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ARTIFICIAL INTELLIGENCE AND ROBOTICS ON THE BATTLEFIELDS OF 2020?

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ABSTRACT

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The incredible speed at which computer power is increasing will soon make available exotic technologies, which may provide significant strategic and operational advantages on future battlefields. Artificial Intelligence and Robotics (AI&R) are two such technologies. Though they are not yet viable, trends indicate that in the coming decades they may become as fully incorporated into our society as the INTERNET is today. If strategic and operational military planners are to effectively incorporate AI&R into the future military force, they must contemplate its potential today. This paper looks twenty years to the future, envisions the future battlefield environment, and proposes a military role for AI&R in the year 2020.

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If at first the idea is not absurd, then there is no hope for it

— Albert Einstein

Artificial Intelligence (AI) is "the science of making machines do things that would require human intelligence if done by man."[1] Robotics aims to design machines that can move, perceive, navigate, avoid obstacles, and manipulate objects. Robotic activities may also require a certain degree of AI, albeit not necessarily at a human level. Computer power is the "engine" that drives both AI and Robotics.

Today, Artificial Intelligence and Robotics (AI&R) are innovative but immature technologies. With further rapid advancement in computer power, however, they may provide an operational advantage on future battlefields. Current military leaders should, therefore, be aware of and consider seriously the impact of AI&R on future military operations so that their incorporation into future military forces can be timely and effective.

Why should current leaders concern themselves with the potential of an as yet non-existent technology? Because indications are the new technology will be viable in the coming decades. Furthermore, current military research supports the development of the new technology. Finally, when the new technology does emerge, it will have a vital military role on the projected battlefield environment. Therefore, current strategic and operational military leaders must begin now to map out a plan to incorporate the new technology into the future force if it is to have its most beneficial effects.

This paper specifically analyzes the future military potential of Artificial Intelligence and Robotics. Section 1 argues that AI&R can be expected to become viable by 2020. Section 2 identifies current military R&D that supports the development of AI&R. Section 3 projects applications of 2020 technology and depicts the potential 2020 battlefield environment. Section 4 describes a role for AI&R on that battlefield. The paper concludes by arguing for the importance of preparing today to incorporate AI&R into tomorrow's military force.

SECTION 1: WHY AI&R TECHNOLOGY WILL EMERGE IN OUR GENERATION.

THE CHALLENGES TO THE FOUNDING FATHERS OF AI

The field of AI was inaugurated in 1956 at the Dartmouth Conference when a group of enthusiastic researchers accepted the challenge of replicating human intelligence by utilizing the computer technology of the day. These pioneers postulated that computers, if loaded with proper software, could outperform humans in all tasks.[2]

Unfortunately, the early researchers overestimated the power of the computer with respect to the mind. The most powerful supercomputer at the time of the Dartmouth Conference was rated at about ten kilohertz and valued at $500,000 (100,000 times slower than today's fastest PC's valued at $2,000).[3] It was unlikely that such an expensive piece of equipment would be dedicated to the efforts of researchers who were trying merely to replicate the abilities of an individual man. Supercomputers and their single-minded raw computational power were allocated to solve the headier problems of math and physics.

Another obstacle to AI development was the requirement to merge the disciplines of psychology and computer engineering without really understanding the architecture of neural biology. Researchers asserted that creating intelligence required a solid theory of the mind and a set of algorithms to describe the components of intelligence. But the reality was that the AI pioneers did not know how the brain modeled knowledge, stored and accessed memory, or processed data.[4]

Some early researchers did focus on the field of neural networks. They believed that a primitive mind could be constructed without completely understanding its inner workings and sought to recreate the parallel architecture of the brain. But few joined this effort, which was vociferously discredited by the AI heavy weights.[5] This was unfortunate, because it is now believed that the parallel approach is probably the correct path to emulating brain operations.

ACHIEVING THE PROCESSING POWER OF THE HUMAN BRAIN

In one respect, memory capacity, computers have already reached brain parity. It is estimated that the brain contains approximately 20 billion bits (2.5 gigabytes) of memory.[6] Computers exceeded this in the 1990's and today's PC hard drives have memory capacities in excess of 40 gigabytes.

In total processing capability, however, computers still lag behind. Different approaches have been used to estimate the brain's processing power, which is often measured in terms of the bits of information processed per second (bps). From known properties of the retina, the brain's processing speed has been extrapolated to be 10^{14} bps. [7] In another model, an electronic micrograph was used, and it was estimated that the brain processed 10^{19} bps.[8] A bps can be equated to about one hertz, the unit used as a measure computer speed.

In terms of processing power, IBM's supercomputer, Deep Blue, which beat the world's human chess champion in 1998, was clocked at about 1000 gigahertz. [9] Despite its phenomenal speed, Deep Blue's processing power still fell far short of that of the human brain. But computer technology is rapidly closing the gap. Advancements in computer science will lead to progress in the development of AI and as AI develops, robots will become more sophisticated. Today, after decades of unfulfilled promise, computer power is approaching levels that will make AI&R feasible

THE OF ADVANCEMENT OF COMPUTER TECHNOLOGY AND MOORE'S LAW

In 1965, Gordon Moore, the inventor of the Integrated Circuit, proposed that the surface area of a transistor is reduced by fifty percent every eighteen months.[10] This doubled the number transistors that could be mounted on a single Integrated Circuit and resulted in a doubling of its speed. This assertion is known as Moore's Law. The phenomenon that Moore recognized in the mid-sixties had actually existed throughout the entire 20th Century. Between 1910 and 1950, computational speed doubled every three years. Between 1950 and 1966 it doubled every two years. Thereafter computational speed has doubled annually.[11] These trends indicate that not only are computers getting faster, but the rate at which they are getting faster is also accelerating. This should continue into the 21st Century, pushing the rate of speed doubling below the one-year threshold.[12]

The increasing power of computers is of significant importance to military leaders. The Gulf War, our showcase for "cutting-edge" military technology, was fought with weapons whose controlling computers were designed in the mid-seventies.[13] If 1980 is a taken as a baseline for measuring the speed of Gulf War processors, then the computers available in 1991 were 2000 times faster than those used in Desert Storm. Computational speed today is one million times faster. By 2020, computational speed will be an astronomical one trillion times faster.[14] The potential capability emerging as a result of this ever-increasing computer power is unimaginable ... or is it?

Desktop computers have recently broken the one-gigahertz (one billion calculations per second) barrier.[15] Supercomputers far surpassed this milestone in mid-1980.[16] As already noted, neither can support the demands placed on the human brain. Most computers are serial processors performing only one task at a time. When focused on a single computational task, they outperform humans in every endeavor. The brain, however, is a parallel processor capable of conducting thousands of tasks concurrently. It must receive and interpret simultaneous inputs from the five senses several times a second, negotiate quickly changing surroundings, coordinate the movements of hundreds of muscles, learn from experience, and solve complex problems.[17] AI researchers have yet to simulate any of these tasks with the same precision as humans. The reason for this remains that even today's most powerful supercomputers do not approach the computing power of the brain.

Nonetheless, it can be predicted when processing parity with the brain might be reached. Using the Deep Blue as a baseline (1000-gigahertz @ 1998), the retinal model for brain processing power (10^{14} bps) as the target, and assuming that computer speed doubles steadily once per year, a supercomputer may rival the brain as early as 2005. The more conservative electronic micrograph estimate (10^{19} bps) suggests that a supercomputer will not reach human brain equivalency until 2022. However, AI products must be affordable to be commercially viable. A million-dollar supercomputer will not be used to replace a man who can do the job much more economically. Therefore, the present day one-gigahertz PC is a more suitable baseline for estimating when a processor on par with the brain will be affordable. An analysis similar to that used above suggests that a PC with human computational capacity will be available as early as 2017 and as late as 2034.

Thus, a new generation of AI researchers enjoys many advantages that their predecessors did not. They have access to cheap computing power whose processing speeds are astronomically faster than those of unwieldy supercomputers in the 1950's. Additionally, advanced medical scanning equipment has given them a greater understanding of the architecture of the brain and of neurons. Neural network research is again in vogue. Finally, many have modified their expectations, and now pursue the emulation of lower levels of intelligence. They believe that robots do not necessarily have to be as smart as man to serve man. These researchers are proponents of nature based artificial intelligence.

NATURE BASED ARTIFICIAL INTELLIGENCE

Nature based AI is a concept that clashes with the vision of the original AI pioneers. Nature based AI researchers consider the requirement for human intelligence to be overrated. Stephen Kaplan of the University of Michigan, states:

> The only reason that we are so smart is that all the good niches were taken. ... Intelligence is not so much a refinement as it is a consolation prize. A way for the naked ape to survive a world filled with hardier and faster proliferating creatures such as bacteria and insects.[18]

Accordingly nature based AI researchers seek to replicate those capabilities at the base of the intellectual pyramid. Rodney Brooks of the Massachusetts Institute of Technology asserts:

> Insects have immensely slow computers with just a few hundred thousand neurons, and yet they fly around in real time and avoid stuff. They're doing far fewer computations per second [than a] robot's computer [is]. Insects must organize their intelligence in some better way that allows them to get around so well.[19]

Deep rational thought is a newly acquired ability, perhaps less than 100,000 years old.[20] Nature based AI researchers recognize that the technology does not exist to replicate such high levels of intelligence. Hence, they conclude that the greatest progress toward the design of intelligence would be made if animal minds were simulated first. By adding a few capabilities at a time, more complex animal behavior might be replicated. Eventually a mind of human equivalence might be built, but in the interim useful technologies can be reaped by replicating lesser minds.[21]

APPLYING AI TO ROBOTICS

The ultimate product of AI is the mobile, autonomous robot. The two AI approaches are pursuing the creation of two entirely different prototypes. Traditional AI researchers seek to create a single, stand-alone intelligent device that will look and act human, and will have at least the brainpower of a human. However, today their sophisticated thought algorithms reside within immobile mainframes. On the other hand, nature based AI proponents have developed the field of distributed robotics. Their creations are small mobile robots (MOBOTS) with little or no ability for rational thought. These small mechanical creatures move about, respond to specific stimuli, and avoid danger. They are being “raised” in groups to develop communal behavior.[22] The seemingly divergent disciplines of traditional and nature based AI may merge in this century as powerful processors become smaller and more mobile while MOBOTS become smarter. In the meantime, the smart mainframe and the dumb MOBOT will continue to occupy their respective niches; both, however, have the potential to revolutionize military operations on the battlefields of 2020.

Despite their military potentials, in many cases the civilian market will drive the development of these 2020 technologies, and a great deal of them will be available through commercial off-the-shelf (COTS) sources. COTS will provide a serendipitous array of equipment not necessarily appropriate for military operations. And militarily useful COTS technologies will likely be equally available to both friendly forces and potential adversaries. In order to tailor more of these technologies for our own military use, US military agencies must guide their development.

SECTION 2: CURRENT MILITARY RESEARCH THAT SUPPORTS THE EMERGENCE OF AI&R

Two large organizations that explore technologies for potential military use are the Defense Advanced Research Project Agency (DARPA) and the Office of Naval Research (ONR).[23] Both dedicate a portion of their efforts to ongoing AI&R projects. These are supported by numerous civilian research institutions including such intellectual hubs as MIT, Carnegie Mellon, and Stanford.[24] A review of ONR and DARPA projects reveals that military R&D does indeed support the development of AI&R technologies.

One of the four grand challenges for the Navy as stated by ONR is the development multifunctional electronics for intelligent sensors. To support this, ONR is pursuing the development of 3D integrated circuits, an architecture that is required for parallel processing and artificial neural nets. The ONR goal is to build circuits that are 100 times smaller, 100 times faster, and require 1000 times less power than components currently available. Such processors will be used to autonomously detect, store, analyze and display information while adapting in real time to changing battlefield conditions and aims to eliminate human and software controls.[25] These circuits would also be useful to ONR's Artificial Intelligence Division, which seeks to create computers that can make decisions autonomously, learn new tasks, read, speak, and interpret what they see.[26] ONR further seeks to develop AI by reverse engineering the processing architecture of the human brain.[27]

Much of military R&D is geared to achieving information dominance and aims to increase both the volume and the value of data that flows to and from the battlefield. DARPA's Information Management project envisions a global information infrastructure that allows organizations to process information rapidly toward problem solving ends. This will assist military analysts in the assessment of rapidly changing, multi-faceted situations.[28] The Information Management project directly supports another DARPA project called the Command Post of the Future (CPOF). CPOF will refine the flood of information into quickly digestible graphics that reveal critical vulnerabilities and battlefield trends. This system will assist commanders in developing quick, effective operational and tactical decisions.[29]

DARPA is also addressing the vulnerability of the ever-expanding information network (INFONET) as well as its importance to the adversary. DARPA's Wolfpack project aims to develop a distributed system of autonomous ground based components. They will be linked together into a cooperative network that will jam and spoof the enemy's use of the bandwidth while avoiding disruption to friendly forces.[30]

A good deal of military R&D is geared toward developing distributed robotic systems. Potential applications include surveillance, reconnaissance, pathfinding, deception, and weapons delivery.[31]

Significant DARPA and ONR projects that support the development of distributed robotics are listed in TABLE 1.

TABLE 1: DARPA AND ONR PROJECTS THAT SUPPORT THE DEVELOPMENT OF AI&R

Project	**Goal**
Mobile Autonomous Robot Software (MARS)	Develop missing software technologies needed for vehicles/MOBOTS that will operate independent of human operators or net inputs.[32]
Software for Distributed Robots (SDR)	Develop missing software technologies needed for extreme resource constrained (i.e. very small) micro-robots.[33]
Micro Air Vehicle (MAV)	Develop a family of vehicles less than 15 centimeters in any dimension to accomplish diverse missions such as precision main laying, covert imaging, urban battle field communications, etc.[34]
Biomimetc Robotics	Discover the principles of control and biomechanics that provide agility, dexterity, and intelligence.[35]
Legged Locomotion	Emulate simple nervous systems to design circuits that will mimic the adaptive legged locomotion of invertebrates.[36]

SECTION 3: THE BATTLEFIELD OF 2020

In order to propose a military role for AI&R, the potential application of technology in 2020 as well as the 2020 battlefield environment must be projected. A reasonable understanding of future technologies may allow the military to design and maximize its potential to revolutionize future weapon systems. This, coupled with a vision of the battlefield environment, should drive the development of sound strategy, doctrine, and tactics.

PROJECTED TECHNOLOGIES FOR THE YEAR 2020

Computers in 2020 will be at least one million times faster than computers today if their speeds continue to double annually. Assuming the more conservative projections, in 2020 supercomputers will have half the processing power of the human brain.[37] Although subhuman in terms of intelligence, when focused on a small number of tasks, supercomputers will exponentially outperform humans. They may contain knowledge bases that allow them to rapidly sift through and draw useful inferences from the trillions of bits of data that pass through an INFONET. Civil and military strategic leaders alike may rely on supercomputers to provide early warnings that require rapid action. Supercomputers may recommend courses of action that leaders may apply in response to the changing environment. They also may be able to predict potential second and third order effects of strategic decisions. These supercomputers will still be expensive, immobile and considered a high-level asset. Such supercomputers, therefore, will not provide the intellectual foundation for robots.

PC's will provide robotic brainpower. The PC, however, will possess only one ten-thousandth the power of the human brain.[38] Even though this seems minuscule, it represents a processing power that is two trillion times greater than "smart" Gulf War cruise missiles. PC Memory capacity also doubles yearly and will be in excess of 20000 terabytes (over ten times the information contained in the Library or Congress).[39] PC's will be voice activated eliminating the need for keyboards. They will possess language recognition capabilities, making conversation possible.

The less capable terahertz chips that powered the high-end PC's of 2010 will cost pennies. They will be embedded in cellular telephones, uniforms, small arms, navigation systems, automated identity devices, etc, which will be linked together through short-range wireless technology. This "body LAN" will tie into larger server nets that will contain the bulk of the world's knowledge. Computer displays will be built into eyeglasses and give the individual "net-on-the-go" capabilities. Telephones with real time language translation systems will be commonplace.

As technology continues its blistering rate of advance, humans will spend a significant portion of their employment learning new skills. Distance education will be tailored to the individual, as standard classroom training becomes obsolete. Books will become relics and give way to portable electronic media.[40] Eventually, the requirement to continually retrain humans may become inefficient, and perhaps unnecessary. Intelligent agents that can rapidly reprogram and acclimate themselves to unending changes in the technological landscape will be employed to monitor and administrate an increasingly complex society.

The first generation of universal robot, a product of traditional AI researchers, will be commercially available. This robot will combine wheels to efficiently traverse flat, smooth ground, and legs to move through rougher, uneven terrain. Universal robots will have a rudimentary ability to manipulate objects using a vice grip design. The robot will use built-in navigation systems to move about its immediate environment. Longer-range navigation will be achieved through systems linked to GPS or the INFONET. This robot will recognize text and speech and be able to converse and read. It will have a capability to take instructions remotely and download new programs for new kinds of work. However, the first generation universal robot will not possess human intelligence.[41]

Nature based AI researchers will have continued to develop the field of distributed robotics. Their small machines will assume a variety of sizes and forms and be tailored or programmed to conduct specific missions. While they will exhibit even less intelligence than the first generation robot, they will have a degree of common sense and some instinct for survival. These small robotic units will be programmed with a tenacious drive to fulfill their function. Their construction will be relatively simple and inexpensive. The units will be released in groups that are linked to a group smart robot (SMARTBOT) via a group INTRANET. The size of the group will very from less than ten to more than a thousand depending on is function. The SMARTBOT will guide the group's movements and communicate with a more extensive server net. The SMARTBOT will also have a limited capability to independently direct the group in the absence of an information signal. If the SMARTBOT fails, individual group members may have the capability to react on pre-programmed reflexes.

THE BATTLEFIELD ENVIRONMENT OF THE YEAR 2020

Based on today's trends, three assumptions that will shape the battlefields in the year 2020 can be made. First, every advanced weapon developed and used in the 20th Century will eventually fall in the hands of potential adversaries. Second, any force that dominates outer space will dominate the electromagnetic spectrum. Finally, the force that dominates the electromagnetic spectrum will possess superior battlefield awareness and hence have a significant operational advantage. These assumptions can be further used to extrapolate military capabilities required to achieve success on the 2020 battlefield.

Two advanced capabilities demonstrated by the United States in the Gulf War have long since become part of the military repertoire of others. During Desert Storm, night observation devices (NODS) made it possible for our forces to fight with equal effectiveness both day and night. In 1991 NODS were expensive and not available to Iraqi troops who fell victim to our nighttime assaults. This technology provided us definite operational and tactical advantages.[42] A similar advantage was obtained from hand-held geo-positioning system (GPS) repeaters, which allowed our troops to precisely navigate on a battlefield void of telling landmarks.[43] Since the Gulf War, both advantages have been lost, as NODS and GPS repeaters have become inexpensive and flooded the market.[44] A similar fate awaits the technology that allows us to conduct deep strike, a military capability demonstrated repeatedly in the 1990's.

The operational advantage of deep strike is well understood by our adversaries as they aim to obtain similar technologies. Again, decreasing costs may make this possible. Today, space lift is more prevalent and affordable, allowing countries of lesser means to obtain the reconnaissance services of satellites.[45] Inexpensive long-range missile technology is also for sale and proliferating.[46] Together these technologies may give secondary military powers the opportunity to possess their own cruise missile capabilities. In this not-to-distant future battlefield dominated by the threat of long-range precision weapons, humans may not be able to make initial entry without suffering unacceptable casualties.

It also appears likely is that the future battlefield will be flooded with data exchanges. The amount of information required to develop acceptable theater awareness may increase significantly as the range of the adversary's stand off weapons increase. This in turn may demand a more robust reconnaissance capability to provide acceptable awareness in the expanded battlefield. A widely dispersed autonomous sensor network might be used to accomplish this. The adversary, however, will target such a network vigorously. Hence the network will require a high degree of redundancy and its individual components must be programmed with some adaptable survival instincts to enhance their useful mission lifetime.

In the effort to obtain a more detailed and reliable battlefield picture, we may inevitably confound our own mental ability to process the data generated. The deluge of bits into our command and control systems may overwhelm man's biological processing abilities and force bad decisions. The accidental downing of the Iranian airliner by the USS VINCENNES supports this point. A failure to interpret a relatively finite amount of data resulted in this tragic error.[47] Humans can no longer display, analyze, and disseminate information in real-time. Old information loses its value, and on the fast-paced battlefield of 2020, information may become worthless in minutes or even seconds. To properly utilize a highly detailed, real time battlefield picture, machines may be required to handle all data processing and analysis. Eventually, as the speed of battle overwhelms human reaction time, machines may make tactical, as well as operational decisions. The Navy has already designed this inevitability in the Close-In Weapons System (CIWS), which performs the entire detect-to-engage scenario for an inbound, supersonic missile without human intervention.[48]

The dependence on information will also place huge demands on the electromagnetic spectrum or bandwidth. Since military units are mobile, they must transmit data through air and space vice terrestrial cables. This medium, known as ether, is finite. In fact, even today the demand for ether is quickly outstripping the supply.[49] In contrast, the availability of bandwidth transmitted through terrestrial sources such as fiber optic cable is virtually unlimited. Since our forces are typically expeditionary and mobile, their ability to transmit data is limited by the constraints of the ether. A force with the "home field advantage" may not have similar restrictions, as a portion of its information infrastructure will be terrestrial. In any event, there will most likely not be enough ether to satisfy the information needs of both forces. Accordingly, each force will attempt to deny enemy use of the ether. Attacks on sensor and satellite systems are likely. A force that succeeds in dominating space may monopolize the ether, and hence the flow of information. A force denied information will be degraded in its command and control capabilities and its ability to deploy exotic technologies.

Based on these assumptions of the battlefield of 2020, the following can be generalized: First, initial entry into a hostile theater may be extremely dangerous and pose unacceptable risk to human forces. Second, the flow of data may be so immense and the pace of battle so fast, that man may not have the ability to process or react to the information. Finally, in the battle for bandwidth, we may be denied portions of the electromagnetic spectrum, degrading many of our information dependent systems. Based on these generalizations, a mission for both highly intelligent, immobile main frames and less intelligent mobile robots emerges.

SECTION 4: AI&R ON THE BATTLEFIELDS OF 2020

In this information dependent battlefield environment, "intelligent" mainframes will provide processing power for combat information centers. These computers will possess enormous knowledge systems and analytic capabilities. They will focus their effort on the analysis of data streaming from both within and outside the battlefield. Due to the singularity of this task, data will be synthesized into information and disseminated as knowledge in near real time. Information will be tailored and displayed in concise graphical form useful to the field commander. Tailored data packets containing tactical information or mission orders will be disseminated to smaller manned or unmanned field units. The mainframe will constantly analyze the battle picture and make operational as well as tactical recommendations. In the fury of a high-pitched skirmish, a commander will be able to switch the mainframe to a battle automatic mode allowing it to autonomously call fire from dispersed elements.

Early in a campaign, the battle space will be too dangerous for access by humans. Therefore, distributed robotics systems will make initial entry. Individual robots will be bird-, rodent-, or fish-sized and will maneuver through the air, on land, or in the water in groups of varying sizes. The group will pool its intelligence, and its movements will be coordinated by a more sophisticated SMARTBOT. The SMARTBOT will obtain tactical data and mission modifications from the theater INFONET. SMARTBOTs will have some autonomous capabilities that will allow them to continue to manage the group and complete the mission if the INFONET signal is lost. Should the SMARTBOT become non-functional individual group elements will resort to pre-programmed responses that will serve to enhance survival and harass the enemy.

The missions of robot groups will be varied. Some may be strictly sensors passing data into the INFONET for interpretation by the mainframe. Others may actively prep the battlefield and be involved in mine-clearance, sabotage, deception, INFONET protection, choke point denial missions, etc. Some groups will be strictly offensive. They will search for and then destroy elements of the enemy force, including opposing robot groups. Robot groups will be multi-faceted and easily reprogrammed for different types of missions. Individual components of the group will be inexpensive, easily produced, and disposable. The group will be designed with attrition in mind. Should a portion of the group be destroyed, the mission will not be jeopardized.

Joint Vision 2010 suggests that success on the future battlefield, with or without AI&R, will be rely on a healthy and robust INFONET.[50] In a race to gain or deny physical access to the battle space, the use of cyberspace, upon which the INFONET depends, will be vigorously targeted. If the INFONET is in any way constrained or destroyed, the resulting denial of battlefield awareness to our commanders will significantly inhibit our ability to effectively operate forces. However, a theater saturated with widely dispersed AI&R components will adjust quickly and resort to autonomous mission completion behavior. Meanwhile, distributed robotic groups will be deployed to reestablish INFONET connectivity in order to regain information dominance in the battle space bit by bit. Data-hungry agents, though degraded, will not cease to be mission effective if the information infrastructure is disrupted. Battlefield supercomputers, though denied full battle space awareness, will analyze the reduced flow of data and intelligently deduce information useful to the commander.

Such may be the nature of warfare in 2020. Mainframes will perform strategic and operational mental tasks for battlefield commanders. Robot groups will carry out the missions that are too dangerous for man. The mission ability of both will be enhanced by but not completely dependent on the INFONET.

CONCLUSION: WHY CONTEMPLATE THE EMERGENCE OF AI&R TODAY?

Artificial Intelligence and Robotics is not a whimsical musing of science fiction, but rather a technology that will likely become viable in our lifetime. Existing civilian and military research projects predict that AI&R will emerge within the next two decades, and reasonable analysis shows that it may have a definite role on increasingly dangerous battlefields. Today's senior officers must not risk preoccupation with the impact and integration of current technology at the expense of not considering what lies ahead. Unfortunately, speculations that AI&R may dominate battlefields in the next 20 years are often met with bemused looks.[51]

Technology is advancing at such a rapid pace that the military does not have the luxury to casually consider its impact. If formalized technology projection methods are not utilized, technology may continue to speed ahead of the military and force leaders into reactionary planning. This has been the case with information technology. Already fully developed and utilized by the commercial sector, its architecture in the military is barely emerging. Worse yet, when it does arrive, soldiers and sailors are frequently uncertain of its use or intent. Often its value is interpreted in terms of its use in civilian society (i.e. great for email and web surfing), but its impact on military operations goes unrecognized.[52] Outside of a few elites, the vast preponderance of military personnel ten years ago did not consider the impact of the information revolution or the INTERNET on military operations. It has only now entered our cone of consciousness because it has so inundated our everyday life.

Regrettably, despite this lesson, we still may be designing tomorrow's force with today's technology. Considering the slowness of our military procurement cycle, the new force will be obsolete on arrival. The timeline from concept to delivery is in excess of ten years. Within a nominal ten-year procurement cycle, computer power increases by a factor of one thousand. In many cases ten years is a liberal estimate. Consider the Army's Comanche helicopter proposed in 1983. It is now estimated that the new helicopter will be fielded in 2005, 22 years after the initial concept.[53]

In a future force whose capabilities are driven by computational technologies, we cannot afford such a lag. By the time the military fully incorporates information technology into its arsenal, AI&R will be on the cusp of fruition. If its potential to affect military operations is not formally discussed today, tomorrow's military leaders will be required to haphazardly incorporate AI&R into the force. This will leave personnel once again untrained and unfamiliar with the military application of new technology. To close the technology gap, military planners must determine a way to design a force around the technology projected at the date of delivery. The bold nature of this process will have a secondary effect; R&D efforts will be better managed, which will, in turn, better support the vision of future military strategy.

The independent projects of DARPA and the ONR indicate support for the development of military AI&R applications. However, the aggregate research effort also reveals that coordination between projects could be improved. There exists no clear project hierarchy that defines which projects are supporting and which are supported. AI&R encompasses a large number of technological challenges. Coordinating the numerous independent projects that address these challenges into overarching goals would accelerate the realization of a primary vision. Military thinkers who have a firm grasp of the strategic environment and a realistic notion of future technologies should provide this vision in order to further guide and catalyze the development of these technologies for future military use.

The inventive nation that takes advantage of the potential of as yet immature technologies may rapidly rise to world power status. Consider the inter-war years when Germany contemplated the military advantages of tactical and operational mobility. Such thinking enabled them to build a military force designed to doctrinally achieve this by incorporating the increasing applications of the internal combustion engine. By exploiting the rapid mobility made possible by this technology, Germany unleashed "Blitzkrieg" on an unsuspecting Europe. The immobile defenses of Germany's adversaries fell quickly, as they were unable to react to the speed of the German onslaught.[54] By professionally training leaders who were open to new concepts and who could recognize the potential of rapidly improving technologies, Germany reestablished itself as a world power.

The possibility for a similar revolution in the application of military power is likely as advances in computer technology make possible the development of Artificial Intelligence and Robotics. The force that comes closest to envisioning the strategic, operational and tactical application of AI&R today – and educates and trains its leaders to be open to its potentialities – will dominate the battlefield of 2020.

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ENDNOTES

[1] Marvin Minsky quoted in Daniel Crevier, AI: The Tumultuous History of the Search for Artificial Intelligence (New York: Basic Books, 1993), 9.

[2] Hans Marovec, Robot: Mere Machines to Transcendent Mind (New York: Oxford University Press, 1999), 19-20.

[3] Ibid., 68.

[4]Daniel Crevier, AI: The Tumultuous History of the Search for Artificial Intelligence (New York: Harper Collins Publishers, INC), 1-8.

[5] David Freedman, Brainmakers (New York: Simon and Schuster, 1994), 71-72.

[6] Crevier, 294.

[7] Ibid., 288.

[8] Ibid., 302.

[9] Moravec, 68.

[10] Ray Kurzweil, The Age of Spiritual Machines (New York: Viking, 1999), 20-21.

[11] Ibid., 102.

[12] Many argue that the silicon chip is rapidly reaching its speed limitation and that the pace at rate of computer speed doubling will slow. However, this is not the first time in the 20th century that a computational medium was stretched to its limits. The mechanical wheels and levers of the 1900's gave way to relays, which in turn gave way to vacuum tubes, transistors, and Integrated Circuits. This would seem to indicate that as Integrated Circuits reach their limit, a new medium will emerge to carry the torch for Moore's Law.

[13] "COMOPTEVFOR: Tomahawk Missile System;" available from http://www.cotf.navy.mil/code70/74_thawk.htm. Internet; accessed 25 March 2000.

[14] All figures are calculated by applying the accelerated version of Moore's Law, which assumes that computing power doubles every year. Computers in 1991 were 2^{11} (or about 2,000) times more powerful than computers in 1980.

[15] "The Gigahertz Goal", PC Magazine, 8 February 2000, 77.

[16] Moravec, 68.

[17] Freedman, 95.

[18] Ibid., 158.

[19] Ibid., 24.

[20] Moravec, 22.

[21] Freedman, 21-22.

[22] James McLurkin, "The Ants: A Community of Microrobots;" available from http://www.ai.mit.edu/projects/ants/. Internet; accessed 25 March 2000.

[23] "Defense Advanced Research Project Agency;" available from http://www.darpa.mil/ and "Office of Naval Research;" available form http://www.onr.navy.mil/. Internet; accessed on 25 March 2000.

[24] "The Artificial Intelligence Laboratory at MIT;" available from http://www.ai.mit.edu, "Advanced Mechatronics Laboratory;" available from http://www.cs.cmu.edu/afs/cs.cmu.edu/project/chimera/www/aml.html, and "Stanford Robotics Lab;" available at http://robotics.stanford.edu. Internet; accessed 25 March 2000.

[25] "Grand Challenge: Multifunctional Electronics for Intelligent Naval Sensors," 16 November 1999; available from http://www.onr.navy.mil/sci_tech/chief/Multifunctional.htm; Internet; accessed on 02 February 2000.

[26] Dr. Michael Shneier, "Artificial Intelligence – ONR," 20 March 1997; available from http://www.onr.navy.mil/sci_tech/information/onrpgaag.htm; Internet; accessed on 31 January 2000.

[27] Sevgi Bullock, "Human Systems," 27 December 1999; available form http://www.onr.navy.mil/sci_tech/personnel; Internet; accessed on 31 January 2000.

[28] "Information Management;" available from http://www.darpa.mil/ito/research/im/vision.html; Internet; accessed on 31 January 2000.

[29] Ward Page, "Command Post of the Future (CPOF);" available from http://dtsn.darpa.mil/iso/programtemp.asp?mode=125; Internet; accessed on 31 January 2000.

[30] "Wolfpack," 1 February 2000; available from http://www.darpa.mil/ato/programs/wolfpack.html; Internet; accessed on 3 February 2000.

[31] "Distributed Robotics;" available from http://www.darpa.mil/MTO/DRobotics/index.html; Internet; accessed on 31 January 2000.

[32] Colonel Mike Swinson, "Mobile Autonomous Robot S/W;" available from http://www.darpa.mil/ito/research/mars/vision.html; Internet; accessed on 31 January 2000.

[33] Colonel Mike Swinson, "Software for Distributed Robots;" available from http://www.darpa.mil/ito/research/sdr/vision.html; Internet; accessed on 31 January 2000.

[34] "Micro Air Vehicles (MAV)," 5 November 1999; available from http://www.darpa.mil/tto/Programs/mav.html; Internet; accessed on 31 January 2000.

[35] Dr. Teresa A. McMullen, "Biomimetic Robotics," 6 October 1999; available from http://www.onr.navy.mil/sci_tech/personnel/ONRPGALX.asp; Internet; accessed on 31 January 2000.

[36] Dr. Thomas McKenna, "Legged Locomotion," 21 March 1997; available from http://www.onr.navy.mil/sci_tech/personnel/ONRPGALT.HTM; Internet; accessed on 31 January 2000.

[37] This projection is based on the capability of Deep Blue in 1998, the more conservative electronic micrograph projection of brain processing power, and the assumption that computer speed doubles every year (See Page 3.)

[38] This projection is based on the 2000 one giga-hertz, the more conservative electronic micrograph projection of brain processing power, and the assumption that computer speed doubles every year (See Page 3.)

[39] Douglas S. Robertson, The New Renaissance: Computers and the Next Level of Civilization (New York: Oxford University Press, 1988), 9.

[40] Kurzweil, 189-198.

[41] Moravec, 95-98.

[42] Les Aspin, Assessments of the lessons of the Gulf War found in "Interim Report of the Committee on Armed Services, House of Representatives," 30 March 1992; available from http://es.rice.edu/projects/Poli378/Gulf/aspin_rpt.html. Internet; accessed 25 March 2000.

[43] Michael R. Gordon and Bernard E. Trainor, The Generals War (Boston: Little, Brown and Company, 1994), 353.

[44] "Night Vision Systems;" available from http://www.tracertechnology.com/index.html and Mike Bush, "Handheld GPS Roundup;" available from http://www.avweb.com/articles/gpsround.html. Internet; accessed 25 March 2000.

[45] Richard J. Newman, "The New Space Race," US News and World Report, 8 November 1999; available from http://www.usnews.com/usnews/issue/991108/space.htm. Internet; accessed 25 March 2000.

[46] Bill Gertz, "The US Protests Chinese Shipment of Missile Technology to Iran", Washington Times; available from http://www.house.gov/hunter/missiledef3.htm. Internet; accessed on 25 March 2000.

[47] David Evans, "Naval Science 302: Navigation and Naval Operations II; Lesson 20: Crisis Decision Making: USS Vincennes Case Study;" available from http://navy.rotc.psu.edu/pub/classes/302/notes/20note.html. Internet; accessed on 25 March 2000.

[48] "MK 15 Phalanx Close-In Weapons System (CIWS);" available from http://www.fas.org/man/dod-101/sys/ship/weaps/mk-15.htm. Internet; accessed on 20 December 1999.

[49] "The Battle for Bandwidth;" available from http://www.afa.org/magazine/1099bandwidth.html. Internet; accessed on 20 December 1999.

[50] The Chiefs of Staff, "Joint Vision 2010," 1995; available from http://www.dtic.mil/jv2010/jv2010.pdf; Internet. Accessed 21 January 2000.

[51] This observation is based on conversations and remarks made by speakers and students in the Army War College's "Digitization of the Force" course which convened in Winter of 2000.

[52] During my tenure as Executive Officer of the USS JUNEAU, the Information Technology 21st Century (IT-21) system was installed. However, the crew was not indoctrinated in its use, capabilities, and

limitations. Consequently, it was seen merely as an email/internet portal, and even in this function, its performance was inferior to those products available on the market.

[53] James A. Calpin, "The Tyranny of Moore's Law," Proceedings 126/2/1,164 (February 2000): 64-65.

[54] "World War II, 1939-1945", Encyclopedia Britannica; available from http://www.britannica.com/bcom/eb/article/6/0,5716,108376+1,00.html. Internet; accessed on 25 March 2000.

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