SECTION 8 - INFORMATION SYSTEMS TECHNOLOGY

SUMMARY

Overview (See Figure 8.0-1) Information Systems (IS) are defined as the entire infrastructure, organization, personnel and components that collect, process, store, transmit, display, disseminate and act on information. IS include several functional areas: acquisition, organization, and management of data; processing and manipulation of data; information storage and retrieval; human-system interfaces; and means for ensuring the reliability and security of information and system resources. Most technologies used in information systems are dual use. New technologies and products are emerging daily. Performance of processors and capacity of memory chips has doubled every 18 months since 1970. This exponential growth is expected to continue until the year 2005. In addition to technology for the hardware and software components of reliable and secure information systems, other technology, in the form of specialized know-how for system design and integration, is necessary to meet important military requirements for C^4I^2, intelligent systems, modeling and simulation, and strategically essential industrial CAD/CAM uses. Also, IS are the primary "enabler" and a target for Information Warfare (see Section 9). The technology areas listed in the box nearby contain militarily critical technologies. To avoid duplication, specific technology items are listed under the most appropriate heading in Figure 8.0-2, which highlights the key dependencies among the technology areas and Information Warfare.

Rationale IS are pervasive in virtually all activities of the military establishment, the commercial and industrial section, and all levels of government. IS technologies are vital to US warfighting capabilities. Uses of IS encompass a range of applications from IS systems embedded in individual smart weapons and sensors, to local processing and communication systems, including transportable and personal hand-held devices, to international wide area networks (i.e., the Internet). Access to these technologies by potential adversaries could enhance the performance of their military systems and could also be used to counter US capabilities.

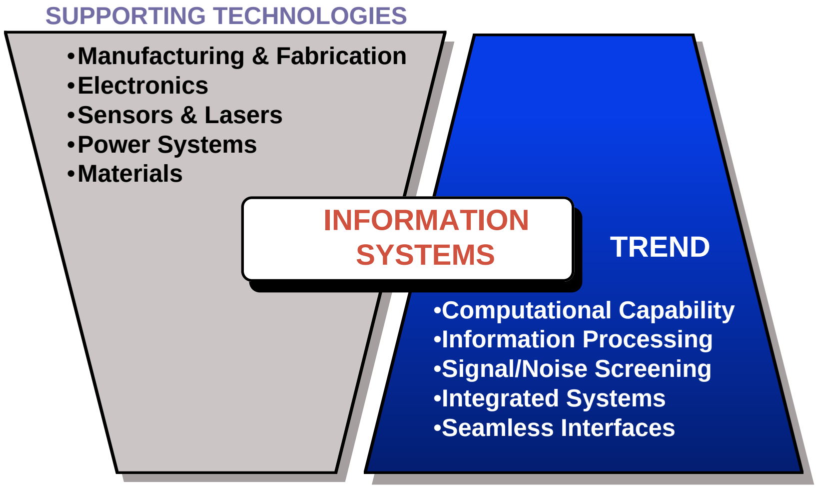

Figure 8.0-1. Information Systems Overview

Foreign Technology Assessment (See Figure 8.0-2) The US leads in system engineering and integration of complex information systems specially designed for military use. The US is closely followed by the UK, France, Germany, Canada and Japan. The underlying technologies for IS and for wide area integration of such systems are being driven largely by commercial infrastructure needs and markets. A significant number of countries have developed capabilities equivalent to those of the US in network switching and transmission. The US has sustained its lead in computing hardware because of superior microprocessor design and fabrication capabilities (see Sections 5 and 10). While the US continues to be the only country with critical capabilities in all IS technology areas, equivalent capabilities are found in one or more other countries in every area. The growing multi-nationalizaton of information systems developments has increased the worldwide availability and accessibility of critical technologies. A high rate of IS knowledge transfer from the US to foreign competitors occurs through open source US trade journals, technical literature, various international fora, the Internet, and intelligence. As a result, the US technology leadership in communications and computer systems has declined in recent years relative to Europe and Japan. However, the US is the only country with the ability to supply empirically validated system engineering and integration know-how to large, complex military systems. This capability sets the US apart as the world leader.

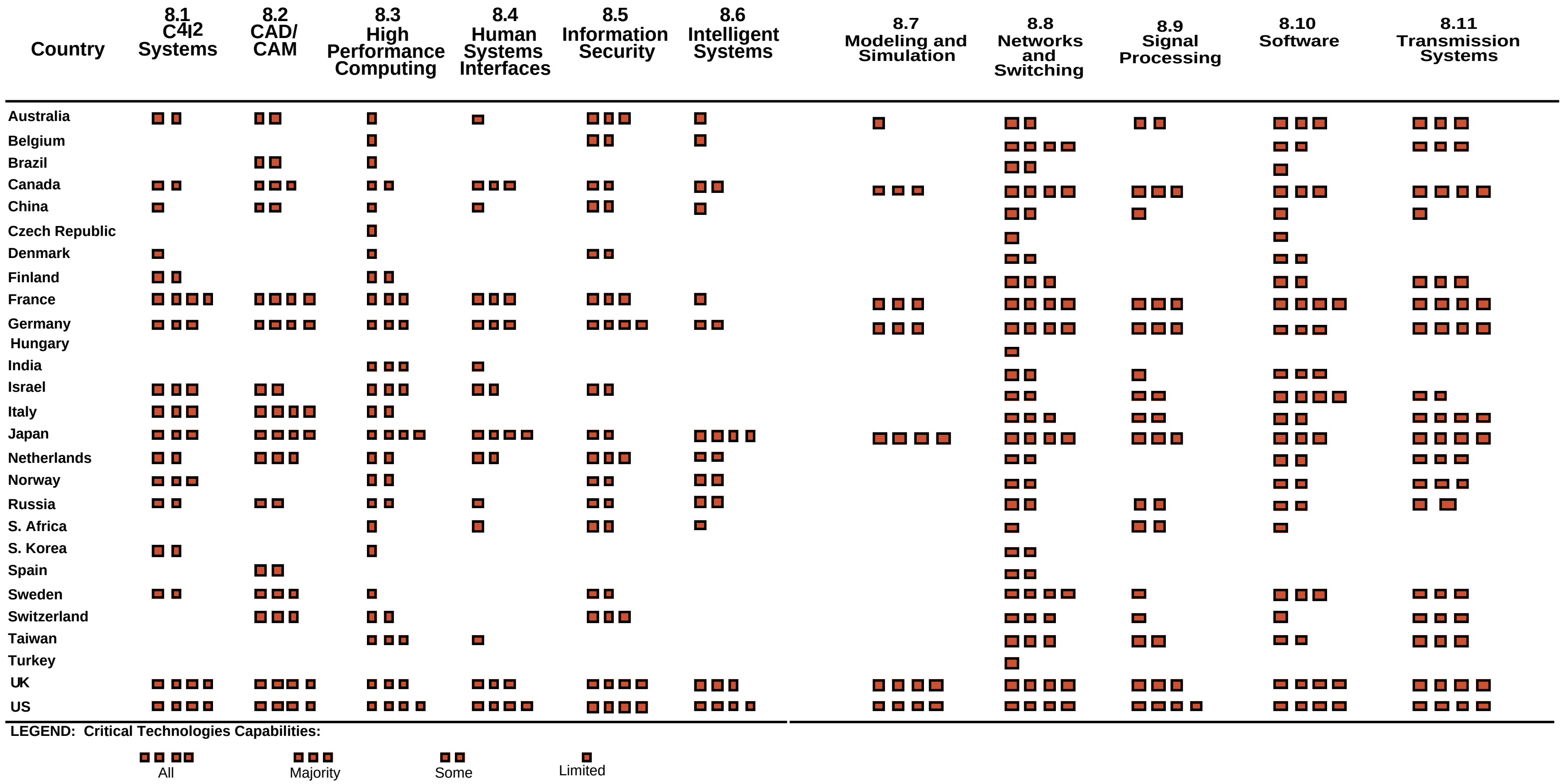

Figure 8.0-2. Information Systems FTA Summary

SECTION 8.1 COMMAND, CONTROL, COMMUNICATIONS, COMPUTING, INTELLIGENCE, AND INFORMATION SYSTEMS (C^4I^2)

Overview (See Figure 8.1-1) C^4I^2 comprises a multi-disciplined set of techniques to provide seamless communications, information management, and distribution, and decision-making in the new JCS Vision 20/0, improving situational awareness and effectiveness of warfighting forces in high-intensity combat situations. C^4I^2 is dependent on underlying hardware and software technologies covered elsewhere in this section. In addition, elements of C^4I^2 are also essential for development and operational integration of dynamic training, modeling, and simulation (see Figure 8.1-2). Battlespace environment has been explicitly identified as one of DoD's key technology areas for C^4I^2 and encompasses the following as key elements: weather prediction; propagation sensor modeling and performance prediction; and the underlying information management and human interface technologies required for effective use. While primarily aimed at military situational awareness and dynamic training and combat simulation, the technologies in question will find widespread commercial use in entertainment, education, and science and engineering.

8.3	High-Performance Computing
8.4	Human Systems Interface
8.5	Information Security
8.6	Intelligent Systems
8.7	Modeling and Simulation
8.8	Networks and Switching
8.9	Signal Processing
8.10	Software
8.11	Transmission Systems
9.0	Information Warfare Technology

Figure 8.1-2. Primary Supporting Technologies for Command, Control, Communications, Computing, Intelligence, and Information Systems

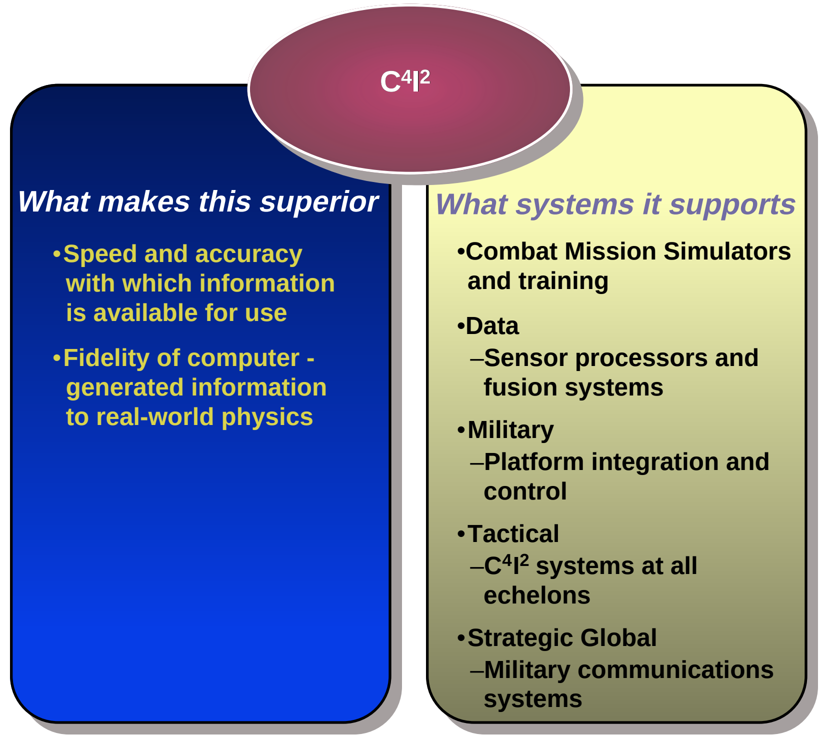

Figure 8.1-1. C^4I^2 Overview

Rationale (See Table 8.1-1) C^4I^2 systems are needed to sustain US forces' superior ability to detect, localize, and effectively engage enemy forces in a high threat/target-rich environment. The ability to synthesize and predict the complex effects of weather on sensors, vehicle maneuver capabilities, and communications gives commanders information that enhances their tactical decision-making ability. Synthetic battlespace environments will enable commanders to review the progress and project the course of battles under existing and predicted conditions; optimize tactics in real time; rehearse missions; and execute mission plans in real time. This will provide a level of situational awareness and real-time decision-making that is essential to sustain the JCS warfighting capabilities (see Introduction, part A) defined by the JCS in the face of an increasingly mobile and lethal threat.

Foreign Technology Assessment (See Figure 8.0-2) While the United States leads in C^4I^2 integration of complete battlespace environment capabilities, other nations have many of the key underlying elements essential to its development and operational use. France is a world leader in military communications. The Army's mobile subscriber equipment (MSE) is, in fact, based on French technology. Weather prediction, which plays an essential role, is a global activity in which Canada and the European Union have strong capabilities. Most nations with active sensor programs also have active efforts to improve their modeling and simulation of atmospheric effects, including obscurants used on the battlefield.

Table 8.1-1. Command, Control, Communications, Computing, Intelligence, and Information Systems (C^4I^2) Militarily Critical Technology Parameters

TECHNOLOGY	MILITARILY CRITICAL PARAMETERS MINIMUM LEVEL TO ASSURE US SUPERIORITY	CRITICAL MATERIALS	UNIQUE TEST, PRODUCTION, AND INSPECTION EQUIPMENT	UNIQUE SOFTWARE AND PARAMETERS	CONTROL REGIMES
SHORT TERM, NEAR REAL-TIME WEATHER PREDICTION, OCEANOGRAPHIC MODELING TO SUPPORT LITTORAL WARFARE AND OTHER ACTIVITY	4-hr turnaround of 72-hr weather prediction of dispersion patterns, rates of transport, and effective concentrations of aerosols, particles, or gases	None identified	None identified	Software characterizing the dispersion characteristics of aerosols and gases in realistic weather and terrain conditions	WA ML 17, 21
SENSOR MODELING AND PERFORMANCE PREDICTION	Validated performance of one or more operational or developmental military sensors under battlefield conditions	None identified	Anechoic chambers Other modeling support equipment	Software (operational and design models) characterizing clutter and interference effects and sensor response to same	WA ML 17, 21
VEHICLE MODELING TO PREDICTO PREDICT OFF-ROAD TRAFFICABILITY ACCURATELY	Validated off-road trafficability of operational or developmental military vehicles in one or more environmental scenarios	None identified	Empirically validated vehicle test facilities	Models and simulations of vehicle traction (for land vehicles) and dynamics	WA ML 17, 21
EM PROPAGATION CHARACTERIZATION TO PREDICT PERFORMANCE OF SENSORS, COMMUNICATIONS, AND ELECTRONIC AND LASER CM EFFECTS	Validated models of EM propagation in which military sensors or communication systems are exposed to two or more measured environmental effects	None identified	None identified	Software (operation and design models) characterizing propagation effects and sensor response to same	WA ML 17, 21

SECTION 8.2 COMPUTER-AIDED DESIGN AND COMPUTER-AIDED MANUFACTURING (CAD/CAM)

Overview (See Figure 8.2-1) Computer-aided design (CAD) is a technology enabling the design of intricate and often complex devices, mechanisms, and/or systems. The finished designs have detailed design data that permit a quality release for parts modeling and manufacturing. Computer-aided manufacturing (CAM) is a companion technology that supports the fabrication of a wide variety of devices and mechanisms with favorable impact on scheduling, flexibility, quality, and costs. The principal users of CAD and CAM systems have integrated the essentials of both CAD and CAM into a single, central data base that contains complete repositories of pertinent design and manufacturing data from which their entire engineering and manufacturing operations are driven. The ability to build and test computer models of proposed designs without having to construct expensive and time-consuming hardware is extremely beneficial to industry. Currently evolving is a functional hierarchical extension, based on CAD/CAM, that progresses through Virtual Prototyping, Data Visualization, Visually Coupled Systems, and Virtual Reality Systems, elements that underpin sophisticated computer modeling and simulation.

Rationale (See Table 8.2-1) As the complexity and capability of weapon systems mount, the operating characteristics of a given design and its producibility must be well-defined and understood before an expensive build-up program is fully launched. Extensive computer modeling and simulation has become essential for a wide variety of major military components, such as ships, submarines, aircraft, surface vehicles, and missiles, and the subsystems incorporated within them. Because of increased operating cost and decreasing availability of assets, computer-based simulators are now used to obtain data that would previously have been acquired through live operational tests and exercises. Computer-based simulators, employing elaborate 2D and 3D graphic techniques, enable designers to exercise an otherwise unattainable range and variety of tactical situations. Virtual Prototyping and Data Visualization are extensions of CAD/CAM and are being used in the modeling and simulation of a variety of designs requiring high-performance computers and supercomputers for execution.

Foreign Technology Assessment (See Figure 8.0-2) US industry maintains a dominant lead in the development and use of CAD/CAM tools. Several NATO nations—viz., France, Germany, Italy, the UK, and Canada—as well as Japan, Sweden, and Switzerland are also active and effective in the field.

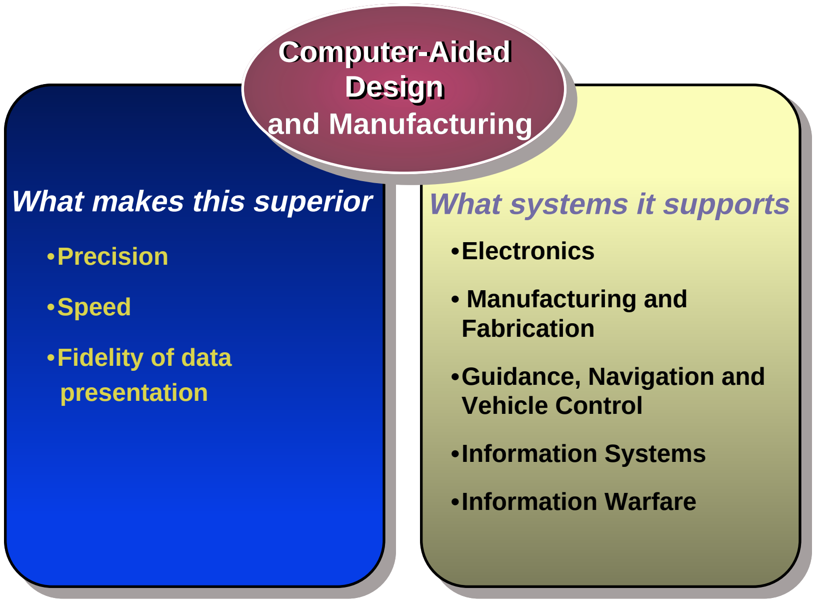

Figure 8.2-1. Computer-Aided Design and Manufacturing Overview

Unique support hardware is normally not required because current systems depend upon widely available computers and computer ancillaries for operation. The critical know-how is imbedded in algorithms and software, much of which is available on the open market. In striving for market edge, major CAD/CAM users supplement their systems with in-house-developed proprietary CAD/CAM tools. Military users have benefited from commercial advances. US defense contractors have been able to adapt CAD/CAM systems, often developed in-house for commercial use, to fit military design and manufacturing needs. The systems then become a base for further enhancement. NATO and the Japanese academic and commercial research efforts have initiated the functional hierarchical extensions herein mentioned. Military developers have been quick to use the concepts to produce the sophisticated weaponry modern military requires.

Table 8.2-1. Computer-Aided Design and Computer-Aided Manufacturing (CAD/CAM) Militarily Critical Technology Parameters

TECHNOLOGY	MILITARILY CRITICAL PARAMETERS MINIMUM LEVEL TO ASSURE US SUPERIORITY	CRITICAL MATERIALS	UNIQUE TEST, PRODUCTION, AND INSPECTION EQUIPMENT	UNIQUE SOFTWARE AND PARAMETERS	CONTROL REGIMES
COMPUTER AIDED DESIGN (CAD)	Capable of assisting in the design of microcircuits with feature sizes less than 1 micron.	None identified	Specialized analysis software and test equipment for verifying that CAD designs conform exactly to the manufacturing requirement	Fully integrated CAD system with predictability of software process and product capable of yielding first pass parts of dense microcircuits with feature size less than 1 micron or CAD system with data capability of laying out complex physical structures.	WA IL Cat 2, 3, and 4
COMPUTER AIDED MANUFACTURING (CAM)	CAM tools, dimensional inspection or measuring systems with capability to control the manufacture of microcircuits with feature size less then 1 micron.	None identified	Computer driven machine and robotic tools capable of fabricating and testing equipment manufactured to militarily critical parameters	Unique tool driving software with capability to control the manufacture of advanced hardware.	WA IL Cat 2, 3 and 4
VIRTUAL PROTOTYPING	Extension of CAD design to the structure of military part models in the "virtual" manner for modeling and simulation using computers with CTP's > 1500 MTOPs.	None identified	None identified	Application specific software used in structuring computer based prototypes	WA IL Cat 4 WA ML 14
DATA VISUALIZATION	Process of converting a set of numbers resulting from militarily related complex numerical simulations or experiments into a graphical image, using computers with CTP's > 1500 MTOPs.	None identified	None identified	Large parallel processor software utilized in analyzing military based research data	WA IL Cat 4 WA ML 14
VISUALLY COUPLED SYSTEMS TO ACHIEVE USER IMMERSION	Field of vision 70 degrees vertical, > 120 degrees horizontal. Helmet sensing and tracking system; Miniature cathode ray tube with 25 micron line widths @ luminance levels above 2000 foot Lamberts	None identified	Miniature transducer winding, alignment and Helmholtz fixturing. Precision, nonferrous, automated mapping fixture.	Dynamic scattering and scene generation algorithms. Other display related algorithms	WA ML 14, 24
VIRTUAL REALITY SYSTEMS	Minimum of 10,000 polygons per frame at a frame rate of 30 Hz	None identified	Currently helmet mounted display and sensor equipment are key items but requirements are still unfolding as the technology matures	Application specific software for the manipulation of data bases representing over 1,000 designs each containing hundreds of parameters	WA IL Cat 4 WA ML 14

SECTION 8.3 HIGH-PERFORMANCE COMPUTING

Overview (See Figure 8.3-1) High-performance computing encompasses conventional general-purpose digital computer processing equipment, including microprocessor-based single and multi-processor systems (including vector processors, array processors and other computers) and massively parallel and scalable computing. Also addressed in this section are graphic accelerators and image generators and programmable interconnections specially designed for aggregating high-performance processors to increase effective system power. Computers and software are explicitly identified as key technology areas in the DoD Technology Area Plans. High-performance computing is also critical to meet long-range S&T goals for battlefield digitization, human systems interfaces, manufacturing science and technology, and battlespace environment. High performance computing is an evolving technology for design of advanced military systems. (See also Section 8.2, CAD/CAM Technology.)

Rationale (See Table 8.3-1) High-performance computing is an enabling technology for modern tactical and strategic warfare. It is the principal technological force multiplier that gives US forces their superior ability to detect, localize, and effectively engage enemy forces in a high threat/target-rich environment. It is also an enabling technology for processing the massive amounts of imagery and sensor data for real-time data fusion and generating synthetic environments for dynamic training and simulation, mission planning and rehearsal, and operational battle management. Embedded computers are key enabling elements for improved sensors and smart weapons; for navigation, guidance, and control of military platforms; and for all aspects of operational C^4I^2. Advanced computing is also important in the development of WMD and represents an enabling technology for deployment and use of WMD, particularly for CBW delivery, where the problem of predicting precise patterns of dispersion is computationally demanding. Access to unique software revealing operational limitations or vulnerabilities of US systems or to threat information and intelligence sources and methods might be exploited to defeat or degrade US mission performance. The ability of recipients to cluster computers on low-cost (~ $3500 per dual port) switching hubs is a growing factor in setting practical effective lower limits for proliferation reasons. Such hubs, using a variety of technologies and protocols, are increasingly being used to network small enterprises to allow more effective aggregation of processing power.

Figure 8.3-1. High Performance Computing Overview

Foreign Technology Assessment (See Figure 8.0-2) Japan and the US have traditionally shared a worldwide lead in supercomputers. However, the emphasis in high performance computing is moving rapidly from mainframes to scalable or massively parallel processor architectures, in which the US enjoys a lead. The Free World's increasing availability of technology to support assembly and integration has resulted in the proliferation of sources for computers up to a CTP level of approximately 700 Mtops. Other countries capable of assembling military computing with higher CTPs from widely available, lower performance (less than 700 Mtops) components, assemblies, and computing hardware (predominantly of US origin) include Germany, the UK, France, Italy, Taiwan, South Korea, and India.

Table 8.3-1. High-Performance Computing Militarily Critical Technology Parameters

TECHNOLOGY	MILITARILY CRITICAL PARAMETERS MINIMUM LEVEL TO ASSURE US SUPERIORITY	CRITICAL MATERIALS	UNIQUE TEST, PRODUCTION, AND INSPECTION EQUIPMENT	UNIQUE SOFTWARE AND PARAMETERS	CONTROL REGIMES
GENERAL-PURPOSE DIGITAL PROCESSING EQUIPMENT, INCLUDING COMPUTERS, DIGITAL SIGNAL PROCESSORS, AND ARRAY/VECTOR PROCESSORS HAVING A COMPOSITE THEORETICAL PERFORMANCE	Exceeding 1500 million theoretical operations/second (Mtops)	None identified	None identified	Operational software for military systems with performance parameters and sensitive threat information	WA IL Cat 4 WA ML 17, 21
USAGE GENERATION ENHANCEMENT WRITING RATES GRAPHICS ACCELERATORS AND PROCESSORS	10 Million 3D vectors/second	None identified	High-resolution lithography (below 0.6 micron).	Image processing algorithms tailored for military C^4I^2 and data fusion, especially those incorporating ATR	WA IL Cat 4 WA ML 17, 21
INTERCONNECTION EQUIPMENT FOR AGGREGATING COMPUTATIONAL POWER	Having data transfer rates of > 80 Mbytes/second with aggregate throughput > 400 Mbytes	None identified	None identified	Operating systems specially designed for dynamic reconfiguration of computing clusters for specific military operations	WA IL Cat 4 WA ML 21
RADIATION HARDENING OF COMPUTER PROCESSING HARDWARE	Radiation hardened to withstand either of the following: - a total dose of 5×10^5 rads (si) or higher; or - a dose rate upset of 5×10^8 Rads (Si)/s or higher or - dose rate survivable $\geq 10^{12}$ Rad(Si)/s	None identified	Specially constructed facility to simulate the Electromagnetic Pulse characteristics	SEU and dose rate effects including SGEMP, software, analysis and simulation tools	WA IL Cat 4 WA ML 11
TEMPERATURE HARDENING OF COMPUTER PROCESSING HARDWARE	Designed to operate within the temperature range from 218 K (– 45 °C) to 397 K (+ 85 °C)	None identified	None identified	None identified	WA IL Cat 4 WA ML 11

SECTION 8.4 HUMAN SYSTEMS INTERFACE

Overview (See Figure 8.4-1) Human systems interface, as covered in this subsection, encompasses all ways in which human operators interact with information systems. While the primary interfaces at present are visual output and manual input, the broader technology area also includes other forms of sensory inputs including auditory (voice and other audible indicators and warning), tactile, and haptic devices for both input and output. Human interface technology is being driven by a variety of requirements, ranging from those of the entertainment industry to the need to grasp and manipulate extremely large data sets in scientific research. For two-way communication, the state of the art remains mechanical (keyboard, joystick, etc.), which provides an input that is inherently unambiguous. Hands-off input devices (including eye-tracking, voice input) are being pursued as a way of dealing with increased workload, without increasing operator stress. Ultimately, the goal is to achieve total immersion of the operator in a virtual reality with which he or she interacts in a manner that is perceived as normal.

Rationale (See Table 8.4-1) Significant advances in human system interfaces are required for circuit and projected military operations in the high-threat, information-rich battlefield of the future. In combat operations, two-way human interfaces facilitate an operator's ability to handle large quantities of information in real time to improve situational awareness and decision-making capability in periods of high stress. In weapons systems, they will also improve reaction time and control in tactical vehicles, particularly in attack helicopters and combat aircraft. While the notion of unmanned drones for reconnaissance and targeting has been largely accepted by operational forces, higher fidelity, robust human interfaces will be a key enabling technology for deployment and use of unmanned engagement systems. Human system interfaces are also key to the kind of virtual prototyping of systems and production processes essential to maintaining industrial-base preparedness and responsiveness.

Foreign Technology Assessment (See Figure 8.0-2) Because of its widespread potential for entertainment mass markets, several countries have been active in pursuing human system interface technology. Canada is one of the world leaders in visually coupled, virtual reality helmet-head-mounted displays. Japan, the UK, and Israel are also active in this area. Japan's primary emphasis has been on applying the technology to designing, manufacturing and controlling complex systems and enterprises (for example very large, distributed electrical power systems). In the last year, virtual reality has developed as an area of worldwide research, with strong capabilities also emerging in France and Germany. Israel is reported to have significant capabilities in military helmet-mounted display and also has wartime operational experience with unmanned drones that might apply to human interfaces for teleoperation.

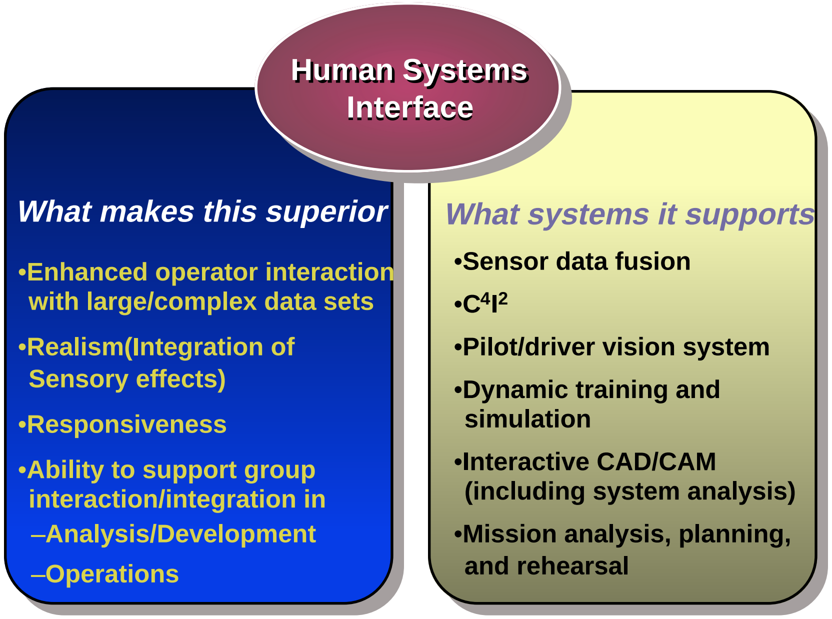

Figure 8.4-1. Human Systems Interface Overview

Table 8.4-1. Human Systems Interface Militarily Critical Technology Parameters

TECHNOLOGY	MILITARILY CRITICAL PARAMETERS MINIMUM LEVEL TO ASSURE US SUPERIORITY	CRITICAL MATERIALS	UNIQUE TEST, PRODUCTION, AND INSPECTION EQUIPMENT	UNIQUE SOFTWARE AND PARAMETERS	CONTROL REGIMES
VISUALLY-COUPLED DISPLAYS WITH RESOLUTION AND FIELD OF VIEW (FOV) DESIGNED TO MATCH HUMAN VISUAL PERFORMANCE	Better than: 2.5 Arc-minute resolution; Vertical FOV > 70°, and Horizontal FOV > 120°	None Identified	None Identified	Dynamic scene generation algorithms; Feedback algorithms for scene orientation and presentation; Smoothing algorithms for variable resolution, stereo displays	WA ML 17, 21
DYNAMIC SCENE GENERATION WITH REAL-TIME CAPABILITY	To sense line of sight and subject movement and generate appropriate scene with < 10 millisecond delay (>100 Hz refresh rate)	None Identified	None Identified	Characterization of dynamic scenes, texturing, etc.; information relating same to effectiveness of mission training	WA ML 17, 21
HAPTIC SENSORS	Force feedback in three dimensions, having 3 or more degrees of freedom	None identified	None identified	Software characterizing control responses of military systems	WA ML 17, 21

SECTION 8.5 INFORMATION SECURITY

Overview (See Figure 8.5-1) This subsection covers Information Security technologies whose principal elements are cryptographic algorithms and cryptanalytic algorithms. These technologies are used by the US military forces, certain US Government (USG) departments and agencies, and authorized industrial users. Some special cryptographic systems are shared with US treaty allies.

Rationale (See Table 8.5-1) The cryptographic and cryptanalytic technologies are essential to provide information security for US military weapons systems and research and development activities and to support essential USG cryptographic and cryptanalytic functions. Information security systems, equipment, subassemblies, and components are essential elements of intelligence, global surveillance, computer and communications networks, and C^4I^2 systems that provide reliable wide band communications links and information management nodes through the chain of command and channels of communications from the National Command Authorities (NCA) to the warfighters.

Foreign Technology Assessment (See Figure 8.0-2) The US is the largest producer and exporter of telecommunication and networking equipment and computer hardware and software. Although its technology leadership in communications and computing systems declined during the year 1990–1994 period relative to Europe and Japan, the US enjoys increasing leadership in information management. The imagination and creativity of the US information system industry and the ability to provide system engineering and integration of the information security technologies into information systems are what sets the US apart as the world leader. Information security technologies and products, especially those that are cryptology based, are developed independently in both government and industrial sectors by most nation states. The militarily critical information security technologies in this subsection are often highly classified by nation states and closely held by both governments and industries. An accurate assessment of foreign information security technologies and products is usually not feasible. It may be possible to infer the state of a country's information security technologies from the quantity of the commercial information security products that are offered in world markets. The ranking illustrated in Figure 8.0-2 assumes that a close relationship exists between the state of the art of the commercial information security products a country offers for sale and its closely held military technologies and products. The ranking also assumes that commercial cryptography products are a reliable indicator of a country's full information security suite of military technologies and products.

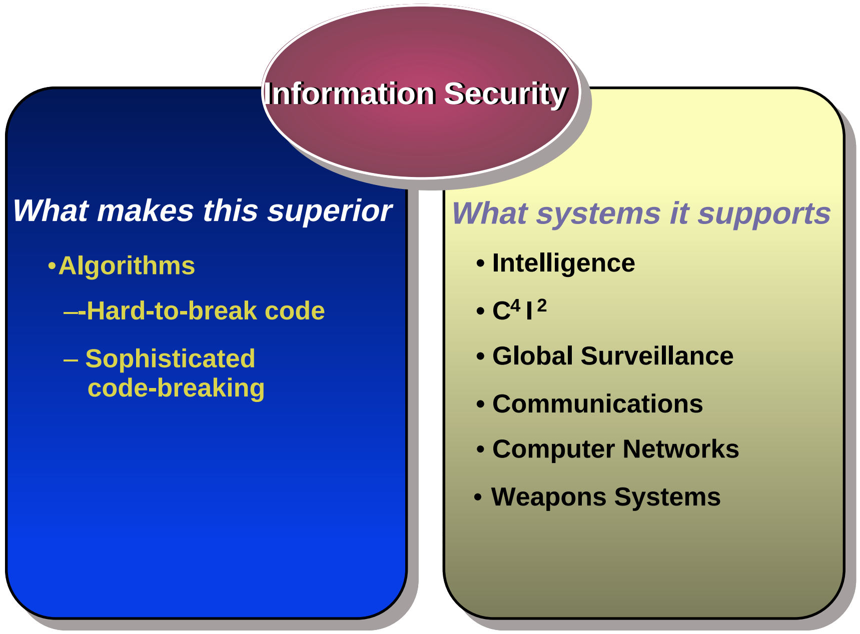

Figure 8.5-1. Information Security Overview

Table 8.5-1. Information Security Militarily Critical Technology Parameters

TECHNOLOGY	MILITARILY CRITICAL PARAMETERS MINIMUM LEVEL TO ASSURE US SUPERIORITY	CRITICAL MATERIALS	UNIQUE TEST, PRODUCTION, AND INSPECTION EQUIPMENT	UNIQUE SOFTWARE AND PARAMETERS	CONTROL REGIMES
CRYPTANALYTIC TECHNOLOGIES (FOR BREAKING CIPHERTEXT)	Due to the numerous variables required to implement an information security scheme and the wide range of products and services in which information security can be deployed this technology does not lend itself to specifically enumerated parameters.	None identified	Computers of 10,000 CTP, or greater, and software specially designed to test the ability of cryptanalytic systems to perform key searches, statistical, linear and differential cryptanalyses; and, factor 110 decimal digit, or larger, numbers.	Operating systems and applications for massively parallel cryptanalytic processors (> 16 processors) specially designed to perform statistical, linear and differential cryptanalyses, exhaustive key searches and quadratic and number field sieve factoring.	WA ML 11, 21 WA IL Cat 5
CRYPTOGRAPHIC TECHNOLOGIES (FOR KEEPING DATA SECURE)	Due to the numerous variables required to implement an information security scheme and the wide range of products and services in which information security can be deployed this technology does not lend itself to specifically enumerated parameters.	None identified	Computers of 10,000 CTP, or greater, and software specially designed to perform Randomness, Correlation, Weak Key and Symmetry Under Complementation tests to evaluate the strength of new USG encryption algorithms during development.	The software providing the cryptographic functionality must be specially designed and integrated into each application. The system engineering and integration, user system interface, algorithms and key generators must have zero defects.	WA ML 11, 21 WA IL Cat 5

SECTION 8.6 INTELLIGENT SYSTEMS

Overview (See Figure 8.6-1) Intelligent systems encompass several hardware and software items whose ultimate objective is to build systems that autonomously adapt their functionality—without human operator intervention or preprogrammed logic constraints—in response to changing requirements and conditions. Intelligent systems can be implemented in software on general-purpose digital computers or on specially designed analog or hybrid analog/digital neural networks and fuzzy logic chips. Interest continues in high-volume applications (such as in consumer products and appliances), particularly in the use of fuzzy logic/neural combinations wherein the training functionality of the neural net is used to optimize the fuzzy logic. Expert views of what constitutes machine or artificial intelligence have changed substantially in recent years, with advancing computer technology. Expert systems, once the predominant type of AI, no longer meet the basic criteria accepted for machine intelligence and are not considered by many experts to belong to the field of AI as it is now generally accepted.

Rationale (See Table 8.6-1) The range and lethality of weapons available to potential adversaries have increased dramatically. Intelligent systems, in the form of smart sensors and autonomous vehicles and weapons, have the potential of increasing mission effectiveness while reducing exposure of human operators. As pilot's assistants, this technology can also reduce manpower and training requirements, again while maintaining or improving effectiveness. These same features will also enhance our ability to analyze military operations in realistic scenarios and conditions for system development, development of tactics and doctrine, and mission planning and rehearsal. Finally, intelligent systems are needed as part of battle management and C^4I^2 systems to sustain US forces' superior ability to detect, localize, and effectively engage enemy forces in a high-threat/target-rich environment.

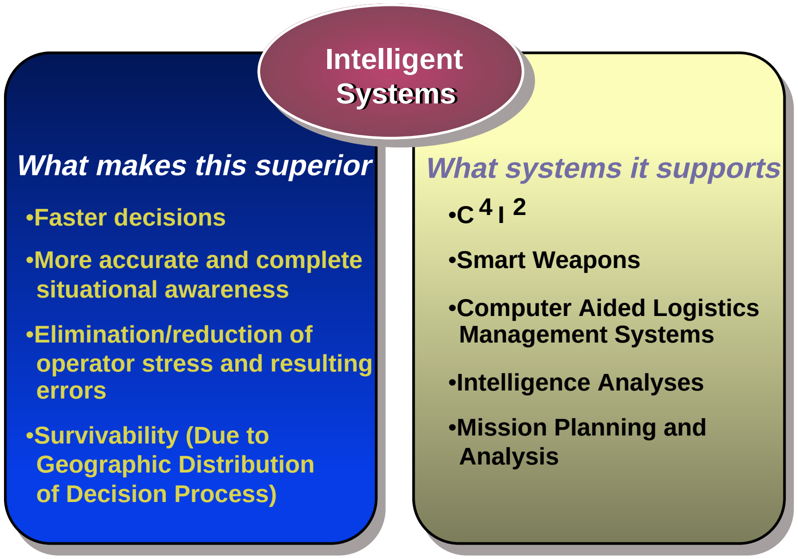

Figure 8.6-1. Intelligent Systems Overview

Foreign Technology Assessment (See Figure 8.0-2) Machine intelligence or intelligent systems are a field of general worldwide research. Much of this research, however, is still theoretical and in the area of machine cognition, per se, and not in specific hardware and software implementations. As noted previously, the growing availability of increasingly powerful microprocessor-based systems has reduced the emphasis on the development of special-purpose neural network hardware. Much of what work is continuing is being done in Japan, specifically in the area of simple fuzzy-logic/neural net combinations for use in consumer products. Japan is also interested in dual-use applications, including use of the technology in helicopter flight controls, that have potentially important military applications.

Table 8.6-1. Intelligent Systems Militarily Critical Technology Parameters

TECHNOLOGY	MILITARILY CRITICAL PARAMETERS MINIMUM LEVEL TO ASSURE US SUPERIORITY	CRITICAL MATERIALS	UNIQUE TEST, PRODUCTION, AND INSPECTION EQUIPMENT	UNIQUE SOFTWARE AND PARAMETERS	CONTROL REGIMES
INTELLIGENT SYSTEMS	Ability to self modify and validate any two or more of the following, without expert/human intervention • Acceptable inputs/problem set • Rule logic, or statistical methods and clustering • Criteria • Outcomes	None Identified	Neural networks exceeding 100,000 logical inferences/second	Military systems software revealing limitations vulnerabilities, tactics, etc., or threat characteristics. Encryption and digital signature techniques to ensure the validity and authorization of automated artificial intelligence functions (so-called "intelligent agents").	WA ML 17, 21 WA IL Cat 4
HIGH SPEED, LOW LATENCY SWITCHING DISTRIBUTED, INTELLIGENT SYSTEM	Data transfer rate (DTR) > 156 Mbits/second	None Identified	Production equipment for development of optical, optical-digital hybrid equipment for communications	Network operating systems capable of automatic redistribution of machine intelligence function within a system to adapt optimally to new (not preprogrammed) conditions and requirements	WA IL Cat 5

SECTION 8.7 MODELING AND SIMULATION

Overview (See Figure 8.7-1) Advanced simulation and modeling encompasses a wide range of dual-use applications, ranging from engineering design and manufacturing process optimization to dynamic flight trainers and simulators to distributed, interactive simulations of entire engagements and battles. The key elements of this technology involve digital processing to manipulate the data, human system interfaces through which the users interact with the data, and the knowledge embedded in the software discussed in related subsections of this MCTL (see Figure 8.7-2 for cross-reference). The modeling and simulation technologies are particularly important in the context of engineering problems and manufacturing processes, where critical know-how is specific to applications not addressed here.

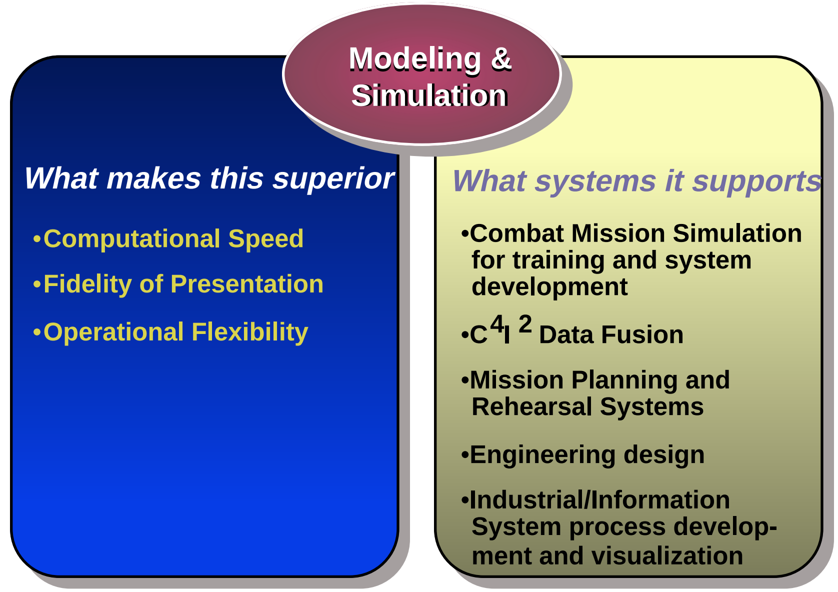

Figure 8.7-1. Modeling and Simulation Overview

8.3	High-Performance Computing
8.4	Human Systems Interface
8.5	Information Security
8.6	Intelligent Systems
8.8	Networks and Switching
8.10	Software
8.11	Transmission Systems

Figure 8.7-2. Primary Supporting Information Systems Technologies for Modeling and Simulation

Rationale (See Table 8.7-1) Three considerations drive the criticality of this technology. The first is force training and readiness. Decreasing funding, increasing operating costs, and escalating sophistication of threats and the operational scenarios in which those threats will be encountered make it impossible to develop essential combat skills in the field. The second is in industrial base preparedness. One of the effects of downsizing has been the deferral of engineering and manufacturing development of advanced systems in favor of extended technology development and demonstration programs. The risk of delaying engineering and production is reduced directly in proportion to our ability to do the critical engineering in modeling and to simulate manufacturing processes accurately. Finally, this technology plays an essential role in operations, where modeling and simulation will be critical to effective representation of battlespace environments. In C^3I, modeling and simulation enable commanders to do realistic mission rehearsal and preparation, explore options, and optimize force disposition and tactics.

Foreign Technology Assessment (See Figure 8.0-2) France and the UK are among the world leaders in dynamic training and combat simulation, followed closely by Germany. Japan is a world leader in most of the underlying technology and is probably the world leader in distributed interactive simulation of complex enterprises. Canada is also strong in this technology, particularly in visually coupled systems and dynamic scene generation.

Table 8.7-1. Modeling and Simulation Militarily Critical Technology Parameters

TECHNOLOGY	MILITARILY CRITICAL PARAMETERS MINIMUM LEVEL TO ASSURE US SUPERIORITY	CRITICAL MATERIALS	UNIQUE TEST, PRODUCTION, AND INSPECTION EQUIPMENT	UNIQUE SOFTWARE AND PARAMETERS	CONTROL REGIMES
GRAPHICS ACCELERATORS AND PROCESSORS WITH REAL-TIME VECTOR WRITING RATES	≥ 10 million 3D vectors/second	None identified	High-resolution lithography (below 0.6 micron).	Image processing algorithms tailored for military C^3I and data fusion, especially those incorporating ATR	WA IL Cat 4 WA ML 17, 21
SPEED AND RESPONSIVENESS OF DISTRIBUTED INTERACTIVE SIMULATION	Network speed > 623 Mbits/second Latency < 30 milliseconds	None identified	None Identified	Real-time adaptive network operating systems. Applications data files incorporating doctrine, tactics, or force element/weapon characteristics.	WA IL Cat 4, 5 WA ML 17, 21

SECTION 8.8 NETWORKS AND SWITCHING

Overview (See Figure 8.8-1) This subsection covers the militarily critical technology for telecommunication equipment used for the electronic transfer of information. It encompasses technologies for "stored-program-controlled" circuit and packet switching equipment and network routers used for establishing a communication channel between two or more points. Switches may be categorized as circuit, message, and packet or any combination thereof. The technologies found in information networking and network control are heavily dependent on the automation of the monitoring and controlling functions within the network. The monitoring and controlling functions are combined in separate systems, which are capable of working over a widely dispersed geographical area with equipment using various transmission media and switches using common channel signaling. These systems provide a centralized control capability to configure transmission equipment to optimize networks for loading and failures and to configure switches and routers to optimize the call distribution within a network. Technologies identified are optical switching, radiation hardened telecommunications equipment, and equipment capable of operating in extremely cold and hot temperatures. Related technologies are multi-level priority and pre-emption; dynamic adaptive routing; optical switching; and asynchronous transfer mode (ATM).

Rationale (See Table 8.8-1) Information systems serve as the vital link in providing current information exchange in the C^2 function. The technologies that have provided the classical telecommunication capabilities have been broadened and have become the vehicle for more encompassing and capable information systems technologies. While access to large quantities of information is important, technologies that provide for the timely receipt of alerting information on enemy status (transmitted even at low data rates) provide for reorganization of combat battle plans and response to changing battlefield situations. Effective C^2 of forces is dependent on maintaining continuity of communications at all times with all elements, fixed or mobile. Continuity can be achieved by switching and reconfiguring networks to provide alternate means in the event of damage or jamming in a hostile environment.

Foreign Technology Assessment (See Figure 8.0-2) The majority of the technologies associated with information in networks and switching are common to both military and civil systems and have become readily available through joint developments or through foreign sales. In foreign sales involving technology transfer, secondary transfer of technology by the original purchaser results in additional proliferation of this technology. Consequently, many countries have acquired technological capabilities in this manner and have rapidly improved their own products. The ranking (which is shown in Figure 8.0-2) largely reflects international standardization activity. Belgium, Canada, France, Germany, Japan, Sweden, and the UK have overall capabilities equal to those of the US. US technology surpasses them in niche technologies such as laser transmission. All of the foregoing countries plus Australia, Finland and Italy sell switching equipment worldwide. In most cases this equipment is quite technologically advanced but usually contains technologies of lesser capability. For example, the multi-level switching and preemption capability will contain only two levels rather than three to five levels.

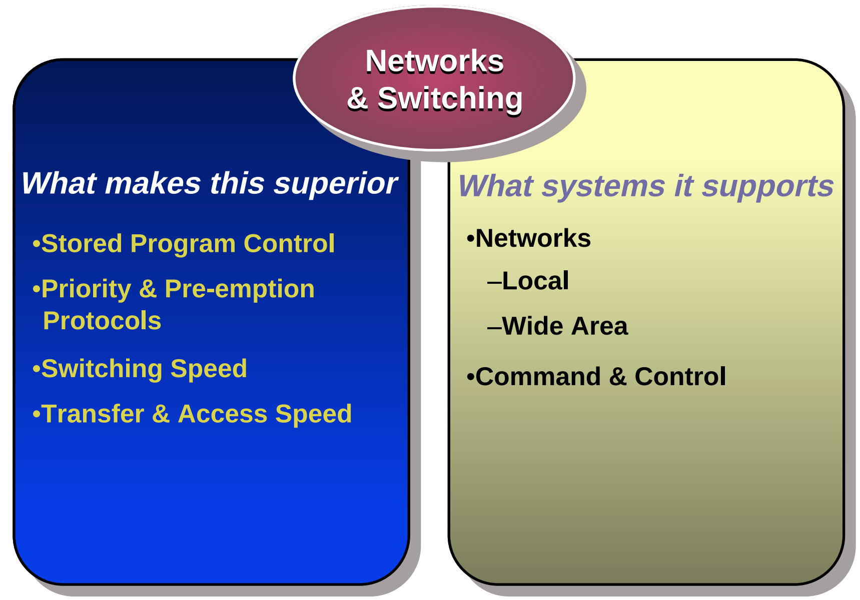

Figure 8.8-1. Networks and Switching Overview

Table 8.8-1. Networks and Switching Militarily Critical Technology Parameters

TECHNOLOGY	MILITARILY CRITICAL PARAMETERS MINIMUM LEVEL TO ASSURE US SUPERIORITY	CRITICAL MATERIALS	UNIQUE TEST, PRODUCTION, AND INSPECTION EQUIPMENT	UNIQUE SOFTWARE AND PARAMETERS	CONTROL REGIMES
OPTICAL SWITCHING	Switching speed of 1.0 msec < 0.8 dB loss at wavelength of 1300 nanometers. Operates with either single or multimode optical fibers. Provides up to 4 port switch positions. Robustness to operate under shock condition of 1500 gs at 0–1000 Hz.	None identified	None identified	None identified	WA IL Cat 5
NETWORKING AND SWITCHING	Accommodate simultaneous access and transfer of scaleable & seamless variable speed information in a network operating between 16 Kbits/s and 10 Gbits/s	None identified	None identified	Real time software for ATM call control	WA IL Cat 5
TELECOMMUNICATIONS EQUIPMENT	Specially radiation hardened to withstand: total dose of 5×10^5 rads(si) or dose rate upset of 5×10^8 rads(si)/s or higher	None identified	Specially constructed facility to simulate the Electromagnetic Pulse characteristics with a field intensity of 50,000 volts/meter	None identified	WA IL Cat 5
TELECOMMUNICATIONS EQUIPMENT	Operating temperature from 218 K (– 55 °C) to 397 K (124 °C).	None identified	None identified	None identified	WA IL Cat 5

SECTION 8.9 SIGNAL PROCESSING

Overview (See Figure 8.9-1) A signal is any physical quantity that varies with time, space, or any other independent variable or variables. Signal processing encompasses all aspects of conditioning, formatting, and extraction of useful information from such signals. Functions performed by signal processing include filtering to separate desired signals from undesired signals (noise) and analysis of the spatial or temporal characteristics of signals to extract information regarding the content of messages or the location and identification of targets. Image processing analysis and characterization of the spatial distribution of signals occur in two or more dimensions. The patterns generated may correlate to visual images or be entirely synthetic representations of nonvisual data from multiple sensors. Such 2D signal processing may or may not also include analysis of the temporal characteristics, such as moving target imagery.

Rationale (See Table 8.9-1) Signal processing is a basic enabling technology for all telecommunications and military sensors. The ability to control and exploit the electromagnetic spectrum has become an increasingly vital element of the electronic battlefield. Signal processing is, in effect, the first layer of quality assurance for information that will ultimately be used for decision-making in the battlefield. The accuracy and reliability of that data, particularly in environments with high levels of interference (both unintentional and countermeasures induced), is critical to mission success.

Foreign Technology Assessment (See Figure 8.0-2) The basic principles and, increasingly, the components necessary for implementing advanced digital processing techniques are increasingly available. Implementation of militarily critical signal processing functions rests largely on empirically validated target and engineering design databases and empirically optimized algorithms. The US, by virtue of many years of investment in development, test, and operational use of advanced military sensors, has a significant worldwide lead, followed closely by the UK, France, and Germany. Japan also has all of the underlying technology elements and has developed a variety of military systems (IR sensors, mortar location radars, satellite communications, etc.) that require state-of-the-art signal processing. Italy, Sweden (airborne radar), and other members of the EU have capabilities in specific sensor areas, as do Russia, Israel, India, and South Africa.

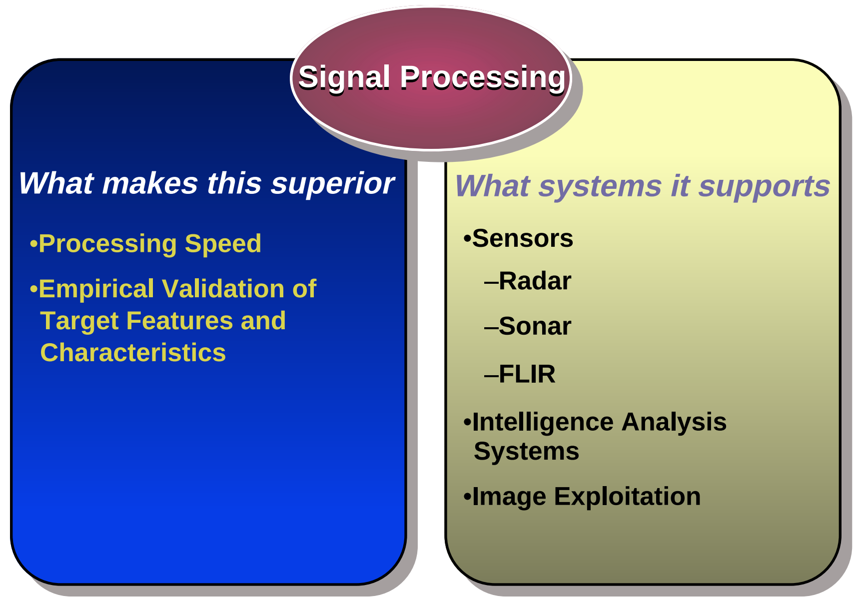

Figure 8.9-1. Signal Processing Overview

Table 8.9-1. Signal Processing Militarily Critical Technology Parameters

TECHNOLOGY	MILITARILY CRITICAL PARAMETERS MINIMUM LEVEL TO ASSURE US SUPERIORITY	CRITICAL MATERIALS	UNIQUE TEST, PRODUCTION, AND INSPECTION EQUIPMENT	UNIQUE SOFTWARE AND PARAMETERS	CONTROL REGIMES
DIGITAL SIGNAL PROCESSING EQUIPMENT AT HIGH COMPOSITE THEORETICAL PERFORMANCE	1500 million theoretical operations/second (Mtops)	None identified	None identified	Signal processing algorithms for detection in noise and clutter; Image processing algorithms tailored for military C^4I^2 and data fusion, especially those incorporating ATR	WA IL Cat 4 WA ML 11, 17, 21
IMAGE PROCESSING SYSTEMS INTEGRATING ONE OR MORE SYSTEM SUPPORT FUNCTIONS	Integrate one or more of following system support functions: Automated electronic scanning and beam forming, Motion compensation and clutter/counter-measures rejection, Real-time feature extraction	None identified	Imagery displays, capable of 10 million 3D vectors per second or greater	Empirically validated criteria and algorithms for feature extraction, classification, and identification of military targets; Empirically validated techniques for processing degraded or partial images of military targets	WA ML 11, 17, 21
AUTOMATIC, REAL-TIME ACOUSTIC SIGNAL PROCESSING, SONAR	CTP = 1500 Mtops	None identified	None identified	Validated techniques for discriminating undersea noise, and localization algorithms accounting for undersea propagation effects	WA IL Cat 4, 6 WA ML 21
AUTOMATIC, REAL-TIME TERRESTRIAL ACOUSTIC PROCESSING	CTP = 1500 Mtops	Not applicable	None identified	Validated algorithms incorporating military target data and battle noise	WA ML 17, 21
AUTOMATIC REAL-TIME TARGET RECOGNITION	Specially designed to incorporate one or more empirically validated features for real-time detection and identification of military targets	None identified	None identified	Validated algorithms and detection criteria for military targets	WA ML 17, 21
ON BOARD-PROCESSING AND ANALYSIS OF COMPLEX SIGNATURES	Specially designed for capturing and analyzing complex dynamic (range > 100 dB) signals in real-time Able to withstand shock and accelerations to 300 g.	Special antenna radome and optical/IR window materials	Specially designed equipment for assembly of G-hardened components	Empirically-validated target detection algorithms, and target acquisition, aimpoint selection and firing criteria	WA ML 11, 17, 21

SECTION 8.10 SOFTWARE

Overview (See Figure 8.10-1) Software consists of two components: (1) the *applications* matters, which contains algorithms, functions or logic, and parameters and (2) the *code*, which enables electronic computers to implement the applications. Militarily critical software applications are included in other sections of the MCTL as separate technology items or as "Unique Software and Parameters" in data tables. These applications use validated software that is generally related to one or more operational or developmental military systems. This subsection identifies the know-how that makes the second component, software code, militarily critical. There are two aspects to code: *product and process*. As product, code is considered militarily critical when it meets criteria in Table 8.10-1 under Military Critical Parameters. Process technologies in the development and life cycle support of software code—in such activities as configuration management, testing, metrics/measurement, integrated documentation, and architecture—involve technologies that are not currently militarily critical.

Rationale (See Table 8.10-1) Software code is the lifeblood of countless models, simulations, decision systems, and information systems in innumerable military and nonmilitary applications. Attributes by which code is judged include *predictability, reliability, error immunity*, and *confidence level*. Predictability refers to the degree to which code enables applications to function as expected (e.g., target damage is, in fact, measured by a vulnerability model). Reliability is the measure of the code's ability to enable an application to be executed without interruption. Immunity to errors covers internal causes (e.g., virus) and external causes (e.g., power outage). Confidence level is a quantified measure of trust warranted by the software code. Table 8.10-1 identifies the levels at which these attributes are militarily critical.

Foreign Technology Assessment (See Figure 8.0-2) Two main considerations in scoring a country's software capability are (1) the ability to apply software development processes consistently to large or complex systems integration programs and (2) the ability to develop code of the quality listed under Militarily Critical Parameters in Table 8.10-1. Besides the US, countries with the best military software capability are France, Israel, and the UK. Next in capability are Australia, Canada, Germany, Japan, and Sweden. A great deal of technology exchange takes place in conferences and publications on software development. The use of the Internet has also broadened the base of discussion on software development techniques throughout the world. Currently, the US leads the world, largely because of national attention and concentration on developing military software. Other countries have gained expertise in certain aspects of software development, often from personnel transfers and training by US companies and US universities or through international conference participation and internationally available publications. Certain individuals and groups have obtained expertise in hacking and insertion of "rogue code".

Figure 8.10-1. Software Overview

Table 8.10-1. Software Militarily Critical Technology Parameters

TECHNOLOGY	MILITARILY CRITICAL PARAMETERS MINIMUM LEVEL TO ASSURE US SUPERIORITY	CRITICAL MATERIALS	UNIQUE TEST, PRODUCTION, AND INSPECTION EQUIPMENT	UNIQUE SOFTWARE AND PARAMETERS	CONTROL REGIMES
SOFTWARE THAT ENABLES ELECTRONIC COMPUTERS TO IMPLEMENT APPLICATIONS	100% functional predictability High confidence > 99% High reliability ~ 100% Immunity < 1 error in 10^{12} External > cryptographic data integrity probability of error > 10^{-9} Internal-detect-fix < 1 operational cycle	None identified	Unique software tools for production, testing, and inspection needed to achieve the Militarily Critical Parameters.	Validated input data and military software provide the capabilities that make militarily critical systems superior	WA ML 17, 21 WA IL Cat 1–9

SECTION 8.11 TRANSMISSION SYSTEMS

Overview (See Figure 8.11-1) This subsection covers the militarily critical technology for information transmission equipment and components used for transfer of voice, data, record, and other information by electromagnetic means either through atmospheric, exoatmospheric, or subsurface (water) media or via metallic or fiber optic cable. Information being exchanged is predominantly in digital form for voice, text, graphics, video and databases. This facilitates the application of security as required. The majority of the technologies for telecommunication transmission equipment are common to both military and civil systems. The information may be analog or digital, ranging in bandwidth from a single voice channel to video or multiple channels occupying hundreds of megahertz. Technologies identified as militarily critical include those for laser communications through atmospheric, exoatmospheric, and subsurface media or over optical fiber; radio transmission equipment operating at frequencies > 30 GHz with spread spectrum for low probability of intercept communications; phased array antennas for beam forming or nulling of interfering signals; and high-capacity, digitally controlled radio receivers. Other technologies considered were cable transmission technology for cables used where reduced vulnerability to intercept is of concern and underwater communications for concentrated naval operations. The types of cables considered are single or multiconductor, twisted pair or coaxial metallic cable, and those using optical fiber conductors. Cables can be employed on the surface for rapid deployment or buried in the earth for protection or as means of providing a required degree of hardness. Other applications are underwater inter-island or intercontinental connections. Technologies identified are those for single mode fibers with low dispersion; halide-based fibers of extremely low loss; and components and accessories for fiber.

Rationale (See Table 8.11-1) The technologies for developing and producing a variety of types of telecommunications equipment used for electromagnetic transmission of information over any media provide for information exchange to control forces without impeding their mobility. The technology used minimizes the probability of information intercept by any third party. It nullifies the effect of electronic warfare assets that may be employed by a third party to counter the accurate receipt by the intended recipient of the information transmitted.

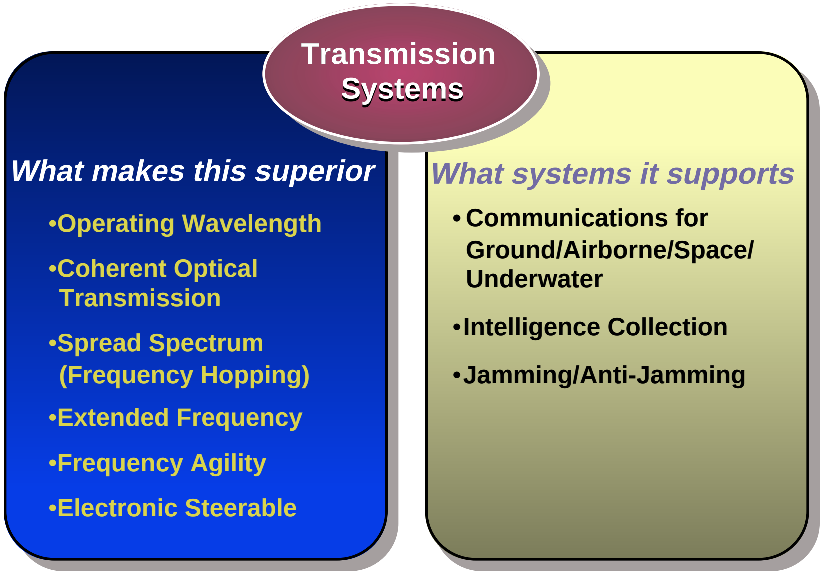

Figure 8.11-1. Transmission Systems Overview

Foreign Technology Assessment (See Figure 8.0-2) The majority of the technologies associated with information transmission equipment operating in the electromagnetic media or over fiber or cable are common to both military and civil systems and have been made readily available in the foreign market or through joint development. Consequently, many countries have not developed their own unique products but have acquired technological capabilities incrementally as products have undergone improvement and standardization. The ranking shown in Figure 8.0-2 is based on the information systems produced by the individual countries and their activity in acquiring or producing products in the world markets. Six countries—Canada, France, Germany, Italy, Japan, and the UK—have capabilities that rival those possessed by the US. Eight countries—Australia, Belgium, Finland, Netherlands, Norway, Sweden, Switzerland, and Taiwan—have technological capabilities in the majority of the critical technology areas.

Table 8.11-1. Transmission Systems Militarily Critical Technology Parameters

TECHNOLOGY	MILITARILY CRITICAL PARAMETERS MINIMUM LEVEL TO ASSURE US SUPERIORITY	CRITICAL MATERIALS	UNIQUE TEST, PRODUCTION, AND INSPECTION EQUIPMENT	UNIQUE SOFTWARE AND PARAMETERS	CONTROL REGIMES
OPTICAL INFORMATION TRANSMISSION	Using single mode optical fiber with dispersion < 0.12 ps/nm/km at 1520–1580 nm	None identified	Pulse degradation measurement	Intrusion detection techniques	WA IL Cat 5
LASER TRANSMISSION - FINE LINE	Linewidth < 300 MHz	None identified	None identified	None identified	WA IL Cat 5
RADIO EQUIPMENT	Frequency > 31 GHz	None identified	Semi conductor manufacturing technologies at higher frequencies	Frequency control and agility	WA IL Cat 5
RADIO EQUIPMENT - SPREAD SPECTRUM (FREQUENCY HOPPING)	User programmable spreading codes; total transmitted bandwidth > 100 times the bandwidth of any one information channel and > 50 kHz.	None identified	None identified	Spread spectrum necessary to detect and track hop rates and apply counter measures to deny use of the spectrum	WA IL Cat 5
RADIO RECEIVERS	Digitally controlled > 1000 channels: Automatic, search and scan Switching time < 1 ms.	None identified	Signal display and analyses equipment	Software with processors to cover and analyze the spectrum of interest	WA IL Cat 5
PHASED ARRAY ANTENNAE	Steering angle > 60 deg at frequency > 31 GHz.	None identified	None identified	None identified	WA IL Cat 5