Small Unmanned Systems

Next-generation prospects

by Mr. Ed Darack

>Mr. Darack is the author of several books about the Marine Corps, including *Victory Point, The Warriors of Anbar,* and *War Moments.* He has also published numerous articles in the **Marine Corps Gazette** and **Leatherneck**, three of which have been included in anthologies by the History Division, United States Marine Corps. He develops small unmanned systems for military use through his company, Darack Research. He first wrote about unmanned systems for the **Marine Corps Gazette** in the November 2014 issue with the article, "Unmanned Multirotor Aircraft System."

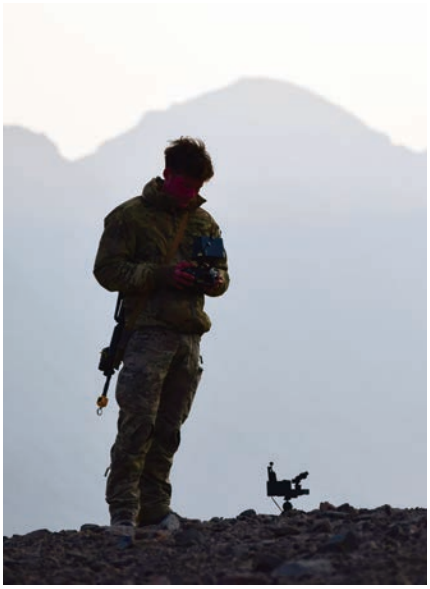
Military use of small unmanned systems, particularly small unmanned aircraft systems, has expanded significantly in the past decade. ("Small" describes a system—inclusive of vehicle, control system, power, and accessories—that can be carried and operated by a single person; these systems today typically weigh less than 20 pounds.) Components for these systems continue to become more functionally robust while their physical size and expense have decreased substantially. Today, small unmanned systems perform several military roles operationally, including intelligence, surveillance, and reconnaissance (ISR) collections and loitering munition strikes. A broad and expanding base of practitioner experience, combined with continuously improving componentry and novel innovations, is propelling the development of new and refined capabilities. Prospects for next-generation systems include integrating active systems for optimizing situational awareness, multi-domain functionality, dramatically prolonged mission endurance, adaptable architectures, and novel integration of engagement systems. Deployed and operated by small units and specialized teams, detailed integration of these next-generation systems into multi-domain, combined-arms constructs promises to further enhance warfighting efficacy at the tactical and operational levels.

Historical and Developmental Reference

The world of military unmanned systems has a long and rich history, with notable innovations dating to the early 20th century. The Hewitt-Sperry Automatic Airplane of 1917, which could carry 1,000 pounds of explosives and was guided by an early inertial navigation system, was among the first powered unmanned aircraft to fly. In 1921, the U.S. Navy repurposed the USS *Iowa* (BB-4) battleship as Coast Battleship No. 4, a radio-controlled surface vessel used for target practice. In the 1930s, the Soviet Union created radio-controlled land combat vehicles dubbed "teletanks" by modifying several of their manned tank designs. In 1957, the U.S. Navy's Office of Naval Research funded the development of the Self-Propelled Underwater Research Vehicle, SPURV, the world's first autonomous underwater vehicle.[1]

Evolving electronics and radio technology enabled the miniaturization of unmanned systems beginning in the 1930s, notably with developments by the California-based Radioplane Company. The OQ-2, which measures eight feet, eight inches in length and has a wingspan of twelve feet, three inches, was one of the first mass-produced unmanned aerial vehicle (UAV) models in aviation history. Remotely piloted using a radio control system, the OQ-2 performed the function of flying target for U.S. Army and Navy surface-to-air anti-aircraft gunnery training exercises during World War II.[2] The 1947 invention of the transistor and subsequent development of integrated circuits ushered in a new era of capabilities for virtually all industries and disciplines, including aviation, imaging, and

View of a monitor on a C2 unit showing real-time feed from an experimental small unmanned system targeting a Marine Corps MV-22 B Osprey parked at the airfield of the Marine Corps Mountain Warfare Training Center. The user controlled the vehicle from 2.65 miles distant. (Photo by Ed Darack.)



A Royal Marine operates a small surveillance and targeting pod during a training exercise at the Marine Corps Mountain Warfare Training Center. The system comprises a day/night video camera, a self-marker, and a laser pointer boresight mounted to the camera. The system, which can be deployed by a small UAV, can provide persistent ISR and can actively build situational awareness under the command of a remote operator. *(Photo by Ed Darack.)*

communications. These developments would eventually enable engineers to create the next generation of unmanned systems—those used primarily for ISR—and make these craft small and light enough to be man-portable.

In the early 1960s, the Central Intelligence Agency funded a top-secret initiative called Project Aquiline. This was a small UAV to fill strategic- and operational-level ISR gaps present among the U-2 and A-12 (precursor to the SR-71 Blackbird) strategic reconnaissance aircraft and photoreconnaissance satellites. Resembling an eagle, the "small powered glider intelligence collection system" had a wingspan of six feet and comprised a "TV Eye" in its nose to provide imagery intelligence. Although the Central Intelligence Agency conducted several tests of the Aquiline UAV in Nevada, it never entered production.[3] The U.S. Navy introduced the radio-controlled Gyrodyne QH-50 DASH (Drone Anti-Submarine Helicopter) UAV for antisubmarine warfare in the mid-1960s. The world's first operational helicopter UAV, the DASH weighed more than 2,000 pounds (gross) and was the first UAV and first rotorcraft to carry a nuclear weapon.[4] The Israeli-built Tadiran Mastiff UAV, which first flew in 1973 and served in the Yom Kippur War and the 1982 Lebanon War, is generally considered the first operational military UAV dedicated to ISR collections. The piston-powered Mastiff was developed to provide operational- and tactical-level situational awareness with "over the hill views," and while smaller than manned craft, it is too large to be man-portable.[5]

The Emergence of Small Unmanned Systems

In the years following the debut of the Tadiran Mastiff, companies throughout the world developed smaller and lighter aircraft systems for tactical- and operational-level ISR collections, many of these being electric-powered. Electric power is quieter and more operationally efficient due to ease of use, but batteries are less energy dense than hydrocarbon fuels, and hence, endurance suffers. In 1988, American aviation company AeroVironment introduced the FQM-151 Pointer, an electric-powered, fixed-wing ISR UAV featuring a fixed video sensor in its nose and a real-time downlink. The complete system, including command and control (C2) unit, accessories, and extra batteries, weighs 45 pounds. The aircraft, which weighs 9 pounds and has an endurance of 60 minutes, can be disassembled within 5 minutes and stored within a backpack.

By the early 2000s, services throughout the DOD operated roughly 200 different types of UAVs, many of which were small, electric-powered, man-portable systems.[6] AeroVironment developed the Pointer into the RQ-11 Raven, a UAV introduced in 2003 that can be piloted from a ground station or operate autonomously using pre-programmed GPS waypoints. Advanced iterations of the Raven have endurances of up to 110 minutes and can carry high-resolution day/night video cameras. The model was used by the Marine Corps until January of 2023 with great success throughout the world for ISR collections at the platoon and company levels and remains in the inventories of the U.S. Army, Navy, and Air Force, as well as those of the militaries of several foreign nations.[7]

First introduced in the late 1980s, small multirotor aircraft (also called multicopter aircraft) are VTOL (vertical take-off and landing) systems that can fly and hover with great precision. These aircraft typically comprise between three and eight motor-rotor thrust assemblies, with the most common configuration, a "quadrotor" or "quadcopter," using four.[8] One of the first commercially available small multirotor UAVs, the Canadian-made Draganflyer (a quadrotor), debuted in 1999.[9] By the late 2010s, multirotor flight controller technology had progressed substantially, becoming inexpensive, robust, powerful, and lightweight.

Small multirotor UAVs have proven to be extremely capable for military use for several reasons. Their size allows them to be carried and deployed by a single person, and because they launch and land vertically, they can be operated with minimal signature as an operator can continuously remain in a covered position during operation.[10] Due to the miniaturization of components, small multirotor UAVs can carry several subsystems, including ISR and engagement systems (as demonstrated with the loitering munition multirotor UAVs employed prolifically in the Russo-Ukrainian War). The key disadvantage with multirotor UAVs

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has been their mission time, which is typically less than 40 minutes, and depending on payload, altitude, temperature, and winds, often less than 15 minutes. Electric-powered hybrid multirotor fixed-wing UAVs have debuted in recent years that combine VTOL functionality with fixed-wing flight profiles. Some of these have endurances of up to 90 minutes in ideal conditions.

Several unmanned ground vehicles, including tracked vehicles and wheeled vehicles, are small enough to be deployed and operated by individuals. Small unmanned ground vehicles have been used to collect imagery intelligence and to perform basic robotic tasks, such as retrieval and manipulation. Such vehicles are often used for explosive ordnance disposal tasks and for the delivery of engagement systems, particularly kinetic engagement systems (as demonstrated in the Russo-Ukrainian War).

View of a small UAV in flight, showing multiple tie-down points, easily configurable landing gear, and two remotely-actuated attachment points (hardpoints). *(Photo by Ed Darack.)*

Next-Generation Concepts

Several novel capabilities and constructs for small unmanned systems have emerged by studying current and past systems and leveraging the broad base of available experience and technology available today. Development includes not just technology and design, but novel implementations, unique combinations of subsystems, tactics, techniques, and procedures, implementation into training exercises, doctrine analysis, and user feedback loops.[11]

Passive and Active Systems Are Used in Concert for Optimized Situational Awareness

Most small unmanned systems used today for ISR comprise just passive systems, typically a visible wavelength video camera and/or an infrared video camera. Adding active systems, including illuminators, laser pointers, and remotely activated marker beacons, serves to functionally extend and project the capabilities of individual warfighters, small units, and specialized teams like scout sniper teams and special reconnaissance teams. Furthermore, this extension of capability promotes an optimized signature, as the user can remain in a covered position during operation. An unmanned system, either ground or air, equipped with such active systems in addition to imagery capabilities, can illuminate a remotely visualized target or sparkle (point at with a laser pointer) a target. This can help build situational awareness for other participating entities, including other ground units and inbound aviation platforms. This parallels the capabilities of an on-site warfighter using an integrated pointing and illumination module (like a PEQ-16B, which comprises a visible and an infrared laser pointer and a visible and an infrared illuminator).

A small unmanned system equipped with deployable, remotely activated marker beacons and a self-marker can mark targets and create landing zones/drop zones/pickup zones (similar to hand-deploying chemlights). The small unmanned system can also be used for battle damage assessment after an engagement through its onboard video camera(s). Several such systems were tested at the Marine Corps Mountain Warfare Training Center during a notional raid on an airfield for phase 0 shaping from several miles distant.

Multi-Domain Design

Small unmanned systems designed to operate in multiple domains (small unmanned multi-domain systems, or SUMIDS) can dramatically synergize warfighting capability. For example, a small multirotor UAV designed with an articulating sensor / active system module mounted atop the main body of the craft (for unobstructed field of view), combined with a versatile, field-modifiable landing gear system, can function optimally while in the air or on the ground. A user who has had full-spectrum training in such a system can identify key terrain features, modify its landing gear appropriately, and fly the craft to an identified location. The user can then remotely articulate the sensor to gather imagery intelligence and employ active systems such as an illuminator or laser pointer if appropriate to help build situational awareness. Such a system was tested at the Marine Corps Mountain Warfare Training Center with success. The system tested comprises a means that allows a user to remotely de-energize most of the craft's systems for power conservation. This allowed a mission time of up to 48 hours, the vast majority of which was spent on key ter-

Demonstration of a UAV performing ISR from the ground. The UAV is equipped with an articulating day/night camera, a boresight-mounted laser pointer, a visible illuminator, and an infrared illuminator. This system was designed with its ISR/active situational awareness systems atop the craft for maximum field of view and easily configurable landing gear. Before system deployment, a user would identify key terrain features, determine the length and configuration of landing gear legs based on vegetation, snow depth, etc., fly the system to a key terrain feature, and then could perform ISR with the articulating camera. The user could then sparkle a target, illuminate an area, or deploy remotely-activated marker beacons for landing-zone creation or target marking. ***(Photo by Ed Darack.)***

rain features. The system was flown to several locations to perform passive ISR, active marking and illumination of targets, and placement of remotely activated marker beacons for targeting and landing-zone designation for notional raid packages.

A multi-domain architecture also comprises interoperability among multiple systems and multiple system types, including remotely deployable, stationary ISR pods and small unmanned ground vehicles (including ground vehicles deployed by air vehicles). Such interoperability was tested at the Marine Corps Mountain Warfare Training Center with positive results.

Design for Versatility, Expandability, and Modularity

Systems developed for easy modification, expansion, and modularity anticipate and facilitate the inevitable interest by warfighters for customization, including during training to develop new tactics, techniques, and procedures or operationally for tactical adjustments. Designs comprising an open architecture with basic construction allow easy modifications and repair, including in austere environments lacking robust support systems. Multiple tie-down points allow users to easily add subsystems of all types, including those for all types of environments and weather conditions—"every clime and place." Designs featuring multiple remotely-actuated attachment points ("hardpoints") allow systems to carry and deploy beacons, small stationary pods, small vehicles (like small unmanned ground vehicles), small packages, and engagement systems. Engagement systems may include those used for: low-power electronic warfare, cyber penetration of wireless networks, small kinetic strikes, information operations, and the interdiction of other unmanned systems.

Flight control systems that are designed for modularity and adaptability allow users to quickly customize a small unmanned system for a variety of command-and-control needs, from remote piloting to waypoint navigation. Each operational environment will dictate unique requirements, and hence the use of such features as automatic return-to-home, position hold, autoland, and waypoint navigation, and obstacle avoidance. Real-time image analysis tools, including those utilizing deep learning mechanisms to identify movement, patterns, and other visual signatures, can be integrated into modularized control systems as well as intelligence-gathering systems.

Detailed Integration

Detailed integration into current, evolving, and emerging multi-domain, combined-arms warfighting constructs is critical to maximizing the capabilities of small unmanned systems that possess next-generation capabilities. Building situational awareness, including using active systems, is arguably the most salient role for these systems. Beginning with phase 0 shaping, and including *in extremis* situations, small unmanned systems can significantly advance combat efficacy. During Phase 0, a warfighter can remotely perform passive ISR, imaged from the air and ground, while he maintains an optimized signature in a covered position miles from the area of interest. The ISR performed with systems designed to function from the air and the ground can provide imagery intelligence from perspectives unattainable from satellite or aerial imagery. He can then remotely mark targets and target areas for talk-ons and visually outline helicopter landing zones with marker beacons, each of which can be remotely activated at the appropriate time. The highest levels of integration would allow C2 handoff of deployed beacons so that others, including aviation platforms, can control these beacons.

These systems, positioned on key terrain features for persistence, can provide passive ISR feed throughout an operation—and be repositioned when appropriate throughout an operation. A user can then, when appropriate, sparkle, illuminate, self-mark, or deploy marker beacons based on operational progression. During the progression of the operation, such systems can provide real-time battle damage assessment, adjustment of fires, and aid in *in extremis* situations, including close air support and mortar

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and artillery packages. The ability to self-mark with an onboard beacon can be used to build situational awareness with close air support platforms in concert with a talk-on, or as a sacrificial target mark.

Next-generation systems, when comprising the ability to de-energize all but its C2 receiver, are optimized for persistence and low signature. Operated by an adequately trained user, a system can persist for more than two days in an area of interest with the ability to conserve power. During this time, the user can minimize the system's electromagnetic signature by remotely powering appropriate systems, such as the video transmitter, only when necessary. High-endurance, low-signature operation significantly increases the functional relevancy of such systems throughout the course of an operation.

Designed for modularity and versatility, small unmanned systems can deploy a host of subsystems, such as those used for intelligence collections, including signals intelligence, measurement and signature intelligence, communications intelligence, environmental and weather intelligence, and geographic intelligence. They can be used to deploy engagement systems of a variety of types, including cyber, electronic warfare, information, and kinetic.

Multiple systems, including small unmanned aerial vehicles, small unmanned ground vehicles, and small pods, can synergize efficacy through appropriate integration. For example, an unmanned aerial vehicle can deploy a small surveillance pod at a key terrain feature to perform ISR and possibly spark targets of opportunity. The UAV can then occupy another key terrain feature for similar roles. The two systems, controlled by the same operator or two operators working in concert, can provide wide-area, persistent overwatch, situational awareness optimization, and targeting.

Human-Machine Integration

Despite advanced capabilities, these systems should always be viewed as synergizing extensions of a warfighter's capabilities, not replacements, specifically regarding warfighter decision making. The "human-machine team" has proven repeatedly to be most successful when the machine is subordinate to the human, even with much heralded artificial intelligence systems.[12] With military applications, these systems are best conceptually viewed as tools with which to become intimately familiar (as with a service rifle and night vision devices) rather than appliances. Appliances, intended to accomplish complex tasks for a human user, often hinder or completely derail a process due to machine errors that require a user's attention to rectify (a common example is an autocorrect error when using a smartphone).

Notes

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