[US DOD developing swarming, autonomous UAVs to counter Anti-access /Area Denial environments]

Most of the current inventory of Unmanned Aerial Systems is not well-matched against more technologically advanced enemies who present higher levels of threats, contested electromagnetic spectrum and re-locatable targets, according to DARPA. Drones, which currently are flown individually, "are operated by large crews," "This is expensive and incompatible with an organic system able to react quickly to a dynamic situation."

Anti-access /Area denial is a set of overlapping military capabilities and operations designed to slow the deployment of U.S. forces to a region, reduce the tempo of those forces once there, and deny the freedom of action necessary to achieve military objectives . "A2/AD capabilities enabled by integrated air defense systems that include advanced fighters, advanced surface-to-air missiles, active and passive cuing systems, and directed energy weapons" make many U.S. fixed facilities vulnerable to attack in ways hard to imagine a decade ago, according to Harry Foster from National Defense University.

UAV Swarms is emerging enabling technology that could prove revolutionary for defeating A2/AD Strategies. These swarms can find, fix, and communicate precise target location of ground, sea, and air targets; they can serve as weapons platforms to attack air defense systems from multiple axes; or they can pass missile targeting data to any platform carrying a counter air missile. DARPA is planning to develop UAS swarm capability under its Collaborative Operations in Denied Environment program (CODE).

An ability to send large numbers of small unmanned air systems (UAS) with coordinated, distributed capabilities could provide U.S. forces with improved operational flexibility at much lower cost than is possible with today's expensive, all-in-one platforms—especially if those unmanned systems could be retrieved for reuse while airborne. So far, however, the technology to project volleys of low-cost, reusable systems over great distances and retrieve them in mid-air has remained out of reach. Gremlins program, seeks to develop innovative technologies and systems enabling aircraft to launch volleys of low-cost, reusable unmanned air systems (UASs) and safely and reliably retrieve them in mid-air.

The U.S. Department of Defense (DOD) will seek a $582.7 billion Fiscal Year 2017 budget that includes research and development spending on a new "arsenal plane," swarming autonomous micro drones, and "gun-based" missile defense. The Pentagon seeks to spend $71.4 billion on research and development in the budget, Carter told The Economic Club of Washington, D.C.

One of the projects being pursued by the Pentagon's Strategic Capabilities Office (SCO), is developing swarming, autonomous vehicles that will operate as groups in multiple domains. "In the air they've developed micro drones that are really fast, really resistant," Carter said. "They can fly through heavy winds and be kicked out the back of a fighter jet moving at Mach 0.9, like they did during an operational exercise in Alaska last year, or they can be thrown into the air by a soldier in the middle of the Iraqi desert." The miniature drones make use of some commercial and 3D-printed components, he added.

U.S. Deputy Secretary of Defense Bob Work outlined the pillars of the “third offset strategy,” a plan to develop the technologies that will maintain the American military’s technological superiority. “United States would need to make progress in five key areas: autonomous “deep learning” systems, human-machine collaboration, assisted-human operations, advanced human-machine teaming, and semi-autonomous weapons, “he further said.

DARPA programme to explore Offensive swarming operations (OFFSET)

The US Defense Advanced Research Projects Agency (DARPA) has commenced a project to explore how swarms of robots could be used to operate alongside army and marine units at the company level and below.

OFFensive Swarm-Enabled Tactics (OFFSET) seeks to dramatically increase the effectiveness of small-unit combat forces operating in urban environments by developing and demonstrating 100+ operationally relevant swarm tactics that could be used by groups of unmanned air and/or ground systems numbering more than 100 robots.

These swarm tactics for large teams of unmanned assets would help improve force protection, firepower, precision effects, and intelligence, surveillance, and reconnaissance (ISR) capabilities. OFFSET plans to offer frequent opportunities for engagement with anticipated end users in the U.S. Army and U.S. Marine Corps and would share successfully tested swarm tactics with them on a rolling basis.

DARPA is also reaching out to industry to help it build a game-based open architecture system to test swarm drone tactics in cities. Creating an open architecture system allows small businesses more opportunities to help DARPA develop swarm tactics for unmanned systems. DARPA also emphasized their interested in rapid development prototyping projects as part of their OFFSET program. Rapid development prototyping often times means quicker acquisition programs, which means more opportunities for startups.

for more information in OFFSET: http://idstch.com/home5/international-defence-security-and-technology/military/air-231/innovations-in-swarm-behaviors-improve-self-improve-military-force-protection-firepower-precision-effects-and-isr-capabilities-in-urban-operations/

DARPA's Collaborative Operations in Denied Environment program (CODE)

The U.S. military's investments in unmanned aircraft systems (UAS) have proven invaluable for missions ranging from intelligence, surveillance and reconnaissance (ISR) to tactical strike, but most current systems demand continuous control by a dedicated pilot and sensor operator supported by numerous telemetry-linked analysts. This requirement severely limits the scalability and cost-effectiveness of UAS operations and compounds the operational challenges posed by dynamic, remote engagements against highly mobile targets in contested electromagnetic environments.

DARPA's Collaborative Operations in Denied Environment (CODE) program aims to overcome these limitations with new algorithms and software for existing unmanned aircraft that would extend mission capabilities and improve U.S. forces' ability to conduct operations in denied or contested airspace.

CODE intends to focus in particular on developing and demonstrating improvements in collaborative autonomy—the capability of groups of UAS to work together under a single person's supervisory control. The unmanned vehicles would continuously evaluate themselves and their environment and present recommendations for UAV team actions to the mission supervisor who would approve, disapprove or direct the team to collect more data.

CODE Phase 2

DARPA is planning to develop UAS swarm capability under its Collaborative Operations in Denied Environment program (CODE). DARPA recently awarded Phase 2 system integration contracts for CODE to Lockheed Martin Corporation (Orlando, Fla.) and the Raytheon Company (Tucson, Ariz.). Further, the following six companies—all of which had Phase 1 contracts with DARPA to develop supporting technologies for CODE—will collaborate in various ways with the two prime contractors:

- Daniel H. Wagner Associates (Hampton, Va.)
- Scientific Systems Company, Inc. (Woburn, Mass.)
- Smart Information Flow Technologies, LLC (Minneapolis, Minn.)
- Soar Technology, Inc. (Ann Arbor, Mich.)
- SRI International (Menlo Park, Calif.)
- Vencore Labs dba Applied Communication Sciences (Basking Ridge, N.J.)

"During Phase 1, we successfully demonstrated, in simulation, the potential value of collaborative autonomy among UASs at the tactical edge, and worked with our performers to draft transition plans for possible future operational systems," said Jean-Charles Ledé, DARPA program manager. "Between the two teams, we have selected about 20 autonomous behaviors that would greatly increase the mission capabilities of our legacy

UASs and enable them to perform complex missions in denied or contested environments in which communications, navigation, and other critical elements of the targeting chain are compromised. We have also made excellent progress in the human-system interface and open-architecture framework."

CODE's prototype human-system interface (HSI) is designed to allow a single person to visualize, supervise, and command a team of unmanned systems in an intuitive manner. Mission commanders can know their team's status and tactical situation, see pre-planned and alternative courses of action, and alter the UASs' activities in real time.

For example, the mission commander could pick certain individual UASs from a team, circle them on the command station display, say "This is Group 1," circle another part of the map, and say "Group 1 search this area." The software then creates a sub-team with the circled UASs, divides up the search task among those assets, and redistributes the original tasks assigned to Group 1 assets to the remaining UASs. This capability significantly simplifies the command and control of large groups of UASs. Other parts of the HSI research focused on how to display the new plan, including potential impact on other mission objectives, and—depending on pre-set mission rules—either directly executes the plan or waits for the commander's approval to act

Using collaborative autonomy, CODE-equipped UASs would perform their mission by sharing data, negotiating assignments, and synchronizing actions and communications among team members and with the commander. CODE's modular open software architecture on board the UASs would enable multiple CODE-equipped unmanned aircraft to navigate to their destinations and find, track, identify, and engage targets under established rules of engagement. The UASs could also recruit other CODE-equipped UASs from nearby friendly forces to augment their own capabilities and adapt to dynamic situations such as attrition of friendly forces or the emergence of unanticipated threats.

“Further, CODE aims to decrease the reliance of these systems on high-bandwidth communication and deep crew bench while expanding the potential spectrum of missions through combinations of assets—all at lower overall costs of operation. These capabilities would greatly enhance survivability and effectiveness of existing air platforms in denied environments.”

CODE’s envisioned improvements to collaborative autonomy would help transform UAS operations from requiring multiple operators for each UAS to having one mission commander simultaneously directing all of the unmanned vehicles required for the mission. Commanders could mix and match different systems with specific capabilities to suit individual missions instead of depending on a single UAS with integrated capabilities, the loss of which would be potentially catastrophic. This flexibility could significantly increase the mission- and cost-effectiveness of legacy assets, reduce development times and costs for future systems, and enable new deployment concepts.

“Just as wolves hunt in coordinated packs with minimal communication, multiple CODE-enabled unmanned aircraft would collaborate to find, track, identify and engage targets, all under the command of a single human mission supervisor,” said Jean-Charles Ledé, DARPA program manager.

CODE researchers seek to create a modular software architecture beyond the current state of the art that is resilient to bandwidth limitations and communications disruptions yet compatible with existing standards and amenable to affordable retrofit into existing platforms.

CODE program aims to develop open architecture, algorithms for collaboration and autonomy functions that will bolster UAS scalability, cost effectiveness, interoperability and operational capability and expand UAS operations in hostile environments, according to DARPA.

Challenge of enhancing endurance of Swarms

To make the swarm a reality, the Pentagon would need to invest in smaller unmanned systems, they also need to bring long endurance and persistence, which means the ability to refuel or recharge in flight.

“Remote recharging would be ideal, perhaps by some sort of directed-energy transmission” According to Cololnel John McCurdy, director for remotely piloted aircraft programmes at the Air Force Academy. The UAS will also require stealth, passive sensors, secure communication links and host of countermeasures.

DARPA’s Distributed Airborne Capabilities

Small UAS have limited range and responsiveness, however, compared to larger airborne platforms. In November 2014, the Defense Advanced Research Projects Agency (DARPA) request released request for information seeking information from industry on how to expand the operational envelopes of smaller UAS by using existing military aircraft to transport multiple small UAS into the theatre of operations and launch them while airborne.

“We want to find ways to make smaller aircraft more effective, and one promising idea is enabling existing large aircraft, with minimal modification, to become ‘aircraft carriers in the sky’,” said Dan Patt, DARPA program manager. “We envision innovative launch and recovery concepts for new UAS designs that would couple with recent advances in small payload design and collaborative technologies."

DARPA's "Gremlins" Could Enable Cheaper, More Effective, and Distributed Air Operations

Gremlins program, seeks to develop innovative technologies and systems enabling aircraft to launch volleys of low-cost, reusable unmanned air systems (UASs) and safely and reliably retrieve them in mid-air. The program also aims to prove that such systems, or "gremlins," could provide significant cost advantages over expendable systems, spreading out payload and airframe costs over multiple uses (expected lifetime 20 uses) instead of just one. The gremlins' expected lifetime of about 20 uses could provide significant cost advantages over expendable unmanned systems by reducing payload and airframe costs and by having lower mission and maintenance costs than conventional manned platforms.

The program envisions launching groups of gremlins from large aircraft such as bombers or transport aircraft, as well as from fighters and other small, fixed-wing platforms while those planes are out of range of adversary defenses. When the gremlins complete their mission, a C-130 transport aircraft would retrieve them in the air and carry them home, where ground crews would prepare them for their next use within 24 hours.

"Our goal is to conduct a compelling proof-of-concept flight demonstration that could employ intelligence, surveillance and reconnaissance (ISR) and other modular, non-kinetic payloads in a robust, responsive and affordable manner," said Dan Patt, DARPA program manager.

DARPA plans to focus primarily on the technical challenges associated with safe, reliable aerial launch and recovery of multiple unmanned air vehicles.

The Gremlins program plans to explore numerous technical areas, including:

- Launch and recovery techniques, equipment and aircraft integration concepts
- Low-cost, limited-life airframe designs
- High-fidelity analysis, precision digital flight control, relative navigation and station keeping

Additionally, the program will address new operational capabilities and air operations architectures as well as the potential cost advantages.

DARPA recently completed Phase 1 of its Gremlins program, which envisions volleys of low-cost, reusable unmanned aerial systems (UASs)—or "gremlins"—that could be launched and later retrieved in mid-air. Taking the program to its next stage, the Agency has now awarded Phase 2 contracts to two teams, one led by Dynetics, Inc. (Huntsville, Ala.) and the other by General Atomics Aeronautical Systems, Inc. (San Diego, Calif.).

"The Phase 1 program showed the feasibility of airborne UAS launch and recovery systems that would require minimal modification to the host aircraft," said Scott Wierzbanowski, DARPA program manager. "We're aiming in Phase 2 to mature two system concepts to enable 'aircraft carriers in the sky' using air-recoverable UASs that could carry various payloads—advances that would greatly extend the range, flexibility, and affordability of UAS operations for the U.S. military."

Gremlins Phase 2 research seeks to complete preliminary designs for full-scale technology demonstration systems, as well as develop and perform risk-reduction tests of individual system components. Phase 3 goals include developing one full-scale technology demonstration system and conducting flight demonstrations involving airborne launch and recovery of multiple gremlins. Flight tests are currently scheduled for the 2019 timeframe.

References and Resources also include:

- http://www.afcea.org/content/?q=Article-researchers-advance-autonomous-isr-technology
- http://www.wired.co.uk/news/archive/2016-01/08/drone-swarms-change-warfare
- http://www.darpa.mil/news-events/offset-proposers-day
- https://www.darpa.mil/news-events/2017-03-15