To understand the breadth and focus of the BRAIN initiative, it may be useful to look at DARPA, which has already provided substantial information about its expectations. For each of the programs mentioned below, program managers and descriptions are available. For more information, see http://www.darpa.mil/NewsEvents/Releases/2013/04/02.aspx.

“The President’s initiative reinforces the significance of understanding how the brain records, processes, uses, stores and retrieves vast quantities of information,” explained DARPA Director, Arati Prabhakar. “This kind of knowledge of brain function could inspire the design of a new generation of information processing systems; lead to insights into brain injury and recovery mechanisms; and enable new diagnostics, therapies and devices to repair traumatic injury.”

DARPA plans to explore two key areas to elicit further understanding of the brain. New tools are needed to measure and analyze electrical signals and the biomolecular dynamics underpinning brain function. Researchers will also explore, abstract and model the vast spectrum of brain functions by examining its incredible complexity.

Like all potentially powerful new technologies, this research can lead to societal questions about its use. DARPA plans to engage a broad set of experts to explore these issues.

DARPA’s planned investment includes new programs to address the areas outlined and ongoing efforts designed to advance fundamental understanding of the brain’s dynamics to drive applications (Revolutionizing Prosthetics, Restorative Encoding Memory Integration Neural Device, Reorganization and Plasticity to Accelerate Injury Recovery, Enabling Stress Resistance), manufacture sensing systems for neuroscience applications (Reliable Neutral Interface Technology, Blast Gauge), and analyze large data sets (Detection and Computational Analysis of Psychological Signals).

For the programs that appear most relevant to UCSB, here are the specific pages referenced:
• **Restorative Encoding Memory Integration Neural Device (REMIND)**

Memory loss and inability to acquire new memories are common consequences of traumatic brain injury, and memory dysfunction is an expensive, long-term treatment problem for the military. Recovery from loss of memory associated with critical work and life tasks is essential to the recovery of a brain-wounded warfighter. A biomimetic model of the hippocampus could serve as a neural prosthesis for lost cognitive function and memory impairment.

The Restorative Encoding Memory Integration Neural Device (REMIND) program will determine the nature and means by which short-term memory is encoded to enable restoration of memory through use of devices programmed to bypass injured regions of the brain. Researchers will demonstrate the ability to restore performance on a short-term memory task in animal models, as well as determine quantitative descriptive methods for describing the means and processes by which memory is encoded.

**Program Manager Dr. Geoffrey Ling, geoffrey.ling@darpa.mil**

• **Reorganization and Plasticity to Accelerate Injury Recovery (REPAIR)**

The Reorganization and Plasticity to Accelerate Injury Recovery (REPAIR) program aims to uncover the mechanisms underlying neural computation and reorganization to improve modeling of the brain and our ability to interface with it.

Current models of the brain based on invasive measurements are region specific and compartmentalized, while noninvasive measurements are used to build descriptive models of how the brain behaves with low degrees of specificity. New approaches to multiregion, multiscale recording present an opportunity to determine the sequencing of neural signaling from initial cues through task completion, and correlate these neuron-level signals to changes in brain activity. These approaches could lead to new classes of devices that rehabilitate individuals following brain injury, restore impaired sensory function, and manipulate external systems, such as robotic arms, at much faster rates than conventional interfaces.

REPAIR will create a new neuroscience community, bringing together previously separate but complementary approaches to solve old problems and address new ones. The program will also improve our ability to treat and restore the injured brain through development of neural interfaces and compensatory strategies derived from brain models.

**Program Manager Dr. Geoffrey Ling, geoffrey.ling@darpa.mil**
• **Enabling Stress Resistance**

Negative impacts of stress on the cognitive, emotional, and physical well-being of warfighters is irrefutable. Recent technological developments in neuroscience present the opportunity to address these challenges as never before. Novel molecular biological techniques, coupled with in vivo measurement technologies, can allow assessment of the effects of stress with extreme temporal and anatomical precision, leading to a better understanding of stress and opportunities for intervention.

The Enabling Stress Resistance program will create a comprehensive, quantitative description of the impact of stress on the brain by leveraging revolutionary technologies and recent advances in molecular neurobiology, neuroimaging, and molecular pathway modeling. This program's objective is a proactive approach to stress mitigation starting with the development of a comprehensive animal model of the complex effects of multiple stressors on the brain. The program strives to develop and implement cognitive, behavioral, and pharmacological interventions that will prevent the deleterious effects of stress on warfighters.

• **Program Manager Dr. Christian Macedonia, christian.macedonia@darpa.mil**

• **Reliable Neural-Interface Technology (RE-NET)**

Research and development of neural prostheses based on stimulation, such as cochlear implants, has led to clinically reliable, commonplace, and publicly accepted products that have restored lost function to a large number of patients. Although prostheses based on recording neural activity hold great promise and have high relevance to the Department of Defense (DoD), there are two fundamental and well-known obstacles that are preventing their successful transition to clinical use. Both obstacles deal with reliability. First, miniature and portable neural-machine interfaces cannot reliably obtain accurate information from neural tissue over a period of decades. Second, prosthesis systems cannot reliably use measured signals to control the prostheses with high speed and resolution.

DARPA is interested in addressing the specific fundamental challenges preventing clinical deployment of Reliable Neural-Interface Technology (RE-NET), facilitating its potential to enhance the recovery of injured Service Members and assist them in returning to active duty. Program developments will impact the broad community of patients with medical amputations, spinal cord injuries, and neurological diseases.

The RE-NET program will first build a foundation of understanding why these neural interfaces do not remain operational over multiple years. The Histology for Interface Stability over Time team will delve into the interactions between biotic and abiotic systems and what mechanisms lead to interface failure. The direct interface between tissue and electronics is not the only factor that affects reliability. The Reliable Peripheral Interfaces (RPI) and the Reliable Central-Nervous-System Interfaces (RCI)
teams will build complete systems that develop a deeper understanding of how motor-control information is conveyed from neural tissue through implanted interfaces and electronics to efficient and robust decoding algorithms. RPI will interface with the peripheral motor system, and RCI will interface directly with the brain and spinal cord.

- **Program Manager** [Dr. Jack Judy](mailto:jack.judy@darpa.mil)

- **Detection and Computational Analysis of Psychological Signals (DCAPS)**

As a result of combat exposure, warfighters may return home from deployments with psychological health challenges and find it difficult to reconnect with family and society at large. According to the Department of Veteran Affairs’ National Center for PTSD, studies show that between 12 and 25 percent of military personnel who had returned from Afghanistan and Iraq as of 2008 may suffer from PTSD. (1) Despite best efforts to improve awareness and care, additional studies reveal that only a small fraction of warfighters seek help dealing with psychological health issues. The Detection and Computational Analysis of Psychological Signals (DCAPS) program aims to develop novel analytical tools to assess psychological status of warfighters in the hopes of improving psychological health awareness and enabling them to seek timely help.

DCAPS tools will be developed to analyze patterns in everyday behaviors to detect subtle changes associated with post-traumatic stress disorder, depression and suicidal ideation. In particular, DCAPS hopes to advance the state-of-the-art in extraction and analysis of “honest signals” from a wide variety of sensory data inherent in daily social interactions. DCAPS is not aimed at providing an exact diagnosis, but at providing a general metric of psychological health.

DCAPS also aims to develop novel algorithms for detecting distress cues from users who opt in to provide data such as text and voice communications, daily patterns of sleeping, eating, social interactions and online behaviors, and nonverbal cues such as facial expression, posture and body movement. The outcomes of these analytical algorithms would be correlated with distress markers from neurological sensors for improved understanding of distress cues.

Privacy and security are of paramount concern to the DCAPS program. Program data will be collected with the informed consent of individuals involved and stored in a secure, private data-sharing framework. DCAPS will develop, in conjunction with leading privacy experts, a novel trust framework such as envisioned in the National Strategy for Secure Identity in Cyberspace. This trust framework will allow warfighters to control and safely share their “honest signals” data.

References:

1) United States Department of Veterans Affairs, National Center for PTSD (October 2009). How Deployment Stress Affects Children and Families: Research Findings.
Program Manager **CAPT Russell D. Shilling, Ph.D.**, russell.shilling@darpa.mil

Quantum effects in Biological Environments (QuBE)

Biological sensors often display high sensitivity, selectivity, and low false alarm rates while being fabricated and operated in dirty, noisy natural environments. Attempts to emulate these sensors synthetically have not fully met expectations. Recent evidence suggests that some biological sensors exploit nontrivial quantum mechanical effects to produce macroscopic output signals. Examples of such sensors include the highly efficient energy transfer properties of photosynthesis in plants, bacteria, and algae; magnetic field sensing used by some birds for navigation; and the ability of some animals to detect odors at the single molecule level. The Quantum Effects in Biological Environments (QuBE) program is laying the foundation for novel sensor designs by challenging the long-held view that biological sensors utilize primarily classical physics. QuBE will verify, understand, and exploit these effects to develop new scientific foundations for sensor technologies for military applications.

Program Manager **Dr. Matthew Goodman** matthew.goodman@darpa.mil

Program Manager, Dr. Justin Sanchez joined DSO as a program manager in 2013. Dr. Sanchez will explore neurotechnology, brain science and systems neurobiology.

Before coming to DARPA, Dr. Sanchez was an Associate Professor of Biomedical Engineering and Neuroscience at the University of Miami, and a faculty member of the Miami Project to Cure Paralysis. He directed the Neuroprosthetics Research Group, where he oversaw development of neural-interface medical treatments and neurotechnology for treating paralysis and stroke, and for deep brain stimulation for movement disorders, Tourette’s syndrome and Obsessive-Compulsive Disorder.

Dr. Sanchez has developed new methods for signal analysis and processing techniques for studying the unknown aspects of neural coding and functional neurophysiology. His experience covers in vivo electrophysiology for brain-machine interface design in animals and humans where he studied the activity of single neurons, local field potentials and electrocorticogram in the cerebral
cortex and from deep brain structures of the motor and limbic system.

He is an elected member of the Administrative Committee of the IEEE Engineering in Medicine and Biology Society.

He has published more than 75 peer-reviewed papers, holds seven patents in neuroprosthetic design and authored a book on the design of brain-machine interfaces. He has served as a reviewer for the NIH Neurotechnology Study Section, DoD’s Spinal Cord Injury Research Program and the Wellcome Trust, and as an associate editor of multiple journals of biomedical engineering and neurophysiology.

Dr. Sanchez holds Doctor of Philosophy and Master of Engineering degrees in Biomedical Engineering, and a Bachelor of Science degree in Engineering Science, all from the University of Florida.