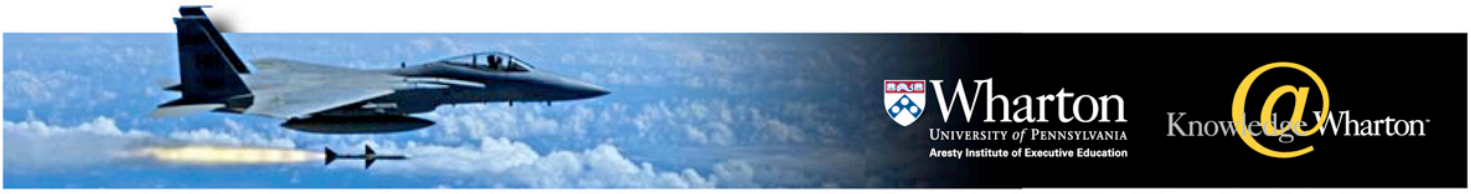

WHARTON AEROSPACE & DEFENSE REPORT
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The Rise of Robotics in Warfare:

Former Vice Admiral Joe Dyer, president of iRobot's Government & Industrial Robots division, discusses the future of unmanned vehicle warfare as it moves from the air to the ground – and now underwater.

October 2, 2009

On Budget & Procurement

Wharton Aerospace & Defense Report: The Pentagon is shifting its strategic focus away from having so many "exotic" and "expensive" weapons systems. How will iRobot fit into that strategic shift? It seems like a perfect match.

Dryer: I think it is a perfect match. iRobot, both in terms of its disruptive and emerging technology and because of its innovation in size and speed, is very much a part of this transition that you see going on today in Department of Defense (DoD). The DoD is beginning to shift resources from areas where the U.S. clearly dominates -- like manned tactical aircraft, ships, and large tanks, large armor -- to areas where we find more applicability to today's changing battlefield.

They also hope to reset the cost equation.

When Secretary Gates, reorganized and reprioritized the Future Combat System program, the FCS program, he canceled much of the classic parts of the program, but he preserved and accelerated those like the Honeywell UAV, the Textron Unattended Ground Sensors and the iRobot's Small Unmanned Ground Vehicle. He expanded their future assignments to all combat brigades.

Wharton Aerospace & Defense Report: What changes do you see there that will benefit iRobot and robotic weapons systems in general in the new budget? Are you able to compete for new contracts this year because of the new budget?

Dyer: Well yes. Now there is an issue with the budget in that the new technologies are conveyed in the supplemental budget, and are just starting to find their way into the core budget**.** The supplemental budget is by its very nature, more urgent, more directly linked to war-fighting shortcomings. To a significant extent the supplemental is more discretionary than the POM, the Program Objectives Memorandum, which is the department's five years strategic plan.

So given that background, perhaps it is not surprising that much of the UAV and UGV growth over the last few years is borne on the supplemental…

Wharton Aerospace & Defense Report: And now it is transitioning to the core...

Dyer: …and now it is transitioning to the core and it's important that it do so. It is interesting I think that new technologies have an easier birth within the supplemental than they do within the POM. In the POM you are competing with the entrenched Eisenhower companies.

Wharton Aerospace & Defense Report: Many procurement officers have been in their positions for a long time and are more used to systems designed for the old Cold War security concerns by, as you call them, "Eisenhower companies." What hurdles does iRobot encounter in this acquisition process and how do you get around any hurdles?

Dyer: Well, the challenges are being able to strategically look forward. One of the advantages of the POM and the core budget is you can see what is coming. The supplemental is an annual appropriation and consequently the confident look ahead has been annual rather than every four or five years. Now the rate of growth of the UAVs and now UGVs gives testimony to its success and future traction. But you cannot find it in the budget the way you can with a major aircraft procurement, for example.

Let me give you another data point: There have been UAV experiments that go all the way back even to World War II, but I mark the beginning of the UAV-era with the Navy's procurement of the Israeli-pioneered UAV in 1985. Since that time, it has taken UAVs almost 20 years to reach a half billion-dollar market.

It has taken UGVs, Unmanned Ground Vehicles 10 years to get to a half-billion dollar market—half the time. I think you will see UUVs, Unmanned Underwater Vehicles, again following that.

Competition & Collaboration:

Wharton Aerospace & Defense Report: You have many competitors--some very large, established defense contractors -- who jumped into robotics. How do you see iRobot fitting into this more competitive environment?

Dyer: Surprisingly very well. I say very well because companies like iRobot do a good job of advancing product development and research on three time horizons.

It has been my observation over the years that the big defense folks have active Horizon One: what they are selling today. They have an active Horizon Three: research and development. But they are terrible at Horizon Two: those products that are 18 months to three or four years out.

We have the PackBot product in production today and our Small Unmanned Ground Vehicle product is coming into production, which is Horizon one. We have an active long-term research and development program, which is Horizon Three. And we have Horizon Two: products in development that are anywhere from 18 months to four years (away).

You have to have both faith and courage to pursue Horizon Two. Most of the large defense companies do not do that well, and I think that drives a lot of their acquisitions. Their acquisitions are trying to fill in that Horizon Two.

But even when they acquire it rarely works for them.

Wharton Aerospace & Defense Report: Because they have to fit an innovative small company within a larger system?

Dyer: Exactly. In his book 'Crossing the Chasm,' Geoffrey Moore calls it 'swallowing innovation in the belly of the whale' and I think that is an excellent statement of what happens.

Wharton Aerospace & Defense Report: Speaking of the Horizon Three, how closely is iRobot working with the Pentagon?

Dyer: Well we are very actively involved both with the Army Research Lab and with DARPA (Defense Advanced Research Projects Agency) and with Army's Tank and Automotive Command. One thing we are researching is the integration of UGVs with UAVs. We want to deal with the two units as an integrated system rather than two stand-alone systems -- for example, integrating those together via software and display so that the user can concurrently get the large view from the UAV and the up close and personal view from a UGV.

We are also working on some genuinely DARPA products, like soft molded robots with a design to be able to squish underneath the door or through a small orifice.

Wharton Aerospace & Defense Report: Are you also working closely with university-based labs to introduce new functionality and technologies to your military products?

Dyer: Very closely. The iRobot is a spread out of MIT. But we also have worked with Carnegie Melon, Harvard, University of Chicago, Brown, Vanderbilt, Duke, and North Carolina State. It's is very important that we did so because robotics really is an emerging technology. There is a lot of work yet to be done and it's far from a risk-free venture.

The Future:

Wharton Aerospace & Defense Report: The military robots in use now -- the unmanned aerial, land and sea vehicles -- are still controlled remotely and do not yet have autonomous functionality, or artificial intelligence. What is iRobot doing to bring autonomous functionality to its military products?

Dyer: This is an area in which we are very active and strategically we view as our most important undertaking. iRobot has some 2,500 systems in service today -- mostly with the Explosive Ordnance Disposal technicians -- in Iraq and Afghanistan. The vast majority are tele-operated systems. But we are starting to introduce, what I would call limited or leading-edge autonomy. But before I give you more details, let us look at an analogy: How did autonomy come in to aerospace?

It really starts in the very late the 50's and the 60's with Yaw Augmentation. Early planes were very capable but their Yaw stability was weak and they literally wiggled their tails. So we build a control to dampen up this Yaw oscillation.

Then people said "we could probably do that with pitch and then with roll**"** and then you had three-Axis augmentation. Then somebody said "well you know if you got the augmentation, it is not really far to do the earliest autopilots. We could maintain wings level with the controlled loop in lower Yaw." That led to automatic landing and automatic takeoff.

And then you wake up one day and say "you know we can really do this without a man in the loop."

The message is that autonomy comes in on little cat's feet. It is not a big bang. It is not a quantum leap that arrives one day. So with that background let me tell you what iRobot is doing this year.

This year we are introducing three small pieces of autonomy. The first is, if one of our FasTac robots turns over, you can stand it back up, remotely. But it is a hard thing to do and takes a good bit of operative precision. You have to operate multiple controls concurrently to accomplish it. Now we are unburdening the operator from that task by providing a soft switch that says, "Hey, get back up right."

We are building in another capability that helps overcome loss of communication with the robot, a very unpopular thing to happen today because it means somebody has to go get the robot back. It's a small piece of autonomy that says, "If you lose your ability to communicate, just make your way back to where you could talk the last time."

Another piece is that right now, we have to drive the tele-operated robot every step of the way. But another small piece of autonomy is what we call "control stick steering" or you might call it 'cruise control.' This autonomy says, "Just maintain your vector, unless I tell you to do something else." Taken together**,** these pieces of autonomy start to alleviate the operational duty cycle.

As the Navy's chief test pilot for number of years, I have lived this: Airplanes over the last 30 years have gone from 80% of the pilot's time required to attend to the airplane, the engine and navigation with 20% of his time or her time**,** left to the mission. Thirty years later, it is almost exactly reversed. The airplane, the engine and the navigation problem take care of themselves by and large and if they need help, they will ask you for it. Now it requires about 20% of the operator's duty cycle, leaving 80% of the duty cycle to the mission.

Wharton Aerospace & Defense Report: We have to control robots over a network. What safeguards can we take to prevent a takeover or sabotage by hackers?

Dyer: The topic is getting a good bit of attention. I would say one of the good things to come out of the Future Combat System that is still going is a much more secure and robust network. So that problem is being addressed.

Wharton Aerospace & Defense Report: When it comes to hacking and security measures, it's always a cat-and-mouse game. Would you agree that it would be the same for this technology as well?

Dyer: The limitations of electronic warfare are just exactly as you say, a game of spy-versus-counter-spy. You never take security for granted and always try to be ahead.

Wharton Aerospace & Defense Report: It would be ideal if we could send robots further into a combat zone. But that would also mean their energy and power consumption needs would increase. What advances do you see for powering your robots?

Dyer: Yes, this is another area in which iRobot has been directly engaged in developing those technologies.

Robots are difficult in terms of the power management. They need moderate power when they are just sitting and watching, or navigating on easy terrain. They require high peak power when moving fast or climbing difficult terrain.

So a fuel cell alone is not capable of powering a military robot. But a system that is made up of both a fuel cell and a battery backup would use the fuel cell to get long range and peak power out of the battery. We have demonstrated this with our robots.