From Unique Needs to Modular Platforms: The Future of Military Robotics
By PJ Neal

"They are unbound by human limitations.
They can remain airborne for long durations,
do not require life support systems,
do not need to eat or sleep,
and they will never say no to a mission." [1]

It's no wonder political and military leaders are increasingly resting their futures on unmanned systems. From the mature Unmanned Aerial Vehicles (UAVs) circling the skies above our troops (and enemies) in Iraq and Afghanistan, to the embryonic cargo haulers and unmanned ground vehicles being developed in academic and industry labs, future military operations are clearly heavily dependent on robots. Yet, for all the use robots are seeing in current combat operations around the globe, and for all the money being spent on their development and acquisition, there is no clearly articulated and agreed upon roadmap for their future growth and development.

This essay seeks to fill that void by using a commonly accepted framework for understanding the roles for robotic devices, overlaying it with the current state of robots and anticipated future development, and plotting out a logical end state. But first, to understand all of this, it's necessary to start by looking at a much simpler creature: the fruit fly.

Biologists have studied fruit flies to understand human development since 1910, when Thomas Morgan began using them in his research at Columbia University. Their rapid life cycle, the ability to study multi-generational development in short periods of time, and their genetic overlap with humans (among other measures, half their protein sequences have mammalian equivalents[2]) mean scientists can study the fruit fly, and end up better understanding people. Humans are too complicated, and live too long, to be able to do all necessary life-cycle studies on them. Today, the fruit fly is being used to understand a range of human conditions, including Parkinson's, Huntington's, Alzheimer's, and diabetes[3].

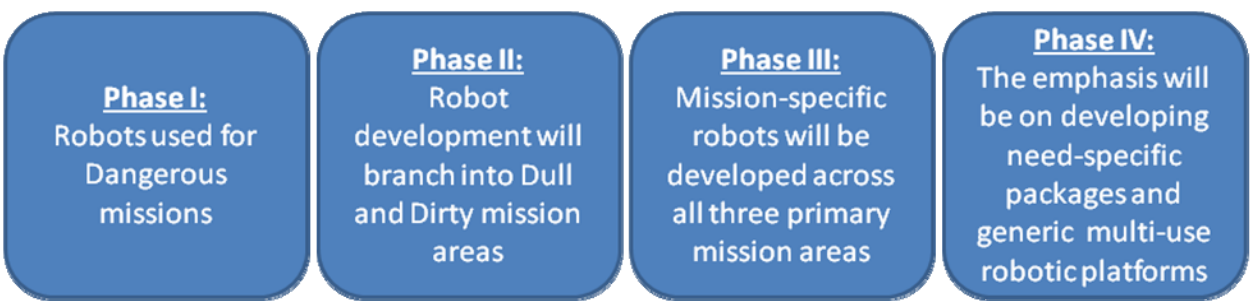
People studying military robotics face a similar challenge. The field of robotics is so expansive that to try understanding it all requires focusing on a single robot with significantly overlapping qualities to the rest of the robotics field, as the humble fruit fly has to humans. For that reason, this essay looks at the growth and development of UAVs in order to understand the broader issues surrounding military robotics as a whole.

UAV use has seen rapid growth in operations around the globe. Defense contractors are constantly looking for new ways develop these vehicles, especially given the strong desire to increase their use in combat. These robots are often described as being good for three types of missions: Dangerous, Dull, and Dirty[4].

Dangerous missions are those that put the vehicle in danger from violent retaliation by our enemies, be it flying over Iraq or Afghanistan to target an al Qaeda leader, or silencing a MANPAD threatening our troops. *Dull missions* require exceptionally long flight times; surveillance and 'INT-collection missions all fall into this category. Lastly, d*irty missions* go where humans can't: combat zones after nuclear, chemical, or biological weapon usage; or in extreme environments, such as the arctic, near volcanoes, or in the deep sea.

These three mission areas are not always stand alone; in fact, as will become clear, there is significant and growing overlap between them.

Presently, the overwhelming majority of military robotic efforts are focused on dangerous missions. But, technological growth and development, as well as political, legal, and practical needs, show that this singular focus is not maintainable, and will likely force robotic development down a four phase roadmap. A near-singular focus on dangerous missions will be Phase I. In Phases II and III, there will be a growing focus on dull and dirty mission needs. In Phase IV, the focus will shift from away from mission-specific robots to multi-use robotic platforms that can be highly customized based on mission need.



Today, we are at a point of transition from Phase I to Phase II. To understand this transition, it's important to understand how robots are being used now, and the challenges they're facing from foreign war zones to domestic court rooms.

Phase I: Robots in Dangerous Places - But For How Long?

The headlines have become so common we almost overlook them: "US Predator Strike Kills Four in South Waziristan," [5] " U.S. Airstrike Kills 20 People in Pakistan," [6] and "UAV strike kills 13 in Saidgi, NW

Pakistan." [7] More than a dozen al Qaeda leaders have been killed by UAV strikes since 2009[8], including Mustafa Abu al Yazid, the founder of al Qaeda, believed killed in May 2010[9].

Drone strikes against enemy targets (a "dangerous mission") are so vital that CIA chief Leon Panetta went so far as to say that they are "the only game in town" to fight al Qaeda in Pakistan[10]. Indeed, they have been so successful for the CIA that reports say the new head of the National Clandestine Service, John Bennett, was elevated to his new role in part because of his previous position overseeing the Agency's use of drones in locations such as Pakistan[11].

But, despite clear success of UAVs in dangerous missions, there are growing challenges to their use. Enemies have developed ways of downing them, legal experts are debating their use, and military experts are beginning to believe their use does more harm than good, particularly within counterinsurgency operations.

Given the heavy reliance by the US on UAVs, it is no surprise that weapons are being developed to more-easily shoot them down. As one expert said, "Today's killer drones are sitting ducks. Loud, slow-moving, and simple to spot, any air defense more potent than a militant with an AK is liable to take one of the robotic planes down." [12]

While some drones are eliminated by traditional anti-aircraft weapons, more technologically advanced efforts are in development. In July 2010, a solid-state 32 MW laser beam, mounted on a Phalenx weapons system, shot down four UAVs in a test off the coast of California[13]. Similarly, UAVs not killed with kinetic weapons or lasers are susceptible to electronic warfare attacks[14]. This creates the possibility of a UAV being turned against allied troops. Or, enemies can allow a drone to stay overhead, but tap into its data feed and see what is being transmitted back to our warfighters, as is happening in Iraq with the use of $26 worth of electronics[15].

Industry isn't oblivious to these threats, and efforts are underway to develop vehicles designed to operate in contested environments. In one example, General Dynamics executive Frank Pace has stated that their Avenger/Predator C will come in two models, "with the second featuring radar absorbent materials, a Joint Strike Fighter-type electro-optical sensor and other features for survival in heavily defended airspace." [16]

In the future, adversaries will attack not only the technological systems that allow unmanned vehicles to operate, but they will increasingly go after their human controllers. This has already begun, and may prove successful. The leader of the Haqqani Network in Afghanistan claims that "accurate drone-strike operations against the mujahideen decreased 90 percent'" following the December 2009 attack on a CIA base in Khost that killed seven CIA officers[17].

Attacks on the use of UAVs go beyond military action, to include legal challenges. While drone attacks are widely believed to be legal in declared combat areas (Iraq and Afghanistan), their use elsewhere falls into a legal gray area. Complicating matters is that their use in places such as Pakistan is not controlled by the military, but by the CIA.

In March 2010, Harold Koh, Legal Adviser to the US Department of State, remarked "that US targeting practices, including lethal operations conducted with the use of unmanned aerial vehicles, comply with all applicable law, including the laws of war." [18] The UN's Philip Alston, who is opposed to the use of drones outside combat zones, countered in May 2010 that this position "does not address some of the most central legal issues including: the scope of the armed conflict in which the U.S. asserts it is engaged, the criteria for individuals who may be targeted and killed, the existence of any substantive or procedural safeguards to ensure the legality and accuracy of killings, and the existence of accountability mechanisms." [19]

While the Obama administration may not slow down the use of drone strikes based on these concerns, they may do so after listening to their own advisors.

David Kilcullen, arguably the world's leading expert on counterinsurgency, and a previous aide to General David Petraeus, argues that "if we want to strengthen our friends and weaken our enemies in Pakistan, bombing Pakistani villages with unmanned drones is totally counterproductive." [20] In a *New York Times* editorial, Kilcullen argues that with the high civilian casualty rate from drone strikes, "every one of these dead noncombatants represents an alienated family, a new desire for revenge, and more recruits for a militant movement that has grown exponentially even as drone strikes have increased." [21]

John Brennan, the White House counterterrorism advisor, agrees. In May 2010, Brennan stated that, "an action that eliminates a single terrorist but causes civilian casualties can in fact inflame local populations and create far more problems. A tactical success but a strategic failure." [22]

Phase II and Phase III: The Growth of Robots for Dull and Dirty Missions

Given the growing challenges to the use of robots for dangerous missions, it's no surprise that a large number of companies are beginning to see value in shifting development to focus on presently unaddressed dull and dirty mission needs.

For drones to successfully address these needs, new technology needs to be developed and put into service. UAVs need to improve their long loiter ability, so as to stay over targets for days at a time. They'll need to be more able to operate without human control in congested airspace, and they'll need to be aware of their surroundings and how other vehicles can be expected to act.

The US Air Force has long recognized the value of a long-loiter, unmanned aerial vehicle. They attempted to develop the classified Advanced Aerial Reconnaissance System, with the intent of it being able to loiter over the USSR to track mobile ICBMs. It was forward thinking, but never built[23]. The British see a similar need, however, and recently unveiled the Taranis, a BAE-built long-range unmanned strike aircraft[24].

Northrop Grumman's Ed Walby gave an interview at Farnborough 2010 that shared his belief that the Global Hawk may someday replace the legendary U-2[25] especially for flights over potential enemies such as Iran and China[26]. Boeing's Phantom Eye is designed with a similar need in mind. The UAV, fueled by liquid hydrogen, is designed for flights lasting up to 96 hours[27]. Abroad, Turkish Aerospace Industries recently rolled out the Anka, a long-endurance UAV for the Turkish military. Tellingly, the long-endurance version for surveillance missions was developed first, to be followed later by an armed "hunter-killer" version[28].

While Mr. Walby and others see the future of these UAVs for long (dull) missions over enemy airspace, others see value in similar missions at home.

There's a growing use of UAVs for border security within the continental United States,[29] although numerous issues still need to be worked out to fully integrate unmanned systems into the National Aerospace System (NAS)[30]. The fleet of UAVs currently being operated by US Customs and Border Protection (CBP) will likely see rapid growth, especially for the task of monitoring the open border between the US and Mexico. Defense experts believe the United States Coast Guard will soon follow CBP, leading to a rapid increase in the number of unmanned aircraft supporting border and coastal patrol operations[31].

In the commercial sector, startups like Massachusetts-based CyPhy Works are looking to take this type of technology, combine it with strong sensor packages, and use it for critical infrastructure protection, including the inspection of bridges and dams[32]. This work is now done, slowly and manually, by humans.

To successfully execute very long missions, a number of current technical challenges need to be resolved. The above mentioned integration into NAS is one. Another is the need to refuel drones mid-flight. At least one company is already working to address this challenge: Northrop Grumman was recently awarded $33M to develop the KQ-X, a UAV capable of mid-air refueling with another UAV[33]. It's not a stretch to imagine a future when this technology can be used to refuel manned aircraft - a current mission need that is both dull and dangerous in nature.

Given the amount of time unmanned aircraft will be aloft, they will increasingly come into contact with other manned and unmanned vehicles. Drones need to be able to operate in congested environments, on the ground and in the air, without relying on human intervention.

To that end, the Air Force Research Lab (AFRL) is beginning work to supply unmanned systems with the ability to logically process data, given specific 'rules' and standard operating procedures (SOPs). The first place these will be used? Take off and landing, when drones will now be able to sense on their own how to maneuver in and around airfields and other moving aircraft[34]. Technologically, this isn't entirely new territory for AFRL, which is currently developing the Intelligence Robo-Pallet[35]:

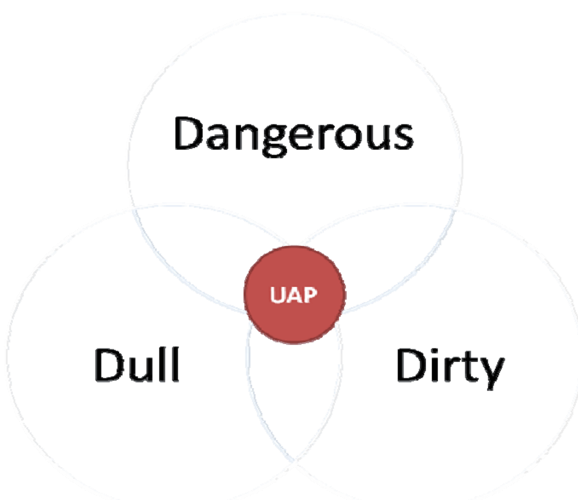
"mechanical platforms that can haul stuff onto its planes autonomously. It's got to be able to move on its own, lift and stack as cargo masters instruct, possess a built-in navigation capability, fit and operate in tight quarters, and talk with all other tech that's used to get things on and off planes. Basically, imagine a C-130 full of gear opening up and the pallets in the center raise up and roll out of the belly."

Unmanned systems to haul cargo would also prove valuable to both commercial and military users. For companies with large fleets of aircraft, this military research could lead to lower operating costs and reduced need to train and employ human pilots. It also reduces the likelihood of accidents due to human pilot error. FedEx is one of those interested companies. CEO Fred Smith has expressed his interest in switching "their fleet to UAVs as soon as possible... Unmanned cargo freighters have lots of advantages for FedEx: safer, cheaper, and much larger capacity. The ideal form is the 'blended wing.' [...] The result is that the price premium for air over sea would fall from 10x to 2X (with all the speed advantages of air)." [36]

The growth of unmanned vehicles for dull and dirty missions is currently taking place in parallel to the developments of robotics for dangerous missions. In Phases II and III, the overall number of unmanned vehicles increases, as they are all designed for single-mission roles in each of the three mission areas. However, in a period of decreasing defense spending, the elimination or substantial reduction of supplemental funding, consolidations in the defense industry, and rapid technological development, this duplication of effort isn't maintainable. Something entirely new must emerge.

Phase IV: The Ultimate Robotics Machine Will Be A Multi-Purpose, Modular Platform

Given the need to stop duplicating efforts, Phase IV of robotic development will be a shift away from large numbers of mission-specific robots to a small number of highly customizable, modular Unmanned Aerial Platforms (UAPs - or the all encompassing "UxP" for Aerial, Ground, and Water).



Much like the ALICE, MOLLIE, and ILBE military backpacks, UAPs would provide a basic platform that would be highly customizable to hold specific mission-need systems, such as weapon systems and sensor packages, to meet the environmental constraints and mission needs of the operator.

While this shift may appear to be a simple one, it would have profound impacts across the military and the defense contractors.

The UAP essentially becomes a commodity, and the value-added activity in military robotics shifts to the add-on system and away from the device that holds it. Single-mission UAVs would still exist, but in tiny numbers, due to very specific needs or technical constraints. Mid-air refueling, for instance, would likely require a mission-specific vehicle, but most surveillance and strike missions would not.

For the military, this means being able to buy and support a smaller number of drones, saving money in both procurement and operations & maintenance. Savings can be invested in improved systems. The result will be a single drone flying a surveillance mission in the morning, a strike mission in the afternoon, and serving as an unmanned AWACS craft at night. Before, this would have taken three separate machines. Now, it simply takes one platform.

Large companies could continue to be the primary supplier of UAPs to the military, spending their time investing and improving on one or two UAPs rather than having to offer a large diverse range of UAVs. Many large companies would likely take on new systems integration roles, assembling UAPs with numerous platforms, sold to the military as a single package.

Small companies wishing to develop innovative systems or packages to meet critical mission needs could do so without having to develop a new platform to put them on. This could potentially level the playing field for small companies who would now more easily compete against major defense contractors in supporting military activity.

Conclusion

Military robots have seen a rapid growth in military operations, and they are here to stay. Our military leaders depend on them, our troops want them, and our enemies fear them. But in order to continue to serve the needs of the military, and to adapt to operating constraints in and out of theater, robots need to continue down the four phase development roadmap. Only in reaching the end, and transitioning into multi-use, modular platforms, will these devices reach their full potential.

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