S&T That Will Impact DoD Over The Next 15 years

Baker's Dozen

Alternative Energy

Biology

Cognitive Computing

High Productivity Computing Systems

LASER Systems

Manufacturing Science

Materials

Mathematics

Micro-Electronics

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Quantum Information Science

Real-Time Accurate Language Translation

Trustworthy Integrated Circuits

Alternative Energy: Reduce the military's reliance on petroleum. Portable sources of electric power are critical to today's military. To Napoleon's dictum that an Army moves on its stomach, today's modern warfighting forces could add, "…and on energy." Developing portable, efficient, and compact power supplies has important ramifications for increasing our military's reach, decreasing our logistics burden, and improving the overall efficiency of our warfighting forces – especially for distributed and net-centric operations.

Biology: Advances in biological warfare defense (BWD) will protect warfighters not only from traditional and modern biowarfare agents, but also from the infectious diseases they regularly encounter overseas.

Developing defenses against biological attack poses daunting problems. Strategies using today's technologies to counter future biological threats are seriously limited. Rapidly and inexpensively manufacture millions of doses of life saving drugs or vaccines in weeks, instead of the years required to ramp up today's manufacturing practices.

It is nearly impossible to predict what threats might emerge in two decades, particularly engineered threats. From the moment a new pathogen is first identified – either a weapons agent or a naturally emerging pathogen – today's technology requires at least 15 years to discover, develop, and manufacture large quantities of an effective therapy.

It would be exorbitantly costly to attempt to "cover the bases" with the research and development required to deal with a wide range of potential threats, and then stockpile, maintain, and indefinitely renew population-significant quantities of vaccines or other therapeutics just in case one or more of those threats might emerge. And if, in spite of all this, a previously unknown or unpredicted pathogen does appear, there may well be no therapeutics available that are effective against it.

New insights from neuroscience to find images of interest amongst clutter; improve individual training; identify the origins of traumatic brain injury; and create prosthetics that can be perceived and controlled by the brain just like a natural limb.

Cognitive Computing: Computer systems are essential to military logistics and planning, command and control, and battlefield operations. However, as computing systems have become pervasive in DoD, they have also become increasingly more complex, fragile, vulnerable to attack, and difficult to maintain. The computing challenges facing DoD in the future – autonomous platforms that behave reliably without constant human intervention, intelligence systems that effectively integrate and interpret massive sensor streams, and decision support systems that can adapt rapidly – will depend on creating more flexible, competent, and autonomous software.

DoD needs revolutionary new computer technology to overcome these challenges.

An ambitious mission to create a new generation of computing systems – cognitive computers – to dramatically reduce military manpower and extend the capabilities of commanders and warfighters.

Cognitive computing systems can be thought of as systems that "know what they're doing." Cognitive computing research is developing technologies that will enable computer systems to learn, reason and apply knowledge gained through experience, and respond intelligently to new and unforeseen events.

Success will have enormous benefits for our military. In the real-time environment of military operations, cognitive systems that can learn, reason, and draw on their experience to assist their users will make a huge difference. Cognitive systems will give military commanders and their staffs better access to a wide array of rapidly changing information, reduce the need for skilled computer system administrators, and dramatically reduce the cost of system maintenance.

For example, today's computers handle low-level processing of large amounts of raw data and numeric computations extremely well. However, they perform poorly when trying to turn raw data into high-level actionable information because they lack the capabilities we call "reasoning," "interpretation," and "judgment." Without learning through experience or instruction, our systems will remain manpower-intensive and prone to repeat mistakes, and their performance will not improve.

The DoD needs computer systems that can behave like experienced executive assistants that learns on the job and adapts on its own, and new learning technologies that observe users' actions and learn their activities, roles, topics, and preferences; respond to users' advice; anticipate their information needs; and, learn new tasks, while also retaining their ability to process data like today's computational machines.

High Productivity Computing Systems: supercomputers are fundamental to a variety of military operations, from weather forecasting to cryptography to the design of new weapons by speeding up the development and deployment of new weapon systems by more complete and rapid design and testing These innovative systems will address the difficulties now limiting the productivity of high-end computing systems by emphasizing programmability, portability, scalability, and robustness as well as high performance goals of achieving multiple petaflops and thousands of global updates of memory per second. High productivity computing systems will help design and develop advanced vehicles and weapons, plan and execute military operations, conduct cryptanalysis and image processing, maintain the nuclear stockpile, and generally serve as powerful tools for security-related research.

LASER Systems: Lasers are a core technology that has been important to the Department for over 40 years. Lasers have multiple military uses, from sensing to communication to electronic warfare to target designation. Since the technology was first demonstrated, DoD has maintained a steady interest in High-Energy Laser Systems for a wide range of speed-of-light weapon applications.

Manufacturing Science: The DoD requires a continuous supply of critical, defense-specific materiel and systems. To ensure reliable, robust, and cost-effective access to these items, manufacturing technologies that can meet DoD's needs must be available in the DoD industrial base. Examples are new manufacturing process initiatives in microwave electronics, adaptive software development, and advanced materials, with a focus on producing microwave amplifiers for electronic and information warfare, radar, and communication systems; designing and producing adaptive software-intensive systems; and revolutionary new, faster, and lower-cost methods for producing polymer matrix composites for aerospace components, superalloy high-strength blades that power aircraft turbine engines, and boron carbide inserts for body armor.

Materials The importance of materials technology to Defense systems is critical and longstanding: many fundamental changes in warfighting capabilities have sprung from new or improved materials. The breadth of this impact is large, ranging from stealth technology, which succeeds partly because materials can be designed with specific responses to electromagnetic radiation, to information technology, which has been enabled by advances in materials for electronic devices.

Current work in materials includes the following areas:

Structural Materials and Components: low-cost and ultra-lightweight materials designed for structures or to accomplish multiple performance objectives in a single system;

Functional Materials: advanced materials for non-structural applications such as electronics, photonics, magnetics, and sensors; and

Smart Materials and Structures: materials that can sense and respond to their environment.

Mathematics: includes topological and geometric methods, inverse methods, multiresolution analysis, representations, and computation that are applied to design and control complex systems, extract knowledge from data, forecast and assess risk, develop algorithms, and perform efficient computations. These techniques underlay key Defense applications such as signal and image processing; understanding biology, materials, and sensor data, design, and deployment; and design of complex systems.

Mathematical concepts and techniques are needed to determine the fundamental structure of massive data sets along with the tools to exploit that knowledge. The result will be easy-to-use algorithms that find and display hidden properties of massive data sets and allow greater and faster understanding of the phenomena they represent. Recent program results include key insights in such diverse fields as images, material science, cancer biology, virus evolution and medical diagnostics.

Distinguishing high-dimensional patterns in the statistics of natural images is leading to the development of a novel, non-linear, compression scheme that will revolutionize the way that images are analyzed. In addition, these methods will transform the way that doctors triage patients, through construction of non-linear, non-invasive medical statistics to assess patients in intensive and critical care situations.

Micro-Electronics: alternatives to traditional silicon chips are providing key military systems advantages in terms of operating speed, handling enormous power levels or, on the other end of the spectrum, dramatically reducing power consumption. Shrinking ever-more-complex systems into chip-scale packages, integrating microelectronics, photonics, and microelectromechanical systems (MEMS) into "systems-on-a-chip" have new capabilities.

It is at the intersection of these three core hardware technologies of the information age where some of the greatest opportunities for DoD arise.

By combining elements from the core technologies and using advanced architectures and algorithms, bulky existing systems can be reduced to sugar-cube size, and completely new capabilities can be developed. A key driver for this integration is the spectacular reduction in transistor circuit size under Moore's Law. Electronics that once occupied entire racks now fit onto a single chip containing millions of transistors. Similar gains are achieved by scaling non-electronic components.

Also exploiting advances in nano-science and nanotechnology, where matter is manipulated at the atomic scale enable still-more-complex capabilities in ever smaller and lower-power packages.

Taken together, these capabilities will create information superiority by improving the ability of the mobile warfighter to collect, process, manage, and act on information – ultimately allowing U.S. forces to think and react more quickly than the enemy in a rapidly changing battlespace

Work in microsystems includes:

Signal Processing – manipulate electrons in digital, analog, and mixed signal monolithic circuits for sensing, processing, and communications;

Photonics – generate, detect, and modulate photons for imaging, communications, and sensing;

MicroElectroMechanical Systems (MEMS) – exploit the processing tools and materials from semiconductor technology to build electro-mechanical structures at the micro- and nano-scale; and

Combined Systems-on-a-Chip – integrate microelectronics, photonics, and MEMS technologies into systems on a single chip.

Conventional 2-D circuits are limited in performance by the long signal interconnects across ever larger circuits and by existing circuit architectures.

Moving to three dimensions shorten the signal paths and introduce additional functions in each layer of 3-D stacked circuits that will change the way designers can exploit circuit complexity.

One of the most important roadblocks to increasing chip performance is, heat dissipation. As the number of transistors on a chip and their clock frequency increase and the size of the transistors decrease, the waste heat generated rises sharply. Today, some chips radiate as much heat per square inch as a hotplate. As a result, chip clock speeds cannot be increased further, which threatens to break Moore's Law of continued performance improvement through transistor scaling and increasing clock speed.

Networks: self-forming, robust, self-defending networks at the strategic and tactical level are the key to network-centric warfare; these networks will use spectrum far more efficiently and resist disruption if the GPS time signal is unavailable.

The DoD is in the middle of a transformation to what is often termed "Network-Centric Operations." The promise of network-centric operations is to turn information superiority into combat power so that the U.S. and its allies have better information and can plan and conduct operations far more quickly and effectively than any adversary.

At the core of this concept are robust, secure, and self-forming networks. These networks must be at least as reliable, available, secure and survivable as the weapons and forces they connect. They must distribute huge amounts of data quickly and precisely across a battlefield, a theater, or the globe, delivering the right information at the right place at the right time. DoD's networks are becoming as important to its military success as its weapons platforms.

But in order for these networks to realize their full military potential, they must form, manage, defend, and heal themselves so they always function at the enormously high speeds that provide their advantages. This means that *people* can no longer be central to establishing, managing, and administering them.

Normally, large, homogeneous networks are quite vulnerable to cyber attack: if all the network computers have identical operating systems and software, then a software vulnerability or fault in any one component can make the entire network vulnerable to catastrophic disruption. However by sharing knowledge about attacks, bugs and possible recovery strategies, a community of commercial off-the-shelf systems could use automated actions to prevent the spread of problems to other systems and restore normal function.

Quantum Information Science: exploiting quantum phenomena in the fields of computing, cryptography, and communications, with the promise of opening new frontiers in each area. Until recently, quantum effects in electronic devices have not exhibited overriding significance. However, quantum effects not only have to be taken into account, but can dominate how devices perform as they shrink to atomic dimensions.

Key among the challenges is integrating improved single- and entangled-photon and electron sources and detectors into quantum computation and communication networks. Defense applications include highly secure communications, algorithms for optimization in logistics, highly precise measurements of time and position on the earth and in space, and new image and signal processing methods for target tracking.

Real-Time Accurate Language Translation: Improved real-time translation of foreign languages at both the strategic and tactical levels is another important way computers can assist our warfighters by providing real-time machine language translation of structured and unstructured text and speech with near-expert human translation accuracy Real-time language translation technology will help U.S. forces better understand adversaries and overall social and political contexts of the operational areas. This improved awareness will decrease costly mistakes due to misunderstandings, and also improve the chances of success.

Today, linguists translate important information, but it is a slow and arduous process. Massive amounts of raw data are being collected, but there are not enough linguists to handle the constant streams of information. To deal with the volume of data and intelligence we capture and receive, we must dramatically reduce the growing reliance on linguists at both the strategic and tactical levels by providing revolutionary machine translation capabilities.

Trustworthy Integrated Circuits: Techniques to ensure that integrated circuits upon which critical DoD systems depend will operate exactly as designed and not contain possible malicious circuitry or programming. At the hardware component level, our network and computer security requires that the microelectronics from which they are built can be trusted, particularly when more and more of those electronics may be purchased from around the globe. Ways to determine if malicious features have been inserted during the design or fabrication of application specific integrated circuits, or if malicious features might have been inserted during the loading of field programmable gate arrays.

How To Ensure
That Tomorrows Youth
Will Want To Learn
Science and Technology?

This is a Difficult Problem

They Have To Want To Learn

They Would Want To Learn
Only If The Result
Leads to Something Exciting.

I Believe the Solution Is Straight Forward

Solution

Change The 7th to 9th Grade Syllabus

To

Have At Least A

Half-Year Course

Reading

One

Science Fiction Book

A

Week

"As The Twig is Bent, So Shall The Tree Grow"