predator team: The sensor operator (SO), a "career enlisted aviator," has three tasks—"put the thing on the thing," "optimize the picture," and be "master of the laser." The Pilot leads the crew on the mission. He or she makes the tactical decisions.

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Captain Joe's summary reveals just how many opportunities exist for confusion and failure. For example, the SO might act by simply putting crosshairs on the target or working a problem "as complex as finding enemy personnel via a talk-on from a confused and disoriented, hunkered-down JTAC [joint tactical attack controller] taking effective fire." Meanwhile, the pilot's situational awareness "needs to reach outside of his crew position to envelop the aircraft, the crew, the JTAC, and the tactical situation on the ground."

In 2015, MQ-1/9 pilots reportedly flew, on average, 13 to 14 hours a day, six days a week, imposing pressures that lead more pilots to leave the service than the Air Force can train. Demand across the battle spectrum continues to ratchet up as well. In 2005, 11 combat air patrols (CAPs) at a time could only fill a third of the demand in Iraq. CAPs over battle areas worldwide increased to 65 per day by 2014 but only satisfied 21 percent of requirements.

A Drone Revolution in Military Affairs?

Let's close with a range of questions concerning the future of UAS in U.S. military procurement and practice that go far beyond the reduction of crew positions in airframes. Does seeing drones as tools too easily obscure their ambiguous role in tracking down terrorists or conducting persistent surveillance? How readily can the military and civilians use the same technologies? How much will the current U.S. edge in drone experience and range of systems decrease over time? How much money and talent will be diverted from other "rice bowls"? At what rate will the counter-drone response require more investment in counter-counter-drone systems?

The answer to the foregoing questions is the same cliche: "Only time will tell." The single guarantee about drones is that they are here to stay, and we are only seeing the tip of a very large technological/political/tactical iceberg that is growing at an incredible rate. The future of drones is going to be interesting. ✈

Developed from the Predator and stepping past the role of surveillance and data gathering, the MQ-9 Reaper is the first "hunter-killer" UAV with weapons-delivery capabilities. It can be flown remotely by a ground-based pilot or flown autonomously by preprogrammed onboard intelligence systems. Unit cost, not counting R & D, is reported to be $16.9 million. It is built by General Atomics. (Photo courtesy of Wikimedia Commons)