I. Intellectual Merit

Neural prostheses are a developing technology that uses electrical stimulation of the nervous system to restore functions to individuals with neurological impairment, thus provide greater independence to individuals with disability. In addition to the implanted electrodes, a stimulator is also implanted inside the patient to generate stimulation pulses to the electrodes. The neural stimulators are powered with primary cell batteries and require surgical replacement when they are depleted. Deep brain stimulators for treating Parkinson's disease have a median lifetime of less than 4 years and in applications requiring high charge injection they may last less than 1 year. Similarly, spinal cord stimulators for pain fail due to battery depletion at an average of 41-48 months with the patient-preferred higher settings. Surgical replacement is expensive and carries associated risks. The complication rate is three times higher for replacement of implanted stimulator than for original device placement. The **first goal** of the study is to design novel high-efficiency electrode geometries that reduce power consumption and thus increase implant lifetimes. High efficiency electrode will also induce fewer side effects and discomfort to patients, as it requires less stimulation current to achieve the same therapeutic effect.

Following electrode implantation, the parameters of stimulation, including voltage, frequency, and pulse width are selected to produce symptom suppression. Current approaches to the selection of stimulation parameters are a significant clinic burden and often yield sub-optimal outcomes for patients. Recording electrical signal through inactive stimulating electrodes could offer insight into the activity of neurons directly affected by stimulation, and therefore provide a potential feedback signal for the rational selection of stimulus parameters. This close-loop stimulation-recording-stimulation approach has become a recent hot spot in deep brain stimulation research. New electrode geometries, such as directionally segmented electrodes, have been proposed to improve spatial targeting of stimulation volume and show great promise to become next-generation electrode leads. However, these new designs are optimized for stimulation purposes, and the neural recording properties of these electrodes have not yet been analyzed. The **second goal** of the study is to use computational modeling to better understand factors that impact neural recording with novel electrodes used in deep brain stimulation.

Project #1) Determine the volume of tissue activated by novel high-efficiency electrodes. Previously, I have proposed high-perimeter serpentine cylindrical electrode design for deep brain stimulation in peer-reviewed journal articles. The novel electrode design decreased power consumption by ~25% in a modeling study. However, in this study modeled nerves are either oriented in directions parallel or perpendicular to the electrodes. The assumption of these predetermined orientations are not adequately justified and put limitations on how the models can represent the realistic nerve orientations in the brain. I have developed a realistic nerve model that accounts for nerve anisotropy in my recent accepted journal article. In this first project, by employing this realistic nerve model, Naina will determine the volume of tissue activated by the novel electrodes as compared to traditional electrodes.

Project #2) Characterize the recorded neural signal by the novel electrodes. Recently, a novel high spatial-resolution electrode design has been proposed in peer-reviewed journal articles. However, the recording properties of these electrodes have not been investigated. In this project, Andrew will use computational modeling to study the effects of novel electrode geometries on neural recordings. Previously I have developed a rudimentary model to simulate the forms of neural signals recorded with electrodes with various geometries for a course project as a PhD student. Andrew will further elaborate this model by adopting the novel electrodes and a more realistic representation of brain nerves, edema and tissue encapsulation.

SUMMARY TIMELINE	WEEK							
Project Elements	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
a. Construct finite element models of electrodes in tissue medium	•	•						
b. Build and implement neuron models		•	•					
1 Determine the volume of tissue activated by novel high-efficiency electrodes								
1.c. Analyze volume of tissue activated novel high-efficiency electrodes				•	•	•		
1.d. Visualize modeling results						•	•	
1.e Write-up and documentation								•
2 Characterize the recorded neural signal by the novel electrodes								
2.c. Analyze recorded signals in traditional electrodes				•	•			
2.d. Analyze recorded signals in proposed electrodes						•	•	
2.e. Write-up and documentation								•

II. Role of Students and Mentor

The above two projects represent the entry point of my future research as an independent researcher at TCNJ. I will need the help of two students because the two projects, although applied in the same area of deep brain stimulation, have distinct clinical significance. Both these projects will employ similar approaches at the early stages of the projects. Naina and Andrew will work together as a team in building finite element models (Task a) and neuron models (Task b) in the first 3 weeks. By the 4th week, the two projects will diverge and each will investigate the electrode design from its distinct point of view (Tasks c, d, e). Both students will be familiar with the big picture of the research by discussing their finding in weekly group meetings. I will work side by side with students in the first 3 weeks and allow them increasing freedom after they have developed critical skills in building and simulating models.

Both students have expressed interests in starting the project during the spring semester. As a mentor, I recognize that these projects require intensive training to develop the technical skills necessary for them to conduct research in the area of neural prostheses. Therefore, I will organize a bi-weekly journal club in the spring semester and assign literature reviews to the students that are related to their individual projects, so they can develop the critical thinking and communication skills essential for doing research. In addition, I will provide hands-on tutorials and assignments to the students on the software and methods that will be used for the projects, such as finite element methods and neuron modeling, in the spring semester so they will be equipped with knowledge to utilize the tools for conducting this research. Both students plan to carry out Independent Research with me in the 2014/2015 academic year.

III. Broader Impacts

This is my first summer as an Assistant Professor at TCNJ so having summer students supported by the MUSE program would provide me the opportunity to make significant progress on my research program. The research topic has been relatively unexplored, and addresses an unmet need that I have found through my experience interacting with patients and physicians working in a clinical setting as a postdoc. Therefore, I expect that the data collected by Naina and Andrew during MUSE and the subsequent academic year will lead to peer-reviewed journal articles with intended submission for the Fall of 2015. My target journals include *Journal of Neural Engineering* and *Frontier in Neuroengineering*. Before full-length journal articles, I plan to attend IEEE Engineering in Medicine & Biology Society (EMBS) Conference with Naina in October 2015 (4-page conference paper required to be submitted by March 2015. Andrew will be graduated at the time of this conference). Both Naina and Andrew plan to attend graduate school for biomedical engineering, specifically neural engineering. Naina is a rising junior. As a woman in engineering, she is eager to embark on my academic research that she can continue over the next several semesters. Andrew is a rising senior, and the summer research experience will undoubtedly a highlight in his application to graduate schools which he begins this fall.