Exhibit R-2, RDT&E Budget Item Justification: PB 2011 Defense Advanced Research Projects Agency										DATE: February 2010	
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 2009 Actual**	**FY 2010 Estimate**	**FY 2011 Base Estimate**	**FY 2011 OCO Estimate**	**FY 2011 Total Estimate**	**FY 2012 Estimate**	**FY 2013 Estimate**	**FY 2014 Estimate**	**FY 2015 Estimate**	**Cost To Complete**	**Total Cost**
Total Program Element	122.810	144.236	90.143	0.000	90.143	88.462	87.592	86.773	91.963	Continuing	Continuing
COG-02: *COGNITIVE COMPUTING*	81.549	99.825	54.641	0.000	54.641	46.460	44.090	48.022	48.212	Continuing	Continuing
COG-03: *COLLECTIVE COGNITIVE SYSTEMS AND INTERFACES*	41.261	44.411	35.502	0.000	35.502	42.002	43.502	38.751	43.751	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) 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.

(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.

Exhibit R-2, RDT&E Budget Item Justification: PB 2011 Defense Advanced Research Projects Agency	DATE: February 2010
APPROPRIATION/BUDGET ACTIVITY 0400: *Research, Development, Test & Evaluation, Defense-Wide* BA 2: *Applied Research*	**R-1 ITEM NOMENCLATURE** PE 0602304E: *COGNITIVE COMPUTING SYSTEMS*

B. Program Change Summary ($ in Millions)

	FY 2009	FY 2010	FY 2011 Base	FY 2011 OCO	FY 2011 Total
Previous President's Budget	144.869	142.840	0.000	0.000	0.000
Current President's Budget	122.810	144.236	90.143	0.000	90.143
Total Adjustments	-22.059	1.396	90.143	0.000	90.143
• Congressional General Reductions		-0.604			
• Congressional Directed Reductions		0.000			
• Congressional Rescissions	-6.989	0.000			
• Congressional Adds		2.000			
• Congressional Directed Transfers		0.000			
• Reprogrammings	-11.000	0.000			
• SBIR/STTR Transfer	-4.070	0.000			
• TotalOtherAdjustments	0.000	0.000	90.143	0.000	90.143

Congressional Add Details ($ in Millions, and Includes General Reductions)	FY 2009	FY 2010
Project: COG-02: *COGNITIVE COMPUTING*		
Congressional Add: *BioButanol Production Research*	0.000	2.000
Congressional Add Subtotals for Project: COG-02	0.000	2.000
Congressional Add Totals for all Projects	0.000	2.000

Change Summary Explanation

FY 2009

Decrease reflects Omnibus Reprogramming action for the H1N1 vaccine development, SBIR/STTR transfer, and the Section 8042 rescission of the FY 2010 Appropriation Act.

FY 2010

Increase reflects the congressional adds (as identified above) offset by the Section 8097 Economic Assumption.

FY 2011

Not Applicable

Exhibit R-2A, RDT&E Project Justification: PB 2011 Defense Advanced Research Projects Agency			DATE: February 2010
APPROPRIATION/BUDGET ACTIVITY 0400: *Research, Development, Test & Evaluation, Defense-Wide* BA 2: *Applied Research*	R-1 ITEM NOMENCLATURE PE 0602304E: *COGNITIVE COMPUTING SYSTEMS*	PROJECT COG-02: *COGNITIVE COMPUTING*	

COST ($ in Millions)	FY 2009 Actual	FY 2010 Estimate	FY 2011 Base Estimate	FY 2011 OCO Estimate	FY 2011 Total Estimate	FY 2012 Estimate	FY 2013 Estimate	FY 2014 Estimate	FY 2015 Estimate	Cost To Complete	Total Cost
COG-02: *COGNITIVE COMPUTING*	81.549	99.825	54.641	0.000	54.641	46.460	44.090	48.022	48.212	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 2009	FY 2010	FY 2011 Base	FY 2011 OCO	FY 2011 Total
Personalized Assistant that Learns (PAL)	27.344	26.275	16.298	0.000	16.298
(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 ongoing and future Command and Control Systems programs. (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					

Exhibit R-2A, RDT&E Project Justification: PB 2011 Defense Advanced Research Projects Agency		DATE: February 2010
APPROPRIATION/BUDGET ACTIVITY 0400: *Research, Development, Test & Evaluation, Defense-Wide* BA 2: *Applied Research*	R-1 ITEM NOMENCLATURE PE 0602304E: *COGNITIVE COMPUTING SYSTEMS*	PROJECT COG-02: *COGNITIVE COMPUTING*

B. Accomplishments/Planned Program ($ in Millions)

	FY 2009	FY 2010	FY 2011 Base	FY 2011 OCO	FY 2011 Total
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. (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 2009 Accomplishments:* - Developed 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. - Extended, improved, and optimized 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. - Develop the ability for an integrated cognitive system such as PAL to model its own behavior. - Create the ability for cognitive systems to exchange locally-learned knowledge. *FY 2011 Base Plans:* - Extend dialogue capability to enable user-defined extensions to descriptions of Web semantics. - Develop and demonstrate cognitive agents that greatly reduce the time it takes users to find and process information on the World Wide Web.					
Integrated Learning	10.317	8.276	0.000	0.000	0.000

Exhibit R-2A, RDT&E Project Justification: PB 2011 Defense Advanced Research Projects Agency		DATE: February 2010
APPROPRIATION/BUDGET ACTIVITY 0400: *Research, Development, Test & Evaluation, Defense-Wide* BA 2: *Applied Research*	R-1 ITEM NOMENCLATURE PE 0602304E: *COGNITIVE COMPUTING SYSTEMS*	PROJECT COG-02: *COGNITIVE COMPUTING*

B. Accomplishments/Planned Program ($ in Millions)

	FY 2009	FY 2010	FY 2011 Base	FY 2011 OCO	FY 2011 Total
(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 2009 Accomplishments:* - Modified the integrated learning systems so they can incorporate new software components dynamically and utilize the new capabilities while learning. - Created 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. - Created control algorithms that reason about the costs/benefits of resolving a particular conflict and direct system performance accordingly. - Evaluated systems by having them compete against expert humans. *FY 2010 Plans:* - Expand the scope of the problems being learned so the systems learn multi-user task models. - 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. - Evaluate systems by having them compete against expert humans.					

Exhibit R-2A, RDT&E Project Justification: PB 2011 Defense Advanced Research Projects Agency		DATE: February 2010
APPROPRIATION/BUDGET ACTIVITY 0400: *Research, Development, Test & Evaluation, Defense-Wide* BA 2: *Applied Research*	R-1 ITEM NOMENCLATURE PE 0602304E: *COGNITIVE COMPUTING SYSTEMS*	PROJECT COG-02: *COGNITIVE COMPUTING*

B. Accomplishments/Planned Program ($ in Millions)

	FY 2009	FY 2010	FY 2011 Base	FY 2011 OCO	FY 2011 Total
Bootstrapped Learning	9.081	8.650	0.000	0.000	0.000
(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. *FY 2009 Accomplishments:* - Developed a single system capable of being instructed to perform in three diverse domains. - Demonstrated the ability of a system to repeatedly acquire new knowledge that drives future learning and cumulatively adds to the system’s knowledge. - Validated through simulation that diagnosis, 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 instructible situational awareness.					
Machine Reading and Reasoning Technology	7.807	18.638	0.000	0.000	0.000

Exhibit R-2A, RDT&E Project Justification: PB 2011 Defense Advanced Research Projects Agency		DATE: February 2010
APPROPRIATION/BUDGET ACTIVITY 0400: *Research, Development, Test & Evaluation, Defense-Wide* BA 2: *Applied Research*	R-1 ITEM NOMENCLATURE PE 0602304E: *COGNITIVE COMPUTING SYSTEMS*	PROJECT COG-02: *COGNITIVE COMPUTING*

B. Accomplishments/Planned Program ($ in Millions)

	FY 2009	FY 2010	FY 2011 Base	FY 2011 OCO	FY 2011 Total
(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 the 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). 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 that “read” natural text and insert it into AI knowledge bases 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. These concepts and technology development efforts will continue in PE 0602305E, Project MCN-01 beginning in FY 2011. *FY 2009 Accomplishments:* - Initiated research into techniques for reasoning with ambiguous and conflicting information found in texts. - Extended 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. - Produced 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.					

Exhibit R-2A, RDT&E Project Justification: PB 2011 Defense Advanced Research Projects Agency		DATE: February 2010
APPROPRIATION/BUDGET ACTIVITY 0400: *Research, Development, Test & Evaluation, Defense-Wide* BA 2: *Applied Research*	R-1 ITEM NOMENCLATURE PE 0602304E: *COGNITIVE COMPUTING SYSTEMS*	PROJECT COG-02: *COGNITIVE COMPUTING*

B. Accomplishments/Planned Program ($ in Millions)

	FY 2009	FY 2010	FY 2011 Base	FY 2011 OCO	FY 2011 Total
- Develop knowledge representation and reasoning capabilities to support simple temporal reasoning using ordered relationships in text. - Demonstrate the ability of machine reading systems to extract knowledge from texts that employ varied writing styles and require contextualization for proper interpretation.					
Foundational Learning Technology	10.000	14.196	13.843	0.000	13.843
(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. The techniques developed under Foundational Learning Technology address diverse machine learning challenges in processing of sensory inputs, language acquisition, combinatorial algorithms, strategic analysis, planning, reasoning, and reflection. 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. *FY 2009 Accomplishments:* - Demonstrated 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. - Demonstrated improved entity extraction performance with multiple languages and styles of writing by transferring knowledge between problem classes. *FY 2010 Plans:* - Formulate learning approaches applicable to processing of sensory inputs. - Develop techniques to enable generalization of knowledge across application areas such as language acquisition, strategic analysis, planning, reasoning, and reflection.					

Exhibit R-2A, RDT&E Project Justification: PB 2011 Defense Advanced Research Projects Agency		DATE: February 2010
APPROPRIATION/BUDGET ACTIVITY 0400: *Research, Development, Test & Evaluation, Defense-Wide* BA 2: *Applied Research*	R-1 ITEM NOMENCLATURE PE 0602304E: *COGNITIVE COMPUTING SYSTEMS*	PROJECT COG-02: *COGNITIVE COMPUTING*

B. Accomplishments/Planned Program ($ in Millions)

	FY 2009	FY 2010	FY 2011 Base	FY 2011 OCO	FY 2011 Total
FY 2011 Base Plans: - Implement and test machine learning approaches on selected problems in processing of sensory inputs, language acquisition, strategic analysis, planning, reasoning, and reflection. - Explore concepts for universal emergent reasoning built from rich, embedded interaction directed by multiple instincts and drives. - Conceptualize new non-symbolic formulations that exploit multiple sources of constraint, feedback, and guidance to address more complex tasks.					
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 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 intelligent control of mobile manipulators to independently perform subtasks over a broad range of domains of interest to the warfighter, thereby reducing operator workload, time on target, training time, bandwidth, and hardware complexity. Another key objective is robust navigation and locomotion even in the absence of GPS, 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. Robust Robotics is also developing techniques for robots to perform in dynamic environments by improving robotic vision and scene understanding. This includes the capability to predict the future location and even the intent of moving objects in order that robots can handle both movement and clutter simultaneously and plan a collision-free course through the environment. Future autonomous systems must also achieve a much higher autonomy level when performing complex tasks, and so Robust Robotics is developing techniques that will enable robotic agents to achieve	15.000	16.490	20.500	0.000	20.500

Exhibit R-2A, RDT&E Project Justification: PB 2011 Defense Advanced Research Projects Agency		DATE: February 2010
APPROPRIATION/BUDGET ACTIVITY 0400: *Research, Development, Test & Evaluation, Defense-Wide* BA 2: *Applied Research*	R-1 ITEM NOMENCLATURE PE 0602304E: *COGNITIVE COMPUTING SYSTEMS*	PROJECT COG-02: *COGNITIVE COMPUTING*

B. Accomplishments/Planned Program ($ in Millions)

	FY 2009	FY 2010	FY 2011 Base	FY 2011 OCO	FY 2011 Total
effective levels of autonomous reasoning whether humans are present or not. Future 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. *FY 2009 Accomplishments:* - Created new and modified existing learning algorithms to enable legged laboratory robots (small scale versions of operational sized platforms) to run over terrain at speeds proportional to humans. - Evaluated the new learning algorithms on a series of different terrain settings in a competitive fashion. - Prepared learning locomotion algorithms to port to larger scale vehicles to increase mobility of larger scale robots. - Created learning locomotion toolkits that 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. - 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.					

Exhibit R-2A, RDT&E Project Justification: PB 2011 Defense Advanced Research Projects Agency		DATE: February 2010
APPROPRIATION/BUDGET ACTIVITY 0400: *Research, Development, Test & Evaluation, Defense-Wide* BA 2: *Applied Research*	R-1 ITEM NOMENCLATURE PE 0602304E: *COGNITIVE COMPUTING SYSTEMS*	PROJECT COG-02: *COGNITIVE COMPUTING*

B. Accomplishments/Planned Program ($ in Millions)

	FY 2009	FY 2010	FY 2011 Base	FY 2011 OCO	FY 2011 Total
FY 2011 Base Plans: - Refine motion understanding by combining geometry and recognition to establish object identity over time. - Refine reasoning techniques to predict object motion based on object type, intent, mover dynamics, and scene configuration. - Develop techniques for handling adversarial (actively impeding robot) movers. - Develop bi-manual manipulation primitives for handling deformable materials, such as opening a satchel with one hand holding a handle and the other zipping a zipper or opening a clasp. - Develop kinesthetic search techniques based on tactile and haptic sensing.					
Biomimetic Computing (U) Biomimetic Computing's goal is to develop the critical technologies necessary for the realization of a cognitive artifact comprised of biologically derived simulations of the brain embodied in a mechanical (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 Accomplishments:* - Created a special purpose processor and associated assembly language to enable systems to have one million neuronal processing units. - Created simulations of complex neural dynamics found in brains including the spontaneous formation of neural groups with short term memory capacity. - Demonstrated a first-generation, knuckle-walking, ape-inspired robotic platform with complex sensing and actuation capabilities (wirelessly) connected to a large computer cluster simulating the neural system attached to the robotic sensors and actuators.	2.000	5.300	4.000	0.000	4.000

Exhibit R-2A, RDT&E Project Justification: PB 2011 Defense Advanced Research Projects Agency		DATE: February 2010
APPROPRIATION/BUDGET ACTIVITY 0400: *Research, Development, Test & Evaluation, Defense-Wide* BA 2: *Applied Research*	R-1 ITEM NOMENCLATURE PE 0602304E: *COGNITIVE COMPUTING SYSTEMS*	PROJECT COG-02: *COGNITIVE COMPUTING*

B. Accomplishments/Planned Program ($ in Millions)

	FY 2009	FY 2010	FY 2011 Base	FY 2011 OCO	FY 2011 Total
FY 2010 Plans: - Develop the capability to simulate a system of one million thalamocortical neurons with spike time dependent plasticity connected to an ape-inspired robot. - Investigate the ability of the robot and simulated neural system to organize its visual system and associate sensory inputs and motor output. - Improve and extend neural system models to include capabilities to make decisions on the basis of reward in the environment and internal value systems. *FY 2011 Base Plans:* - Demonstrate an autonomous robot with a simulated neural system capable of mentally rotating images in order to grasp complex three dimensional objects.					
Accomplishments/Planned Programs Subtotals	81.549	97.825	54.641	0.000	54.641

	FY 2009	FY 2010
Congressional Add: BioButanol Production Research *FY 2010 Plans:* - Continue to investigate bio-butanol production capabilities.	0.000	2.000
Congressional Adds Subtotals	0.000	2.000

C. Other Program Funding Summary ($ in Millions)

N/A

D. Acquisition Strategy

N/A

Exhibit R-2A, RDT&E Project Justification: PB 2011 Defense Advanced Research Projects Agency		DATE: February 2010
APPROPRIATION/BUDGET ACTIVITY 0400: *Research, Development, Test & Evaluation, Defense-Wide* BA 2: *Applied Research*	R-1 ITEM NOMENCLATURE PE 0602304E: *COGNITIVE COMPUTING SYSTEMS*	PROJECT COG-02: *COGNITIVE COMPUTING*

E. Performance Metrics

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

Exhibit R-2A, RDT&E Project Justification: PB 2011 Defense Advanced Research Projects Agency			DATE: February 2010
APPROPRIATION/BUDGET ACTIVITY 0400: *Research, Development, Test & Evaluation, Defense-Wide* BA 2: *Applied Research*	R-1 ITEM NOMENCLATURE PE 0602304E: *COGNITIVE COMPUTING SYSTEMS*	PROJECT COG-03: *COLLECTIVE COGNITIVE SYSTEMS AND INTERFACES*	

COST ($ in Millions)	FY 2009 Actual	FY 2010 Estimate	FY 2011 Base Estimate	FY 2011 OCO Estimate	FY 2011 Total 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*	41.261	44.411	35.502	0.000	35.502	42.002	43.502	38.751	43.751	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 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 2009	FY 2010	FY 2011 Base	FY 2011 OCO	FY 2011 Total
Advanced Soldier Sensor Information System and Technology (ASSIST)*	11.633	9.450	7.000	0.000	7.000
*Formerly a part of Collaborative Cognition. (U) 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. This includes an integrated system using advanced technologies for processing, digitizing and analyzing information captured and collected by soldier-worn					

Exhibit R-2A, RDT&E Project Justification: PB 2011 Defense Advanced Research Projects Agency		DATE: February 2010
APPROPRIATION/BUDGET ACTIVITY 0400: *Research, Development, Test & Evaluation, Defense-Wide* BA 2: *Applied Research*	R-1 ITEM NOMENCLATURE PE 0602304E: *COGNITIVE COMPUTING SYSTEMS*	PROJECT COG-03: *COLLECTIVE COGNITIVE SYSTEMS AND INTERFACES*

B. Accomplishments/Planned Program ($ in Millions)

	FY 2009	FY 2010	FY 2011 Base	FY 2011 OCO	FY 2011 Total
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. Real-time data collection and analysis of civilian interviews and field observations will facilitate understanding of the local and regional political, social, economic, and infrastructure situation for both dismounted soldiers on patrol and battalion/brigade-level analysts. *FY 2009 Accomplishments:* - Established a Memorandum of Agreement with the U.S. Army to delineate the transition of the Tactical Ground Reporting System (TIGR) to a program of record, as well as a three-year schedule for transition. - Demonstrated real-time reporting using on-soldier sensors and an intuitive information push/pull user interface. - Addressed the technical challenges associated with providing ASSIST as a real-time capability for the dismounted soldier in the field. - Integrated ground sensor “Street View” data and manipulation capability into TIGR. - Developed components that enable in-field data sharing and retrieval on a wearable computing/ sensor platform. - Demonstrated eyes-free, hands-free, attention-free collection of key events and experiences for reporting. - Demonstrated tools for analyzing blue-force and red-force trends and patterns. *FY 2010 Plans:* - Develop the means for efficient transfer of ASSIST information across Army Tactical Networks.					

Exhibit R-2A, RDT&E Project Justification: PB 2011 Defense Advanced Research Projects Agency		DATE: February 2010
APPROPRIATION/BUDGET ACTIVITY 0400: *Research, Development, Test & Evaluation, Defense-Wide* BA 2: *Applied Research*	R-1 ITEM NOMENCLATURE PE 0602304E: *COGNITIVE COMPUTING SYSTEMS*	PROJECT COG-03: *COLLECTIVE COGNITIVE SYSTEMS AND INTERFACES*

B. Accomplishments/Planned Program ($ in Millions)

	FY 2009	FY 2010	FY 2011 Base	FY 2011 OCO	FY 2011 Total
- 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. - 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. - Develop and demonstrate a real-time variant for use by dismounted soldiers, with enhancements that include video feeds from airborne platforms. - Integrate advanced multimodal sensor event and object extraction techniques and evaluate the enhanced capabilities. - Integrate biometric feature extraction and comparison capabilities into TIGR. - Automate the extraction of relevant portions of feeds for indexing into the TIGR database. *FY 2011 Base Plans:* - Implement robust operation over wireless networks of very limited bandwidth. - Develop prototype operation on hardware of limited capability. - Demonstrate enhanced capability in the ingest and extraction of multimodal sensor events and objects. - Develop real-time collaboration tools for dismounted soldiers. - Develop fast, graph-based, information analysis algorithms that can run on handheld devices in the field. - Develop techniques for real-time analysis to identify knowledge gaps, provide information on the individuals being interviewed, and generate information requests.					
Cognitive Networking (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	22.075	16.459	7.502	0.000	7.502

Exhibit R-2A, RDT&E Project Justification: PB 2011 Defense Advanced Research Projects Agency		DATE: February 2010
APPROPRIATION/BUDGET ACTIVITY 0400: *Research, Development, Test & Evaluation, Defense-Wide* BA 2: *Applied Research*	R-1 ITEM NOMENCLATURE PE 0602304E: *COGNITIVE COMPUTING SYSTEMS*	PROJECT COG-03: *COLLECTIVE COGNITIVE SYSTEMS AND INTERFACES*

B. Accomplishments/Planned Program ($ in Millions)

	FY 2009	FY 2010	FY 2011 Base	FY 2011 OCO	FY 2011 Total
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. Cognitive information processing will be used to optimize networked communications based on current conditions, past experience and high-level user guidance. 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. SAPIENT technology enables the automatic adaptation of protocols to the operational environment to dramatically reduce the effect of network impairments on applications while demonstrating a positive trend in capability as new situations are encountered and learned. • 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.					

Exhibit R-2A, RDT&E Project Justification: PB 2011 Defense Advanced Research Projects Agency		DATE: February 2010
APPROPRIATION/BUDGET ACTIVITY 0400: *Research, Development, Test & Evaluation, Defense-Wide* BA 2: *Applied Research*	R-1 ITEM NOMENCLATURE PE 0602304E: *COGNITIVE COMPUTING SYSTEMS*	PROJECT COG-03: *COLLECTIVE COGNITIVE SYSTEMS AND INTERFACES*

B. Accomplishments/Planned Program ($ in Millions)

	FY 2009	FY 2010	FY 2011 Base	FY 2011 OCO	FY 2011 Total
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. Machine learning techniques will enable real-time characterization of an adversary's radio dynamics and provide cognitive, networked responses to new enemy threats. Ultimately this effort will develop Software Communications Architecture (SCA)-compliant waveforms suitable for implementation on a tactical software radio system. *FY 2009 Accomplishments:* Situation-Aware Protocols in Edge Network Technologies (SAPIENT) - Integrated and enhanced the prototypes by expanding link handling, and evaluated their performance. - Implemented a functional cognitive learning system that facilitates real-time selection and composition of protocols. - Updated protocol stack composition components and adapted the cognitive engine implementation to use the new protocol components. Local Area Network droids (LANdroids) - Evaluated a 10-node LANdroids network with respect to self-configuration, self-optimization and self-healing. Brood of Spectrum Supremacy (BOSS) - Developed high-accuracy, RF geolocation algorithms for embedding into RF devices of interest.					

Exhibit R-2A, RDT&E Project Justification: PB 2011 Defense Advanced Research Projects Agency		DATE: February 2010
APPROPRIATION/BUDGET ACTIVITY 0400: *Research, Development, Test & Evaluation, Defense-Wide* BA 2: *Applied Research*	R-1 ITEM NOMENCLATURE PE 0602304E: *COGNITIVE COMPUTING SYSTEMS*	PROJECT COG-03: *COLLECTIVE COGNITIVE SYSTEMS AND INTERFACES*

B. Accomplishments/Planned Program ($ in Millions)

	FY 2009	FY 2010	FY 2011 Base	FY 2011 OCO	FY 2011 Total
- Performed field measurements for verification of RF geolocation algorithms. - Established contracts to enable the use of the radios developed on the DARPA Wireless Network after Next (WNaN) program for use with the BOSS program. *FY 2010 Plans:* Situation-Aware Protocols in Edge Network Technologies (SAPIENT) - Demonstrate an adaptive cognitive prototype for a tactical environment using mobile, airborne, and stationary nodes. 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. - 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. Brood of Spectrum Supremacy (BOSS) - Collect RF data with WNaN radio to evaluate BOSS algorithms with these radios. - Perform minor modifications on the WNaN radio to extend the frequency range for BOSS applications. This will enable BOSS to be used with a wider range of signals of interest. - Optimize BOSS software as necessary for use with WNaN radios. - Begin embedding the BOSS algorithms into radios for real-time testing and evaluation. - Evaluate network understanding algorithms with collected RF data.					

Exhibit R-2A, RDT&E Project Justification: PB 2011 Defense Advanced Research Projects Agency		DATE: February 2010
APPROPRIATION/BUDGET ACTIVITY 0400: *Research, Development, Test & Evaluation, Defense-Wide* BA 2: *Applied Research*	R-1 ITEM NOMENCLATURE PE 0602304E: *COGNITIVE COMPUTING SYSTEMS*	PROJECT COG-03: *COLLECTIVE COGNITIVE SYSTEMS AND INTERFACES*

B. Accomplishments/Planned Program ($ in Millions)

	FY 2009	FY 2010	FY 2011 Base	FY 2011 OCO	FY 2011 Total
FY 2011 Base Plans: Brood of Spectrum Supremacy (BOSS) - Complete implementation of BOSS capabilities utilizing WNaN radios with BOSS frequencies. - Test and evaluate BOSS real-time performance in "real-world" scenarios. This includes testing and evaluation of RF geolocation performance and network understanding performance.					
Cloud Computing (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 concepts and technology will continue in PE 0602305E, Project MCN-01 under Web-Scale Information Integration. • 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,	7.553	5.502	0.000	0.000	0.000

Exhibit R-2A, RDT&E Project Justification: PB 2011 Defense Advanced Research Projects Agency		DATE: February 2010
APPROPRIATION/BUDGET ACTIVITY 0400: *Research, Development, Test & Evaluation, Defense-Wide* BA 2: *Applied Research*	R-1 ITEM NOMENCLATURE PE 0602304E: *COGNITIVE COMPUTING SYSTEMS*	PROJECT COG-03: *COLLECTIVE COGNITIVE SYSTEMS AND INTERFACES*

B. Accomplishments/Planned Program ($ in Millions)

	FY 2009	FY 2010	FY 2011 Base	FY 2011 OCO	FY 2011 Total
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 2009 Accomplishments:* Digital Object Storage and Retrieval (DOSR) - Developed and refined concepts for the repository architecture. - Prototyped subsystems that address access control and security in a networked environment and support a public/private key infrastructure (PKI) as a means of authentication. - Prototyped subsystems that address the intelligent search and access of heterogeneous information. - Prototyped subsystems to support intermittently connected operations. Data Integration and Exploitation SystEm that Learns (DIESEL) - Demonstrated preliminary ideas for learning-based entity resolution, data source modeling, and schema mapping technologies. - Evaluated automated alignment and translation technology through tests with realistic military information systems and a variety of new data sources. - Designed an automated system to evaluate the accuracy of new, unknown data sources such as confiscated hard drives with questionable provenance. *FY 2010 Plans:* Digital Object Storage and Retrieval (DOSR)					

Exhibit R-2A, RDT&E Project Justification: PB 2011 Defense Advanced Research Projects Agency		DATE: February 2010
APPROPRIATION/BUDGET ACTIVITY 0400: *Research, Development, Test & Evaluation, Defense-Wide* BA 2: *Applied Research*	R-1 ITEM NOMENCLATURE PE 0602304E: *COGNITIVE COMPUTING SYSTEMS*	PROJECT COG-03: *COLLECTIVE COGNITIVE SYSTEMS AND INTERFACES*

B. Accomplishments/Planned Program ($ in Millions)

	FY 2009	FY 2010	FY 2011 Base	FY 2011 OCO	FY 2011 Total
- 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 enabling information search, access, and proactive distribution of information based on user models and provenance to enhance availability and support intermittently connected operations. - Demonstrate secure, geographically distributed and replicated storage with superior retrieval performance characteristics. Data Integration and Exploitation SystEm that Learns (DIESEL) - Design user models based on the task to be performed (aided by the Army's Tactics, Techniques, and Procedures manuals), which will provide semantic context to refine search results. - Integrate with existing automated visualization services to provide 'at a glance' understanding of relevant content, customized to the user and task. - Design an automated data integration technology through tests with realistic military information systems and a variety of new data sources of increasing complexity.					
Transformative Apps (U) The goal of the Transformative Apps effort is to put mobile, tactical applications (apps) in the hands of warfighters and to create a new military apps marketplace with a vibrant apps development community. The effort will demonstrate a broad array of apps supporting command and control, enhanced situational awareness, collaboration, geo-spatial visualization, training, and language translation. Many of the applications will require ongoing network connectivity; other applications will require occasional data synchronization. While commercial networks benefit from robust cellular networks and the presence of large data centers, tactical networks are notorious for their limited bandwidth, frequent outages, and high-latency links. Specialized backend architecture and middleware will be developed to enable apps to run while providing optimal user experience and without over-burdening the network. Of particular importance is new data synchronization architecture between the handhelds and the backend computing/storage nodes. Additionally, appropriate middleware	0.000	7.000	12.000	0.000	12.000

Exhibit R-2A, RDT&E Project Justification: PB 2011 Defense Advanced Research Projects Agency		DATE: February 2010
APPROPRIATION/BUDGET ACTIVITY 0400: *Research, Development, Test & Evaluation, Defense-Wide* BA 2: *Applied Research*	R-1 ITEM NOMENCLATURE PE 0602304E: *COGNITIVE COMPUTING SYSTEMS*	PROJECT COG-03: *COLLECTIVE COGNITIVE SYSTEMS AND INTERFACES*

B. Accomplishments/Planned Program ($ in Millions)

	FY 2009	FY 2010	FY 2011 Base	FY 2011 OCO	FY 2011 Total
services and libraries will be developed to facilitate shared capabilities such as map viewing, apps management, and collection of logs, usage statistics and user feedback. Apps, together with handhelds and networks, will be tested in different training environments as well as in deployed environments. Performance and usage will be carefully tracked and user feedback collected to guide rapid enhancement of apps. The effort will create a vibrant apps development community by aggressively reaching out to non-traditional performers and will explore new models for software acquisitions based on end-user empowerment. The effort will leverage the resources, experience, and lessons-learned derived from the Tactical Ground Reporting System (TIGR). *FY 2010 Plans:* - Launch a series of user conferences. - Establish innovation and collaboration tools. *FY 2011 Base Plans:* - Develop initial set of middleware services and tools. - Develop initial apps suite available on BETA repository. - Perform operational evaluation testing with military and commercial networks.					
Healing Heroes (U) Healing Heroes will bring the power of social networking, modern information technology, and machine learning to bear on the medical problems facing America's veterans by creating the infrastructure for a social networking site where veterans can share their medical experiences and find mutual support. In addition, Healing Heroes will connect active duty service members, veterans, and their families to the military medical establishment to facilitate the flow of information between care-givers and patients. Natural language processing and advanced machine learning techniques will be implemented to quickly alert caregivers to any emerging physical or mental health crisis based on a patient's medical history and the content and nature of their social interaction. Healing Heroes will be implemented using strong information security to ensure its confidentiality, integrity, and availability.	0.000	6.000	9.000	0.000	9.000

Exhibit R-2A, RDT&E Project Justification: PB 2011 Defense Advanced Research Projects Agency		DATE: February 2010
APPROPRIATION/BUDGET ACTIVITY 0400: *Research, Development, Test & Evaluation, Defense-Wide* BA 2: *Applied Research*	R-1 ITEM NOMENCLATURE PE 0602304E: *COGNITIVE COMPUTING SYSTEMS*	PROJECT COG-03: *COLLECTIVE COGNITIVE SYSTEMS AND INTERFACES*

B. Accomplishments/Planned Program ($ in Millions)

	FY 2009	FY 2010	FY 2011 Base	FY 2011 OCO	FY 2011 Total
FY 2010 Plans: - Develop core Healing Heroes functional and security services. - Implement initial Healing Heroes infrastructure in preparation for 1000 member alpha test/user trial. *FY 2011 Base Plans:* - Perform 1000member alpha test/user trial. - Complete development of Healing Heroes functional and security services. - Implement complete Healing Heroes infrastructure in preparation for 10,000 member beta test/user trial.					
Accomplishments/Planned Programs Subtotals	41.261	44.411	35.502	0.000	35.502

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.