ADAPTIVE SYSTEMS TECHNOLOGY

Goal: To generate creative pathways and natural interfaces between human and physical systems that will revolutionize the development of novel anticipatory and adaptive systems.

Description and Scientific Rationale: Beneath the "skins" of modern machines, robots, or computational systems lies an electro-mechanical nervous system sporting a complex network of sensors, relays, wires, fiber optics, wireless communications, and other devices. The parallels and synergies between machine and human nervous and sensory systems are striking and are of great scientific and practical interest. The human brain, neural-sensory, and neural-muscular systems are, however, far more adaptive, anticipatory, resilient, and versatile than any electro-mechanical system, and our recent progress in probing their secrets has been potentially transformative. We are only just beginning to see the application of these new and transformational neuroscience discoveries to the development of engineered systems, especially at the human-machine interface. New applications, technologies, and products resulting from the convergence of human and physical systems have already demonstrated enormous economic potential (e.g., artificial retinas and cochlea, assistive devices, advanced diagnostic instrumentation and probes, electronic language translators, smart PDAs). Adaptive Systems Technology (AST), an environment that encourages and supports innovative research at the convergence of many disciplines, will better tap this enormous potential.

NSF will initiate and support this interdisciplinary environment and engage scientists and engineers from across the Nation. The nonlinear, dynamic design of complex engineered systems requires that a diversity of scientists and engineers work together on problems and concepts that extend from molecules to entire organisms. In the pursuit of a single, overarching challenge, each discipline contributes critical knowledge. Biology elucidates the evolution from simple to complex neural systems; physics and chemistry contribute the general principles of the neural organization and communications pathways; and mathematics, computer science, and cognitive science explain how the system computes. Learning and behavioral science provide insights into how the system learns and adapts to its environment, and engineering and computer science allow the design, analysis, and construction of systems that interface with or mimic the living neural network, to explore and expand human abilities. In developing applications from this research that are flexible, adaptive, and resilient, these pursuits must be integrated in ways such that the scientists and engineers mutually benefit from shared knowledge and experience, and inform each other's work through real-time collaboration. NSF has a long and successful history of supporting a broad segment of the science, engineering, and education communities in their achievement of interdisciplinary advances.

Most industrialized countries recognize that in a knowledge-based economy improved couplings at the human-machine interface can revolutionize human productivity and workforce development. AST is essential to advances in highly-innovative adaptive control systems, hybrid computer architectures, improved electronic PDAs, and computer-based, self-paced, learning and training tools. A series of recent NSF-supported workshops have highlighted this potential and noted that Europe and Asia are aggressively investing in this area of research ("human-physical adaptive systems"). This research will principally engage physical scientists, computer scientists, and engineers, consistent with the ACI, to conduct research collaboratively with biological, neural, and social scientists to bridge gaps in human-machine interfaces, and, in doing so, create new, natural interfaces. New methodologies will break the long-standing paradigm that requires the human to adapt to the requirements of the machine. The requested funding will enable selective small, high-risk, transformative research projects, consistent with the mandate of the America COMPETES Act, to explore promising research directions in this emerging field.

Potential for Impact: AST has high impact potential stemming from two paradigm-shifting concepts. First, it uses the "time-tested" analog of human and machine nervous systems to accelerate the design and development of innovative and adaptive technologies at the human-machine interface. Second, it employs a framework and research questions that naturally integrate the scientific disciplines with engineering in an area of technology that is primed for growth.

Integration of Research and Education: A full realization of AST requires truly interdisciplinary scientists and engineers. An investment in AST will create a dynamic environment to educate the next generation of scientists and engineers and train them to integrate knowledge from separate disciplines, as well as work together collaboratively. More generally, AST will be inspirational—drawing students into science and engineering because of the awe-inspiring increases in human productivity and accomplishment that can be imagined at the human-machine interface.

Leveraging Collaborations: NSF is taking full advantage of its greatest strength, a broad representation of science and engineering in one organization. BIO, CISE, ENG, MPS and SBE will support this activity.

Urgency and Readiness: Our knowledge of biological structures and processes in the nervous system is growing exponentially, largely because of non-invasive, multi-modal measurement tools that have time, position, and chemical resolution properties that were previously unobtainable. This greatly expanded understanding of the form and function of living neural systems can lead us to quantum leaps in the theory and technologies of adaptive control systems. An August 2006 workshop of leading scientists and engineers concluded that this field of human-physical adaptive systems stands at "a moment of revolutionary change in the kinds of questions that can be asked and the kinds of answers that can be achieved." Investments in Europe and Asia have increased substantially. The US community of scientists and engineers stands ready to hasten this avenue of discovery and urges haste to avoid lost opportunities.

Evaluation and Management: Success will be measured in discoveries that advance basic theory and in the application of that theory to answering questions of relevance to science and society. Novel collaborations will be expected among practitioners that promise to stimulate and sustain a "culture of innovation" in the United States. The development of innovative technologies and products will be measured by the number of new patents, the development of startup companies, expanded economic activity derived, and the hiring of new faculty in the area of Adaptive Systems Technologies. Assessment of the program will be conducted through community workshops, principal investigator meetings, and formal Committee of Visitor reviews. The program will be successful if external evaluators judge that it has effectively fostered discoveries in critical areas that lead to innovation, expanded economic activity, and service to society.

Funding: The Request is for $15.0 million in FY 2009.