RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit)								DATE February 2000	
APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA2 Applied Research					R-1 ITEM NOMENCLATURE Extensible Information Systems PE 0602302E, R-1 #14				
COST *(In Millions)*	FY 1999	FY2000	FY2001	FY2002	FY2003	FY2004	FY2005	Cost To Complete	Total Cost
Total Program Element (PE) Cost	0.000	30.000	69.282	105.196	90.000	90.000	95.000	Continuing	Continuing
Deeply Networking Systems AE-01	0.000	5.405	13.513	12.860	25.000	30.000	42.000	Continuing	Continuing
Software for Autonomous Systems AE-02	0.000	16.873	17.171	44.851	35.000	32.000	33.000	Continuing	Continuing
Software for Embedded Systems AE-03	0.000	7.722	23.821	27.700	12.000	15.000	10.000	Continuing	Continuing
Gigabyte Applications AE-04	0.000	0.000	14.777	19.785	18.000	13.000	10.000	Continuing	Continuing

(U) Mission Description:

(U) This program is part of a multi-agency initiative to greatly extend the reach and effectiveness of networked computation. It is funded in the applied research budget activity because it is pursuing network and software research to facilitate the "deep networking" of computers, such as those embedded within DoD platforms and weapons. It will also conduct research to greatly increase the autonomy of those systems, so as to promote the human role from that of operator to supervisor.

(U) The Deeply Networked Systems project is developing the software for designing and managing a single complex system, which is composed of multiple sub-systems, and each sub-system has many embedded devices. The challenge is to network such devices that are located in different sub-system/components. Doing so will require a much “deeper” approach to information systems – one that manages the vast quantities of “physical” information that can be accessed by sensors and actuators in direct contact with real world processes. To enable this transition, both the network and embedded software infrastructure must be extended to deal with: challenges created by a wide diversity of embedded devices dealing in physical world information which must be addressed by network research; vast increases in the numbers of nodes with real-time transmission requirements; and operating regimes in which network-based nodes must host services on behalf of embedded clients. Research on embedded software creation must radically extend the technology to enable the composition of software systems subject to physical constraints.

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(U) The Software for Autonomous Systems project develops software to enable reliable, safe, and cooperative operation of free ranging, autonomous systems. This effort includes software for mobile robots (air, land or maritime unmanned vehicles) performing tasks in dynamic, unstructured (physical) environments without the need for synchronous, operator control inputs or high quality communications links. Similarly, this effort includes the development of software agents (knowbots) that can range over cyberspace performing information services, including the capability to negotiate for and assign selected resources. Further, these autonomous systems should be able to learn and adapt to change and uncertainty while improving with experience.

(U) The convergence of processing power, vanishing size and decreasing cost of today's microprocessors has created new devices and micro sensors that enable a new wave of DoD applications. For example, cheap, smart micro-sensors can be deployed quickly in large quantities in the battlefield to perform new monitoring and control functions; and a host of sensors can be attached to warfighters and assets to autonomously monitor safety and health information, and equipment condition. The Software for Embedded Systems project is developing the software for networking the untethered micro sensors in a relatively wide area environment, for example, a sensor net on the ground and water. A unique processing capability, collective processing, due to this networking environment will also be explored. This new class of software will deal with the processing of physical world information by networked embedded devices.

(U) The Gigabyte Applications project is developing the technology to enable robust operation of DoD's mission-critical systems and platforms that are inherently geographically dispersed and are dependent on extremely high data flows. Capabilities for end-applications to tie in with other applications as well as with signals from multiple hardware sources and with human users will be developed with technologies that allow ultra high-throughput, sustained low-latency data delivery and processing. Gigabyte to terabyte flow transfers across end applications will be demonstrated over wide-area networks. The project will also develop robust, survivable inter-networking architecture that will minimize vulnerability posed by the growing complexity and brittleness that is seen across physical layer networking architecture today.

(U) **Program Change Summary:** (*In Millions*)	**FY1999**	**FY 2000**	**FY 2001**
Previous President's Budget	0.000	70.000	70.000
Current Budget	0.000	30.000	69.282

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(U) Change Summary Explanation:

FY 2000 Decrease reflects a Congressional program reduction and government-wide rescission, partially offset by minor program repricing.

FY 2001 Decrease reflects inflation adjustments.

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APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA2 Applied Research				R-1 ITEM NOMENCLATURE Extensible Information Systems PE 0602302E, Project AE-01					
COST (In Millions)	FY 1999	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	Cost to Complete	Total Cost
Deeply Networked Systems AE-01	0.000	5.405	13.513	12.860	25.000	30.000	42.000	Continuing	Continuing

(U) Mission Description:

(U) Extending DoD's ability to monitor and control the physical environment will require a much "deeper" approach to information systems – one that manages the vast quantities of "physical" information that can be accessed by sensors and actuators in direct contact with real world processes. To enable this transition, both the network and embedded software infrastructure must be extended to deal with: challenges created by a wide diversity of embedded devices dealing in physical world information which must be addressed by network research; vast increases in the numbers of nodes with real-time transmission requirements; and operating regimes in which network-based nodes must host services on behalf of embedded clients. Research on embedded software creation must radically extend the technology to enable the composition of software systems subject to physical constraints.

(U) The large scale networking of embedded and autonomous devices creates new requirements for: embedded technologies that can achieve drastic reductions in costs while being compatible with a wide range of network and computation media; flexible mechanisms for naming, addressing, configuring and administering communication and computation resources; and system design technology which shifts the emphasis from static verification and validation to dynamic behavior guarantees. These challenges are addressed in the Networked Embedded Systems component of this project.

(U) Future defense uses of the network will have an increased emphasis on the direct exchange of real-time sensor-derived information among autonomous embedded devices. This reflects a significant change in network traffic from the present environment, which is dominated by the exchange of symbolic information among human users. The architectures and protocols needed to effect this transition will be investigated in the Networked Embedded Systems component of this project.

(U) Many applications of deeply networked systems will perform data dissemination and fusion operations that could most efficiently be performed at nodes within the network. The Networked Embedded Systems component of this project will leverage the capabilities of a programmable network substrate to deploy middleware that is nomadic in nature and can go where network connectivity permits. This capability will permit network elements to host services on behalf of embedded and autonomous devices.

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(U) Tight integration of information processing with physical processes demands new technology for the integrated modeling of software and physical systems. These models will enable designers to capture complex cross cutting physical constraints that the embedded software must satisfy. The Model-Based Integration of Embedded Software component of this project will use integrated models to analyze and verify the aggregate behavior of software and physical processes, and to automatically customize, integrate system components.

(U) Program Accomplishments and Plans:

(U) FY 1999 Accomplishments:

- Not Applicable.

(U) FY 2000 Plans:

- Networked Embedded Systems. ($ 5.405 Million)
  - Investigate new modeling methods capturing physical constraints in embedded systems such as avionics and vetronics.
  - Develop customizable modeling tools that can be rapidly adjusted to different modeling views and application domains.
  - Investigate new generation technology with capability to configure, customize and synthesize software directly from models.

(U) FY 2001 Plans:

- Model-Based Integration of Embedded Software. ($ 9.925 Million)
  - Develop modeling tools that can manage overlapping modeling views.
  - Investigate methods for the mathematical modeling and composition of model-based software generators.
  - Develop customizable frameworks for embedded software.
  - Demonstrate the rapid synthesis of embedded systems using customizable frameworks and model-based generators.

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- Networked Embedded Systems. ($ 3.588 Million)
  - Develop methods for maintaining and updating critical information (system and resource states, global time, etc.) system-wide, without centralized depository.
  - Investigate event/time triggered system synthesis methods subject to time, functional, performance, safety and security constraints.
  - Investigate design methods of embedded generators that guarantee selected behaviors of the generated systems.

(U) Other Program Funding Summary Cost:

- Not Applicable.

(U) Schedule Profile:

- Not Applicable.

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APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA2 Applied Research				R-1 ITEM NOMENCLATURE Extensible Information Systems PE 0602302E, Project AE-02					
COST *(In Millions)*	FY 1999	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	Cost to Complete	Total Cost
Software for Autonomous Systems AE-02	0.000	16.873	17.171	44.851	35.000	32.000	33.000	Continuing	Continuing

(U) Mission Description:

(U) This project develops software to enable predictable, safe, and cooperative operation of free ranging, autonomous systems. This effort includes software for mobile robots (air, land or maritime unmanned vehicles) performing tasks in dynamic, unstructured (physical) environments without the need for synchronous, operator control inputs or high quality communications links. Similarly, this effort includes the development of software agents (knowbots) that can range over cyberspace performing information services, including the capability to negotiate for and assign selected resources. Further, these autonomous systems should be able to learn and adapt to change and uncertainty while improving with experience.

(U) Autonomous systems will enable revolutionary, asymmetric military capabilities, such as the ability to autonomously convey military payloads (both lethal and non-lethal) to any portion of the battlefield without requiring human operators and the ability to autonomously retrieve, process and deliver information.

(U) The Common Software for Autonomous Robotics component of this project will develop a combination of critical, enabling software technologies that can be reused across a wide range of mobile autonomous robotic systems.

(U) The Software Enabled Control component will leverage increased processor and memory capacity to vastly increase our ability to maintain control over mobile devices through the development of novel techniques, such as: predictive mode changes, dynamic control scheduling, composable coordinated control, and dynamic sensor and actuator allocation.

(U) The Agent Based Negotiation component will enable the autonomous operation of large collections of agents negotiating resource allocation issues, such as those encountered in logistics and countermeasures.

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(U) Program Accomplishments and Plans:

(U) FY 1999 Accomplishments:

- Not Applicable.

(U) FY 2000 Plans:

- Common Software for Autonomous Robotics. ($ 6.734 Million)
  - Develop architectures for the integration of deliberative, reactive and learning behaviors, including knowledge representations.
  - Laboratory demonstration of alternative approaches to off-line learning.
  - Laboratory demonstration of rapid sensor-motor mapping.
  - Laboratory demonstration of "engineered" behaviors.
  - Laboratory demonstration of "statistical" control.

- Software Enabled Control. ($ 6.950 Million)
  - Specify architecture for a hybrid control system that synthesizes the control law approach with computationally-enabled mode logic scalable to very large state spaces of 100K+ states.
  - Develop active transition control and joint mode logic/control law designs.
  - Design services for active model creation, augmentation, and query.

- Agent Based Negotiation. ($ 3.189 Million)
  - Develop framework for bottom-up organization of autonomous software.
  - Define strategy for tasking and consolidation of responses from large numbers (thousands) of software agents with minimal human intervention.

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(U) FY 2001 Plans:

- Common Software for Autonomous Robotics. ($ 4.963 Million)
  - Experimental evaluation of networking protocols for distributed robot controls that are more energy efficient than conventional implementations.
  - Prototype demonstration and experimental evaluation of software for distributed robotics capable of coordinating the operation of 10+ robotic devices in a collective task.

- Software Enabled Control. ($ 9.727 Million)
  - Alpha-level prototype implementation of multi-mode control architecture and framework.
  - Develop predictive active model framework.
  - Develop parametric predictive and adaptive control frameworks.
  - Complete multi-level, multi-modal advanced design tools.

- Agent Based Negotiation. ($ 2.481 Million)
  - Prototype demonstration of autonomous software ability to utilize negotiation in logistics scenario.
  - Develop analysis strategy for predicting global behavior of large negotiating teams.

(U) Other Program Funding Summary Cost:

- Not Applicable.

(U) Schedule Profile:

- Not Applicable.

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APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA2 Applied Research				R-1 ITEM NOMENCLATURE Extensible Information Systems PE 0602302E, Project AE-03					
COST *(In Millions)*	FY 1999	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	Cost to Complete	Total Cost
Software for Embedded Systems AE-03	0.000	7.722	23.821	27.700	12.000	15.000	10.000	Continuing	Continuing

(U) Mission Description:

(U) This project develops a new class of software to deal with the processing of physical world information by networked embedded devices. The convergence of processing power, vanishing size and decreasing cost of today's microprocessors has created new devices and micro-sensors that enable a new wave of DoD applications. For example, cheap, smart micro-sensors can be deployed quickly in large quantities in the battlefield to perform new monitoring and control functions; and a host of sensors can be attached to warfighters and assets to autonomously monitor safety and health information, and equipment condition.

(U) Harnessing the full potential of micro-sensors and embedded devices requires addressing new information technology challenges. Networking these untethered devices creates new requirements on hardware and software, including rapid self-assembly, timely acquisition, processing and exchange of sensor data, and energy efficient operation. Accurate identification of events and collection of information require new ways of cooperation among these devices to process physical world signals, and to integrate information in the network. Additionally, remote querying and accessing data collected by the sensor net should be simple, with easy to use interfaces.

(U) This project will build on Software and Networking R&D activities, extending and specializing them to geographically distributed micro-sensor networks. A major challenge is the development of software technologies that spans a variety of sensor nets, on ground and water, on buildings and bodies. Another challenge is to design reliable networked embedded systems retaining only supervisory control, while automating traditional "in-the-loop" tasks. The sensor tasking, data collection, integration and analysis must be fully automated to enable operation within time constraints far shorter than could be achieved by human operators.

(U) As software systems become more complex, they must be able to reconfigure and evolve themselves dynamically, while the system is in operation. This project will develop the dynamic gauges or measures of composability necessary to enable software components from any source to support assured applications (Dynamic Assembly for Systems Adaptability, Dependability and Assurance (DASADA)). Outputs from this program will ensure that the critical properties of complex, heterogeneous software systems are maintained during and after composition, adaption and deployment.

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(U) Program Accomplishments and Plans:

(U) FY 1999 Accomplishments:

- Not Applicable.

(U) FY 2000 Plans:

- Large Scale Networks of Sensors. ($ 7.722 Million)
  - Specify diffusion based approaches to networking, and aggregation and distribution of information from large numbers of multi-taskable sensor nodes.
  - Explore low-latency system designs; develop experimental platform and simulation capability.
  - Develop methods for collaborative signal processing and information integration.
  - Investigate use of declarative interfaces for tasking and querying of networked embedded systems; develop experimental prototype based on relational database query technology and lightweight operating environment.

(U) FY 2001 Plans:

- Large Scale Networks of Sensors. ($ 16.873 Million)
  - Implement experimental prototype supporting automated aggregation and distribution of sensor derived information involving at least 50 nodes and 100 sensors.
  - Investigate methods for efficient interoperation of fixed and mobile sensors.
  - Implement networked detection, estimation, tracking, and information integration.
  - Demonstrate multi-node sensor network software and benefits of collaborative signal processing for military operations such as fast moving target detection and urban operations.
  - Prototype demonstration using declarative interfaces for tasking and querying of multi-taskable sensor networks.
  - Specify interfaces supporting common run-time services required by signal processing and generation applications.

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- Dynamic Assembly for Systems Adaptability, Dependability and Assurance (DASADA). ($ 6.948 Million)
  - Conduct preliminary demonstrations of dynamic software component composability with multiple standard communication (e.g. Distributed Component Object Model (DCOM), Common Object Request Broker Architecture (CORBA), Distributed Computing Environment (DCE)) or structuring (e.g., Extended Markup Language (XML), Resource Description Framework (RDF), Document Object Model (DOM)) infrastructures.

(U) Other Program Funding Summary Cost:

- Not Applicable.

(U) Schedule Profile:

- Not Applicable.

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APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA2 Applied Research				R-1 ITEM NOMENCLATURE Extensible Information Systems PE 0602302E, Project AE-04					
COST *(In Millions)*	FY 1999	FY2000	FY2001	FY2002	FY2003	FY2004	FY2005	Cost to Complete	Total Cost
Gigabyte Applications AE-04	0.000	0.000	14.777	19.785	18.000	13.000	10.000	Continuing	Continuing

(U) Mission Description:

(U) This project is developing the technology to enable robust operation of DoD's mission-critical systems and platforms that are inherently geographically dispersed and are dependent on extremely high data flows. Capabilities for end-applications to tie in with other applications as well as with signals from multiple hardware sources and with human users will be developed with technologies that allow ultra high-throughput, sustained low-latency data delivery and processing. Gigabyte to terabyte flow transfers across end applications will be demonstrated over wide-area networks. The project will also develop robust, survivable inter-networking architecture that will minimize vulnerability posed by the growing complexity and brittleness that is seen across physical layer networking architecture today.

(U) The efforts will leverage some of the advances made within earlier programs, such as the Next Generation Internet for high-speed communications and networking, but will largely target breakthroughs in DoD focused gigabyte applications, in gigabyte dataflows over wireless as well as wireline infrastructure, and in enhancing the robustness of these heterogeneous links and resources. Advances in architectural work and tools in ultra-high-performance heterogeneous flow-based communications will be pursued to enable a large number of end applications with extremely diverse traffic characteristics – expected for DoD supporting applications - to be simultaneously deployed. With the optical communications techniques that can now support many hundreds of Gigabits Per Second (Gbps) data transfer over terrestrial fiber cables, there exists today a huge bandwidth gap between wireless and wired link capability. In the Gigabit Multi-Link component of this project, new gigabit per second communication capabilities over alternate physical media will be demonstrated such that gigabyte flow transfers can be demonstrated to sites lacking in fiber infrastructure and connectivity. Multi-channel techniques in temporal, spatial, and spectral domains will be invoked to enable the new capabilities.

(U) Program Accomplishments and Plans:

(U) FY 1999 Accomplishments:

- Not Applicable.

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(U) FY 2000 Plans:

- Not Applicable.

(U) FY 2001 Plans:

- Ultra-High Performance Heterogeneous Flow-Based Communications. ($ 7.300 Million)
  - Develop software and physical interfaces that can adapt or be programmed to support diverse link protocols, symbol rates and signaling technologies.
  - Demonstrate gateway technology that can segregate long flows from short flows.
  - Prototype implementation for transparent, vertical handoff between flow-based and circuit-based connectivities.

- Gigabit Multi-Link. ($ 7.477 Million)
  - Demonstrate an order of magnitude increase in wireless spectral efficiency for non-mobile end nodes.
  - Establish feasibility of 10 Gbps transmission over 10km free-space link.
  - Demonstrate adaptive multi-link coding technique to enhance immunity to degradations due to mobility or environmental (weather, obstruction) changes.

(U) Other Program Funding Summary Cost:

- Not Applicable.

(U) Schedule Profile:

- Not Applicable.