The Strategic Computing Program

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Early in 1984, a document called *Strategic Computing* [1] began to circulate among computer specialists. Some readers were startled by its visions of battling robots in the 1990s:

> Instead of fielding simple guided missiles or remotely piloted vehicles, we might launch completely autonomous land, sea, and air vehicles capable of complex, far-ranging reconnaissance and attack missions. . . . In contrast with previous computers, the new generation will exhibit human-like, "intelligent" capabilities of planning and reasoning. . . . Using this new technology, machines will perform complex tasks with little human intervention, or even with complete autonomy. . . . The possibilities are quite startling, and could fundamentally change the nature of human conflicts.

The document was from the Pentagon's Defense Advanced Research Projects Agency, usually called DARPA or ARPA. American computer scientists regard DARPA as the most enlightened and generous patron of their field, and its ten-year, billion-dollar Strategic Computing program is the largest single commitment of funds for computing research in the country. Yet much of its content suggests a science fiction movie—perhaps titled after a *Newsweek* story about the project: "Birth of the Killer Robots."[2] Defense contractors and university laboratories are now at work on a series of fantastic-sounding pilot projects, including an unmanned robot truck, a robot assistant for fighter pilots, and battle management programs intended to plan tactics and monitor progress in war at sea in the Pacific or on the ground in Europe.[3–13]

Early Roots

ARPA was created in 1958, in the aftermath of Sputnik. One of its beneficiaries was computer science. In 1961 its Information Processing Techniques Office, or IPTO, was created and placed under the direction of J. C. Licklider from MIT's Lincoln Laboratory. During the 1960s IPTO flourished under a series of visionary directors including Licklider, computer graphics pioneer Ivan Sutherland, and future Xerox and DEC executive Robert Taylor. Along with the Office on Naval Research, ARPA was a major force in building academic computing research in this country. It sponsored seminal work in computer graphics and in time-sharing, the now-familiar technique which allows many users at separate terminals to share the same computer. Its most exotic beneficiary was artificial intelligence (AI): programming computers to solve problems using symbolic reasoning, rather than numerical calculation. During the 1970s IPTO's most important innovation was ARPANET, the nationwide research computer network for ARPA's far-flung contractors. ARPANET hosted the first large-scale experiments in computer mail and electronic bulletin boards, evolved into today's MILNET military computer network, and served as the model for several commercial data communications services like GTE Telenet.[14–16]

During the Vietnam war, ARPA became embroiled in the application of high technology to jungle warfare. As the war became unpopular, particularly on campuses, there was widespread sentiment that the Department of Defense should not support university research. In the war's wake, ARPA's charter was modified. The Mansfield amendment, passed in 1969, decreed it was to limit its activities to projects with clear military applications. ARPA accordingly became DARPA, the *Defense* Advanced Research Projects Agency. Thanks to DARPA most academic computer scientists remained comfortable with the Pentagon, even after the war. In 1985 they received about 60 percent of their support from this source, far more than their colleagues in other fields.[17]

Meanwhile, DARPA continued to fund work in artificial intelligence. In April 1983, DARPA presented Congress with a first-year request for $50 million to begin a project in the military application of AI called "Strategic Computing and Survivability."

The Birth of Strategic Computing

Strategic computing was quite controversial within DARPA. Tension exists within the agency between those who would prefer to emphasize basic research and those eager to put innovations to work. The former preference is often personified in the directors of IPTO. In their view, technical and scientific prowess so obviously contributes to American strength that the Department of Defense should nourish it however it can; it is not necessary to channel it directly into weapons development. This view prevailed in the 1960s. ARPA's description of its fiscal year 1966 program, for example, justified its computer efforts on the grounds that

DoD was a very large user of computer technology. It boldly asserted that DoD was a beneficiary of the research largely in a secondary sense: ARPA's work would improve the quality of products of commercial manufacturers and DoD would ultimately benefit as a buyer of such products. In the 1980s, this view continued to be held by many who joined the agency prior to the Reagan administration, including IPTO director Robert Kahn. In 1985 Kahn left DARPA to found the nonprofit Corporation for National Research Initiatives, which is often described as an attempt to raise civilian funding for the sort of work DARPA used to support.[18]

A contrary view holds that DARPA's work should be directed toward weapons applications in the near term. This view was held by the agency leadership appointed after Reagan's election, including the new director, Robert Cooper. When Strategic Computing was introduced, Cooper's role extended beyond DARPA; he simultaneously served as assistant secretary of defense for science and technology. An important component of the Reagan administration's stance toward the Soviet Union is to apply high technology to military advantage. The philosophy is expressed by the title of an article co-authored by William Perry, undersecretary of defense for research and engineering during the early Carter years: "Winning through sophistication."[19] The general idea is that an allied force equipped with computer-controlled "smart weapons" could carry the day in battle against a much larger Soviet force. Artificial intelligence's attraction is its promise of substituting technology for people. In summer 1981, the Defense Science Board, a panel of civilian experts that advises the Pentagon, ranked artificial intelligence second from the top of its opportunity list—the opportunity to make an order-of-magnitude impact on defense in the 1990s.[20] Cooper explained the rationale to the House Armed Services Committee in 1983:

> More than ever, the ability of our forces to overcome those of our opponents requires us to leverage high technology effectively against their massive investments in conventional military hardware. . . . This new technology, along with a strong and determined military establishment, will be our first line of defense in the 1990's.[21]

Cooper told the committee that "We (at DARPA) measure our accomplishments really by the transition of our research efforts into military service development programs." He said the agency hoped that Strategic Computing would deliver "fieldable capabilities" ready for battle "within seven years"—that is, by 1990. Later, Cooper elaborated to the House Committee on Science and Technology:

> This program represents somewhat of a departure for DARPA in that up to now funding limitations restricted significant follow up programs with industry on interesting computer science research ideas developed in the universities and research labs we normally fund. We left it to industry on their own to pick up whatever ideas seem most interesting to them. We feel this laissez-faire approach is no longer appropriate for Defense. . . . Of course, we plan to continue our basic 6.1 research program . . . but we intend to substantially augment it by this new 6.2 exploratory development effort.[22]

In the Defense R&D budget, 6.1 is the category for basic research; 6.2, for exploratory development; and 6.3, for advanced development. All the money allocated by Congress to strategic computing falls into the 6.2 category. Charles Buffalano, DARPA's deputy director for research, explained the emphasis to *Aviation Week*: "One of the first decisions we made in the Strategic Computing Program was that it would not be just an open-ended research program, with application left to some future time." Richard DeLauer, undersecretary of defense for research and development, told a meeting of electronics industry leaders that past DARPA research "was allowed to sit around; we didn't do anything with it. That is not going to happen again."[23]

Besides scientists and military planners, strategic computing also enjoys the support of many who favor "industrial policy": federal guidance and subsidy of industrial research and development on the Japanese model. In 1981 Japan's Ministry of International Trade and Industry, or MITI, announced a $450 million, ten-year project to develop what it called fifth-generation computing. The Japanese announcement galvanized financial seers in the United States. Features about AI filled the popular press, including cover stories in *Fortune* [24] and *Newsweek* [25].

Early in 1983 Stanford University AI researcher Edward Feigenbaum and science writer Pamela McCorduck published a book called *The Fifth Generation* [26] in which they predicted that AI programs capable of significantly augmenting or replacing human professional workers would become commonplace in the 1990s. Prowess in computing would replace industrial capacity and pretty much everything else as the vital ingredient in a nation's economic health. Should their advice be ignored, they threatened, America could become "the first great agrarian post industrial society." Feigenbaum and McCorduck recommended that the United States undertake its own national computing initiative, based on the MITI model. They wrote that the nearest thing we had to MITI was DARPA, an "enlightened corner" of the Pentagon where "human beings were betting taxpayers' money on projects that would have major benefits for the whole human race." Feigenbaum and McCorduck also claimed that a national AI effort was "essential to the national defense," observing of robots that "if they scourge our enemies, we wouldn't mind that either. . . . The so-called smart weapons of 1982, are really just extremely complex wind-up toys compared to the weapons systems that will be possible in a decade."

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Fiegenbaum and McCorduck's book caught the attention of New Mexico Senator Jeff Bingaman. In August 1983, the Department of Energy and the National Security Agency sponsored a meeting at Los Alamos to bring together technical specialists in computing and government policymakers. Senator Bingaman gave the keynote speech [27]. Along with House Armed Services Committee Staff member Tony Battista, Bingaman became the leading advocate for strategic computing in Congress. As the program worked its way through Congress, the word went out that this was the American response to MITI's fifth generation. "This is in response to the Japanese," an unnamed "high-ranking official of DARPA" told the *Washington Post* [28]. "I don't think $50 million is enough," Battista told the *Post*, "this is a problem that goes far beyond DoD; it trends directly into our whole economic base." In February 1984, DARPA director Robert S. Cooper told a meeting of electronics engineers that SCI is "buying an insurance policy against IBM management's decision not to pursue machine intelligence through the 1990's. They have abandoned supercomputers, believing such investments don't yield a good payoff." [29] And Defense Undersecretary Richard DeLauer said, "The Defense Department should press this technology, because no one else is pursuing it, and the Japanese have strong proposals." A favorable *Washington Post* editorial commented: "The Pentagon is one of the great patrons of the arts and sciences in this country. . . . Is it desirable to have those funds come from the Pentagon? It's not ideal. . . . [But] on the historical record, you'd have to say the Pentagon has frequently been more of a benefactor to the basic sciences than it ever really intended." [30]

Thanks to this view, today the SCI program enjoys broad support in Congress. A May 1985 amendment that rescued strategic computing and other Department of Defense computing projects from threatened budget cuts was cosponsored by Senators Bingaman, Heinz, Danforth, Simon, Hollings, Domenici, and the influential Democrats John Glenn and Ted Kennedy. In his speech, Bingaman suggested that the DARPA project was an antidote to the trade deficit and the decline of America's smokestack industries. He characterized the fifth-generation project as Japan's strategic computing program. Senator Glenn noted that the administration had at that time proposed freezing the budgets of NASA and the National Science Foundation. He asked, "Who is going to pick up the slack if we are to, indeed, maintain world leadership as we come under increasing pressure from the Japanese, the Germans, the French, and others, in computer technology areas?" Senator Kennedy lauded the advantages of "smart conventional weapons" which "unlike our dubious expenditures on wasteful and dangerous systems like (the) MX (nuclear intercontinental ballistic missile) can truly strengthen our national security." [31]

The Justification

Strategic computing is broadly divided into two kinds of work: technology base and military applications. What the agency calls technology base are the components from which weapons could be built. Any spin-offs useful in nonmilitary applications would come from this category. The major effort in this area is to build very fast computers. Kahn predicts a "thousand-fold to ten-thousand fold speed improvement." [32] This will be accomplished through parallel processing: harnessing many small computers to work on pieces of the same problem simultaneously. About a third of the strategic computing budget is devoted to this work. Other technology base projects deal with miniaturizing and "ruggedizing" computers so that they can be used in military vehicles and aircraft. Also included in this category are the kinds of AI research DARPA has been funding all along:

computer vision, robotics, speech understanding, and natural language processing.

The technology base category also includes work on building microchips from gallium arsenide rather than the usual silicon. These are of interest because they are potentially much faster than silicon, and are especially useful in optoelectronic components, those that mediate between electricity and light. Gallium arsenide is much more resistant to nuclear radiation than silicon. The strategic computing report calls for circuits hardened against a dose of 50 million rads (the fatal dose for a human being is about 500 rads).

The military applications category includes the experimental weapons themselves. They are not prototypes being evaluated for eventual production. Rather, they are demonstrations intended to act as testbeds for ideas that may be incorporated in future designs. Roughly 20 percent of the budget is earmarked for demonstrations, with most of that spending to occur later in the program after the technology base has been prepared. The strategic computing report proposed three military applications, one for each of the services: autonomous systems, collaborative systems, and battle management.

Autonomous Systems

As Cooper explained to the House Armed Services Committee:

> In the early 1990's autonomous systems such as advanced cruise missiles or advanced undersea vehicles will be needed. Systems like these will require almost human-like capabilities to sense, reason, plan and navigate to fulfill their missions. Above all, they must be able to react effectively in the face of unexpected or unforseen circumstances. [33]

The particular demonstration chosen for the Army was an autonomous land vehicle, or ALV, essentially a driverless robot truck. It was to be capable of roving about independently over rough terrain, ranging up to thirty miles from its home base, at speeds up to forty miles per hour. It would serve as the model for a class of vehicles to be used for "deep-penetration reconnaissance, rear area re-supply, ammunition handling, and weapons delivery." Cooper speculated that such vehicles might "pursue long-term missions, perhaps measured in weeks or months, during which they will intelligently plan and reason in order to achieve their goal." The report noted that the lessons of this demonstration "will be exportable to . . . cruise missile en-route navigation and terminal homing, as well as a wide variety of fire-and-forget weaponry."

Collaborative Systems

The demonstration chosen for the Air Force was the pilot's associate. Cooper told Congress, "As supercomputer capability evolves, men and computers will operate as collaborators in the control of complex weapons systems. . . . Such collaboration could change the role of the human (fighter aircraft) pilot to that of aircraft commander, rather than that of a button and switch technician." Cooper claimed the pilot's associate would "respond to spoken commands by a pilot and carry them out without error." It could "activate surveillance sensors, interpret radar, optical and electronic intelligence and prepare appropriate weapons systems to counter hostile aircraft or missiles."

The October report elaborated that the robot copilot was needed because "Pilots in combat are regularly overwhelmed by the quantity of incoming data and communications and by the dozens of switches, buttons, and knobs that cover their control handles. While each of the aircraft's hundreds of components serve legitimate purposes, the technologies which created them have far outpaced our skill at intelligently interfacing the pilot to them." It said the associate would impart "instruction on advanced tactics from more experienced pilots to aid the less experienced pilot on his first day in combat."

Battle Management

This application is motivated by the perceived inability of today's cumbersome military staffs to deal with the chaotic battles anticipated in the future. As the report explains, "Improvements in the speed and range of weapons have increased the rate at which battles unfold." The report laments the growth of "large, labor-intensive military command organizations," observes that "people are often saturated with information requiring complex decisions to be made in very short times," and worries that "the trend in all areas toward faster moving warfare stresses the whole staff function." Cooper elaborated to Congress, "with increasingly massive amounts of valuable data collected, no commander can possibly keep up and make full use of the information. Adding more personnel will actually make the problem worse—each will see a smaller and smaller percentage of the information, making an accurate overall picture even less likely." Rejecting the possibility that "leaders and planners will be forced to rely solely on their people to respond in unpredictable situations," the report also finds that today's "computers with inflexible logic [are] of limited value" and concludes "revolutionary improvements in computing technology are required to provide more capable machine assistance in unanticipated combat situations."

Artificial Intelligence to the Rescue

Cooper told Congress:

> In the future supercomputers with reasoning ability and natural language interfaces with military commanders will be able to

> participate in Military Assessment and may be able to simulate and predict the consequences of various courses of military action. This will allow the commander and his staff to focus on the larger strategic issues rather than have to manage the enormous information flow that will characterize the battles of the future.

The demonstration chosen for the Navy was the aircraft carrier battle management system, or BMS. Scheduled for installation aboard the carrier USS *Carl Vinson*, the system would

> display a detailed picture of the battle area, including the enemy order of battle (surface, air, subsurface), own force disposition, electronic warfare environment, strike plan, weather forecast, and other factors . . . It would generate hypotheses describing possible enemy intent, prioritize these according to their induced likelihood, and explain the reasons for the prioritization. Drawing upon previous experience, together with knowledge of own force and enemy capabilities, it would generate potential courses of action, use an ultra-rapid rule-based simulation to project and explain a likely outcome for each course of action, and evaluate and explain the relative attractiveness of each outcome considering such criteria as protection of own forces, inflicting damage on the enemy and the rules of engagement. Once the commander selects a course of action, the BMS would prepare and disseminate the operation plan (OPLAN), and compare the effects of option execution with those developed through the simulation both as a check on progress and as a means of identifying the need to replan. At the conclusion of every phase of the engagement, the BMS would modify its expert system in the light of empirical results.

In September 1985 another battle management demonstration project was added. Called airland battle management, it dealt with war in Europe.

The applications are, as the report admits, "quite startling." Cooper speculated that their operational descendants might "eventually change the nature of warfare and international conflict as much as or more than has nuclear technology."

Strategic Computing and Star Wars

Strategic computing and survivability (as it was then called) was unveiled to Congress a few weeks after President Reagan's Star Wars speech. Strategic computing is distinct from the Strategic Defense Initiative (SDI), as Star Wars is officially called, and retains its own administration and budget. None of the strategic computing demonstrations directly concerns missile defense. Yet the DARPA report cites as one motivation for its own project "the projected defense against strategic nuclear missiles, where systems must react so rapidly that it is likely almost complete reliance will have to be placed on automated systems." The report notes that much of the hardware and software developed for the aircraft carrier battle management system might also prove useful for missile defense. The radiation-hardened gallium arsenide microchips are needed because "communication and surveillance systems that can survive in a strategic conflict are important components of a space-based battle management system."

DARPA director Cooper, who was also serving as assistant secretary of defense, became a highly visible point man for the controversial missile defense program. In a heated exchange that was widely reported in the national press in April 1984, Cooper, along with the president's science advisor George Keyworth, and Strategic Defense Initiative Organization chief James Abrahamson were grilled by Senate Foreign Relations Committee members Paul Tsongas and Joseph Biden. The senators ridiculed Star Wars, noting that the president might not be online during those vital few minutes when the decision to strike Soviet booster rockets would have to be made. "By the year 1990, (the decision) may be done automatically," Keyworth suggested. [34] When the senators posited that a bemused president might choose the wrong response option, Cooper responded, "We might have the technology so he couldn't make a mistake." Biden responded: "You've convinced me I don't want you running this program." [35]

DARPA staff planned a preliminary strategic computing program, complete with provisional budget, in the winter of 1982–83, with no foreknowledge of "Star Wars." The "Star Wars" computing requirements are prodigious, and when SDI planners began putting their program together, they must have looked at the Strategic Computing Program and thought, "Here is something we can use." The administration's first systematic study of SDI technical requirements, usually called the Fletcher report after the NASA chief who supervised it, devoted an entire volume to the computing problem, which it also termed battle management.[36] The Fletcher report has much the same flavor as the DARPA document. It says, "Time scales are too short for human decision makers to select among a complex array of alternatives. It seems clear to (the Panel), therefore, that *some degree of automation in the decision to commit weapons is inevitable if a ballistic missile defense system is to be at all credible*. To support automated decision processes . . . requires rules of engagement that are carefully designed and completely explicit" (emphasis in original). The panel adds that "the computing requirements are demanding by current standards, but with programs such as DARPA's Strategic Computing and Survivability, computing architectures with sufficient performance to meet the battle management requirements should be available. The DARPA program (and others) should be continued. It is essential for a BMD system."

Later in 1984, Cooper described strategic computing to the House Committee on Appropriations. Representative

Addabbo asked, "Will we need a supercomputer to be the actual brain for the 'Star Wars' system?" Cooper replied, "It is my personal opinion that the computational capability that we are pursuing is an enabling technology for a defense as complex as may be necessary for ballistic missile defense. . . . We expect that significant results will come from the Strategic Computing program within five to seven years and expect that spectacular capabilities will be available in the early nineties. That is not inconsistent with the timetable for the . . . Strategic Defense initiative program. I am hopeful that we can make progress at the rate that we now project in the Strategic Computing Program so that it will not turn out to be a bottleneck in a potential decision in the middle to late nineties as to the efficacy of a ballistic defense system."[37] Recently, SDIO chief James Abrahamson has reiterated that strategic computing is essential and vital to SDI.

Nevertheless, DARPA officials emphasize the distinction between their program and the SDI. Lynn Conway, DARPA's chief scientist for strategic computing, made a special point of this at a meeting of the American Association for Artificial Intelligence in Austin, Texas, in August 1984. She added that the DARPA project's similar name had, in retrospect, proved an unfortunate choice.[38] In fact, the two programs are by now rather difficult to untangle. When the ballistic missile research that DARPA had been quietly pursuing for decades turned into Star Wars and the SDIO took over DARPA's directed energy weapons research, it also took along the radiation-hardened gallium arsenide semiconductor projects originally included in strategic computing[39]. SDIO officials are not so sensitive on this topic as are DARPA's. An August 1986 cover story in the *New York Times Magazine*, ostensibly about SDI, devoted several hundred words to the strategic computing projects as sources of future Star Wars spinoff.[40] They were described only as "computing projects related to SDI." I asked the reporter how he had decided to include them. He told me that General Abrahamson had suggested them.

Opinions vary on the degree of unofficial coupling between the two programs. New Mexico Senator Jeff Bingaman still supports strategic computing but has voted to limit funds for SDI. One of his staff told me, "Congress thinks of SDI and strategic computing separately. We wouldn't allow SDI's computing requirements to be pulled out of strategic computing. SDI has to pay for its own computing research." But *New York Times* science reporter Malcolm Browne told me, "You can't separate DARPA from SDI—though DARPA might like to. One way the administration can keep SDI going despite congressional opposition and budget limitations is by sneaking a lot of research in through the back door. DARPA is one of those back doors."

Applications and Spinoffs

By 1986 a host of contractors were at work on the demonstration projects. Large aerospace firms including Boeing, TRW, and Hughes had founded AI research centers partly to attract strategic computing dollars, and smaller startups like the Mountain View, California, company Advanced Decision Systems (ADS) are specializing in DARPA work. Each demonstration involves many contractors. For example, Martin Marietta is the system integrator for the autonomous land vehicle (ALV) but is putting together components from many subcontractors on a chassis supplied by yet another firm. Software is coming from subcontractors Hughes and Denelcor, a simulation testbed is provided by ADS, and software research is being done at the University of Maryland and at Carnegie-Mellon University. DARPA's Clinton Kelly, who heads the strategic computing applications office, said, "We hope that these industry-university teams will become a hallmark of our applications programs because they offer a useful mechanism for providing on-the-job training for graduate students."

The modest applications demonstrated so far stand in marked contrast to the grandiose visions of the original DARPA report. Currently, all the demonstrations are using conventional, commercially available minicomputers, so they run quite slowly. Performance limitations imposed solely by computational speed can be expected to improve when parallel processors are installed. While critics charge that the demonstrations are merely expensive and impractical toys, program supporters plead that useful performance cannot be expected at this early stage. However, installing faster computers wil not cure difficulties created by incorrect programs or unsound rationales.

The ALV is a boxy, eight-wheeled van that resembles an oversized windowless panel truck. It bears a TV camera to view its paths and a laser ranging device to look out for obstacles. An onboard computer analyzes the data from these sensors, determines the vehicle's next position, and signals the wheels to move forward. In May 1985, at Martin-Marietta's testing range in the foothills near Denver, the ALV first crept about 1000 yards down a groomed track at about 3 miles an hour. That November, it wended its way around a curving 1.5 mile course, reaching 6 mph on some straightaways and negotiating curves at about 2 mph. In July 1986 the ALV made its first public appearance. The boxy truck bore a large sign reading Warning Unmanned Vehicle Stay Back 100 Feet. It was supposed to navigate a sharp curve at 6 miles an hour. Instead, it headed for the ditch. "It could have been mud on the road or maybe a cloud's shadow obscured its visions," hedged the Martin Marietta engineer who hit the kill switch. "Anything can throw it off," explained Ted Linden, ADS manager of the ALV planning programs. "Dust blowing across the road can confuse it." William Isley, DARPA's director of the ALV project, blamed the weather. "It was very warm that day," he recalled, explaining that one of the computers had overheated. Martin Marietta is not uniquely jinxed. During tests of a similar vehicle at Carnegie-Mellon in 1985, the robot, which had been programmed to stay on the road by following edges of sharply defined contrast, tried to run up a tree.

After the disappointing ALV trials, DARPA and Martin Marietta explained that the bugs would be forgotten when faster computers were installed in the ALV. "One of our incentives is Western Europe, where we are outnumbered more than three to one," Isley explained. "And we are not shying away from aggressive action either." He told reporters that the next step would be to install ALV-derived technology into real military vehicles. "Some of us believe the Howitzer may be the first application in the field because it is not in a combat zone, but in the back fields," he said. But William Bricken, a senior research scientist at ADS, told the San Jose *Mercury*, "A lot of us in the field feel that in five years it will be revealed that what DARPA is trying to do is unachievable. Even with the best of us working on it, it won't happen in five years, it won't happen in 50 years. What they will probably do is redraw the lines to save embarrassment."

Wright-Patterson Air Force Base in Ohio is supervising several experiments in cockpit automation for the pilot's associate. Work is under way on computer-generated displays and voice warnings of equipment malfunctions and battle damage, and aids in planning navigation, taking into account fuel reserves and locations of known antiaircraft batteries. The associate is a long way from getting off the ground. A phase one demonstration, currently scheduled for early 1988, will not involve a human pilot and will not evaluate how rapidly the computers respond. Meanwhile, Boeing and ADS have put together a series of computer flight simulations and videotapes to show the Pentagon and

Congress what a working pilot's associate would look like if it could ever be completed. They suggest that a computer is actually responding to the pilot's commands, calling out warnings, and generating displays. In fact the sound and graphics effects are completely preprogrammed.

Components of the Navy's battle management system are being tested at the Pacific Fleet Command Center in Hawaii and aboard the aircraft carrier, the USS *Carl Vinson*. They build on conventional databases, like those commonly used in business. Rather than typing cryptic commands, users may type queries in English, for example, "Show me the location of Task Force 71," or, "Show me all the cruisers that are Tomahawk- or Harpoon-missile-capable." Rather than printing tables of names and numbers, the system depicts a map on a video display with the requested items highlighted. Experiments in voice recognition are scheduled. The air-land battle management demonstration is being supervised by the Army's Ballistic Research Laboratory and units from the Army's Training and Doctrine Command. It will conduct experiments in battle planning and war games. These exercises are distantly related to the board games in which cardboard tokens representing fighting units are moved about a gridded map. The demonstrations will use computer graphics, and the rolls of the die will be replaced by programs that include hundreds or thousands of mathematical formulas and if-then rules.

In contrast to the applications, some of the technology base projects are doing well. Parallel processing, harnessing many computers together to work on the same problem, looks like the next big wave in computer design; it is potentially the most important advance since the computer itself was invented in the 1940s. DARPA-supported prototypes include Columbia University's Non-Von, BBN's Butterfly, and Carnegie-Mellon's Warp. The best known is the Connection Machine, from the recent MIT spinoff, Thinking

Machines Inc. The Connection Machine debuted in summer 1986 to vast attention from the popular press, much of it focused on the machine's boyish twenty-nine-year-old designer, Danny Hillis. Parallel processing is on its way to becoming another big DARPA win, in the tradition of time-sharing and networks.[41]

Can the Goals Be Met?

Can strategic computing ever meet its technical goals? For this, it is not necessary to resort to subjective impressions. Congress made funding for the program contingent upon DARPA's submission of a report that included concrete objectives and milestones (target dates for achievement of the objectives). These were included in the October 1983 report and have been roundly criticized as unrealistic and irrelevant, even by such friends of the program as Mark Stefik, a scientist at Xerox PARC and occasional consultant for DARPA. Stefik explains, "Development and research are different kinds of activities . . . To be successful, development projects must be *predictable;* success cannot depend on first achieving new research results or on building new kinds of things with which there is no experience." Since strategic computing proposes to do just that, Stefik says, "the development project can no longer be reliably scheduled since the results become unpredictable."[42]

The trouble is, as Stefik points out, "assigning concrete goals and milestones legitimatizes the view that a program should be judged by whether or not they are met." DARPA has been burned this way before. In the early 1970s the agency mounted a Speech Understanding Research (SUR) project. The planners "simply guessed" at some plausible milestones; when they were not achieved the program was abruptly terminated.

Many of the strategic computing milestones are grossly, naively unrealistic. For example, in the areas of speech understanding and natural language processing DARPA proposes these goals:

- 1988: Domain-specific text understanding (e.g., understand paragraph-length intelligence material relating to air threat).
- 1990: Interactive planning assistant which carries on task-oriented conversation with the user.
- 1992: Recognition of sentences, independent of speakers, from a 10,000-word vocabulary with natural grammer under moderate noise and low-stress conditions.
- 1993: Explanation system which provides planning support and substantive understanding of streams of textual information.

Together, these goals comprise a completely general solution to the speech and language problem: the talking robots of science fiction, which no technically informed person expects to happen soon. Scientists fear that these exaggerated claims will result in another SUR-style debacle. Some are beginning to worry aloud about the "AI winter," the freeze in funding that could occur if the autonomous vehicles don't roll and the robots won't talk.[43] Stefik recommends that DARPA "gradually back away from the milestones."

The sharpest technical criticisms of strategic computing appear in a December 1984 report from the Defense Science Board, the same organization that had so enthusiastically recommended AI in 1981.[44] Members of a board task force complained that DARPA had grossly misrepresented the project's potential. Former IBM executive Frederick P. Brooks, Jr., author of the classic work on software project management[45], wrote:

> The Strategic Computing report is so optimistic as to the present state of the AI and parallel computing arts as to be readily

> misunderstood. Our Task Force's 12-month study showed reality to fall well short of what I would have gathered from reading the Strategic Computing report. . . . On AI itself, twenty years of work by our discipline's best minds has produced disappointingly meager results. For example we found only two, or perhaps three, expert systems to be in real operational use. The gap between the ballyhoo and practice is very wide, and the layman could easily misjudge the real status.

Robert Everett, president of MITRE Corporation, a defense contractor which spun off from MIT's Lincoln Laboratory in the 1950s and pioneered the application of computers to military command and control, also wrote:

> I am unconvinced that AI is the answer to all problems and I am unconvinced that increasing computing capacity by a factor of 1000 will be particularly helpful at this time. What we need is a much better understanding of the problems we are trying to solve and of the ways to organize and solve them . . . The suggestion that AI systems may somehow solve problems that we do not ourselves understand may come true in the far future but at the moment is unreasonable and dangerous.

Brooks charged that "The DARPA Strategic Computing Program as now set forth overemphasizes the glamorous and speculative *at the expense of the doable*." He was enthusiastic about the infrastructural elements of strategic computing—support for circuit fabrication technologies and the more generic university research. He noted that in the past, it had not been the results but the by-products of AI research—time-sharing, networks, and programming languages—that had justified the expenditures.

Brooks and Everett both endorsed the principle of driving research by the needs of future military applications but charged that the demonstrations chosen by DARPA were very poorly conceived. The pilot's associate, Brooks felt, was potentially fixable. But of the autonomous vehicle, he wrote, "Today's machine vision technology is so far short of that required for the operational task that one cannot project a credible development path for getting from here to there." Everett wrote, "Vehicles are now full of people. Reducing crew size would be very useful even if the vehicle were not autonomous. Tanks now carry four people and great savings would result from reducing this to three which seems to be difficult enough. . . . If we can't build a successful two-man tank, how can we build one that is completely autonomous?"

As for battle management, Brooks wrote, "It is inconceivable to me that any sane person would trust a machine-generated battle plan." He added, "One wants to automate from the bottom up, not, as proposed, from the top down. The mind of the commander should be the *last* target for replacement." Everett was skeptical that data processing was really the bottleneck in military staff operations, saying:

> We heard a pitch at the last meeting for a large scale planning activity. . . . It was stated that speeding up the computers . . . would reduce the planning time from ten months to one day. . . . My instincts are that 1000 times the computing capacity would not shorten the planning times at all. . . . If the process is to be shortened it must be entirely rethought and redesigned. After that it may turn out to require computer capacity beyond the state of the art but I doubt it. Promising to improve the process significantly with new computer technology alone will just get everyone in trouble sooner or later.

Everett added, "Most of the computer-aided command systems to date have been aids to the staff, not to the commander. The staff remains, plus the staff that goes with the computers . . . This may or may not be all right in peacetime, but in wartime the goal should be to reduce the staff, not help the staff."

Objections Surface

In 1982 a scientist at Xerox PARC named Severo Ornstein posted a message on the company computer network asking whether anyone else was worried about nuclear war. Ornstein had worked on SAGE, the original computer-based air defense system in the 1950s, and had helped design the IMPs (interface message processors), special-purpose computers that glue the ARPANET together. Participants in the computer mail discussion he began decided to form an organization on the model of the then-prominent prodisarmament group, Physicians for Social Responsibility. Computer Professionals for Social Responsibility, or CPSR, was duly incorporated in 1983; Ornstein retired from Xerox to become its chairman. Far-flung PARC alumni and acquaintances soon founded chapters around the country.

Ornstein hoped to influence defense policy and win the regard of a profession that is largely supported by military spending. Ornstein and Xerox PARC colleagues (and fellow CPSR members) Brian Smith and Lucy Suchman wrote an assessment of the DARPA plan which was published in 1984 in the prodisarmament *Bulletin of the Atomic Scientists*[46], and in 1985 in the journal of the largest computing professional society, *Communications of the ACM*.[47] The CPSR pieces appeared at about the same time strategic computing finally began to receive notice in the popular press.[48, 49]

The CPSR assessment is practically the only article to enjoy wide circulation that criticizes the premises and military policy implications of strategic computing. "Our concern is not with the technology base or with military projects as such," the authors wrote:

> Our concern is that increased reliance on artificial intelligence and automated decision-making in critical military situations, rather than bringing greater security, leads in an extremely dangerous direction . . . Like all computer systems artificial

> intelligence systems may act inappropriately in unanticipated situations. We argue against using them for decision making in situations of potentially devastating consequence.

Citing the passages in the DARPA report that allude to automated ballistic missile defense, the authors noted: "The plan makes clear that reliance on automatic systems is meant to include the control of strategic weapons."

Numerous incidents of software failures are related to illustrate practical problems involved in getting any battle management software to work appropriately.

> Computer systems work best in areas that are well understood, highly constrained, predictable and easily controlled. In more complex environments, unanticipated events are liable to trigger anomalous reactions. . . . Systems have to evolve for a substantial period before they are reliable enough to be used. . . . Yet there is no way that military systems—especially nuclear systems—can be fully tested in advance; nor can crisis conditions ever be fully simulated.

Ornstein and the others attacked the premises of the battle management idea:

> In observing that increased uncertainty and confusion are critical problems in modern warfare, the Strategic Computing Plan accepts the situation as inevitable, embracing artificial intelligence and automatic decision-making as a means of coping with it. . . . Ironically, the problems arise in part from the very technology that is proposed as a solution. . . . The push to develop so-called "intelligent" weapons as a way out of that situation is another futile attempt to find a technological solution for what is, and will remain, a profoundly human political problem.

Cooper responded in a letter which was published in both the *Bulletin*[50] and *Communications*[51]. He wrote,

> Some anti-defense groups, in their efforts to achieve notoriety and attract followers, have characterized DARPA's Strategic Computing Initiative as being aimed at creating a computer that

> will automatically control nuclear weapons release. . . . Computer Professionals for Social Responsibility is one such wrong-thinking group. Their characterizations, designed to generate fear among the uninformed, are at odds with the facts. . . . The Strategic Computing Initiative has nothing whatever to do with strategic weapons release.

In fact Ornstein and the others carefully avoided saying that strategic computing proposed automated "release" of nuclear weapons. However, the Fletcher panel report *does* say that Star Wars battle management computers will have to automatically fire nuclear weapons, apparently referring to bomb-powered X-ray lasers or other nuclear antimissile devices. Cooper also complained that

> (CPSR) claim(s) that (Strategic Computing) will generally lead to more reliance on "automated decision making" by essentially unreliable computers [but] we have in hand recent results from basic research in artificial intelligence that . . . will substantially improve the adaptability and accountability of computer systems.

Cooper also speculated that AI might make future weapons so effective that the Western allies may no longer need to rely on nuclear weapons to deter a Soviet conventional attack in Europe. "It is probably true that machine intelligence technology will eventually change the nature of warfare and international conflict as much or more than has nuclear technology," Cooper wrote. "However, since the resulting change will be in a direction away from reliance on nuclear weapons of mass destruction, it should be a welcome one to all—even the most strident anti-defense activists."

In response to the CPSR assessment, several prominent computer scientists came to DARPA's defense. They did not argue that strategic computing was likely to achieve its policy goals nor satisfy any real defense needs; they minimized the importance of the military applications. In a long article in *Communications*, Stefik pooh-poohed "the possibility that defense-policy planners will take plan predictions at face value and make decisions that depend on unrealistic expectations of machine-intelligence technology." He assured readers that "To expect that military planners 'believe everything they read' about Strategic Computing is to assume that they are universally gullible." Stefik also speculated that high-technology weapons might make nuclear war less likely, but concluded, "the primary rationalizations will be less significant over the next decade than the economic considerations. In the next 10 years, Strategic Computing will have little impact on defense. What is more likely is that the new technology will spur another cycle of technological innovation and investment."

The agency's defenders pleaded that continued DARPA funding was vital to the health of American computer science. Michael Dertouzos, director of MIT's Laboratory for Computer Science, reminded *Bulletin* readers of all the innovations spawned by past DARPA projects. [52] "DARPA's contribution to current and prospective U.S. leadership is staggering in its effect, compared to the relatively small funds expended in that direction," he wrote. "People who attack DARPA-funded computer research are, however well intended, striking at an imaginary problem and at the core of our proven national innovative thrust." Peter Denning, past president of the ACM and editor-in-chief of *Communications*, told me, "DARPA wanted a program to rebuild the academic computer scientific infrastructure. It had to create a program that would fly in the political real world. By playing on feelings about Japan and Germany catching up with us, they could sell the research part. By adopting visions of new computer-based defensive systems, they could obtain the DoD support." Stefik wrote, "Historically, DARPA has been the only U.S. funding institution that combined major funding and long-term commitment to research in computer science. . . . DARPA is the only U.S. institution with the funding and vision to undertake a project like this."

Strategic Computing Faces Star Wars

After receiving some attention from the national press in 1984 and 1985, strategic computing has once again practically dropped from sight. By mid-1985, the debate surrounding Star Wars was occupying most of the efforts of CPSR and other technically oriented activists. Their efforts were rewarded by a great deal of press attention, which thus eclipsed strategic computing in the eyes of the public.

In 1986 the strategic computing budget was cut for the first time—and deeply. The $145 million requested for FY1987 was knocked down to $102 million. In 1985, the Senate Armed Services Committee had tried to nick the program, but it was saved by Senator Bingaman. But 1986 was different. Gramm-Rudman was in force, and Congress was presiding over the largest defense budget cuts, in real dollars, in ten years. The Pentagon decided to skimp heavily in research and development. DARPA was hit especially hard because Star Wars was protected from Gramm-Rudman by presidential fiat. It appears that both the technology base and applications components of strategic computing will be cut. [53]

DARPA looms so large in the world of computing that scientists tend to forget that strategic computing is a tiny drop in the Defense budget, always vulnerable to political pressures and fashions. The battered 1987 budget was nicked another $12 million to help fund a lab at Syracuse University, an example of what Bingaman calls "pork barrel science." In 1985 the new undersecretary of defense for research and engineering, Donald Hicks, said "my position is that there will be a reprioritization inside DARPA. . . . DARPA does an awful lot of stuff . . . They have a huge program on advanced computers and on and on and on. We're going to relook at all those things to see about the payoffs to see if we're not putting too much money in certain places. It is important that [DARPA] doesn't become some kind of sandbox for scientists to play in." [54]

The Pentagon and the Scientists

Strains are created by the attempt to meet the needs of several different groups, including military planners, scientists, and industrial policy advocates. For the last group, DARPA deputy director Craig Fields says, "I know of not one example that anyone has ever come up with of how the [technology base] contents of the program would differ if it were a civilian program. . . . We are serving a civilian purpose as well." [55] Supporters of strategic computing often say that the program is an attempt to recreate what is remembered as the enlightened and fruitful environment of the pre-Vietnam years, when Pentagon and the universities cooperated for mutual benefit, free from partisan political feuding.

However, there are important differences between today's programs and those of the 1960s. The Department of Defense R&D budget has not only increased during the Reagan years; the distribution of funds is different. In the early 1960s, 20 to 25 percent of Pentagon R&D spending went toward basic research, while today only 8 or 9 percent does. Defense Department officials frankly acknowledge that the needs of today's projects are not always compatible with basic research. DARPA's Fields has said that universities "would really like us to be more like the (civilian) National Science Foundation." But, he explained, DARPA's mission is different from NSF's. Former ARPA director Stephen Lukasik explained the agency's mission: "The reason why you can't leave certain defense science up to the NSF, is the NSF is going to pick its priorities on the basis of science and it may turn out . . . that the defense (problem) is ninth on that list, and it may be first-rank for defense." For this reason, DARPA administrators do not always welcome the comments of scientists who assert that their agency-sponsored work is unrelated to military needs. Former director Eberhard Rechtin recalled of the Vietnam years that the academic scientists

> didn't dare stand up and say what they were working on was for purposes of defense (because of student and faculty opposition). But suppose they made the other mistake of saying: "Sure we're getting the money from Defense, but we're not really doing anything related to defense." Whish. You got shot through the other temple. The Congress says, "What the hell is Defense putting that money up for? The professor himself doesn't know that it's any good for anything. He says it's not good for defense anyway."

Today's Pentagon believes that the research it sponsors should lead to weapons applications. Undersecretary of Defense Donald Hicks put it bluntly to *Science*: "What I'm saying is that the Department of Defense is given money for *defense*. . . . We're in a situation where we're trying to protect the position of the United States against a power that would like to soak us up." [56] Some observers say that defense science administrators are simply more ideological than they were years ago. Jack Ruina, a former ARPA director who opposed the ballistic missile defense proposals of the 1960s, says "We asked the hawks what they thought, but the present people don't ask the doves. There are no effective checks and balances now—the skeptics are absent." In this highly charged atmosphere, technical or policy criticisms, no matter how respectfully offered, are unwelcome. Hicks recently threatened to stop funding scientists who criticized SDI:

> I am not particularly interested in seeing the (Defense) department money going to someplace where an individual is outspoken in his rejection of department aims, even for basic research . . . If they want to get out and use their roles as professors to make statements, that's fine, it's a free country. But freedom works both ways. They're free to keep their mouths shut [and] I'm also free not to give the money. . . . I have a tough time with disloyality . . . All the internal memos in the world are terrific, but when a guy stands up and gives an interview and goes on television, somehow he's not one of us.

This puts pressure on scientists whose support is coupled to controversial projects. As Dertouzos admits, "If I had to depend on (the civilian) National Science Foundation I'd have a dead laboratory." DARPA administrators understand that the agency can be most effective with scientists if it remains scrupulously apolitical. This probably explains their vehement but not very convincing denials that strategic computing has anything to do with the more overtly politial "Star Wars." Most scientists prefer to steer clear of political controversy regarding their own work, particularly if it deals with generic topics, such as parallel processing, that promise useful applications outside the weapons realm. The scientists' solution is to emphasize the distinction between the applications of strategic computing and its more generic technology base. Thus Denning of the ACM asks why researchers in universities and industry should not take advantage of what he terms "that portion [of strategic computing] offered . . . under terms that are agreeable to them." Dertouzos, defending MIT's strategic computing efforts, said "the idea that the source of funding influences and controls the ultimate deployment of a discovery is just plain false."

Not all computer scientists accept that the applications and technology base are separable. Joseph Weizenbaum, of MIT's AI lab, holds that people are obligated to accept responsibility for the uses others put to the products of their labors, if these uses have been amply described or can easily be inferred in advance. "Is that so surprising?" he asks. Terry Winograd, a Stanford scientist known for his work on natural language processing, observes that an agency that pays for most of the work in a field may exert political control over its practitioners: "Every additional dollar that goes through their budget, regardless of what it ends up being used for, gives them additional economic influence. . . . Once the university has become dependent on military funds for its survival, it is very hard to take a stand on some 'minor' issue which could jeopardize everything." [57] In this view, DARPA's funding for generic research buys political support, or at least acquiescence, for its more controversial weapons work.

In fact, a subtle, mollifying effect does appear to be at work. Scientists who support strategic computing generally tiptoe around the applications component. Readers unfamiliar with obscure DARPA reports and congressional testimony would never guess the project's militant rationale from their writings. In his lengthy *Communications* article and the correspondence that followed, Stefik managed to avoid saying whether he thought the applications were good ideas or not. In a long *Technology Review* article on parallel processing, Dertouzos lauds strategic computing for supporting this work, but never even mentions that the program includes an applications component. He worries vaguely that "the government has begun to seek research results with more immediate military relevance" without enlightening readers about the source of his concern. [58]

Scientists would be happier if the strategic computing initiative were more like the basic research projects which DARPA funded in the past. Unfortunately, it isn't. Some scientists are evasive regarding the real nature of the project, which thus becomes something of a taboo, rarely described in public. They try to maintain the pretense that strategic computing is basic research. In response to a letter to *Communications* expressing alarm over strategic computing's military applications content, David Brandin, then president of the ACM, answered that the concerns "are akin to raising a classical question: Shall we conduct basic research in a field where we cannot predict the results, where one cannot anticipate how the technology will be used?" [59] To various ojections to strategic computing's military implications, Mark Stefik replied: "Many kinds of technology contribute to such possible automation, including such things as mainframe computers, telephones, and databases . . . Given this, it is not clear whether [the author] is against research and development per se. After all, one never knows when someone might find a destabilizing military use even for an apparently harmless and obscure result." [60, 61] Here Stefik and Brandin employ the same tactic recommended to the staff at the AI lab of a large defense contractor. They were issued a memo on how to deal with "tricky media questions," for example, "Will AI technologies be used on offensive military applications?" At the time the memo was issued, the lab was actively seeking strategic computing contracts. The memo advised: "Move from their specific point to a more general one, e.g., from AI in particular to computers in general, or AI technologies to technology in general. . . . Stay with academic principles rather than technical details." Several sample answers were supplied, including, "Any advanced technology today could be used in the military . . . In the past you could have asked this question about radio, airplanes, xerography, etc."

Perhaps this helps to explain the copious but incomplete coverage that AI has received in the trade and popular press. The reader is unlikely to discover why all this activity is really going on in the first place. One of the weirdest examples is the December 1985 article on Danny Hillis and his Connection Machine in *Esquire* [62]. In an issue on "America's new leadership class," Hillis was interviewed "in his toy-strewn office as long-haired, shoeless programmers fiddled with computers in the background." There is absolutely no mention in the article of either DARPA or strategic computing, nor of the $4.7 million in seed money they had given Hillis's company. After entertaining various speculations about AI, the reporter asked what to do about Big Brother. Hillis replied, "You admit that there may be a problem and try to do your best to steer toward the right thing. That's dangerous territory. There's always the temptation to rationalize, to say, 'Well, gee, I really want to work on this project, and even though it's going to be used for guided cruise missiles, I really want to study three-dimensional analysis and these guys are willing to pay me for it.' " In fact, cruise missile route planning and terminal guidance are mentioned several times in strategic computing, and Hillis's first commercial customer, Perkin Elmer, is using its Connection Machine on that very problem.

The Potential for Tragedy

I have followed strategic computing for several years. I have read hundreds of pages of news stories, official reports, technical articles, and congressional hearings. It is mostly dry stuff, but the hope that someone will ask an important question keeps me turning the pages. I keep hoping that some congressman will ask: Can we really count on this stuff? If we're really outnumbered three or four to one, is it wise to depend on high technology to win wars for us? How did we decide that computers could substitute for people, tanks, and planes? Have any wars been won that way? If all those Russian tanks in Europe are a real problem, shouldn't we build a lot of tanks ourselves, or maybe make a lot of antitank weapons and teach people how to use them?

Is it possible that this whole hi-tech strategy is just the product of domestic politics and wishful thinking?

But I never read these hard questions. Perhaps that is because there are no reassuring answers to them. If we really anticipate a war with Russia, then "winning through sophistication" is an enormously risky strategy. While trying to think of wars won by sheer sophistication, I found counterexamples. Near the end of World War II, the Germans had cruise missiles, theater ballistic missiles, and jet aircraft. Each of these was more advanced in some technical sense than anything the allies had, but to no avail. Clearly there is some point past which technical prowess fails to compensate for other disadvantages. Ironically, it is the Russians who have apparently stuck with the proven allied strategy of numerical superiority through mass production, while the Americans have opted for high technology.

In discussions of defense technology the "Soviet threat" apparently serves a mostly rhetorical purpose. Most people seem to think a war with Russia is very unlikely. The implicit assumption is that the future will resemble the last forty years: the nation will have to deal with various challenges to its interests that may involve some fighting, but will nevertheless fall short of life-or-death struggles with our mortal enemy. There may be other Vietnams or Koreas. There will certainly be wars in which our clients fight Soviet clients; indeed, several are in progress already.

If strategic computing gives rise to operational weapons, they are most likely to be employed in proxy wars such as these. I will not speculate much about their combat performance. I am skeptical about AI; I do not expect brilliant autonomous weapons, but there are probably circumstances in which not-so-brilliant but self-propelled weapons would be used in preference to manned vehicles, if they could be made cheaply enough. Despite hopes that precision-guided weapons would make combat less destructive, some recent wars have been unexpectedly long and brutal, in part because the superpowers that help keep them going are far from the destruction and can call upon huge economic and technical resources. Autonomous weapons may further reduce the cost of waging war remotely.

The most important factor in determining how destructive a war is, is whether it occurs at all. Large powers like the United States and Russia must frequently deal with challenges to their power that nevertheless fall short of vital threats to their national interest. In such circumstances, war is optional. The decision to use military force includes some more or less rational assessment of risks and costs, however influenced it may be by ideology and other intangibles. Even the most combatant would agree that there are some gains which are not worth the cost and risk of a large war. In practice these assessments are difficult to make, as is demonstrated every time some nation joins a war that it subsequently loses. This happens so often that there must be some human predilection for overestimating the likelihood of doing well in war. Claims that certain technologies will make war cheaper or victory more likely should thus be regarded with extreme skepticism.

Such claims are now being made on behalf of robot weapons. In a 1983 report on applications of his S-1 supercomputer, Lowell Wood addressed America's troubling reluctance to engage in war. He asked:

> "What if they gave a war and no American had to come? . . . Not only does the political cost of large armed forces continue to climb, but the political toll of deploying them in harm's way has become almost unbearably high. The economic consequences of large American armed forces are nearly as daunting . . . These considerations suggest that the US move to alter its defense posture toward one involving substantially fewer men

under arms. . . . Is this possible? It is suggested here that this is possible by the aggressive use of battlefield robotics." [63]

Wood's speculation ceases to be academic if robotic weapons are built and difficulties in some remote crisis suggest a military solution. The robots could fuel the argument that intervention would be cheap. At that point, it is not so important whether the promised technology actually does work, but whether people believe it works. Many people display a peculiar credulity regarding computers, particularly artificial intelligence. MIT scientist Joseph Weizenbaum encountered this phenomenon when he demonstrated his ELIZA program in the 1960s. This program, named after Henry Higgins's protégé in Shaw's *Pygmalion*, was one of the first to conduct a simple conversation (by means of teletype) in something resembling natural langauge. Weizenbaum's point was to demonstrate that a program with very little knowledge of language (or anything else) could produce a short-lived illusion of comprehension by taking advantage of a few rules. To Weizenbaum's surprise, many hailed his program as progress toward a general solution in natural language comprehension. He was dismayed at the eagerness with which this opinion was seized upon. He recalls:

> This reaction to ELIZA showed me more vividly than anything I had seen hitherto the enormously exaggerated attributions an even well-educated audience is capable of making, even strives to make, to a technology it does not understand. Surely, I thought, decisions made by the general public about emergent technologies depend much more on what that public attributes to such technologies than on what they actually are or can and cannot do. If, as appeared to be the case, the public's attributions are wildly misconceived, then public decisions are bound to be misguided and often wrong." [64]

There is potential for great tragedy if this credulous streak should someday combine with a mood of impulsive belligerence. Exaggerated claims on behalf of computerized weapons should not be casually dismissed. Somebody must believe them, or no one would bother to make them. They are especially troubling when directed at a naive audience. In fall 1984, a traveling exhibit called "Chips and Changes" toured the nation's science museums. It was oriented toward children and their families. Under the headline And What's a Smart War? viewers read, "A home dishwasher can be smart. So can a bomb. The next generation of weapons won't be smart, they'll be brilliant, and they'll be here within the decade." The text discussed the DARPA program and quoted Robert Cooper. Further on, readers were promised "fail-safe, fool-proof futures. Drones may conduct remote-controlled wars. . . . The number of people in the opponent's civilian or military population becomes much less important . . . Fewer Americans would be required to fight such a war." Alongside a discussion of "pilotless planes, unmanned vehicles," and so forth, they had placed the quote from Carl Sandburg's "The People Yes," "Sometime they'll give a war and nobody will come." This was labeled, "New meaning in the 1980s."

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