“P.W. Singer has fashioned a definitive text on the future of war around the subject of robots. In no previous book have I gotten such an intrinsic sense of what the military future will be.” Robert Kaplan, author of *Imperial Grunts*

“*Wired for War* is a wild ride. Drawing from sources spanning popular culture and hard science, Singer reveals how the relationship between man and robot is changing the nature of warfare. He details technology that has, until now, been the stuff of science fiction: lethal machines that can walk on water or hover outside windows, machines joined in networks or thinking for themselves. Singer's appreciation for the human minds behind these machines is real, but so is his warning that the implications of this revolution are poorly understood.” Howard Gordon, writer and executive producer of *24*, *The X-Files*, and *Buffy the Vampire Slayer*

“Singer's book is as important (very) as it is readable (highly), as much a fascinating account of new technology as it is a challenging appraisal of the strategic, political and ethical questions that we must now face. This book needs to be widely read -- not just within the defense community but by anyone interested in the most fundamental questions of how our and other societies will look at war itself.” Anthony Lake, 18th U.S. National Security Advisor

“Will wars someday be fought by Terminator-like machines? In this provocative and entertaining new book, one of our brightest young strategic thinkers suggests the answer may well be “yes.” Singer's sprightly survey of robotics technology takes the reader from battlefields and cutting-edge research labs to the dreams of science fiction writers. In the process, he forces us to grapple with the strategic and ethical implications of the “new new thing” in war.” Max Boot, author of *The Savage Wars of Peace* and *War Made New.*

“Lively, penetrating, and wise ... A warmly human (even humorous) account of robotics and other military technologies that focuses where it should: on us.” Richard Danzig, 71st Secretary of the Navy

“Weaving together immaculate academic research with a fan boy's lexicon of popular culture, *Wired for War* looks at the people and technologies beta-testing tomorrow's wars today. The result is a book both hilarious and hair-raising that poses profound ethical questions about the creation and use of ever more powerful killing machines.” Gideon Yago, writer, *MTV News*

“It’s not science fiction, it’s not fantasy, it’s here now. Read *Wired For War.*” Robert Young Pelton, author of *The World's Most Dangerous Places*
If issues like these sound like science fiction, that’s because many of the new technologies were actually inspired by some of the great sci-fi of our time – from Terminator and Star Trek to the works of Asimov and Heinlein. In fact, Singer reveals how the people who develop new technologies consciously draw on such science fiction when pitching them to the Pentagon, and he even introduces the sci-fi authors who quietly consult for the military.

But, whatever its origins, our new machines will profoundly alter warfare, from the frontlines to the home front. When planes can be flown into battle from an office 10,000 miles away (or even fly themselves, like the newest models), the experiences of war and the very profile of a warrior change dramatically. Singer draws from historical precedent and the latest Pentagon research to argue that wars will become easier to start, that the traditional moral and psychological barriers to killing will fall, and that the “warrior ethos” – the code of honor and loyalty which unites soldiers – will erode.

Paradoxically, these new unmanned technologies will also seemingly bring war closer to our doorsteps, including even with videos of battles downloaded for entertainment. But Singer also proves that our enemies will not settle for fighting our high-tech proxies on their own turf. He documents, for instance, how Hezbollah deployed unmanned aircraft in the Lebanese war of 2006, and how America may even fall behind in this revolution, as its adversaries gain knockoffs of our own technology, or even develop better tech of their own invention.

While his predictions are unnerving, there’s an irresistible gee-whiz quality to what Singer uncovers and the people he meets along the way. It is packed with cutting edge research and hard to get interviews of everyone from four star Army generals and Middle East leaders to reclusive science fiction authors. Yet it also seamlessly weaves in pop culture and illuminating anecdotes to create a book that is both highly readable and accessible. In laying out where our technologies are taking us to next, WIRED FOR WAR is as fascinating as it is frightening.

(continued from previous page)

ABOUT THE AUTHOR
P.W. Singer is a Senior Fellow at the Brookings Institution; at 33 years old, he’s the youngest person ever to hold that position. He’s written for or appeared on a wide variety of media, from “60 Minutes” to the New York Times Op-Ed page. He has a doctorate in Government from Harvard, and, in his personal capacity, serves as the coordinator of the defense policy advisory task force for the Obama campaign. In his previous two books, Singer foretold the rise of private military contractors and the advent of child soldiers – predictions which proved to be all too accurate. For further information, please go to www.pwsinger.com.

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What happens when science fiction starts to become reality on the battlefield? A military expert reveals how technology is changing not just how wars are fought, but also the politics, economics, laws, and ethics that surround war itself.

P. W. Singer's previous two books foretold the rise of private military firms and the advent of child soldiers—predictions that proved all too accurate. Now, he explores the greatest revolution in military affairs since the atom bomb—the dawn of robotic warfare.

We are on the cusp of a massive shift in military technology that threatens to make real the stuff of *I, Robot* and the *Terminator*. More than twelve thousand robotic systems are now deployed in Iraq. Pilots sitting in Nevada are remotely killing terrorists in Afghanistan. Scientists are debating just how smart—and how lethal—to make their robotic creations. And many of the most renowned science fiction authors are quietly consulting for the Pentagon on the next generation.

Blending historical evidence with interviews of an amazing cast of characters, Singer shows that as these technologies multiply, they will have profound effects on the front lines, as well as on politics back home. Moving humans off the battlefield makes wars easier to start but more complex to fight. Replacing men with machines may save some lives, but will lower the moral and psychological barriers to killing. The “warrior ethos,” which so long defined soldiers’ identity, will erode, as will the laws of war that have governed military conflict for generations.

Paradoxically, these new technologies will also bring war to our doorstep. As other nations and even terrorists start to build or buy their own robotic weapons, this revolution could even undermine America’s military preeminence.

While his analysis is unnerving, there’s an irresistible gee-whiz quality to the innovations Singer uncovers. *Wired for War* travels from the battlefields of Iraq and Afghanistan, where these machines are now fighting, to modern-day “skunk works” in the midst of suburbia, where tomorrow’s technologies of war are quietly being designed. In Singer’s hands, the future of war is as fascinating as it is frightening.

P. W. SINGER, a Senior Fellow at the Brookings Institution, has worked in the Pentagon, as well as consulted for the departments of Defense and State, the CIA, and Congress. The author of two previous books, *Corporate Warriors* and *Children at War*, he has also written for publications such as the *New York Times* and *Foreign Affairs*. For further information, visit www.pwsinger.com.

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far better. Companies like Wang or Atari may have been the first out of the gate and dominated the market when they were born, but none of the young officers used them now. The early market leaders had already been swept aside by new competitors. RMAs should come with the standard warnings given to investors looking at mutual funds: “Past performance is not necessarily indicative of future performance.”

This view from the perspective of history is not unique. Concern about America’s future advantage in new technologies like robotics gets repeated in all sorts of quarters. James Lasswell of the U.S. Marines’ emerging technology division laments how “most of the things we do will soon be in the hands of everyone else.” Half a world away, a former Pakistani army general (whose perspective is particularly notable in that he helped train the Taliban in the 1990s) says, “These major advances will not remain the sole monopoly of the U.S. Other major powers, over a period of time, will catch up.”

Such opinions square with how most science fiction writers see the world of technology evolving for America. Orson Scott Card of *Ender’s Game* fame worries that in all our focus on “an enemy that uses asymmetrical technology against us,” the United States is missing that its present advantage may prove quickly fleeting. “We have not abolished the constant back-and-forth of military technology; we have only temporarily rushed ahead of the curve; it will bounce back.”

When it comes to the new unmanned technologies, the bounce-back may be even quicker than previous RMA reversals in history. Despite the billions of dollars the Pentagon has invested in engineering and AI research and development, robots are not like aircraft carriers, spacecraft, or atomic energy, which required a massive industrial complex, not only to build but to operate. Once developed, robotic technology is often cheap and mass producible. In turn, adversaries used to have to steal technology in order to copy it. Today, they need only go to a show like the one in Singapore, or even buy the commercial version off the Internet. Army War College professor Steven Metz predicts, “We will see if not identical technologies, then parallel technologies being developed, particularly because of the off-the-shelf nature of this all. We’ve reached the point where the bad guys don’t need to develop it; instead they can just buy it. For example, people think that because North Korea is a closed society that it can’t do things like information technologies. But all they need to gain that is a briefcase with $2 million and a ticket to Singapore.”

The robotics revolution is only just now under way, but already a looming reality is becoming clear. The United States is making immense use of these systems in its war efforts, but it is certainly not the only player in the game. As of 2008, Unmanned Vehicle Systems International, the industry trade group, had over fourteen hundred corporate members in fifty nations. A survey of government-related research found that forty-two countries were at work on military robotics. A typical example was in 2008, when Iran’s official news agency announced that its researchers had just finished a robot (a SWORDS knockoff) “programmed for blasting opponents’ positions.”

Perhaps the best proof of the spread, though, comes at the air shows, where new military technologies are introduced to the world. While Stayne Hoff’s unmanned product was one of the hits of the 2006 Singapore show, he soon had serious competition. The 2007 Dubai Air Show featured the unmanned military wares companies and expert speakers from the United States, as well as from Belarus, Denmark, Sweden, Turkey, and the United Arab Emirates. At the Paris Air Show later that year, 552 different types of drones and other unmanned systems were marketed to defense buyers.

Not only do U.S. military robotics developers and makers face huge competition, but many think that they are already behind the field in certain areas. For example, one DARPA survey of military robotics scientists found that Japan and Europe are ahead of America in legged robot research. Warned one scientist, “The small U.S. humanoid robot community is at risk of being overwhelmed by foreign research, development and commercialization.” Another worries that DARPA might one day be accused of having “failed in its assigned mission to prevent technological surprise.”

**A STRATEGIC TOUR OF ROBOTS**

U.S. Air Force Lieutenant Colonel Dave Sonntag’s job is not only to figure out who is working on what new technologies, but also to evaluate how good they are. Unlike most officers, Sonntag didn’t join the military after high school or college, but after a career in business, first working as an environmental consultant. However, he explains, “The consultant business was feast or famine. I was young, married, and had lots of loans. Plus, the air force lured me with the dangle of paying for my PhD."

Thus, Sonntag’s military career started by taking him back to school, which fit perfectly with his boyhood love for science and science fiction. Sonntag also credits
his father, himself a PhD. "I still remember the smell of benzene as I would nap in a hammock in his lab, in the early sixties, and then running some of the equipment in his lab in the seventies. What a trip! Nowadays, I get crap at work from the Safety Nazis for showing my kids how to extract DNA from lunch meats."

Once his training in both the sciences and the military was complete, the air force sent Sonntag out to jobs at the Air Force Research Lab, working as a toxicologist, and the Office of the Secretary of Defense, analyzing science and technology futures. Today, his career has taken him to Tokyo, where he serves as deputy director for the Asian Office of Aerospace Research and Development. He describes his role as "the new Asian GNR [genetics, nanotech, and robotics] guy for the Air Force."

Sonntag's mission is essentially to ensure that the United States stays aware of new technologies in Asia. His office works to keep track of everything interesting that is going on in the sciences in Asia ("interesting" translated as anything that is potentially useful in war), as well as try to make sure that the United States has a stake in it. "My job here is to look out 20–30 years and invest in what is today's sci-fi. We invest small seed money in stuff we think might have promise.... Basically it's like prospecting."

When he first was sent to Japan, Sonntag tells how he wondered, "Why the hell do we have an office in Japan? It's expensive. It's tough on the family." But now he describes it as "essential" to his job. About a third of all the world's industrial robots are in Japan. These raw numbers aside, the best visual evidence of Japan's knack for robots comes at the "Big Sight" complex in Tokyo. A massive convention center with ten major halls, it is the host of IREX, the International Robotics Exhibition. Held since 1973, the convention now has some one thousand booths of robot exhibitors that range from factory robots to "life assistance" robots (nursebots). The receptionist who greets the more than one hundred thousand people who visit IREX is Actroid, a humanoid robot modeled after a sexy local newscaster.

Japan's success with robotics and AI comes from a long history of strong government support. In 1981, the Japanese Ministry of International Trade and Industry launched an $850 million program to foster development of AI software and hardware, while today it plans to replace about 15 percent of its workforce with robotics over the next twenty years. Typically, explains Sonntag, the countries that have the most interest in robotics have either a security need to limit casualties or a rapidly aging population base. Japan falls into the "sweet spot" of both. Its birth rate is the second lowest in the world (only Hong Kong's is lower), so the population is both aging and shrinking but still faces a dangerous region. By contrast, the United States and Europe have faced slowing population growth, and the accompanying need for young workers, by opening their borders to greater numbers of immigrants. But Japan, with a population that is 99 percent ethnically pure Japanese, has decided to go the technologic route, with robots used for everything from farming and construction to nursing and elder care.

Because of this commitment to robotics, some even believe that Japan has been undervalued in global power projections. One of the most vehement is an Indian professor of business and global leadership, Prabhu Guptara. "It is now fashionable to talk of the 21st century as if it will be the 'Asian Century'—with China being touted as the coming power, economically and militarily. Given that I am Indian, it will hardly be a surprise to find that I am not among the fans of this theory regarding the future. But you may be surprised to find me only a little more sanguine about India—and putting my money instead on Japan."

Guptara tells how his views on Japan changed after he attended the 2005 World Expo in Aichi, Japan, which hosted some twenty-two million people and put the Japanese robotics trend on full display. "My choice may be particularly surprising, given that Japan’s economy has been dragging for the last 25 or more years, in spite of everything that the Japanese government has tried. So why am I now putting my money on Japan?...It is because of robots!" Dave Sonntag agrees. "Japan is top-notch in robotics.... They have not even begun to realize their strategic potentials."

But Japan is not the only locale for this kind of work. When we spoke, Sonntag was just back from "making the rounds of several Korean GNR labs." The South Korean robotics industry has grown by 40 percent a year since 2003, while South Korea already has the best IT infrastructure in the world, including the world's highest percentage of homes linked into high-speed Internet (80 percent), as well as the world's first nationwide wireless Internet service. It is so far ahead of the United States that companies like Microsoft test out their products in Korea first, before they release them back home.

Korea's push into robotics has been very much promoted and supported by its government, which sees the technologies as a key to future economic competitiveness and power. The South Korean government announced in 2007 plans to "put a robot in every household by 2020" and created a government-supported Center for Intelligent Robots that groups together more than a thousand scientists. Financed by the Ministry of Information and Communication (MIC) and the Defense
Ministry, Korean robotics research ranges from home cleaner robots to a prototype automated combat robot shaped like a large dog.

South Korea's robotics vision will culminate with two "robot theme parks," sponsored by the Commerce Ministry. Scheduled to open in 2013 at a total cost of $1.6 billion, the parks will allow visitors to interact with robots, as well as give Korean robotics companies locations to test and launch new products. Describes the ministry, "The two cities will be developed as Meccas for the country's robot industry, while having amusement park areas, exhibition halls and stadiums where robots can compete in various events."

While many other nations like Singapore, Malaysia, and even Thailand are at work on these new technologies, Sönntag also has to keep an eye on that particular concern of the Pentagon. China. It's not a good-news story from his perch. "The Chinese are just kicking our butts" while "the U.S. is sitting on its thumb."

He tells, for example, how China will soon be ahead of the United States in the production of nanotechnologies, describing this as part of a larger trend that will shortly extend into many other science and technology sectors.

"The Chinese are just kicking our butts" while "the U.S. is sitting on its thumb." He tells, for example, how China will soon be ahead of the United States in the production of nanotechnologies, describing this as part of a larger trend that will shortly extend into many other science and technology sectors.

China's recent economic rise was originally fueled by cheap, relatively unskilled labor producing low-technology goods like toys. But China is now the world's largest user of the Internet, with twice as many broadband users as the United States, and has many of the world's most advanced R&D facilities and high-technology factories. IBM, one of the very first computer companies, actually sold its computer division to a Chinese company in 2005.

As the saying goes, in the twenty-first century, "the geeks shall inherit the earth." So where these geeks increasingly live means a great deal. In this, China's huge population base gives it a massive numeric advantage. Half of China's students graduate in the sciences or engineering (compared to 13 percent in the United States), but this literally translates into millions more skilled Chinese added each year to their workforce. Former ambassador Chas Freeman, co-chair of the United States-China Policy Foundation, says, "This means that they, not Americans, will own and control the intellectual property and 'killer apps' that power it and its evolving technology. We will be paying royalties as we try to catch up with them."

Lying behind China's approach has not just been its raw numbers of scientists and engineers, but also an openness to ideas and technology from abroad. Freeman explains that "much of the momentum for China's success stems from its emulating the past receptivity of the United States to foreigners and their ideas.

Much of our loss of preeminence stems from our new propensity for closing our ears and our borders to ideas and people that are strange to us."

Like what happened in the other technology sectors, many of the early Chinese robots appear to be knockoffs of foreign designs. For example, in 2006, the Institute of Automation of the Chinese Academy of Sciences in Beijing released Rong Cheng, the Chinese version of a "beauty robot" so popular in Japan. The robot can speak in multiple dialects, respond to over a thousand words and phrases, and even dance. Sadly, Rong Cheng is not all that attractive or lifelike, looking like a cheap department store mannequin with a wig glued on. But at a cost of only $37,500, it's hard to expect perfection from your robot beauty queen.

Chinese robot designs, however, are rapidly catching up in their ingenuity and range of innovation. One presentation on Chinese robots, for example, included everything from a robot waiter to a robot chimpanzee made by the Chinese Academy of Sciences. Chinese roboticists appear to be particularly focused on the biomimetic and AI realm. Besides robot monkeys, the "Institute of Robot" at Beijing University had built what the People's Daily calls a "bionic fish." A five-foot-long robot shaped like a fish, the system can swim underwater with automatic navigation. Reportedly, it has only been used in environmental and underwater archaeology research, but Pentagon observers are quick to note that this is exactly how the U.S. Navy's UUVs also got their start. Another example of innovative Chinese work in AI and robotics is a "cyberglove" built at the Robotics Institute at Jiao Tong University in Shanghai. The device is a robotic hand that uses artificial intelligence to learn how to move. It will reportedly combine the dexterity of a human hand with the pinpoint accuracy and strength of a machine, making possible "the perfect artificial limb."

Just as China's growing Internet presence gives it new capabilities in information warfare (the Chinese army has set up a "cyberwarfare" program staffed by some six thousand paid hackers), this growing unmanned research and commercial sector creates new potential in the military domain. Starting in 2005, for instance, the Chinese air force began to replace its older 1960s-model fighter planes with newer, more technologically advanced types. While the obvious concern in U.S. Air Force circles was how it would handle flying against the newer, improved Chinese fighter planes, others began to grow curious about what had happened to the older planes. Many in the Pentagon believe that instead of destroying or mothballing them, the Chinese military is converting its "retired fighter aircraft into UAVs, with numbers potentially in the hundreds." While the older converted
drones might prove easy for U.S. fighters to shoot down in a potential war, at a certain point the tyranny of numbers would weigh in. Eventually, U.S. planes would run out of missiles and have to cede the air to the drones, at least until they could go rearm. More broadly, many are growing concerned that at their present rate of growth and advancement, Chinese robotics could have quality as well as quantity on their side in any future robot wars. A RAND report dourly advised that “the U.S. and its military must include in its planning for possible military conflict the possibility that China may be more advanced technologically and militarily in 2020.”

Sonntag worries whether America’s military and political leaders will heed such warnings. The challenge with important occurrences in science and technology, he explains, “is getting the strategic guys to understand it. It’s now only the very geeky guys who get it.” It’s not just a matter of “how to translate geek speak.” Even within the military intelligence world, the analysis of other countries’ science and technology is “very ill-informed” and “stove piped,” he says. “We really don’t have a good feel for what the trends are.” More broadly among senior policymakers and military leadership, “There is little global awareness of what’s going on.”

NO COUNTRY LEFT BEHIND?

“Technology is like ‘magic shoes’ on the feet of mankind, and after the spring has been wound tightly by commercial interests, people can only dance along with the shoes, whirling rapidly in time to the beat that they set.”

This passage comes from a book called Unrestricted Warfare. Originally forwarded to me by Lieutenant Colonel Sonntag, it was written by Qiao Liang and Wang Xiangsui, two senior colonels in the Chinese military, and published by the People’s Liberation Army Literature and Arts Publishing House. It is known as one of the most influential books shaping the views of the next generation of Chinese military leaders. The book even received the official blessing of a highlighted review in the Communist Party youth league’s newspaper.

Unrestricted Warfare is essentially a strategic guidebook to twenty-first-century war. Its focus is how countries like China might defeat the United States in a war of high technology, despite the apparent American lead in weapons. What is notable is that many think is the only way to defeat the United States. They also argue that foes will be able to defeat America at its own high-technology game.

Qiao and Wang argue that America suffers from an odd combination of being uniquely addicted to technology, but also unable to truly exploit it. “However, this is not a strong point of the Americans, who are slaves to technology in their thinking. The Americans invariably halt their thinking at the boundary where technology has not yet reached.” Moreover, they go on to describe how the United States may be ahead now, but this will not last for long. “Technology is useful, however, because Americans do not do a good job of anticipating technology trends.”

Part of this confidence comes from the fact that Qiao and Wang are great believers in the imminence of an RMA, but they see the key elements of it emerging from the commercial sector, where China is surging forward. “The new concept of weapons will cause ordinary people and military men alike to be greatly astonished at the fact that commonplace things that are close to them can also become weapons with which to engage in war.” They go on to add, “We believe that some morning people will awake to discover with surprise that quite a few gentle and kind things have begun to have offensive and lethal characteristics.”

At face value, the Chinese officers’ prediction seems off base. After all, the American advantage in war technologies doesn’t just stem from its massive defense budget. From Thomas Edison to Bill Gates, it has traditionally been the home of commercial innovation and invention. Even in this latest revolution, Americans invented key enablers like fiber optics and the Internet. And why should this trend not continue? While the United States only has 4 percent of the world’s population, it spends almost 50 percent of the world’s R&D funding.

Yet these Chinese army officers aren’t alone in predicting America’s loss of its advantages in this arena. Indeed, the U.S. Navy agrees with them. In 2006, the navy’s official journal published a warning that “the United States is headed for the ‘perfect storm’ when it comes to how it deals with defense technology. Only if changes are made now, can the U.S. avoid the loss of its technological superiority.”

One of the major challenges to America’s success in a world of high technology is that the same education system that once took its military and economy to the top is now falling behind. Only 54 percent of America’s high school students perform at even a basic level in math and science. And these are by American standards. When matched against international students, American high school students came in twenty-second in the world in basic math and science and twenty-fourth when they had to apply their skills to real-world problems.
With American scientists not being replenished in sufficient numbers, some worry about the health and welfare of both our economy and society. As he explains, it isn’t that American kids are dumb. Rather, our education system is making them dumber. “The longer students are exposed to our K-12 education system, the worse they do—particularly in the critical areas of math and science.” Indeed, while U.S. fourth graders come in at the top eighthieth percentile in the world in science, by the time they reach the twelfth grade they have fallen to the bottom fifth percentile. To paraphrase the failed Bush education reform policy, which worsened the problem by emphasizing rote memorization, nearly every American child is being left behind. As Bill Gates puts it, “When I compare our high schools to what I see when I’m traveling abroad, I’m terrified for our workforce of tomorrow.”

The traditional retort to rising worries about America’s education system is that while our high schools may suck, we have great universities. Unfortunately, when it comes to math and science skills, so key to designing, building, and using new technologies, this may no longer be the case. These high schools feed fewer kids with either skills or interests in science and math into U.S. universities. The universities are then graduating fewer and fewer.

This is starting to create a “futile cycle,” in the words of Princeton University president Shirley Tilghman. There are fewer and fewer American teachers and professors with science and mathematics skills to inspire, supervise, and mentor the next generation of American engineers and inventors. These problems at the university level then feed back into high schools, which rounds the futile cycle. Erskine Bowles, president of the University of North Carolina system (which has 183,000 students at its various campuses), put it this way in 2006. “In the past four years, our 15 schools of education at the University of North Carolina turned out a grand total of three physics teachers. Three.”

In the past, America made up for such a gap by hosting foreign students and researchers in its universities, who would then frequently stay in the United States for the longer term. New post-9/11 visa policies are making it harder for these visitors to both come and stay. Those foreign researchers who do come are more frequently returning to much better job prospects back home. The impact is being severely felt on “the vitality and quality of the U.S. research enterprise,” stated National Academy of Sciences president Bruce Alberts. “This research, in turn, underlies national security and the health and welfare of both our economy and society.”

With American scientists not being replenished in sufficient numbers, some worry about the whole system could fall behind. As the National Science Board warned, “If action is not taken to change these trends, we could reach 2020 and find that the ability of U.S. research and education institutions to regenerate has been damaged and that their preeminence has been lost to other areas of the world.”

The globalization of the world economy is also hammering the U.S. technology establishment. While American workers remain talented, they also are comparatively expensive. In Vietnam, twenty assembly-line workers can be hired for the price of one in the United States. In India, six engineers earn the equivalent of one in the United States. And in China, five chemists can be employed for the salary of one in the United States.

These pay gaps are made even worse by a U.S. health care system that acts like a massive anchor attached to American industry. General Motors, for example, was once the epitome of American industrial might in peace and war. During World War II, its automobile plants were converted to manufacture tens of thousands of tanks, trucks, and planes. Today, it has junk bond status and had to reduce its U.S. workforce by a third. The reason is not just that GM too long expected to sell ugly fuel-guzzlers, but also that it spends more on health care than it does for the steel that goes into its cars. Even a seemingly successful American firm like Starbucks has to spend more on health care than it does on coffee.

It is no surprise then that companies, even the most technological, are outsourcing their business outside the United States. The result is a hammer blow to U.S. technology development and manufacturing, especially in the commercial sector that Qiao and Wang describe as so important to taking full advantage of this RMA. America’s trade balance in high-tech goods and services went from a positive $50 billion in 1996 to negative $50 billion in 2006, while only three out of the top ten companies granted patents for new products and inventions were American. And it bodes to get worse. More than three-fourths of the new R&D facilities planned worldwide will be located in either China or India.

With the huge amount of “civilian off-the-shelf” technologies used in military robotics, these trends actually create a massive dependence on foreign manufacturers to supply America’s next generation of weapons. This dependence has many worried beyond lost market share. Technology security expert Richard Clarke is concerned that the U.S.’s complete reliance on technology made elsewhere makes it far easier for foes to hack or hijack systems, including being able to slip “back doors” in. “There is massive industrial espionage.... China already has the ability tolace technology it is building for us with Trojan horses and time bombs. Most if
not all the computer systems running the Internet, phones, power grid, and robots were built in China."

In turn, others note that the location of manufacturing elsewhere makes it easier for competitors to copy and build their own cloned systems. iRobot engineers tell how they have already seen cloned copies of both their Roomba vacuum cleaner and the PackBot military robot. Indeed, they once angrily confronted a group of Singaporean military officers who were showing off what appeared to be a clone of a PackBot at a demonstration. Stayne Hoff similarly says a good sign a buyer just wants to clone a drone is "when they only want to buy one."

The sum total of these education and economic trends is moving the U.S. security system in a scary direction, warns Rusty Miller of the defense firm General Dynamics. "If the U.S. doesn't wake up and pay attention, we're going to get smoked."

MONEYBALL AND THE CULTURE WARS

William "Billy" Beane was a first-round pick by the New York Mets in the 1980 baseball draft. Beane's career, however, didn't take off the way either he or the Mets planned. He played only in 148 games as a reserve outfielder, hitting just three home runs.

Off the field, Beane met with far more success, and in 1997 he became general manager of the Oakland A's. The A's soon became a perennial playoff team, despite the fact that they came from a small market and couldn't afford a large player payroll. In 2006, for example, the A's ranked twenty-first out of the thirty baseball teams in salaries, but had the fifth best record. In essence, Beane's team paid only a fourth of what big-money teams like the New York Yankees had to pay for each win.

The secret to Beane's success is that he refused to let baseball's culture and traditions get in the way of how he did business. Other teams still selected players based on popular measures that came out of the nineteenth century (typically using only very basic statistics like stolen bases, RBIs, and batting average). Beane and his team of evaluators used a modern, technical method of evaluation, called "sabermetrics" (or the "Moneyball way," after Beane was profiled in a book entitled Moneyball: The Art of Winning an Unfair Game). For example, even though it went completely against the conventional wisdom of baseball, the mathematical data showed that avoiding an out has far more impact on a team's chances of winning than getting a hit. Despite the proof, others wouldn't change. Beane's success came not just from his willingness to eschew the traditional ways of doing business, but also from how, despite all the data to the contrary, his competitors continued to cling to the old ways and old baseball culture, even if it meant fewer wins for their teams and could ultimately cost them their jobs.

Beane's experience illustrates how, even in the most competitive markets, new ideas still have trouble supplanting old doctrines. This especially happens with new technologies. Just because something new and better is discovered doesn't always mean it is adopted. For instance, I typed this book out on a keyboard laid out in the traditional QWERTY manner, which 99 percent of the computers in the world use. Yet this layout actually dates back to 1873, when it was first developed to make typists go slower, so as not to jam their mechanical typewriters. In the time since, numerous new keyboard layouts have been invented that would speed typing by as much as 95 percent. Yet companies and customers alike resist them, as QWERTY is the way it has always been, even if it is nowhere near the best.

War is certainly a far different beast than typing or baseball (other than when a Red Sox fan shows up in the bleachers at Yankee Stadium), but the military is also a highly competitive field that can still be quite resistant to change. Indeed, as one British colonel put it, "In no profession is the dread of innovation so great as in the army." So, ironically, even though militaries often generate great change, they have trouble adjusting to it.

Throughout history, even the most brilliant military minds have often failed to adapt well to new technologies. Napoleon may have conquered most of Europe, but he turned down Robert Fulton's offer to make France both submarines and steamships. At the very start of the American Civil War, the Union army was offered the breech-loading repeater rifle, which could fire seven shots quickly instead of just one. But its makers couldn't even get a hearing, let alone a sale; it wasn't until President Lincoln himself tried out the weapon that the rifles were bought, years into the war, and then only for cavalry. The same thing happened with machine guns. Americans like Richard Gatling and Hiram Maxim may have invented the rapid-firing gun that would revolutionize warfare, but officers in the U.S. Army at the time refused to use them. Indeed, Custer could have had four Gatling guns with him at the Battle of Little Bighorn, which would have mowed down the Indians at his "Last Stand." Instead, Custer left them behind at the base as he felt machine guns had no value in combat and would only slow him down.
Militaries resist change, even when it might help them win wars, for many reasons. The experience of combat is unique, so the latest generation tends to feel a special kinship with the generations before it and doesn’t want to veer too far from what they did in the past. For instance, the ancient Greeks so honored the ideals of war that Homer wrote about in the *Iliad* that they shunned the use of technologies like siege engines. If it wasn’t good enough for their heroes like Achilles or Ulysses, then it wasn’t good enough for them.

Change can also become wrapped up in turf battles and other bureaucratic intransigence. Those vested in the current system, or whose talents and training might become outdated by new technologies, will fight any change that threatens to make them obsolete or out of work, or in any way harms their prestige.

Most important, the stakes are so high in war that militaries place an immense value on going into battle with something that has already proven its worth in the past. When the U.S. Army began to talk about replacing horses with tanks just prior to World War II, cavalry officers argued that horses had four thousand years of experience at war, while tanks had only a few years at the end of World War I. As late as 1938, General Hamilton Hawkins lamented the “foolish and unjustified discarding of horses” and blamed the “sheep-like rush to mechanization and motorization without clear thinking or any apparent ability to visualize what takes place on the field of maneuver or the battlefield.” Even with mechanized vehicles clearly proving themselves in World War II, the U.S. Army didn’t dissolve its last horse unit until three years into the war.

Many think that the same sort of cultural resistance to change may hamper U.S. military adaptation to unmanned systems, even if it is one of the early originators of the technology. Dr. Russ Richards is the director of the Project Alpha program on military unmanned systems at the Joint Forces Command. “The greatest hurdle,” he says, “is likely to be overcoming military culture.”

The many delays that occurred in the use of drones are a prime example of how military culture is perhaps weighing in against the curve. Andrew Krepinevich, a former Defense analyst who is now executive director of the Center for Strategic and Budgetary Assessments, jokes that the reason the air force resisted systems like the unmanned fighter plane is that “no fighter pilot is ever going to pick up a girl at a bar by saying he flies a U.A.V.... Fighter pilots don’t want to be replaced.” The same goes even for pilots beyond fighter aces. One A-10 Warthog pilot, a veteran of Iraq and Afghanistan, said fliers’ biggest fear—being shot down—has been replaced by a fear of being ordered to fly a drone from a ground-based cubicle. “It’s like being a pilot for nerds. Where is the sense of adventure, the sense of danger? ... Let’s put it this way: I don’t think they’re going to make any movies about guys who fly Predators.”

These are jokes, of course, but they have a real underpinning to them. The U.S. Air Force’s professional identity is very much wrapped up in the idea of piloting planes, and fighter planes at that. Indeed, over half of the air force’s generals are fighter pilots, as has been every single air force chief of staff but one since 1982. So being a fighter pilot is not just in the air force leadership’s organizational DNA, it is also seen as the pathway to advancing in the ranks. Given this, it is no surprise then that the air force long stymied the development and use of drones, letting DARPA and the intelligence agencies take the lead instead.

Even once the air force started to buy and use drones (largely because of the competition from these other agencies), this sort of cultural resistance has played out in very real organizational actions. The early Predator pilots in the air force, for instance, were paid less than regular pilots, didn’t get any credit in their career advancement for their flight hours, and were otherwise generally shunned. As one air force helicopter pilot joked, “I was happy when drones came in. It meant that we were no longer at the bottom of the totem pole.”

While this attitude has slowly changed as drones have proven their worth in combat, the air force still holds on dearly to its identity as a force of fighter aces dogfighting against enemy fighter planes in the sky, despite the fact that it hasn’t happened for years. “Today’s Air Force clings to a fight-the-Soviets (or at least the Chinese) model with greater passion than yesteryear’s Army clung to the horse cavalry,” concluded one military analyst. One young air force officer, just months out of the academy, tells how, despite the fact that drone pilots have seen far more combat action than jet fighter pilots over the last decade, “It’s seen as this geeky thing to do.”

The result is that the force will still sometimes put pilots’ career interests ahead of military efficiency, especially when those making the decisions are fighter jocks themselves. For example, many believe that the air force canceled its combat drone, Boeing’s X-45, before it could even be tested, in order to keep it from competing with its manned fighter jet of the future, the Joint Strike Fighter (JSF, a program now $38 billion over its original budget, and twenty-seven months past its schedule). One designer recalls, “The reason that was given was that we were expected to be simply too good in key areas and that we would have caused massive disruption to the efforts to ‘keep ... JSF sold.’ If we had flown and things like survivability had
been evenly assessed on a small scale and Congress had gotten ahold of the data, JSF would have been in serious trouble.'

Military cultural resistance also jibes with problems of technological "lock-in." This is where change is resisted because of the costs sunk in the old technology, such as the large investment in infrastructure supporting it. Lock-in, for example, is why so many corporate and political interests are fighting the shift away from gas-guzzling cars.

This mix of organizational culture and past investment is why militaries will go to great lengths to keep their old systems relevant and old institutions intact. Cavalry forces were so desperate to keep horses relevant when machine guns and engines entered twentieth-century warfare that they even tried out "battle chariots," which were basically machine guns mounted on the kind of chariots once used by ancient armies. Today's equivalent is the development of a two-seat version of the Air Force's F-22 Raptor (which costs some $360 million per plane, when you count the research and development). A sell of the idea described how the copilot is there to supervise an accompanying UAV that would be sent to strike guarded targets and engage enemy planes in any dogfights, as the drone could "perform high-speed aerobatics that would render a human pilot unconscious." It's an interesting concept, but it begs the question of what the human fighter pilot would do.

Akin to the baseball managers who couldn't adapt to change like Billy Beane, such cultural resistance may prove another reason why the U.S. military could fall behind others in future wars, despite its massive investments in technologies. As General Eric Shinseki, the former U.S. Army chief of staff, once admonished his own service, "If you dislike change, you're going to dislike irrelevance even more." It is not a good sign then that the last time Shinseki made such a warning against the general opinion—that the invasion of Iraq would be costly—he was summarily fired by then secretary of defense Rumsfeld.

**BIGGER IS NOT ALWAYS BETTER: THE DEFENSE-INDUSTRIAL COMPLEX**

On the cover of *Life* magazine in April 1957 is a picture of "The Flying Blue Brothers," it shows two smiling brothers, blond and buzz-cut, sitting in the cockpit of a tiny propeller plane. The article inside tells the tale of Neal, twenty-one, and Linden, twenty, two brothers who had taken time off from Yale University to pilot their Piper Tri-Pacer alone across the Andes. Their adventures included "cavorting

"If you build it, they will come." The CIA soon came shopping and the drones, now called by the more fearsome-sounding "Predator," saw action in the Balkans. And the rest is robot history.

The story of the Blues and General Atomics is a classic story of how an industry upset can shake up the system. This small-company approach to contracting carries over to other parts of General Atomics. The company is headquartered in an office district just outside San Diego. There, it builds Predators at a pace of almost fifty a month. "It's like a California speed shop where they hand-build hot rods," says Glenn Buchan, an analyst at the RAND defense research group.

General Atomics can assemble such sophisticated weapons systems so quickly because it places great value on simplicity. The drones' bodies are made of a honeycomb of graphite, paper, and other materials and then literally baked in an oven. Propeller-powered engines may not have been sexy, but the early-model Predator drones used props because they were more efficient and cost less. As *BusinessWeek* wrote of the Blues' success, "The development of the smaller, cheaper plane shows how even in an age of $300 billion Pentagon budgets [note: now double that], nimble entrepreneurs can shake up the Establishment."

The challenge for the United States is that stories like that of the Blues and Predator, where smart, innovative systems are designed at low costs, are all too

with headhunters in the Amazon, trying to right their crashed plane on a mountain ice shelf, and later, lounging on Ipanema Beach with a comely brunette."
rare. The U.S. military is by far the biggest designer and purchaser of weapons in the world. But it is also the most inefficient. As David Walker, the head of the Government Accountability Office (GAO), puts it, "We're number 1 in the world in military capabilities. But on the business side, the Defense Department gets a D-minus, giving them the benefit of the doubt. If they were a business, they wouldn't be in business."

The Department of Justice once found that as much as 5 percent of the government's annual budget is lost to old-fashioned fraud and theft, most of it in the defense realm. This is not helped by the fact that the Pentagon's own rules and laws for how it should buy weapons are "routinely broken," as one report in Defense News put it. One 2007 study of 131 Pentagon purchases found that 117 did not meet federal regulation standards. The Pentagon's own inspector general also reported that not one person had been fired or otherwise held accountable for these violations.

This lumbering process is also heavily undermined by being "hierarchical and top down," as one former army colonel, who now runs a robotics firm, put it. The Pentagon will almost always invest in systems that have bureaucratic and political champions, but not always those that are most efficient or that the troops in the field are finding most useful. One striking example is how the army's massive FCS program originally didn't include the smaller types of robotics, the very types that soldiers were requesting to have in the field.

There is also a Pentagon phenomenon known as "requirements creep." The decision on what to buy and the requirements of what must go into the systems are too frequently made by those least familiar with new technology. Bruce Jette, who has been the point man inside much of the U.S. Army's robotics efforts, likens the current process to how horse cavalry officers were the ones who helped decide the required specifications for the early military automobiles. They originally demanded that the cars come with saddle seats and reins. Some ninety years later, the Pentagon's acquisition office once mandated that small ground robots come equipped with an onboard fire extinguisher, oil change, and trailer hitch. Jette points out, "The thing is 30 pounds and electric!

Whenever any new weapon is contemplated, the military often adds wave after wave of new requirements, gradually creeping the original concept outward. It builds in new design mandates, asks for various improvements and additions, forgetting that each new addition means another delay in delivery (and for robots, at least, forgetting that the systems were meant to be expendable). In turn, the makers are often only too happy to go along with what transforms into a process of gold-plating, as adding more bells, more whistles, and more design time means more money. These sorts of problems are rife in U.S. military robotics today. The MDARS (Mobile Detection Assessment Response System) is a golf-cart-sized robot that was planned as a cheap sentry at Pentagon warehouses and bases. It is now fifty times more expensive than originally projected. The air force's unmanned bomber design is already projecting out at more than $2 billion a plane, roughly three times the original $737 million cost of the B-2 bomber it is to replace.

These costs weigh not just in dollars and cents. The more expensive the systems are, the fewer can be bought. The U.S. military becomes more heavily invested in those limited numbers of systems, and becomes less likely to change course and develop or buy alternative systems, even if they turn out to be better. The costs also change what doctrines can be used in battle, as the smaller number makes the military less likely to endanger systems in risky operations. Many worry this is defeating the whole purpose of unmanned systems. "We become prisoners of our very expensive purchases," explains Ralph Peters. He worries that the United States might potentially lose some future war because of what he calls "quantitative incompetence." Norm Augustine even jokes, all too seriously, that if the present trend continues, "In the year 2054, the entire defense budget will purchase just one tactical aircraft. This aircraft will have to be shared by the Air Force and Navy, three and one half days per week, except for the leap year, when it will be made available to the Marines for the extra day."

Closely linked is a "bigger is better" mentality that has taken hold in American defense contracting. As Pierre Chao at the Center for Strategic and International Studies explains, it would be a "strategic mistake" not to have a massive amount of competition in the military robotics marketplace. "If you think it is a young technology, that the Orville and Wilbur Wrights of the 21st century are running around in the UAV marketplace, then as messy as it makes the environment, it is far more strategically important to have lots of players, different patrons behind those players, and to keep stimulating the useful competition of ideas."

And yet U.S. military acquisitions, even in the field of robotics, are increasingly dominated by an ever smaller number of huge defense contractors, driving down competition. From 1986 to 2006, for example, the number of Pentagon prime contractors that could compete on major programs went from twenty to six. The result? "Only the dinosaurs were allowed" to bid on such major programs as the Army's FCS, laments one robotics firm executive.
These major defense firms do very well for their shareholders, beating the S&P 500 in six of the last ten years. But besides limiting competition, the bigger companies tend to bring a risk-averse approach to the business side of war. In its planning, General Atomics tries to take a twenty-year look into the future. As Neal Blue puts it, “The future belongs to those people who will be thinking out of the box and delivering systems based on the technologies of the future.” By contrast, the old-school firms typically wait to be called upon, rather than pushing forward new ideas for the future. When I interviewed an executive at one of the largest U.S. defense firms about how his company strategized about which new military technologies to research and develop, based on their sense of the various changes in war and technology, he replied that they didn’t. “We just work on what the Pentagon tells us.” The big firms think less like Field of Dreams and more like Waiting for Godot.

This passive mentality also makes them less attractive destinations for the brightest scientists and engineers. The megadefense firms find it tough to compete with the Silicon Valley trendsetters (who, because of their lack of lobbying efforts, rarely do well in Pentagon competitions) in terms of prestige and pay scale. Even among scientists who want to do defense work, the bigger firms are seen as offering less freedom to experiment and innovate.

The bigger firms tend not to be at the cutting edge of change, but they make up for it by wielding far more influence in the halls of Congress and the Pentagon, which gives them greater power to exact costs, even when they fail at the job. Cost overruns happen in any business, but in defense contracting it has become the norm. In 2008, the GAO found that the Pentagon’s major weapons acquisition programs were a combined $295 billion over budget and behind schedule by an average of twenty-one months. Yet even when their projects fall behind, most major contractors still get their performance bonuses, because it is viewed as career suicide to cross them. The F-22, for example, came in at close to triple its original price, but 91 percent of the performance bonus, about $850 million, was paid out to its makers.

The “bigger is better” mentality is not just about the influence of the largest firms. “Larger companies trend towards larger vehicles with all the bells and whistles,” explains one robotics firm executive, who had previously worked with one of the major defense contractors. The reason is not just one of traditional gold-plating and requirements creep, but also financial margins. He recounts submitting an affordable military ground robot design to his bosses. Instead of being praised, he was told that “the profit margin is just too small for a sub $1 million vehicle.”

Because it was perceived as too small to be worth selling, he was told either to figure out how to make it bigger (and thus increase the profit margins), or to “load on million-dollar sensors” that the firm had already developed for other weapons. This kind of thinking similarly led the UCAS to evolve from a small, quick, and disposable attack drone into its current $43 million design the size of a bus.

Such a skewed industry of war could prove to be America’s undoing in the future of war. Sums up retired marine Bing West, “There is no comparison to how we do things so irrationally.”

FIGHT THE FUTURE

History tells us that only rarely can a nation stay ahead in an RMA. For the United States in the robotics revolution, the challenges include the many other nations proving to be just as savvy in these new technologies, an education and economic system that threatens to sap its competitiveness, potential resistance to change within its military culture, and a balky defense-industrial complex. History need not repeat itself, however. As one military journal put it, the United States has definitely made its mistakes, but has ultimately been “more often smart than stupid.” It is also the same country that produced people like Stayne Hoff, Dave Scannag, Billy Beane, and the Blue brothers.

For all the various factors that may challenge the United States in this revolution of technologies, it is also in the traditions of America, and its military, to be flexible and experiment with change. Before World War II, for example, the U.S. Navy built a number of different classes of aircraft carriers, as it didn’t know which type would be best for the new technology of warplanes at sea. By contrast, the British navy tried out only one class, which unfortunately for them proved wrong. A return to this American tradition of experiments and design contests also will rebuild competition in the U.S. defense-industrial space. Indeed, the recent U.S. difficulties in Iraq and Afghanistan may act to dispel conceit and help overcome resistance to any needed changes. The parallel here is how the Boston Red Sox, the definitive big-market, tradition-bound team, eventually got tired of losing and decided to copy Billy Beane’s approach of following a new path. A year later, they won their first World Series in eighty-six years.

Likewise, America may well be a nation uniquely fascinated with technology, as the optimists claim, but they undervalue that this stems from the traditional importance America has placed on education and learning. Scientists turned
founding fathers like Thomas Jefferson and Ben Franklin thus would agree with a lesson that futurist Arie de Geus has for countries today: “The ability to learn faster than your competition may be the only sustainable competitive advantage.”

The U.S. education system may now be “left behind,” but it is not a permanent lost cause. It revitalized itself after Sputnik and can do so once again. In turn, there is nothing to prevent the U.S. military itself, and especially its system of professional education and research centers, from being what change-management expert Peter Senge called a “learning organization,” open to new ideas, including even the thinking of others. This is how you stay ahead, especially in a revolution. “While learning from experience is good, learning from others’ experience is even better,” says General James Mattis, now in charge of developing many of the new American concepts of war at the U.S. Joint Forces Command.

Most of all, whether the United States avoids a repeat of so many other nations’ leader-to-loser experience will depend on whether it eschews the arrogance that dogged most past losers. It must recognize that change is afoot, and not merely one that will only be to America’s benefit.

In the summer of 2005, Sam Bell set out to buy a military-grade robotic drone. As a subsequent article about his experience described, “It was an unusual shopping expedition for a private citizen, much less a 22-year-old only a few months removed from his political science and philosophy studies at Swarthmore College. But, ever since graduation, and even while in school, Bell had been working to do what the U.S. government and the United Nations had so far failed to: stop the genocide in Darfur.”

Bell got into the military robotics business after he and two other Swarthmore students, Mark Hanis and Andrew Sniderman (whose previous college activities included running for student council and playing for the school golf team), decided they wanted to do something to help in Darfur. They formed a group called the Genocide Intervention Network (GI-Net), whose goal was to bring attention to the ongoing killings in Darfur and help raise money for the undermanned and underfunded peacekeeping force deployed there.