Robots on the battlefield

Intelligent machines make warfare more survivable

by Vice Admiral Joseph W. Dyer (U.S. Navy, Ret.)

No one can accurately predict what the robot-inhabited battlefield of the future will look like in five, 10 or 20 years. But we can look at the technical history of military equipment and make some educated guesses.

Over the last two decades, two significant developments have advanced modern warfare. The boom in smart weapons has been a giant leap forward. While they offer the ability to precisely target and other benefits, smart weapons also leave out something critical: the up-close and personal understanding of what's on the other end of that weapons delivery. As a result, ironically, it's the technology that was designed to keep warfighters out of mix that is part of the reason there will always be human armies. It's also a part of the reason that when occupying territories, even in these days of great respect for airpower, that understanding is becoming more and more appreciated.

The proliferation of virtual presence technology has also had an enormous impact. From overhead sensors and unmanned ground systems to everything in between, virtual presence enables modern machines to listen, talk, see, communicate and network. These advanced communication capabilities will continue to evolve and so will their impact on the way battles are fought.

Smart weapons and virtual presence technology are both being driven in part by changes in the American public's tolerance for casualties and prisoners of war, which is much lower than it has been in previous conflicts. Consider this: In World War I, our soldiers charged out of trenches in the face of machine gun fire with the hope that a sufficient number of them would survive to be able to assault the enemy on the other end of the battlefield. Today, thankfully, we would never do that.

These fundamental changes in warfare ideology, strategy and tactics help explain why robots are already being adopted for a range of missions; they keep warfighters at safe standoff distances. This substantial shift also provides insight into how robots will be used on the battlefield in the future.

Proven capabilities

Robots are already a critical security and intelligence component of 21st-century warfare.

On the battlefield and in war games, robots have proven that they make two important contributions. Using a robot, you can much more quickly establish situational awareness. That's no surprise. But what is surprising is a robot's ability to increase the tactical speed of a mission.

Let's use clearing a building as an example. If you did it the "old" way, you might use a squad of 12 guys. It's a daunting and slow task because you'd have to cautiously make your way through the building without knowing what to expect. It's a type of urban warfare task that has changed little in 100 years.

With a robot, you can increase tactical speed because if you search a room and there's nothing there, you can quickly advance to the next room, knowing you can do so without opposition. You can continue advancing quickly through room after room after room until you find something. Once you do find insurgents, an explosives cache or something else, then you know that you have some work to do. But it's that combination of fast situational awareness and increased tactical speed that make robots ideal for a range of missions.

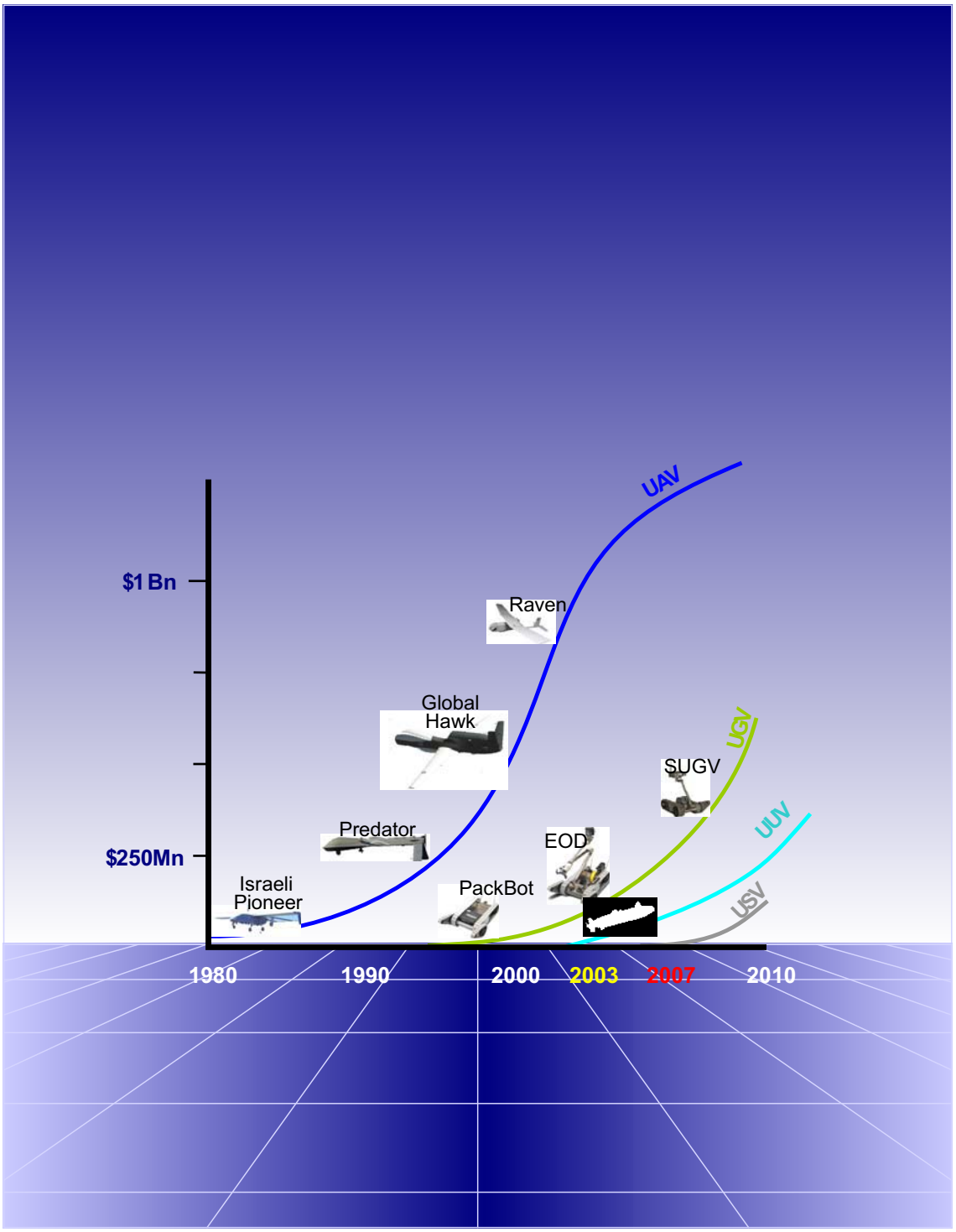
The markets mature

The changing nature of warfare has had a profound effect on the adoption of Unmanned Ground Vehicles (UGVs) and is indicative of the way robots will be developed and deployed going forward. It's interesting to look at the market maturation of unmanned military vehicles, particularly the huge difference in the way that soldiers have embraced UGVs in comparison to the way aviators originally rejected Unmanned Aerial Vehicles (UAVs).

When they were introduced about 30 years ago, Unmanned Air Systems were shackled in their start by the pilot's union. I know that's the case because I was one of those pilots back then. The differences in the types of missions performed by the air forces and armies – and their frequency – are two factors that have heavily influenced the differing adoption experiences of UAVs and UGVs. It's not that aviation isn't dangerous; it is. But aviation is sometimes described as hours of boredom interspersed with moments of stark terror. For the Army, certainly in places like Iraq and Afghanistan, the separations between moments of real danger are much more closely packed. It's more dangerous in a very personal sense, plus it's dirty, tiring and all those things that make the Army's missions so challenging. As a result, soldiers have been much quicker to embrace UGVs as tools they can use to contribute to their survival.

The fast adoption of the iRobot PackBot robot is a clear example of this major cultural difference. In 2002, before PackBot's first deployment in Afghanistan, the tactic for doing cave reconnaissance was literally tying a rope connected to a 12-

foot stick around the waist of a 19-year-old soldier and sending them in to see what's happening. It's easy to see why the first PackBot introduced in the theater was an attractive tool for soldiers and why the Army was much quicker to embrace UGVs than aviators were to accept UAVs.



It took more than 20 years for the market for Unmanned Aerial Vehicles (UAVs) to reach $500 million, but only half as long for Unmanned Ground Vehicles (UGVs) to surpass that same milestone. The markets for Unmanned

Underwater Vehicles (UUVs) and Unmanned Surface Vehicles (USVs) are speeding toward the half-billion mark even more rapidly. (Estimates by iRobot Corp.)

One thousand signs of success

The adoption of the PackBot illustrates what iRobot has done and what other robot companies will need to do in order to transition from innovators and early adopters to the early majority – what's called "Crossing the Chasm" in a book of the same name by Geoffrey Moore that talks about marketing and selling disruptive products to mainstream customers.

In the last several years, iRobot has transitioned from its roots as a pure engineering company. While the company has always had great engineering capabilities, we didn't have everything we needed to cross this chasm. We didn't have logistics, supplier management, contract managers, a sales group and other infrastructure we needed, so we had to build them. At the same time, we developed a bunch of necessary tools, such as earned value management, cost estimation and design for manufacturing and quality. It is that transition that has allowed iRobot to more professionally participate in professional defense acquisition.

Also, unlike other companies, many of which have a very broad product distribution across many marketplaces, iRobot is focused solely on robots. Another differentiating factor is the company's ability to see its way through to a deployed product. That has helped iRobot to break out and distinguish itself; many of the very small robotic companies that have the same solid science and engineering background and innovative culture lack the ability to transform those assets into a marketable product.

The moral of the story is that nothing succeeds like success. PackBot has had an overwhelmingly positive impact on robot acceptance on the battlefield. As a result, iRobot recently delivered its 1000th PackBot. When you build a thousand of a piece of military equipment, the marketplace is telling you that you have demonstrated a desirable and important capability.

Digital as a differentiator

One critical component of PackBot's success – its digital architecture – is a bellwether for military systems. Like the PackBot, the F/A-18 fighter is another example of a military system with a digital architecture. As a result, the aircraft is able to carry more than 50 different payloads and perform many different missions, including gathering reconnaissance, fighting in aerial combat and bombing ground targets. In other words, a digital modular architecture provides a high degree of flexibility that enables fast and easy systems integration and makes the F/A-18 ideal for a variety of missions.

Likewise, the PackBot's digital architecture gives the robot that same degree of adaptability. The PackBot chassis can accommodate a spectrum of payloads, sensors and electronics, making it ideal for a variety of missions. PackBot's digital platform is powered by iRobot's proprietary software, Aware.

The iRobot PackBot 500 with ICx Fido Explosives Detector Kit is the result of very successful third-party integration enabled by Aware and PackBot's digital architecture. iRobot teamed with ICx Technologies to integrate its award-winning, explosive-detection technology onto the combat-proven PackBot platform.

The robot can detect explosive vapors emanating from Improvised Explosive Devices (IEDs). PackBot's dexterous, seven-foot arm allows the robot to place the explosive sensor close to suspicious packages and other objects, as well as reach through car windows and under vehicles. PackBot can then use its on-board capabilities to destroy IEDs, while warfighters remain out of harm's way.

We were able to quickly test the robot in the field, get feedback, refine it and deploy the product based on user requirements. PackBot's digital, modular architecture enabled fast and easy integration of the Fido payload, enabling our troops on the battlefield to quickly benefit from the new innovation.

The partnership has resulted in the first major deployment of explosives-detection robots and also demonstrates a new market application for robots. More than 100 of the explosive-detection robots have been ordered for use by the U.S. military in Iraq. This is a very exciting and promising development; there is a critical need for robots that can safely detect and disrupt explosives, not just for warfighters deployed in the Middle East, but also for first responders around the world.

This example explains why a modular digital architecture is a huge differentiator – and one that has become the standard for military systems.

To encourage the integration of different payloads and behaviors onto our platforms and facilitate an even richer mix of plug-and-play options to meet the needs of warfighters and first responders, iRobot makes its Aware 2.0 software platform available to third-party developers through a rich set of application programming interfaces and utilities. The company also offers the Robot Developer's Kit, a new set of hardware tools for creating next-generation payloads for military robots. The software and related tools are designed to give developers a head start in creating advanced payloads and capabilities for iRobot platforms. In addition, the annual iRobot Payload Developers Conference brings together developers from government, military and university research labs to attend in-

depth sessions on how to create payloads that enable robots to take on a greater variety of real-world challenges.

Overcoming the growing pains

Speaking of challenges, there are some significant but surmountable ones being tackled that will help advance the development and deployment of military robots. Requirements and resources challenges are front and center right now; it's easier for the military to continue funding what they've already been doing than to fund a disruptive technology. So change management is one major part of it. That change is happening though, slowly but surely.

A second challenge also being overcome is the lack of people skilled in robotics to meet the growing demands of the marketplace. Educational programs and degrees in robotics at MIT, Carnegie Melon, Worcester Polytechnic Institute and other institutions of higher learning have finally started to alleviate that shortage.

Both of these challenges highlight the fact that robot industry is very young and still emerging.

Computers 1978	**Robots 2001**
• Locked away from public ▪ too dangerous for computers	• Locked away from public ▪ too dangerous for people
• Used inside large companies	• Used in manufacturing plants
• Operational use in military	• Operational use in military
• First few "home" computers ▪ in the form of games	• First few "home" robots ▪ in the form of toys
• Computer hacking clubs	• Robot hacking clubs
• How-to-build-your-own books	• How-to-build-your-own books
• Undergraduate majors appearing	• Undergraduate majors appearing
• First mass market "serious" home computer attempts	• First mass market "serious" home robot attempts

The parallels drawn between the adoption of computers 30 years ago and robots today by Rodney Brooks, iRobot's co-founder and CTO and the former director of the MIT Computer Science and Artificial Intelligence

Laboratory (CSAIL), provide a perspective on where we are and where we're going.

Surviving the shakeout

Other situations will also impact military robots, resulting in noteworthy ramifications for robot companies, the industry and the military.

Funding, of course, is a key driver of product and industry development. Major initiatives, like the Army's Future Combat Systems program, are funding the future. You've either already won one of those contracts, like iRobot has with the FCS Small Unmanned Ground Vehicle (SUGV), or you've missed out.

A second, very interesting situation I foresee is a shakeout of the market similar to ones we've seen in other industries in the past. Take the aviation industry as an example. In the 1930s, there was Lockheed, Martin, Boeing, Douglas, Curtiss, Wright and a bunch of other independent airplane companies. Over time, they have condensed into the smaller group of major aerospace and defense suppliers doing business today. That same kind of compression is going to happen in military robotics but much more quickly than it did in aviation, in part because the requirement to scurry across that chasm is now critically important. To survive the shake out, it won't be enough to be an innovative company; you'll have to be a company that can produce and also demonstrate the competencies to produce for a major program of record. Most of the original aviation companies I mentioned had never even heard of logistics at that time. To be a successful producer now, however, they all need to have a competency in logistics.

The market shakeout will yield some benefits, including higher quality, more reliability and better managed programs. It will also cause some significant merger and acquisition activity in the industry.

A downside is that it's going to become more difficult for other robot companies to successfully cross the chasm because they won't have the necessary competencies. That's going to mean that only a few of those innovative companies currently doing research and developing products are going to actually ever bring them to market. We have to think nationally about ways to funnel in those and other innovative ideas that will otherwise get excluded.

The future is now

Nevertheless, the future holds tremendous potential for military robots. The Explosive Ordnance Disposal (EOD) market has been a great place for robots to prove themselves. Those 1,000 PackBot robots have performed tens of thousands of missions. But robots are only available to a small number of the potential users at this time. There is a much larger opportunity to use robots to protect more troops. There are many engineers who could use robots for route clearing and all

the other missions they perform. Even larger is the potential to use robots in the infantry as a scout or point man gathering tactical reconnaissance. The robot can go in first, establish situational awareness and let the troops know what they are facing so they have time to plan how to deal with it.

With the addition of more robots, the future battlefield will be more survivable. Conflicts will be fought with greater stand-off distances. They will have better situational awareness and better coordination. We'll still have soldiers on the battlefield, but they'll be able to leverage intelligent machines more so in the future than today -- and we already do a lot today with satellite feeds, tactical reconnaissance, standoff weapons systems, air strikes and more.

Those intelligent machines are sure to include autonomous robots. Right now, all the deployed military robots are tele-operated and that means there's a one-to-one relationship between an operator and the robot. We're early, but we are starting to build the autonomy. That's happening as a part of the development of the smart weapons and virtual presence technology that I mentioned earlier. Robots will definitely be capable of doing more on their own in the not-so-distant future.

Some people talk about it as though there's going to be some giant step of autonomous capability in the field. I don't believe that's true because when you look back at aviation changes came in stages. Augmentation systems were followed by auto-pilots, then automatic landings and automatic take-offs. It was at that point that the people realized you can fly an aircraft without a man in the system. We're seeing the robotic equivalent of those incremental changes today at iRobot in terms of simple but important things, such as autonomous assistance for the robot operator. Those kinds of technical builds will continue to evolve.

In addition, mission builds for robots will also progress, much in the same way they did for aircraft. In WWI, the first airplanes started out doing reconnaissance, serving as artillery spotters. As time progressed, airplanes were used to perform a range of other missions. Eventually, aircraft were used for their strike capability. It is the evolution of military equipment and it will come to robots at some point, too. We will build weaponized platforms when our military customers have a requirement based on the needs of our country. But there is an important detail to consider: Our architecture plans always include a man in the loop and we don't foresee that changing.

Which brings us to one of the big hot-button questions in the discussion about military robots: Will there be autonomous killing machines? I don't think so; we'll never see that life-and-death decision made independent of a human. Based on the movies, however, it's no wonder the American public has a Hollywood-hyped fear of machines taking over the world.

The results of major experiments in the last two years provide a window on the battlefield of tomorrow – and how unmanned systems will play a prominent role. At the Air Assault Expeditionary Force (AAEF) experiment last October at Fort Benning, more than 40 different types of systems were demonstrated, including UAVs, UGVs, command control systems, unmanned ground sensors, hybrid vehicles, lighter-than-air ships and many more. When asked which three systems they would take to war today, soldiers answered: the PackBot UGV and two UAVs. The reason is simple: soldiers want to get situational awareness from the ground and the air. UAVs provide a bird's-eye view, while UGVs provide an up-close-and-personal view. Based on the superior situational awareness they provide while keeping warfighters out of harm's way, UAVs and UGVs working together will play a vital role on the battlefield of the future.

While warfare tomorrow is certain to be different than it is today, the future of military robots is about the incremental development of a growing curve of capabilities, not the implementation of one dramatic, monumental change.

– Joe Dyer is president of iRobot's Government and Industrial Robots Division. His career in the U.S. Navy included positions as the commander of the Naval Air Systems Command, naval aviation's chief engineer, commander of the Naval Air Warfare Center, Aircraft Division and F/A-18 program manager. He chairs NASA's Aerospace Safety Advisory Panel.