Exhibit R-2, PB 2010 Defense Advanced Research Projects Agency **RDT&E Budget Item Justification**	**DATE:** May 2009
APPROPRIATION/BUDGET ACTIVITY 0400 - Research, Development, Test & Evaluation, Defense-Wide/BA 2 - Applied Research	**R-1 ITEM NOMENCLATURE** PE 0602304E COGNITIVE COMPUTING SYSTEMS

COST ($ in Millions)	FY 2008 Actual	FY 2009 Estimate	FY 2010 Estimate	FY 2011 Estimate	FY 2012 Estimate	FY 2013 Estimate	FY 2014 Estimate	FY 2015 Estimate	Cost To Complete	Total Cost
Total Program Element	157.897	144.869	142.840						Continuing	Continuing
COG-01: COGNITIVE SYSTEMS COMPUTING FOUNDATIONS	2.308	0.000	0.000						Continuing	Continuing
COG-02: COGNITIVE COMPUTING	88.331	88.392	98.429						Continuing	Continuing
COG-03: COLLECTIVE COGNITIVE SYSTEMS AND INTERFACES	67.258	56.477	44.411						Continuing	Continuing

A. Mission Description and Budget Item Justification

(U) The Cognitive Computing Systems program element is budgeted in the Applied Research budget activity because it is developing the next revolution in computing and information processing technology that will enable computational systems to have reasoning and learning capabilities and levels of autonomy far beyond those of today's systems. The ability to reason, learn and adapt will raise computing to new levels of capability and powerful new applications.

(U) Military command, control, communications, and intelligence/information systems must support warfighters in operations ranging from conflict and peacekeeping in urban centers to heavy battle actions in remote areas. Current capabilities do not provide the commander with real-time, secure, situational awareness nor with the capability to orchestrate high-tempo planning, rehearsal, and execution. The programs in this project are developing and testing innovative, secure architectures and tools to enhance information processing, dissemination, and presentation capabilities. The programs provide the commander insight into the disposition of enemy and friendly forces, a joint situational awareness picture that will improve planning, decision-making, and execution support capability, as well as secure multimedia information interfaces and software assurance to the warfighter "on the move." Integration of collection management, planning, and battlefield awareness are essential elements for achieving battlefield dominance through assured information systems.

(U) The Cognitive Computing project will develop core technologies that enable computing systems to learn, reason and apply knowledge gained through experience, and respond intelligently to things that have not been previously encountered. These technologies will lead to systems demonstrating increased self-reliance, self-adaptive reconfiguration, intelligent negotiation, cooperative behavior and survivability with reduced human intervention.

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(U) The Collective Cognitive Systems and Interfaces Project will dramatically improve warfighter and commander effectiveness and productivity using advanced cognitive approaches that enable faster, better informed, and more highly coordinated actions than those of our enemies. This will be accomplished by developing revolutionary methods that increase our information processing capabilities, enhance our situational awareness, and enable more cohesive group action by our forces. Critical technical areas addressed in this project include automated coordinated decision support, information sharing, and ensured communications.

B. Program Change Summary ($ in Millions)

	FY 2008	FY 2009	FY 2010	FY 2011
Previous President's Budget	174.680	145.262	135.671	
Current BES/President's Budget	157.897	144.869	142.840	
Total Adjustments	-16.783	-0.393	7.169	
Congressional Program Reductions	0.000	-0.393		
Congressional Rescissions	-2.000	0.000		
Total Congressional Increases	0.000	0.000		
Total Reprogrammings	-10.000	0.000		
SBIR/STTR Transfer	-4.783	0.000		
TotalOtherAdjustments			7.169	

Change Summary Explanation

FY 2008
Decrease reflects Section 8042 rescission, the AFRICOM reprogramming, and the SBIR/STTR transfer.

FY 2009
Decrease reflects the Section 8101 Economic Assumptions.

FY 2010
Increase reflects minor repricing of cognitive computing systems programs, particularly in the area of software/algorithm development.

Exhibit R-2a, PB 2010 Defense Advanced Research Projects Agency **RDT&E Project Justification**	**DATE:** May 2009

APPROPRIATION/BUDGET ACTIVITY	**R-1 ITEM NOMENCLATURE**	**PROJECT NUMBER**
0400 - Research, Development, Test & Evaluation, Defense-Wide/BA 2 - Applied Research	PE 0602304E COGNITIVE COMPUTING SYSTEMS	COG-01

COST ($ in Millions)	FY 2008 Actual	FY 2009 Estimate	FY 2010 Estimate	FY 2011 Estimate	FY 2012 Estimate	FY 2013 Estimate	FY 2014 Estimate	FY 2015 Estimate	Cost To Complete	Total Cost
COG-01: COGNITIVE SYSTEMS COMPUTING FOUNDATIONS	2.308	0.000	0.000						Continuing	Continuing

A. Mission Description and Budget Item Justification

(U) The Cognitive Systems Computing Foundations project made fundamental advances in our understanding of and ability to create more intelligent information and computing systems. New foundational hardware architectures and software methods to facilitate learning and inference capabilities were created that are crucial to intelligent computing. These new computing foundations will help us move far beyond today's standard Von Neumann computing model. Transition goals include next-generation network-centric systems and platform-specific information collection and processing systems. This project will complete with FY 2008 funding and on-going efforts will continue in other Program Elements.

B. Accomplishments/Planned Program ($ in Millions)	FY 2008	FY 2009	FY 2010	FY 2011
Self-Regenerative Systems (SRS) (U) The Self-Regenerative Systems (SRS) program designed, developed, demonstrated and validated architectures, tools, and techniques for fielding systems capable of adapting to novel threats, unanticipated workloads and evolving system configurations. The technology developed under this program employed innovative techniques including biologically-inspired diversity, cognitive immunity and healing, granular and scalable redundancy, and higher-level functions such as reasoning, reflection and learning. These technologies will make critical future information systems more robust, survivable and trustworthy. The SRS program also developed technologies to mitigate the insider threat. (U) SRS-enabled systems are able to reconstitute their full functional and performance capabilities after experiencing an accidental component failure, software error, or even an intentional cyber-attack. SRS systems show a positive trend in reliability, exceed initial operating capability and approach a theoretical optimal performance level over long time intervals. They also maintain robustness and trustworthiness attributes even with growth and evolution in functionality and performance.	2.308	0.000	0.000	

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APPROPRIATION/BUDGET ACTIVITY 0400 - Research, Development, Test & Evaluation, Defense-Wide/BA 2 - Applied Research	**R-1 ITEM NOMENCLATURE** PE 0602304E COGNITIVE COMPUTING SYSTEMS		**PROJECT NUMBER** COG-01	

B. Accomplishments/Planned Program ($ in Millions)	**FY 2008**	**FY 2009**	**FY 2010**	**FY 2011**
FY 2008 Accomplishments: - Developed additional general strategies and techniques to automatically immunize systems against new attacks and preempt insider attacks; combining and correlating information from system layers using direct user challenges.				

C. Other Program Funding Summary ($ in Millions)

N/A

D. Acquisition Strategy

N/A

E. Performance Metrics

Specific programmatic performance metrics are listed above in the program accomplishments and plans section.

Exhibit R-2a, PB 2010 Defense Advanced Research Projects Agency **RDT&E Project Justification**		**DATE:** May 2009
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COST ($ in Millions)	FY 2008 Actual	FY 2009 Estimate	FY 2010 Estimate	FY 2011 Estimate	FY 2012 Estimate	FY 2013 Estimate	FY 2014 Estimate	FY 2015 Estimate	Cost To Complete	Total Cost
COG-02: COGNITIVE COMPUTING	88.331	88.392	98.429						Continuing	Continuing

A. Mission Description and Budget Item Justification

(U) The Cognitive Computing project will develop core technologies that enable computing systems to learn, reason and apply knowledge gained through experience, and to respond intelligently to new and unforeseen events. These technologies will lead to systems with increased self reliance, cooperative behavior, and the capacity to reconfigure themselves and survive with reduced programmer intervention. These capabilities will make the difference between mission success and mission degradation or failure, even in the event of cyber-attack or component attrition resulting from kinetic warfare or accidental faults and errors. Systems that learn and reason will reduce the requirement for skilled system administrators and dramatically reduce the overall cost of system maintenance. As the military moves towards a dynamic expeditionary force, it is critical for systems to become more self sufficient.

B. Accomplishments/Planned Program ($ in Millions)	FY 2008	FY 2009	FY 2010	FY 2011
Personalized Assistant that Learns (PAL) (U) The Personalized Assistant that Learns (PAL) program enables intelligence in information processing systems so that critical DoD systems can better support the warfighter. PAL systems will have embedded learning capabilities that will allow them to retain prior learned knowledge, apply this knowledge to new scenarios and ultimately provide faster and more effective assistance. Overall, the ability to learn will enable the performance of a PAL system to improve over time. Cognitive systems technologies developed in this program will be applied and demonstrated in the Increased Command and Control Effectiveness (ICE) program (PE 0603760E, Project CCC-01) prior to transition into Command Operations. (U) The PAL program is creating the first comprehensive system that will dramatically empower commanders to understand all aspects of the current military situation, radically reduce manpower and labor required in command posts and in the field, and automate the massive number of administrative and analytical tasks characteristic of today's command centers. PAL capabilities will result in the ability to turn diverse, multi-source data into actionable information for commanders and warfighters; dramatic manpower reductions; corporate memory retention of both the larger conflict history and the history of each specific command center; and intelligent information presentation.	34.114	27.344	26.275	

Exhibit R-2a, PB 2010 Defense Advanced Research Projects Agency RDT&E Project Justification		DATE: May 2009
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B. Accomplishments/Planned Program ($ in Millions)	FY 2008	FY 2009	FY 2010	FY 2011
(U) PAL will create an intelligent desktop assistant that enables users to create and share routines to discover, manipulate, and exploit data, services and web content. This work will extend the emerging web services paradigm to produce semantically-enabled search and processing capabilities that make it easier to find information on the Internet and get it into the form a user needs. Ultimately this work will yield cognitive search agents that greatly reduce the time it takes users to find and process information. *FY 2008 Accomplishments:* - Developed, demonstrated, and evaluated core physical awareness, cyber-awareness, multimodal dialogue, machine learning, and representation and reasoning technologies to support cognitive assistant executive functions. - Formulated an approach for receiving user guidance and translating it into the precise machine language necessary for both implementation and verification of user purpose and intent. - Demonstrated the utility of PAL technologies for the Army Knowledge Online's Company Command online community. - Optimized PAL technology to provide maximum benefit to operational users. - Demonstrated PAL technologies on data from a number of operational military systems and used the results of these demonstrations as lessons-learned for integration activities being conducted in military environments. (See PE 0603760E, Project CCC-01 for additional details). *FY 2009 Plans:* - Develop a dialogue system with general and domain-specific semantics for eliciting natural language advice from the warfighter and other end users of PAL technology and PAL-enhanced systems. - Develop the ability for an integrated cognitive system such as PAL to examine its own behavior and learn from that experience. - Extend, improve, and optimize PAL technology based on initial user feedback. *FY 2010 Plans:* - Fine tune all algorithms for scale-up, response time and throughput. - Finalize human-computer interface and complete the debugging of all PAL software.				

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B. Accomplishments/Planned Program ($ in Millions)	**FY 2008**	**FY 2009**	**FY 2010**	**FY 2011**
- Integrate dialogue system with semantically-enabled search capabilities to enable intelligent, user-defined Web search routines. - Create the ability for cognitive systems to exchange locally-learned knowledge.				
Integrated Learning (U) The Integrated Learning program is creating a new computer learning paradigm in which systems learn complex workflows from warfighters while the warfighters perform their regular duties. The effort is focused on military planning tasks such as air operations center planning and military medical logistics. With this learning technology, it will be possible to create many different types of military decision support systems that learn by watching experts rather than relying on expensive and error prone hand-encoded knowledge. The new learning paradigm differs from conventional machine learning in that it does not rely on large amounts of carefully crafted training data. Rather, in the new paradigm the learner works to “figure things out” by combining many different types of learning, reasoning, and knowledge. Such a cognitive system will ultimately need the capability to build and update its own internal model of the world and the objects in it without human input. *FY 2008 Accomplishments:* - Enhanced integrated learning systems so the systems form explicit learning goals, make plans to achieve these goals, create hypotheses about learned knowledge where appropriate, and resolve sources of uncertainty in learned knowledge where it exists. - Expanded systems so they combine different types of knowledge and reasoning, based on the situation and information that is available. - Modified existing algorithms so they track uncertainty about information. - Evaluated systems by having them learn expanded/full processes and procedures for air control order planning and military medical evacuation planning. *FY 2009 Plans:* - Modify the integrated learning systems so they can incorporate new software components dynamically and utilize the new capabilities while learning.	20.011	17.160	15.068	

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B. Accomplishments/Planned Program ($ in Millions)	**FY 2008**	**FY 2009**	**FY 2010**	**FY 2011**
- Create control algorithms for the systems that manage credit-and-blame assignment on a component-by-component basis so that if conflicts arise the system can reason about which piece of conflicting information is more likely to be accurate. - Create control algorithms that reason about the costs/benefits of resolving a particular conflict and direct system performance accordingly. - Expand the scope of the problems being learned so the systems learn multi-user task models. - Evaluate systems by having them compete against expert humans. *FY 2010 Plans:* - Modify the integrated learning systems to be able to abstract the details of the process it is learning and learn general process or meta process knowledge. - Extend capabilities of the integrated learning systems so they can share information (low-level data, mid-level hypothesis, and high-level conclusions) with other learners. - Field test integrated learning systems within operational military environments. - Evaluate systems by having them compete against expert humans.				
Bootstrapped Learning (U) The Bootstrapped Learning program will provide computers with the capability to learn complex concepts the same way people do: from a customized curriculum designed to teach a hierarchy of concepts at increasing levels of complexity. Learning each new level depends on having successfully mastered the previous level's learning. In addition, the learning program will be “reprogrammable” in the field using the same modes of natural instruction used to train people without the need for software developers to modify the software code. At each level, a rich set of knowledge sources (such as training manuals, examples, expert behaviors, simulators, and references and specifications that are typically used by people learning to perform complex tasks) will be combined and used to generate concepts and a similar set of knowledge sources for the next level. This will enable rapid learning of complex high-level concepts, a capability which is essential for autonomous military systems that will need to understand not only what to do but, why they are doing it, and when what they are doing may no longer be appropriate.	6.673	9.081	8.650	

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B. Accomplishments/Planned Program ($ in Millions)	FY 2008	FY 2009	FY 2010	FY 2011
FY 2008 Accomplishments: - Produced a prototype end-to-end system capable of bootstrapped learning, integrating different types of learning, input modalities, and repeatedly building on prior learning. - Developed a complete electronic curriculum for three domains, including prerequisite knowledge, teaching algorithms, as well as curriculum development tools. - Demonstrated the ability to learn a curriculum composed of at least three related lessons via at least three different interaction modalities and at least two different learning processes. *FY 2009 Plans:* - Demonstrate a single system capable of being instructed to perform in three diverse domains. - Demonstrate the ability of a system to repeatedly acquire new knowledge that drives future learning and cumulatively adds to the system's knowledge. - Validate that configuration and control of critical, autonomous military hardware can be addressed with bootstrapped learning technology. *FY 2010 Plans:* - Establish incontrovertible system generality by demonstrating learning performance in a "surprise" domain that is completely unknown to the learning system developers. - Enhance system capabilities to include instructable situational awareness.				
Machine Reading and Reasoning Technology* *Formerly Knowledge Representation and Reasoning Technology. (U) The Machine Reading and Reasoning Technology program will develop enabling technologies to acquire, integrate, and use high performance reasoning strategies in knowledge-rich domains. Such technologies will provide DoD decision makers with rapid, relevant knowledge from a broad spectrum of sources that may be dynamic and/or inconsistent. To address these significant challenges of context, temporal information, complex belief structures, and uncertainty, new capabilities are needed to extract key information and metadata, and to exploit these via context-capable search and inference (both deductive and inductive). DoD systems sense, capture, and store information in the form of text, audio,	2.346	7.807	12.450	

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B. Accomplishments/Planned Program ($ in Millions)	**FY 2008**	**FY 2009**	**FY 2010**	**FY 2011**

imagery, and video. Therefore, advanced machine reasoning capabilities must extract knowledge from, and reason about, all types of multimedia data. This research will explore new computational models to enable command and control systems to use conceptual representations to perform perception-based cognition and to assist the commander in understanding and analyzing complex battlefield scenarios. Perception-based cognition and visual-spatial reasoning are of particular interest.

(U) Machine reading addresses the prohibitive cost of handcrafting information by replacing the expert, and associated knowledge engineer, with un-supervised or self-supervised learning systems, systems that “read” natural text and insert it into AI knowledge bases, i.e. data stores especially encoded to support subsequent machine reasoning. Machine reading requires the integration of multiple technologies: natural language processing must be used to transform the text into candidate internal representations, and knowledge representation and reasoning techniques must be used to test this new information to determine how it is to be integrated into the system’s evolving models so that it can be used for effective problem solving.

FY 2008 Accomplishments:
- Demonstrated novel methods for acquiring new knowledge directly from processing natural language text.
- Developed a proof-of-concept machine reading prototype that learned by reading small focused texts, encoded knowledge from these texts, and answered narrow queries that required deep semantic representations.

FY 2009 Plans:
- Extend knowledge representation to support machine reading of large (e.g. open source web) amounts of material with the goal of encoding and querying at broad, but shallow semantic levels.
- Produce domain representations that enable semi-supervised approaches to knowledge acquisition.

FY 2010 Plans:
- Demonstrate the ability of a system to acquire and organize factual information directly from unstructured narrative text in multiple domains.

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B. Accomplishments/Planned Program ($ in Millions)	FY 2008	FY 2009	FY 2010	FY 2011
- Develop knowledge representation and reasoning capabilities to support simple temporal reasoning using ordered relationships in text. - Demonstrate ability of machine reading systems to extract knowledge from texts that employ varied writing styles and require contextualization for proper interpretation. - Design new cognitive architectures that combine new ideas in visual concept learning, analysis, and imagination with traditional machine reasoning techniques. - Conduct initial development of visual processing modules that provide more intuitive, common sense, human-like and efficient visual reasoning.				
Foundational Learning Technology (U) The Foundational Learning Technology program develops advanced machine learning techniques that enable cognitive systems to continuously learn, adapt and respond to new situations by drawing inferences from past experience and existing information stores. One very promising approach involves transfer learning techniques that transfer knowledge and skills learned for specific situations to novel, unanticipated situations and thereby enable learning systems to perform appropriately and effectively the first time a novel situation is encountered. This is essential because most military operations occur in ever-changing environments; U.S. forces and systems must be able to act appropriately and effectively the first time each novel situation is encountered. (U) The Foundational Learning Technology program will develop techniques that enable cognitive systems to reason about their own reasoning and, hence, learn a self model. This capability will allow the system to explain itself during learning, for example, by constructing memory traces of how reasoning occurred. Meta-level monitoring of traces then produces an explanation of why reasoning might fail, and introspection enables the construction of an explicit learning strategy driven by this self-model. (U) The Cortical Algorithm program will model the sub-symbolic “instruction set” of the brain. It will create a new, non-symbolic representation/reasoning paradigm based upon a universal algorithm that starts with zero knowledge and recursively builds upon learned knowledge through self-direction. This new paradigm would enable systems to learn through immersion, representing structure latent in the environment and	14.603	10.000	14.196	

B. Accomplishments/Planned Program ($ in Millions)	FY 2008	FY 2009	FY 2010	FY 2011
modeling its own behavior on the observed behavior of other agents in the world, resulting in much greater autonomy and reducing the need for human interaction. *FY 2008 Accomplishments:* - Demonstrated the ability of a cognitive agent to learn, combine, and restructure knowledge in multiple domains and applied this to solve novel problems in those domains. - Demonstrated the ability of a cognitive agent to generalize knowledge from particular domains and discovered how to apply it to a problem in a new domain. - Demonstrated the ability of a cognitive agent to synthesize knowledge and skills acquired from multiple domains, applied them effectively to problems in new domains, and demonstrated the ability to propose novel problem solution methods when specified resources are unavailable. *FY 2009 Plans:* - Demonstrate the ability of agents to learn in a visual domain and apply the knowledge to solve problems in an action domain such as robotic grasping. - Conceptualize and propose algorithms that can take unorganized numeric inputs and, through interaction, “see” that these inputs represent some structured universe that obeys structured laws. *FY 2010 Plans:* - Construct a single, general-purpose algorithm which could start with zero knowledge of its environment, and then grow to represent the structure latent in that environment. - Create a self-explaining module that helps debug agent programs by mapping anomaly symptoms to causal faults. - Build infrastructure to support reflective records of decision-making tied to behavior traces.				
Robust Robotics (U) The Robust Robotics program is developing advanced robotic technologies that will enable autonomous (unmanned) mobile platforms to perceive, understand, and model their environment; navigate through complex, irregular, and hazardous terrain; manipulate objects without human control or intervention; make intelligent decisions corresponding to previously programmed goals; and interact	10.584	15.000	16.490	

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B. Accomplishments/Planned Program ($ in Millions)	**FY 2008**	**FY 2009**	**FY 2010**	**FY 2011**
cooperatively with other autonomous and manned vehicles. These capabilities will enable robotic vehicles to support warfighters in diverse environments including urban, ground, air, space, and underwater. A key objective is robust navigation and locomotion, since this underlies the ability to move through the difficult and unpredictable terrain of theater operations, which may include highly irregular and mountainous areas, partially-destroyed roads, rubble-filled urban terrain, and other vehicles and personnel. Efforts are being made to develop learning and reasoning technologies to address specific concerns in both wheeled and legged robotic systems. There is also interest in anthropomorphic humanoid robots that can leverage the worldwide infrastructure built for humans (e.g., occupy seats in transport vehicles, climb stairs, grasp knobs/handles and open doors, etc.) and free our soldiers from dangerous tasks such as search and rescue missions. (U) Robust Robotics is developing techniques for robots to perform in dynamic environments by improving robotic vision and scene understanding, including the capability to predict the future location and even the intent of moving objects. U.S. National security will require future autonomous systems that achieve a much higher autonomy level when performing complex tasks. Robust Robotics is developing techniques that will enable robotic agents to achieve effective levels of autonomous reasoning and manipulation whether humans are present or not. Robotic agents must also be able to effectively perform when they are part of a team and assume semi-independent roles across a variety of activities. This will be achieved by developing robotic systems that can accept and understand instructions to define new activities and their variants from human controllers. Robust Robotics is also addressing the need for future U.S. unmanned vehicles to perform reliably in the absence of GPS, which can be achieved by recognition of local features, including man-made and natural features, for navigation in diverse environments. *FY 2008 Accomplishments:* - Created new learning algorithms that use dynamic gaits to enable legged laboratory robots (small scale versions of operational size platforms) to run over uneven terrain. - Evaluated new learning algorithms on a series of different terrain settings in a competitive fashion. - Transferred the best performing navigation methods learned on a small-scale vehicle to the large robotic vehicle, Crusher, to operate at increased speeds in complex environments. - Funded prizes and support for the DARPA Urban Challenge.				

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B. Accomplishments/Planned Program ($ in Millions)	**FY 2008**	**FY 2009**	**FY 2010**	**FY 2011**
FY 2009 Plans: - Create new and modify existing learning algorithms to enable legged laboratory robots (small scale versions of operational sized platforms) to run over terrain at speeds proportional to humans. - Evaluate the new learning algorithms on a series of different terrain settings in a competitive fashion. - Port learning locomotion algorithms to larger scale vehicles to increase mobility of larger scale robots. - Create learning locomotion toolkits that will control a diverse set of high-degree-of-freedom vehicles on rough terrain. *FY 2010 Plans:* - Develop representations and algorithms to track and classify moving objects despite extensive occlusion and poor GPS coverage. - Develop reasoning techniques for dynamic environments that predict non-deterministic mover behaviors given noisy estimates of mover velocity and unreliable tracking due to occlusions. - Develop motion planning algorithms for cluttered, dynamic environments. - Integrate motion understanding and reasoning for dynamic environments on a Government furnished platform and demonstrate travel at 1 mph with five independent movers over 100 meters of crowded urban terrain. - Develop a mobile manipulator--a four-wheeled mobile base and two arms, each with multi-fingered hands--to serve as a common development platform. - Develop controllers that simultaneously manage the degrees of freedom from the base and from the arms and hands. - Develop recognition-based navigation techniques for the case where all data needed for recognition-based navigation (e.g., landmarks, topography) will either be pre-loaded (i.e., organic) or obtained using on-board sensors, and the vehicle/system will not receive any information from external sources.				
Biomimetic Computing* *Previously this was part of Foundational Learning Technology. (U) Biomimetic Computing's goal is to develop the critical technologies necessary for the realization of a Conscious Artifact comprised of biologically derived simulations of the brain embodied in a mechanical	0.000	2.000	5.300	

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B. Accomplishments/Planned Program ($ in Millions)	**FY 2008**	**FY 2009**	**FY 2010**	**FY 2011**
(robotic) system, which is further embedded in a physical environment. These devices will be a new generation of autonomous flexible machines that are capable of pattern recognition and adaptive behavior and that demonstrate a level of learning and cognition. Key enabling technologies include simulation of brain-inspired neural systems and special purpose digital processing systems designed for this purpose. *FY 2009 Plans:* - Create a special purpose processor and associated assembly language to enable systems to have one million neuronal processing units. *FY 2010 Plans:* - Develop the capability to simulate a system of one million thalamocortical neurons with spike time dependent plasticity.				

C. Other Program Funding Summary ($ in Millions)
N/A

D. Acquisition Strategy
N/A

E. Performance Metrics
Specific programmatic performance metrics are listed above in the program accomplishments and plans section.

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COST ($ in Millions)	**FY 2008 Actual**	**FY 2009 Estimate**	**FY 2010 Estimate**	**FY 2011 Estimate**	**FY 2012 Estimate**	**FY 2013 Estimate**	**FY 2014 Estimate**	**FY 2015 Estimate**	**Cost To Complete**	**Total Cost**
COG-03: COLLECTIVE COGNITIVE SYSTEMS AND INTERFACES	67.258	56.477	44.411						Continuing	Continuing

A. Mission Description and Budget Item Justification

(U) The Collective Cognitive Systems and Interfaces project will dramatically improve warfighter and commander effectiveness and productivity using advanced cognitive approaches that enable faster, better informed, and more highly coordinated actions than those of our enemies. This will be accomplished by developing revolutionary methods that increase our information processing capabilities, enhance our situational awareness, and enable more cohesive group action by our forces. Critical technical areas addressed in this project include automated decision support, information sharing, and ensured communications. Cognitive decision support tools reason about tasks, timings, and interactions so that when plans change or the enemy does not respond as anticipated, U.S. forces can quickly adapt. The quality of such decisions and the effectiveness of our actions depend critically on our ability to take full advantage of all available information in a rapid and flexible manner. This requires the capability to share information and to automatically integrate distributed information bases for broad tactical battlespace awareness. Finally, team cohesion requires effective and reliable communication in difficult environments such as urban settings where radio signal propagation is complex. Here the approach is to develop cognitive communications management and control algorithms that reason about channel conditions, higher-level application connectivity requirements and related factors, and decide (often as a group) what parameters (e.g., frequency) each radio will use. The suite of programs under this project will significantly advance the military's ability to successfully deal with complex situations in operational environments.

B. Accomplishments/Planned Program ($ in Millions)	**FY 2008**	**FY 2009**	**FY 2010**	**FY 2011**
Collaborative Cognition (U) The Collaborative Cognition program is aimed at developing technologies that enable individual cognitive agents to work together as a team to provide cooperative support to warfighters in complex military situations. Such situations typically require multiple coordinated tasks that involve information sharing and cooperative efforts. The Collaborative Cognition program will foster the design and implementation of collaborative software agents that operate in dynamic environments, and include both software agents and people. Applications include collaborative surveillance and reconnaissance, logistics re-planning and decision support for unanticipated operational changes, situational analysis and prediction tools, and warfighter/commander decision aids. The technology will also allow software agents to cope	28.800	17.000	10.000	

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B. Accomplishments/Planned Program ($ in Millions)	FY 2008	FY 2009	FY 2010	FY 2011
with limited and/or noisy sensor information, limited communication capabilities, changing and unforeseen environments, other agents, and limited a priori knowledge of each others capabilities. • The Coordination Decision-Support Assistants (COORDINATORs) effort will develop cognitive software coordination managers that provide support to fielded tactical teams. The coordination managers will help fielded units adapt their mission plans in response to unanticipated changes in the mission by tracking personnel, resources, and situational changes, and proposing and evaluating options (adjustments to task timings, changes to task assignments and selection from pre-planned contingencies). This will enable fielded units to respond faster and more accurately to the dynamically changing battlefield situation, requiring far fewer personnel in the re-planning process. COORDINATORs is a distributed technology where a single COORDINATOR will be partnered with each tactical unit or team, and will be able to collaborate and coordinate with other tactical units to optimize needed mission changes. • The Advanced Soldier Sensor Information System and Technology (ASSIST) effort will develop an integrated information system that exploits soldier-worn sensors to augment the soldier's ability to capture, report, and share information in the field. The ASSIST effort will develop an integrated system using advanced technologies for processing, digitizing and analyzing information captured and collected by soldier-worn sensors. ASSIST draws heavily on the experiences and lessons learned from previous Operation Iraqi Freedom (OIF) missions and other surveillance and reconnaissance missions. A baseline system will demonstrate the capture of video/still images together with voice annotations and location-stamping. The advanced system will demonstrate automatic identification and extraction of key objects, events, activities and scenes from soldier-collected data. The system will create knowledge representations that will serve as an input to an array of warfighter products including augmented maps, situational analysis tools, and query and answer capabilities. *FY 2008 Accomplishments:* Coordination Decision-Support Assistants (COORDINATORs) - Modified coordination algorithms so they can reason about the physical geolocation of units and coordinate changes in unit location.				

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B. Accomplishments/Planned Program ($ in Millions)	**FY 2008**	**FY 2009**	**FY 2010**	**FY 2011**
- Modified coordination algorithms so they can operate effectively in network situations where latency may impact communications as it does in field settings. - Developed a coordination autonomy controller that enables a COORDINATOR system to interact intelligently with its human user, generating desired options and waiting for appropriate periods of time for the human to respond. - Developed a change evaluation module that couples the COORDINATOR technology to GPS units so the system automatically knows the location of a given unit. - Developed a basic representation for military decision making policies and procedures so the COORDINATORs follow procedures, and decisions are made at the proper levels. - Evaluated COORDINATORs technologies in a field setting. Advanced Soldier Sensor Information System and Technology (ASSIST) - Demonstrated an automated, sensor-cued collection system for ground patrols and developed interface with the ASSIST-developed Tactical Ground Reporting System (TIGR). - Developed a software system to interpret and automatically index soldier-centric activities, events, scenes, and objects. - Developed analysis tools for the collected data. - Prototyped a two-way capability for alerting patrols in the field. *FY 2009 Plans:* Coordination Decision-Support Assistants (COORDINATORs) - Develop a full and general purpose representation for military decision making policies and procedures so the COORDINATORs know when information must be propagated, and to whom, and reason about the full spectrum of decision authority. - Add learning algorithms to the change evaluation module so it can learn to anticipate problems before they arise. - Add resources and models of resources to the plan representation language and modify the coordination algorithms to coordinate over resources, (e.g., troop transportation vehicles). - Integrate COORDINATORs technologies with SOFTools, a planning system used by U.S. Special Operations Command.				

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B. Accomplishments/Planned Program ($ in Millions)	**FY 2008**	**FY 2009**	**FY 2010**	**FY 2011**
- Evaluate COORDINATORs in a field setting. Advanced Soldier Sensor Information System and Technology (ASSIST) - Establish a Memorandum of Agreement with the U.S. Army to delineate the transition of the TIGR system to a program of record, as well as the schedule for transition. - Demonstrate real-time reporting using on-soldier sensors and an intuitive information push/pull user interface. - Address the technical challenges associated with providing ASSIST as a real-time capability for the dismounted soldier in the field. - Develop and demonstrate a real-time variant for use by dismounted soldiers, with enhancements that include video feeds from airborne platforms. - Develop key technological components that enable in-field data sharing and retrieval on a wearable computing/sensor platform. - Demonstrate eyes-free, hands-free, attention-free collection of key events and experiences for reporting. - Demonstrate tools for analyzing blue-force and red-force trends and patterns. - Demonstrate the system's ability to improve its event and object classification performance through learning; demonstrate an accelerated capability for recognizing new classes of events, objects and activities. - Integrate advanced multimodal sensor event and object extraction techniques into advanced systems and evaluate the enhanced capabilities. *FY 2010 Plans:* Advanced Soldier Sensor Information System and Technology (ASSIST) - Develop the means for efficient transfer of ASSIST information across Army Tactical Networks. - Integrate multiple real-time sensor feeds including high-bandwidth sensor feeds such as video streams. - Integrate with Army Battlefield Command Systems, including consideration of system latencies, and data exchange formats and modalities. - Automate the extraction of relevant portions of feeds for indexing into the TIGR database.				
Cognitive Networking	28.058	25.263	18.909	

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B. Accomplishments/Planned Program ($ in Millions)	FY 2008	FY 2009	FY 2010	FY 2011
(U) The Cognitive Networking program will develop technologies that provide information systems and communication networks with the ability to maintain and self-optimize their own functionality, reliability and survivability. These technologies will allow the military to focus its critical manpower resources on the mission rather than on the maintenance of its information systems and network infrastructure. Research in this area will create a radical new design for distributed computers, device networks, and the software to manage these systems. Cognitive information processing will be used to optimize networked communications based on current conditions, past experience and high-level user guidance. Robotic technologies will be employed where appropriate, for example, to maintain connectivity with small units and individual dismounts on the move. The Cognitive Networking program is also addressing the warfighter's need for actionable situational awareness in complex radio frequency (RF) environments. This work leverages advances in software-defined radio technology to achieve specific military goals. The program has interest in machine learning techniques that can enhance the effectiveness of jamming and other RF countermeasures. So-called "cognitive jamming" has the potential to deny the enemy's effective use of the RF spectrum. The Cognitive Networks effort funds three programs: SAPIENT, LANDroids, and BOSS. • The Situation-Aware Protocols in Edge Network Technologies (SAPIENT) effort will develop a new generation of cognitive protocol architectures to replace conventional protocols that fare poorly in extreme network conditions and do not provide adequate service for key applications. Technology developed in the SAPIENT effort will have military utility wherever tactical communications are deployed. SAPIENT architectures will represent awareness with a knowledge base that is updated based on specification and observation. This technology enables the automatic adaptation of protocols to the operational environment. SAPIENT will exploit attributes of human cognition, such as learning and self-improvement, and apply them to the automated construction of network protocols. Key research challenges for the SAPIENT effort are the use of these cognitive attributes to dramatically reduce the effect of network impairments on applications while demonstrating a positive trend in this capability as new situations are encountered and learned. Desired capabilities include interoperable knowledge representations and rapid incorporation of new knowledge about applications, network conditions and building blocks from which new protocols can be constructed.				

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B. Accomplishments/Planned Program ($ in Millions)	FY 2008	FY 2009	FY 2010	FY 2011
• The Local Area Network droids (LANdroids) effort will give warfighters reliable communications in urban settings. LANdroids will accomplish this by creating robotic radio relay nodes that move autonomously to configure and maintain a communications mesh by reasoning about their positions relative to one another and relative to the warfighters. LANdroids will move as the warfighters move with the goal of maintaining warfighter connectivity throughout their operations. LANdroids will be pocket-sized so warfighters can carry several and drop or deploy them as they move through an area. The effort is creating both the intelligent radio control software and the small radio platform on which it runs. The technologies will be tested in a physical setting and at an operationally relevant scale. • The Brood of Spectrum Supremacy (BOSS) effort will provide actionable situational awareness to the warfighter in complex radio frequency (RF) environments. BOSS adds collaborative processing capabilities to tactical software-defined radios to achieve specific military goals. BOSS exploits cooperative use of computational, communication and sensory capabilities in a software radio, in aggregate, to generate breakthrough capabilities in the warfighter knowledge of their surroundings, with a particular focus on RF-rich urban operations. The BOSS effort will initially focus on modeling and simulation, resulting in hardware-independent executable specifications of waveforms in an interoperable format. Once the modeling and simulation is verified, the BOSS effort will develop a prototype demonstration for a selected RF platform, using and refining the hardware-independent executable specifications of the waveforms. Ultimately this effort will develop Software Communications Architecture (SCA)-compliant waveforms suitable for implementation on a tactical software radio system. *FY 2008 Accomplishments:* Situation-Aware Protocols in Edge Network Technologies (SAPIENT) - Integrated and enhanced prototypes and evaluated their performance. - Refined new knowledge representations appropriate for describing multiple link situations encountered in tactical military networks and for enabling machine response to these situations including automated learning of effective responses. - Researched and integrated new network and application sensors, and adaptation techniques into prototypes. - Refined protocol selection and composition strategies with integrated learning capability strategies.				

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B. Accomplishments/Planned Program ($ in Millions)	FY 2008	FY 2009	FY 2010	FY 2011
- Demonstrated SAPIENT capabilities in laboratory and experimental airborne venues. Local Area Network droids (LANdroids) - Developed control algorithms for LANdroids so they can self-configure, self-optimize, and self-heal. - Developed small robotic LANdroids platforms that meet basic requirements for size and capability. Brood of Spectrum Supremacy (BOSS) - Performed further testing and evaluation of RF-situational awareness algorithms. - Conducted in-depth assessment of candidate BOSS transition platform. *FY 2009 Plans:* Situation-Aware Protocols in Edge Network Technologies (SAPIENT) - Integrate and enhance prototypes and evaluate their performance. - Implement a functional cognitive learning system that facilitates real-time selection and composition of protocols. - Demonstrate an adaptive cognitive prototype in an urban environment using mobile, airborne, and stationary nodes. - Demonstrate prototypes using actual tactical link types. Local Area Network droids (LANdroids) - Evaluate a 10-node LANdroids network with respect to self-configuration, self-optimization and self-healing. - Develop control algorithms for LANdroids that enable them to tether the network to warfighters so the network moves as the warfighters move. - Develop intelligent power management algorithms for LANdroids so they make intelligent decisions about whether or not to move based on current conditions and expected power expenditures and savings. - Develop network load-balancing protocols for LANdroids that dovetail with the power management algorithms to enable the network to last as long as possible. - Harden the LANdroid robotic platform and reduce its weight.				

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B. Accomplishments/Planned Program ($ in Millions)	FY 2008	FY 2009	FY 2010	FY 2011
Brood of Spectrum Supremacy (BOSS) - Refine capabilities of Software Communications Architecture (SCA)-compliant platforms, while working within the software-defined radio trade space. - Validate implementations for network understanding tasks using SCA-compliant platforms. *FY 2010 Plans:* Situation-Aware Protocols in Edge Network Technologies (SAPIENT) - Create an operating system kernel implementation of cognitive protocol management mechanisms. - Develop a Memorandum of Understanding with a Service transition partner. - Demonstrate cognitive networking capabilities in a Command, Control, Communications, Computers, Intelligence, Surveillance, and Reconnaissance (C4ISR) testbed. - Develop a database of network behaviors based on a long term installation at the C4ISR testbed. - Develop methods to resolve contention of multiple SAPIENT instances. Local Area Network droids (LANdroids) - Evaluate tethering, power management and load-balancing algorithms using a 15-node LANdroids network that spans two indoor floors of a building. - Integrate LANdroids algorithms with hardened and lightened robotic platform. - Develop control algorithms for LANdroids that enable LANdroid modes (programmable objective functions, maximize power savings, and maximize throughput). - Develop control algorithms for LANdroids that enable system heterogeneity (systems consisting of multiple gateways, static relays, warfighter handheld relays, and non-relaying static and mobile radios). Brood of Spectrum Supremacy (BOSS) - Modify the design of an existing handheld radio to provide platform for BOSS algorithms. - Collect field data and implement algorithms in a fashion compatible with handheld/wearable radio platforms.				
Cloud Computing *Formerly Integrated Collective Systems	10.400	14.214	15.502	

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B. Accomplishments/Planned Program ($ in Millions)	**FY 2008**	**FY 2009**	**FY 2010**	**FY 2011**
(U) Cloud Computing is a technique to enable information, applications, services, storage, and other resources that reside on military networks to be used by web-based clients to perform critical mission functions. The Cloud Computing program will create architectures to automatically integrate distributed information bases for broad tactical battlespace awareness. The Cloud Computing program will produce the infrastructure and application technologies needed to automate the integration of multiple media (text, video, and digital photographs) as well as its analysis, indexing, and storage so that it can be easily queried and retrieved by users across the DoD enterprise. Inherent to such ubiquitous availability of enterprise data is the need for strong security including fine-grained/role-based access controls. • The Digital Object Storage and Retrieval (DOSR) effort is pursuing a network-based approach to information storage and management that will enable a network-based repository to hold all digital information. The DOSR repository will reside on the network and provide a mechanism for the virtual (i.e., logical, not physical) centralization of all enterprise information. DOSR technology will enable and facilitate controlled access to information by approved and authenticated users across administrative domains, and in this fashion it will enable transparent sharing of information across the enterprise. Repositories built on DOSR technology will, in addition, provide a single distributed platform/framework for additional document/content/information services including indexing, metadata creation, search, versioning, and records management, resulting in the warfighter's ability to take full advantage of all available pertinent information in a rapid and flexible manner. • The Data Integration and Exploitation SystEm that Learns (DIESEL) effort will address a significant problem facing the warfighter: the lack of interoperability of "stovepiped" information systems. DIESEL will create a new suite of intelligent information integration tools that will learn to automatically understand heterogeneous information systems and integrate them into the existing information environment. The result will be more complete and reliable information as the basis for better decision-making for warfighters. *FY 2008 Accomplishments:* Digital Object Storage and Retrieval (DOSR)				

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B. Accomplishments/Planned Program ($ in Millions)	**FY 2008**	**FY 2009**	**FY 2010**	**FY 2011**
- Extended the digital repository architecture to enable ubiquitous access from multiple devices while providing secure, effective, document sharing. - Developed a prototype repository system with military applicability that can facilitate an open, extensible, and vendor-independent architecture. - Researched and developed technologies to address issues of access control, security, and version tracking. Data Integration and Exploitation SystEm that Learns (DIESEL) - Reviewed the commercial technology baseline and described military needs and representative challenge problems. *FY 2009 Plans:* Digital Object Storage and Retrieval (DOSR) - Develop and refine concepts for the repository architecture. - Prototype subsystems that address access control and security in a networked environment and support a public/private key infrastructure (PKI) as a means of authentication. - Prototype subsystems that address the intelligent search and access of heterogeneous information. - Prototype subsystems that address intelligent pre-positioning of information based on user models and provenance to enhance availability and to support intermittently connected operations. Data Integration and Exploitation SystEm that Learns (DIESEL) - Demonstrate preliminary ideas for learning-based entity resolution, data source modeling, and schema mapping technologies. - Develop technology that observes warfighter information systems to learn system semantics. - Evaluate automated alignment and translation technology through tests with realistic military information systems and a variety of new data sources. *FY 2010 Plans:* Digital Object Storage and Retrieval (DOSR)				

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B. Accomplishments/Planned Program ($ in Millions)	**FY 2008**	**FY 2009**	**FY 2010**	**FY 2011**
- Design a method for controlled, secure access across administrative domains and its potential for integrating diverse, distributed information bases. - Design subsystems for a distributed platform for information search, access, and proactive distribution. - Demonstrate secure, geographically distributed and replicated storage with superior retrieval performance characteristics. Data Integration and Exploitation SystEm that Learns (DIESEL) - Develop ability to identify concepts (e.g., schema element names and types) present in new data sources but not already in data sources of an existing warfighter information system. - Demonstrate ability to surface new concepts from new data sources through semantically and syntactically well-formed input to existing warfighter information systems. - Evaluate automated data integration technology through tests with realistic military information systems and a variety of new data sources of increasing complexity.				

C. Other Program Funding Summary ($ in Millions)

N/A

D. Acquisition Strategy

N/A

E. Performance Metrics

Specific programmatic performance metrics are listed above in the program accomplishments and plans section.