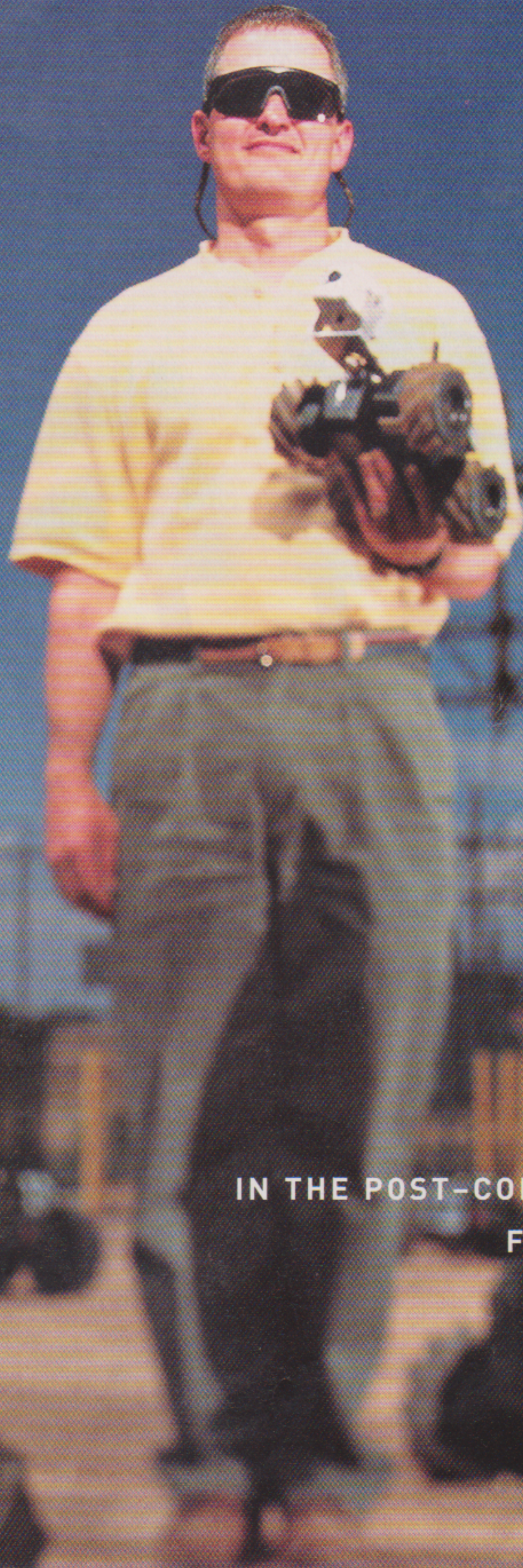


**Robot cop:** Sandia Labs' Rush Robinett is developing some of the robots that will execute the RMA's battle swarm.



IN THE POST-COLD WAR WORLD, THE U.S. MILITARY IS  
FUNDAMENTALLY CHANGING

# MILITARY REVOLUTION

BY MARK WILLIAMS AND ANDREW P. MADDEN

**I**N A CONFERENCE room at the Sandia National Laboratories in New Mexico, Rush Robinett, a manager at the labs' Intelligent Systems and Robotics Center, is impatient. "People continually fall back into old thinking and miss the fact that this technology is a new way to do business," he says. "The way we clear a building in Bosnia now, the Marines go in and may take casualties. Suppose, instead, I run these robots in there." On the table before Mr. Robinett are tiny, highly maneuverable wheeled machines.

**MILITARY IS EMBRACING NEW TECHNOLOGIES THAT WILL CHANGE THE WAY IT WAGES WAR. NOW, THE BEST DEFENSE IS A NETWORKED OFFENSE.**

By the door sits a buggylike vehicle about a meter long: a RATLER, or robotic all-terrain lunar exploration rover, originally developed by Sandia for the National Aeronautics and Space Administration.

Mr. Robinett explains. "I could run this RATLER upstairs and have



it scatter the smaller robots on the building's floors. They'll swarm out like ants, with stun guns or gas on them. Then I knock down everyone inside that building. And I don't care whether they're kids or grownups, because I'm not going to kill them."

Sandia Labs began life as the Manhattan Project's Z Division, developing the fail-safe engineering of America's nuclear bombs. In recent years, the Department of Energy facility has evolved beyond this cold war assignment. Today its job is to ensure not just the absolute dependability of America's nuclear stockpile, but also the surety of all the systems of the country's infrastructure—systems as various as the nation's missile, power, and banking networks. With unparalleled capabilities for large-scale physical testing and supercomputer simulations, Sandia Labs' 3,500 advanced technical personnel are paid to think about how technological advances could increase both America's military strength and the destructive powers available to its enemies.

Recently, Sandia Labs has been researching technologies that would let soldiers control robot swarms from displays on their laptops or from projections on the inner visors of their helmets.



**'IN THIS WORLD WHERE WE'RE CARRYING MOBILE HANDSETS, I'M AFRAID THE COMMUNICATIONS OF THE WORLD'S MOST ADVANCED MILITARY ARE OPERATING AT LEVELS THAT ARE 40 YEARS OUT OF DATE.'**

Such robots could be seeded about battlefields and could attach themselves to enemy tanks, sniff out biohazards, or pull sentry duty, Mr. Robinett explains. Excitedly, he shows a video of a hopping prototype intended to be a component one day in "a self-healing minefield."

According to Mr. Robinett, the most important question that his research group addressed was, "How much can we dumb down the individual machines and make them parts of a network to recoup that intelligence?" Mr. Robinett's project established that simple robots can execute very complex, militarily effective behaviors when they are networked. The tiny machines on the table appear quite unassuming, but that's deceptive. Such technologies could make anachronisms of the Nimitz-class aircraft carriers and heavy tanks that now dominate U.S. military strategy.

The American public has been almost unaware of the extraordinary, acrimonious debate that has erupted during the last decade among military officers, defense experts, scientists, and policy makers about a revolution in military affairs—an RMA, in the defense community's acronym-laden jargon. And that revolution's most significant trends—toward making things smaller and smarter and toward using the power of networks—are embodied in Mr. Robinett's robots.

**ALARMED SERVICES**

America's military is the country's biggest business. According to the House Budget Committee, in 2000, defense expenditures represented 16 percent of discretionary federal spend-

ing. Excluding entitlements like Social Security and Medicare, all nondefense spending combined was only 19 percent of the federal budget. In the Department of Defense's most recently published report, the 2001 defense budget will be more than \$300 billion, of which \$60 billion would be spent on procurement and almost \$40 billion on research and development (see "The Third Way," page 50). The budget for national defense is expected to exceed \$360 billion by 2006.

Thus it was big news in February when, in his first major speech on defense, President George W. Bush announced that his administration would challenge the military status quo by developing new technologies and by significantly increasing spending—particularly on military procurement and R&D. Military analysts, however, already knew that the RMA was about to become a matter of public debate when Defense Secretary Donald Rumsfeld noted at his January inauguration that, as the Ford administration's defense boss, he'd signed off on many of the weapons systems that were now due for replacement. Today's world, Secretary Rumsfeld said, is a quite different place from what it was during that cold war period. Still, he said, "some things don't change." Indeed not: an old friend

of Secretary Rumsfeld's named Andy Marshall, who had attended his previous inauguration ceremony 25 years ago, was once again by his side.

Mr. Marshall used to be described as "the most influential person you've never heard of." No longer. After assuming his old position, Secretary Rumsfeld promised a radical review of U.S. global strategy. Then he named Mr. Marshall—director of the Pentagon's Office of Net Assessment, and a gray eminence in the defense world for 51 years—to lead the review. Mr. Marshall was instructed to pick panels of experts from outside the conventional cabal of defense contractors, members of Congress, and serving officers. Secretary Rumsfeld's review is due to be released any day.

Now, European and Asian capitals are in a state of consternation about the reordering of geopolitical priorities that Mr. Marshall will likely recommend. America's defense establishment is perhaps even more alarmed, with rumors flying that the iconoclastic 79-year-old futurist will argue that large armies and navies are becoming as antiquated as cavalry charges.

Many in the Pentagon are profoundly resistant to this message; most nevertheless accept that *some* kind of RMA is inevitable. Secretary Rumsfeld and his faction of futurists are unlikely to achieve their full agenda. RMA will more likely be a gradual evolution than an abrupt transformation. But the admirals and generals are keenly aware that if military history teaches us anything, it's that the winning side is the one possessing the technological advantage. Indeed, technological supremacy has become the

single, defining characteristic of the American way of war.

And so, in anticipation of Mr. Marshall's review, but with much grumbling, the Pentagon has officially endorsed the RMA.

### YOU SAY YOU WANT A REVOLUTION, WELL...

What is the RMA? Like its enabling technologies, it is vastly diverse, rapidly evolving, and hard to comprehend in its entirety. Still, following the Pentagon's endorsement, a simple definition now exists. This basic vision of the RMA hinges on the "system of systems," a phrase popularized by Admiral William Owens, who was vice chairman of the Joint Chiefs of Staff in the mid-'90s.

Today, Adm. Owens is vice chairman and co-CEO of Teledesic, the satellite communications firm. Last year he published a book, *Lifting the Fog of War* (Farrar Straus & Giroux), to spread the RMA gospel. In it, he describes how, as commander of the 6th Fleet in the Mediterranean, he ordered each of his naval units to communicate directly with any U.S. Army unit in Europe without routing messages through a headquarters or communications center. His whole fleet failed in this exercise—after trying for six months.

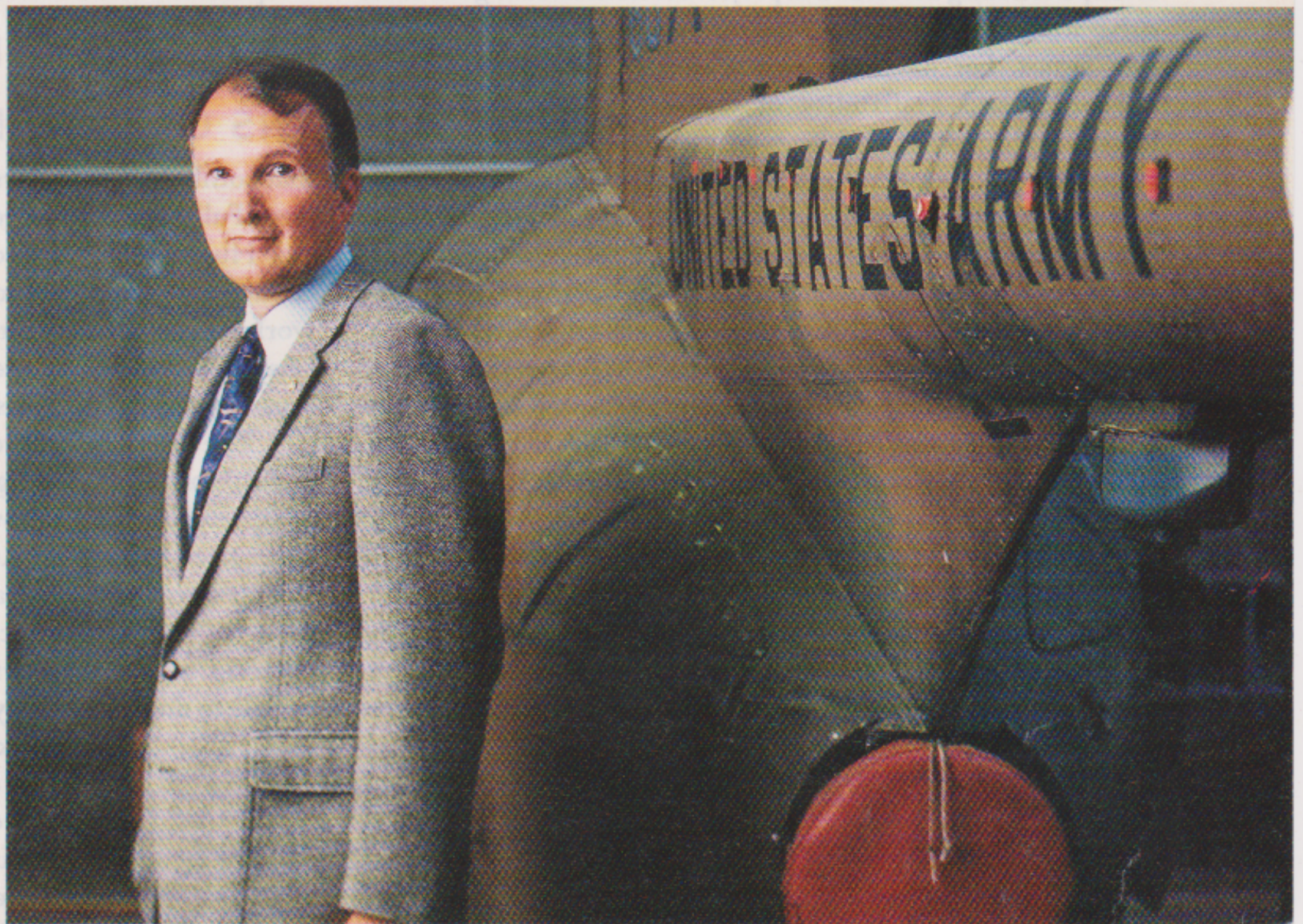
Adm. Owens explains: "The Army was on different frequencies, the Navy didn't understand the Army's systems. The problems were technical and cultural. In this world where we're carrying mobile handsets, I'm afraid the communications of the world's most advanced military are sometimes operating at levels that are 40 years out of date."

The title of Adm. Owens's book derives from Carl von Clausewitz's classic *On War*, published in 1832. In war, the German military theorist wrote, "three quarters of the factors on which action is based are wrapped in a fog of greater or lesser uncertainty." Proponents of the system of systems now believe the U.S. military could lift that fog. By fully exploiting advances in computers, sensor technologies, robotics, and precision-guided munitions, and—most vitally—by integrating all these into one great network, America's armed forces could achieve the RMA theorists' holy grail: dominant "battlespace" knowledge. Adm. Owens, for one, is sure that the U.S. military could gain the capacity to make a battle area totally transparent and target its firepower precisely where needed. "We have the technologies today," he says. "We've spent hundreds of billions on these systems, but they haven't been integrated into one common picture."

"The first thing to understand is that the Gulf War was not

a new kind of war, but the last of the old ones. I know what the press made of Desert Storm. There were technologies like the Stealth aircraft and Tomahawk weapons. But finally it was about mass—about ships, tanks, airplanes, and soldiers," says Adm. Owens. He rates Kosovo a little more highly. "Yet systems integration wasn't good in Kosovo," he points out. "You saw the Apache helicopters fiasco. They probably should have been flown from carriers, but we didn't allow that because the Army is the Army and the Navy the Navy."

When Adm. Owens is asked whether he agrees with Mr. Marshall that U.S. armed forces are unprepared to deal with the 21st century's military challenges, he goes further. "Our military structure today is essentially one developed and designed



**Man-o'-war:** John Arquilla, a teacher at the Naval Postgraduate School in Monterey, California, and a Rand Corporation consultant, has written about the future of conflict.

by Napoléon. We should, firstly, functionally integrate the Army, Navy, Air Force, and Marines. You could eliminate half of these command structures' vertical steps. Of course, you'd get rid of lots of generals and admirals. The military doesn't like that."

In addition to supporting the system of systems, all RMA proponents tend to oppose continued reliance on the large, expensive tanks, bombers, and ships that are now the major "platforms" of the U.S. military. Because most of these platforms are too bulky to be deployed quickly, the Gulf War could not have been fought without a long, preparatory buildup, and in Kosovo the Army was unable to field any force at all.

More importantly, not only are the U.S. military's favorite platforms too big for their deployment to be practicable in

21st-century conflicts, but increasingly they'll be large, vulnerable, and slow-moving targets, too. For instance, a number of new weapons are emerging that will challenge the dominance of tanks on the battlefield. Researchers at Sandia Labs believe that electric guns will appear within the next five years. With ordinary guns or cannons, the propellant force imparted to projectiles is provided by an explosion and limited, because barrels would be blown apart beyond a certain pressure. But with electric guns, no explosion is involved, and electromagnetic pulses timed at fractions of a second could impart great force to projectiles. A modern M-1A1 Abrams tank possesses reactive armor: tiles of solid explosive are stitched together so that any shell striking one sets the tile off. A shell's kinetic energy is thereby dispersed, and the shell prevented from penetrating the tank. But projectiles from electric guns could drive straight through that type of reactive armor. For navies, the increasing cheapness and availability of cruise-missile technologies will be even more devastating. To democratize cruise missiles for use by third world groups doesn't even require the level of technology the United States currently possesses. Swarms of cheap do-it-yourself cruise missiles, constructed on wooden kite frameworks and directed by the Global Positioning System, could do the trick nicely.

For all these reasons, proponents of RMA argue for smaller, lighter, cheaper platforms like wheeled armored vehicles, unmanned planes, stealthy submarines—and entirely new technologies like Mr. Robinett's RATLERS and robots.

**THE RIGHT WAY, THE MILITARY WAY, AND THE SILICON VALLEY WAY**

One of the less obvious benefits of the RMA is that it could bring about much-needed changes in the way the government interacts with defense contractors—and the way defense contractors

develop new products (see "Research Parties," page 56).

According to Christopher Hellman, a senior analyst at the Center for Defense Information, a military research organization, the current problem with most military contractors is that they have little reason to break new technological ground. "There is no incentive for them to be innovative. We pay them not to be. We do not encourage these guys to develop systems that they think will meet our future military needs," he says.

To understand this dynamic better, we met with Pacific Consultants, a group of geeks-for-hire in Silicon Valley that has witnessed the faults of the military procurement process from the inside. Pacific Consultants has played a leading role in the ongoing development of the Army's Land Warrior program, a weapons and communications system for the individual soldier

**'THEY'LL SWARM OUT LIKE ANTS WITH STUN GUNS OR GAS ON THEM.'**



that combines computers, radios, and software (see "Fully Loaded," page 53).

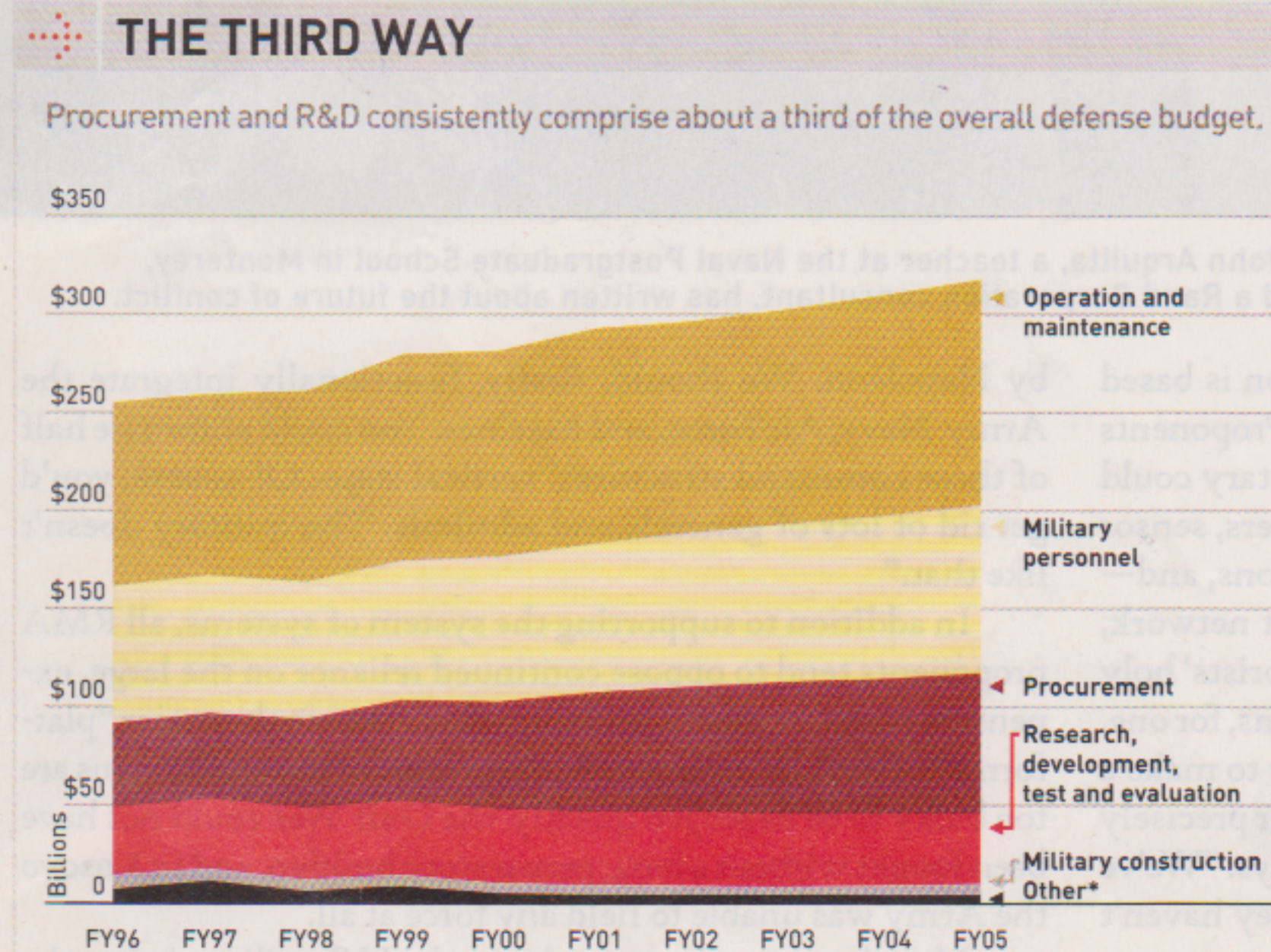
Hugh Duffy, CEO of Pacific Consultants, recalls first encountering a Land Warrior prototype created by Raytheon while working for an engineering consulting firm called Exponent. "Raytheon created a system that was a complete nightmare," he says. "It was the crappiest-looking system you've ever seen."

The problem, according to Mr. Duffy, was that the Army had submitted a set of rigid specifications to Raytheon that the company dutifully followed. Disappointed by the clunky and overpriced results, an Army colonel named Bruce Jette came to Exponent looking for a second opinion. "We've got bad news for you," Mr. Duffy recalls telling Col. Jette. "Raytheon did nothing wrong. You wrote a specification that encouraged people to do things badly. They took your money, and you got what you deserved."

Once at Pacific Consultants, Mr. Duffy and a team of engineers tackled the same specifications, but used them only as a rough guide. They created the initial prototype (using commercial technologies from a local electronics store) in under 12 weeks and for less than \$1 million. By displaying a level of innovation the Pentagon had rarely encountered, Mr. Duffy and his cohorts won the contract to design the system, despite much larger competitors like Raytheon and Motorola.

And according to Mr. Duffy, original estimates from Raytheon indicated the cost of the system would be \$85,000 per soldier. Mr. Duffy believes the system can ultimately be built for \$20,000 or less.

The lesson, says Mr. Duffy, is that "the government has to learn how to get on the Silicon Valley bandwagon and get all this commercial technology. In the good old days, the government could drive the creation of new technologies. They drove



\*"Other" includes family housing, special foreign currency, and defense-wide contingency. May not add up due to small amounts of additional funds received. SOURCE: U.S. Department of Defense

the creation of the Internet; they drove the early development of computers. Those days are gone.”

Lieutenant General Paul Kern, director of the Army Acquisition Corps, is quick to point out that the Army is still focused on its own research efforts through an arrangement with the Defense Advanced Research Projects Agency, the Army laboratories, and a variety of defense contractor teams (see “Up in Arms,” page 54). Still, he recognizes the benefits of the Land Warrior model. “We’re trying to reach out to smaller, innovative companies which work on the Silicon Valley model, and to use different procurement and acquisition strategies along the lines of what Col. Bruce Jette accomplished with the Land Warrior program.”

### THE STATE OF WAR

“I was Reagan’s ray-gunner,” Gerold Yonas says. What the tall, bearded, and theatrically effusive Mr. Yonas means is that he was chief scientist for President Ronald Reagan’s Strategic Defense Initiative. Today he’s Sandia Labs’ principal scientist, heading its Advanced Concepts Group.

Mr. Yonas, like most everyone at Sandia Labs, takes a long view of world history. To understand the events that have made RMA inevitable, it is useful to share something of that perspective. Sandia Labs’ version of military history goes something like this: before 1945, war’s scale only grew. At the 19th century’s turn, a massive escalation occurred: the industrial revolution and the rise of the nation-state began to increase radi-

sive, industrial-era forces seems near to receding into history.

Given that states with enough technological capability to compete in the global market probably could build nuclear weapons, the world is likely to see a few wars between marginal, barely industrial-level nations—like the Ethiopia-Eritrea war—and a greater number of internal conflicts, much like the seemingly permanent gang combats that have ignited inside collapsed states like Serbia, Sierra Leone, and Somalia.

America has to worry about such situations. Their chaos can spill across the borders of neighboring nations and destabilize a whole region, as in the Balkans. Furthermore, they can constitute fertile grounds for terrorist movements striking against the United States itself; Afghanistan, with its support of Osama bin Laden, proves that.

In separate interviews, James Tegnalia, vice president in charge of Sandia Labs’ Department of Defense programs division, and Dan Rondeau, a manager in the same division, both expressed specific concerns about Islamic fundamentalism and future terrorism.

One sure assumption, summed up by the phrase “asymmetric warfare,” underlies all the scenarios that Mr. Tegnalia and Mr. Rondeau discuss. During the Gulf War, America’s technological strength already surpassed that of any other nation, including its allies in the North Atlantic Treaty Organization. At that time, precision-guided ordnance was 8 percent of what U.S. forces used; later, during the Kosovo conflict, it was 35 percent of what was deployed. Because precision-



**‘WE SHOULD FUNCTIONALLY INTEGRATE THE ARMY, NAVY, AIR FORCE, AND MARINES. OF COURSE, YOU’D GET RID OF LOTS OF GENERALS AND ADMIRALS. THE MILITARY DOESN’T LIKE THAT.’**

cally the scale of war and the massing of soldiery. This culminated in what soldiers call total war—the world wars and death camps of the first half of the 20th century. But in 1945, confronted with its supreme product—the nuclear weapons that Sandia Labs helped to build—war’s scale began diminishing slowly and steadily. Since then, only wars where the prospect of total war was specifically prohibited (because one of the belligerents did not have the nuclear bomb, as in the Gulf War, or because one was a mere proxy for a superpower, as in Vietnam) have been prosecuted.

At the close of World War II, the six principal belligerents maintained nearly 45 million soldiers; by 1991, though the world’s population and the number of states had almost tripled, the coalition against Saddam Hussein deployed just half a million troops. Likewise, in 1939 each of the leading air forces had thousands of planes, with America alone manufacturing about 75,000 military aircraft annually from 1942 to 1945; by 1995, while the U.S. Air Force remained the world’s largest, it purchased only 127 aircraft. Overall, just between 1990 and 1997, the global export market for the heaviest conventional weapons and military systems declined 44 percent in real terms to \$30 billion. The era of interstate wars fought on clear battlefields by mas-

guided weapons allow the exact targeting of enemies with extremely limited American casualties, this trend will continue. And because such weapons—alongside networks and enhanced data gathering—are at the RMA’s heart, America’s military superiority is advancing by yet another order of magnitude.

America’s enemies, confronting such fundamental inequality, won’t mass their forces to be blown apart. Instead, they will exploit the advantages inherent in asymmetric warfare, using guerrilla- or terrorist-style attacks to try to undermine American will—exactly the tactics that the Maoist Vietcong used to defeat the United States in Vietnam.

### NOT SO FAST

As with any proposed technological revolution, a number of objections can be made.

The first is that politics and vested interests may limit the scale and completeness of the RMA. The sheer size of the entrenched interest groups may defeat the most astute attempts to transform U.S. military thinking and spending over anything but the long term. During the first Bush and the Clinton administrations, reviews were initiated in 1991, 1993, and 1997 on restructuring America’s armed services for the post-cold war

**UP IN ARMS**

In the Department of Defense budget for advanced technology research and development in 2001, IT was the largest new line item.

	FY 2001 FUNDING (MILLIONS)	% CHANGE SINCE FY 2000
Information Technology Development	\$94.2	N/A*
Space-Based Lasers	\$74.5	N/A
Global Combat Support System	\$72.0	N/A
Line of Site Antitank Weapons	\$26.8	N/A
Advanced Tank Armament System	\$118.1	6,047%
Aircraft Avionics	\$42.3	569%
Advanced Development of Weapons and Munitions	\$28.7	513%
Artillery Systems <sup>1</sup>	\$20.1	320%
Other Missile Product Improvement Programs	\$64.4	264%
Night Vision Systems Advanced Development	\$11.0	247%
Distributive Interactive Simulations	\$20.7	172%
Landmine Warfare/Barrier <sup>1</sup>	\$69.6	133%
Sense and Destroy Armament Missile	\$52.8	119%
Joint Tactical Communications Program	\$38.9	113%
Landmine Warfare/Barrier <sup>2</sup>	\$22.8	109%
Air Defense Command, Control, and Intelligence	\$16.5	107%
Command, Control, Communications Systems	\$49.3	107%
SCAMP Block II (satellite data transmission terminal)	\$20.3	91%
Aerospace Propulsion Subsystems Integration	\$34.4	76%
Joint Tactical Radio	\$62.2	70%
Technical Information Activities	\$26.7	69%
Flight Vehicle Technology Integration	\$13.2	59%
Advanced Aerospace Systems	\$26.8	57%
Space and Missile Rocket Propulsion	\$24.3	47%
Combat Feeding, Clothing, and Equipment	\$86.3	42%
Marine Technology	\$30.3	40%
Land Warfare Technology	\$134.2	39%
Line-of-Sight Technology Demonstration	\$50.7	34%
Artillery Systems <sup>3</sup>	\$355.3	33%
Comanche Helicopter	\$614.0	33%
Logistics Systems Technology	\$13.9	30%
Classified Defense Advanced Research Projects Agency Programs	\$101.4	28%

Among programs with more than \$10 million in 2001 funding. \*Not applicable, program not previously funded. <sup>1</sup>Engineering. <sup>2</sup>Advanced development. <sup>3</sup>Demonstration. SOURCE: U.S. Department of Defense budget

world. All three reviews ended up with only smaller forces and some reductions in major weapons purchases, while preserving the time-honored custom of slicing the federal defense budget into shares that remain consistent for each service.

Already Secretary Rumsfeld's rumblings have caused Congress to take action. In April, when one of his panels recommended scuttling the \$11.1 billion Crusader missile program, citing its inappropriateness for probable future conflicts, the high-ranking Representative J.C. Watts Jr. (R: Oklahoma) took immediate steps to discredit the finding. Representative Watts contended that the Crusader "meets a critical need for next-generation fire support for a lightweight, transformed Army." More to the point, United Defense, the manufacturer of the Crusader, has a factory in his district. Objections like those of the congressman will likely be the rule, not the exception.

The military itself will want to delay or limit the scope of the RMA, even as it covets some new toys. RMA would challenge the services' existing turfs and eliminate many heavy tanks, airplanes, and ships. Generals and admirals who have spent their entire careers engaged in Pentagon infighting are unlikely to accept RMA happily. The military is also concerned about what RMA might do to its command structure. As in the corporate world, information technologies mean that information will become as available to workers at the hierarchy's bottom (the grunts) as to the CEOs



**'RAYTHEON CREATED A SYSTEM THAT WAS A COMPLETE NIGHTMARE.'**

(the generals and admirals). Indeed, information will often be more available to ordinary soldiers, because they will be in the thick of it. Because its soldiers will sooner or later have to be given more power to act on their own initiative, the military will have to fundamentally rethink the relationship between commanders and troops.

There are practical objections to the RMA. Because it assumes total battlespace knowledge, RMA depends on a staggering variety of sensor technologies. Broadly, these technologies fall into three categories: sensors using visible and near-visible light (like ultraviolet and infrared), those using radar and radio waves, and everything else (chemical, nuclear, or biological detectors). The question is, could the sum of all these truly deliver total battlespace knowledge to the American military now or in the near future?

Mr. Tegnalia and Mr. Rondeau believe that in only a few years, if the technological capabilities of America's enemies remain only what they are today, the U.S. military could effectively achieve total battlespace knowledge. But America's enemies, though unlikely to reach technological parity with the United States, will also develop new technologies. To some extent, they'll raise their ability to reimpose war's fog.

The U.S. Navy, for one, believes it can use new technologies to save old ones. By tying all the radar systems of a carrier group's ships and planes into a system it calls cooperative engagement capability, it claims that it will track and destroy enemy

aircraft and cruise missiles sooner. Anybody who knows how simple corporate systems can fail to work together may well be skeptical that any military system of systems will be infallible. But the larger problem is that the U.S. military wants to believe it can have both the new weapons systems and the old. "More money would reinforce the tendency to buy what's already in the pipeline, as opposed to prepare for the transformation force," says Andrew Krepinevich, executive director of the Center for Strategic and Budgetary Assessments, a public policy research institute, and a former member of the Department of Defense's National Defense Panel. And the money almost certainly won't be there: to pay for systems the Pentagon has already ordered and to maintain the U.S. military at its present scale for the next decade, its budget would need to grow at least \$50 billion annually. The greatest dangers, then, are that the American military will proceed piecemeal with new technologies to shore up cherished big toys, and that the military won't accept significant change until some disaster—like an aircraft carrier's sinking—forces it to.

**YOUR MASS IS GRASS**

"As powerful as our existing forces are, they're almost unusable," says John Arquilla, who teaches at the Naval Postgraduate School in Monterey, California, and consults for the Rand Corporation, a policy think tank. "During Kosovo, the Pentagon's stock response—and I stood at the deputy secretary of defense's side during some of these debates—was that we needed six months to put an army on the ground." Mr. Arquilla recently partici-

**'THERE IS NO INCENTIVE FOR THE CONTRACTORS TO BE INNOVATIVE. WE PAY THEM NOT TO BE.'**

pated in one of the expert panels that Mr. Marshall assembled. "Consider a future Gulf War if the aggressor doesn't stop in Kuwait and captures the whole peninsula," Mr. Arquilla continues. "You'd neither have a base from which to build up nor six months to do it. The reality is, by the time you've assembled the overwhelming force the Powell doctrine now calls for, you just have fewer and fewer options, and perhaps not the ability to solve the problem. So that's why an RMA is necessary."

Last year, with his Rand colleague David Ronfeldt, Mr. Arquilla wrote a study called "Swarming and the Future of Conflict," as part of a larger Defense Department project. The study proposes a military of smaller, dispersed, networked units that strike at an enemy from all directions, creating an effect of sustained attack without massing. Mr. Arquilla insists that massed

forces in the 21st century will be increasingly vulnerable as precision-guided weapons technologies become widespread. "In the future, to paraphrase an old Marine saying, your mass is grass." The U.S. Army of 2040, he predicts, will be composed of small, nimble special forces commanding tremendous amounts of firepower and able to call down yet more, possibly from orbital platforms. "I envision many more man-machine interfaces and much greater reliance on teleoperations," he says.

Mr. Arquilla and his colleague Mr. Ronfeldt have proposed the concept of a battle swarm that would integrate the Army, the Navy, and the Air Force. Asked how the services are reacting to their proposed elimination, Mr. Arquilla concedes, "Oh, it's not playing very well at all. Everybody in the military is protecting their turf and maintaining as much hierarchy as possible. As somebody who's in the belly of the beast, I view the near-term future with little hope of positive change. On the other hand, if you look out 20 or 30 years, the chances are very good that these changes will occur because a new generation will be in place."

At the beginning of the 21st century, the U.S. military finds itself in the odd position of developing a series of technologies with doctrinal and operational implications that will one day eliminate today's Army, Navy, and Air Force.

"A true revolution in military affairs destroys almost all that is," Mr. Arquilla concludes. "And we have to do it. Because as incomparable as our existing forces are, as I say, they're also almost unusable." ■

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**RESEARCH PARTIES**

In 2000, aircraft manufacturers, like Lockheed Martin, commanded the bulk of Defense Department R&D spending, but companies specializing in IT, like Mitre, also attracted investment.

COMPANY	RESEARCH, DEVELOPMENT, TEST, AND EVALUATION	OTHER SERVICES AND CONSTRUCTION	SUPPLIES AND EQUIPMENT	TOTAL
Lockheed Martin	\$4.1	\$2.6	\$8.4	\$15.1
Boeing	\$2.7	\$1.2	\$8.0	\$12.0
Northrop Grumman	\$0.8	\$0.9	\$1.3	\$3.1
Raytheon	\$0.6	\$1.7	\$4.0	\$6.3
TRW	\$0.6	\$1.2	\$0.2	\$2.0
United Technologies	\$0.4	\$0.1	\$1.6	\$2.1
Science Applications International	\$0.4	\$1.1	0	\$1.5
Mitre	\$0.4	0	0	\$0.4
Boeing-Sikorsky Comanche Team	\$0.4	0	0	\$0.4
Computer Sciences	\$0.3	\$0.7	\$0.1	\$1.2
Massachusetts Institute of Technology	\$0.3	0	0	\$0.3
Aerospace Corporation	\$0.3	0	0	\$0.3

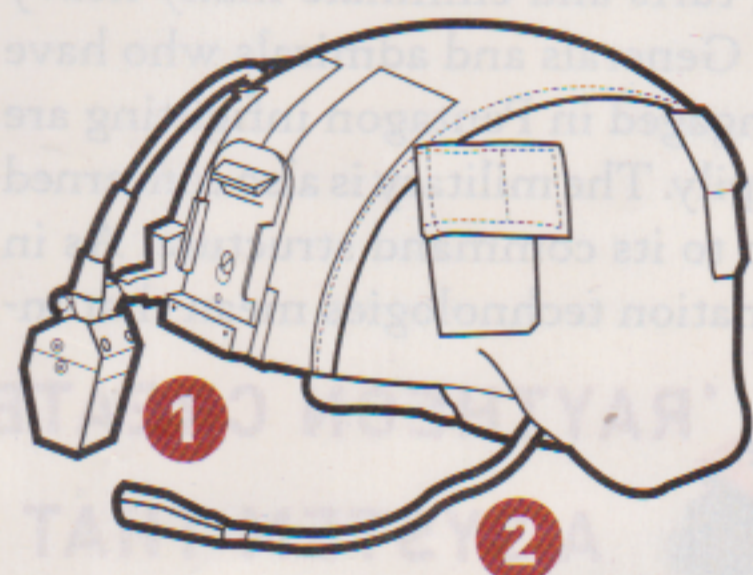
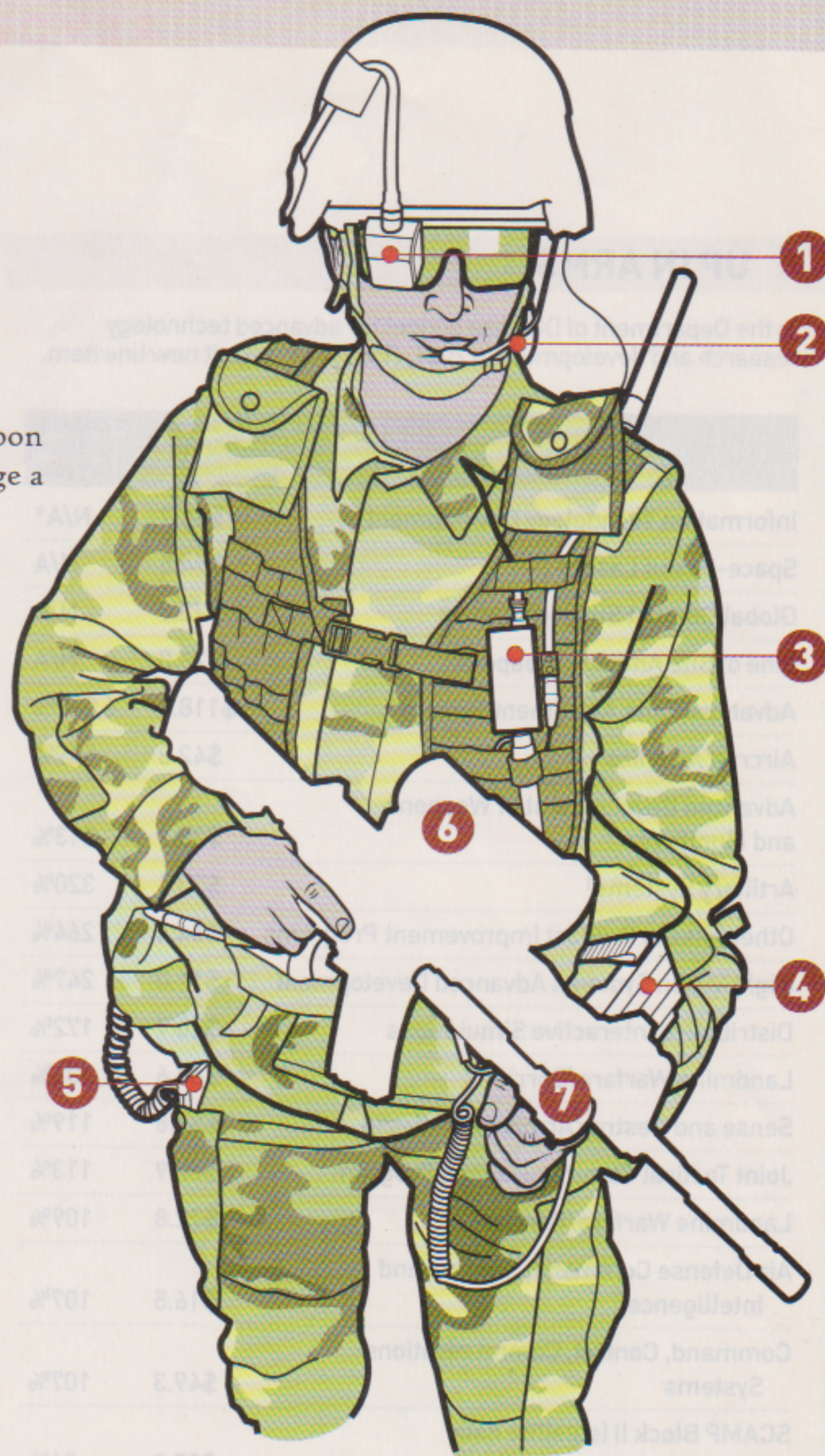
In billions. SOURCE: U.S. Department of Defense





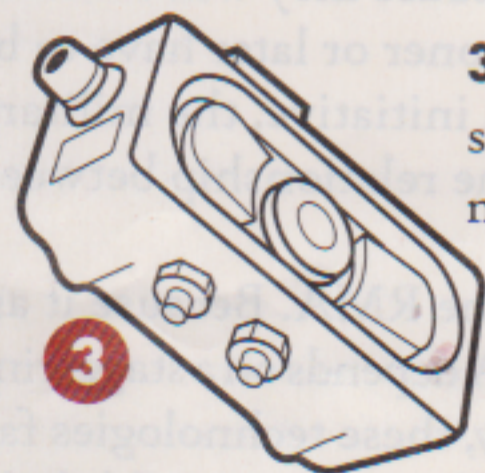
# Fully loaded

**T**HE LAND WARRIOR individual soldier weapon system aims to make total battlespace knowledge a reality. Each soldier—equipped with a wearable computer/radio, heads-up display, and video sight—will become part of a vast mobile network. In theory, a ground soldier scouting an enemy encampment will be able to transmit digitally live images (still and video) and coordinates to a helicopter gunship passing overhead. The U.S. Army plans to outfit 41,000 soldiers with this system, starting in 2003. Below are some of the key components:



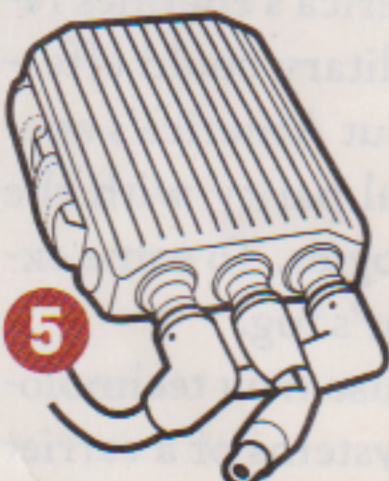
**1. HEADS-UP DISPLAY** Shows maps that include the location of the soldier and of other platoon members, as well as enemy positions. Also connects to the gun's video sight.

**2. MICROPHONE/SPEAKER** Allows for hands-free communications with fellow soldiers and command posts.

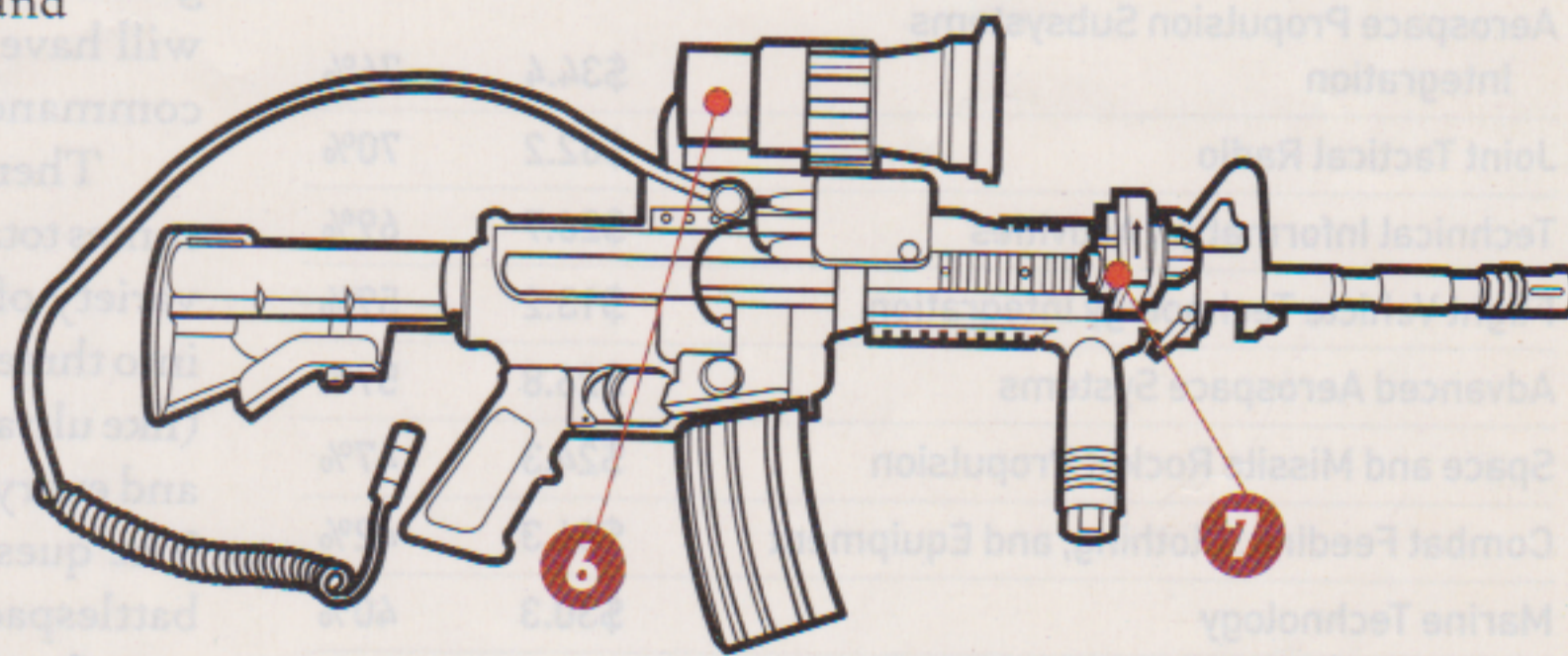


**3. GUN-MOUNTED MOUSE** Allows soldier to control computer and maintain a firing position.

**4. MESSAGING KEYBOARD** Wrist-mounted keypad for email communication.



**5. COMPUTER AND RADIO MODULES** Lightweight computer running Windows, with customized software and embedded Global Positioning System. Radio allows for secure voice over-IP communications with fellow soldiers and command posts.



**6. THERMAL SIGHT** Allows for thermal detection of hidden targets.

**7. DAYLIGHT VIDEO SIGHT** Relays images to heads-up display, allows soldier to peer around corners and fire accurately with minimal exposure.