B. PROJECT SUMMARY

Overview: Impairment of the human neuromusculoskeletal system results in reduced mobility, an increased risk of associated health conditions (e.g., heart disease, diabetes, high blood pressure, obesity), and a decreased quality of life. Common clinical examples include osteoarthritis, stroke, and Parkinson's disease, which together affect roughly 15% of the U.S. adult population. Because extent and characteristics of impairment vary from individual to individual, customized neurorehabilitation approaches are needed to address this important societal problem. However, current clinical treatment paradigms tend to be highly subjective and follow a "one size fits all" approach, resulting in limited restoration of walking function for individual patients with these impairments.

Our *long term goal* is to use computational modeling to design novel patient-specific treatments that improve walking function in individuals affected by neuromusculoskeletal disorders. The *objective of this proposal* is to develop and distribute easy-to-use computationally-efficient optimal control technology that can predict patient-specific walking changes (including motion, ground contact force, muscle forces, and knee contact forces) resulting from a proposed treatment. The technology will use the Matlab programming environment and will be based on optimal control software developed by the co-PI and on the OpenSim musculoskeletal modeling software developed by researchers at Stanford University. A suite of three clinically relevant benchmark problems involving complex three-dimensional walking optimizations will be used to evaluate the technology. The technology and benchmark problems will be broadly distributed to the research community via the web and conferences to help advance the entire field.

Intellectual Merit: This proposal will integrate two traditionally unrelated fields - neuromusculoskeletal modeling and optimal control - through the development of specialized technology to perform complex three-dimensional walking optimizations that reproduce and predict heterogeneous walking data sets. The proposed project will develop optimal control technology that is custom tailored to the unique challenges of walking optimizations (e.g., intermittent foot-ground contact) and can solve three-dimensional walking problems that are currently intractable or extremely time consuming. The primary development challenge will be to use the known structure of the optimal control problem formulation to improve dramatically the computational speed and robustness of the solution process for walking problems. The primary utilization challenge will be to integrate neuromusculoskeletal models with diverse types of walking data so that models and data are consistent with one another. The ability to calibrate patient-specific neuromusculoskeletal walking models and predict patient-specific walking motions in minutes rather than hours or days of CPU time would be an engineering breakthrough and has the potential to transform the way musculoskeletal modeling researchers perform large-scale human moment optimizations.

Broader Impacts: If successful, this project could have wide-reaching benefits to the field, society, and education. For the field, neuromusculoskeletal modeling researchers who are not familiar with optimal control methods or do not possess strong programming skills will be able to develop computationally efficient optimal control solutions of human movement with relative ease. Furthermore, these solutions will be faster than existing methods and easier to implement due to the use of OpenSim for musculoskeletal modeling. Other branches of engineering (e.g., aerospace and chemical) will likely benefit as well from the optimal control advances. For society, researchers will be able to generate patient-specific walking predictions that could provide clinicians with new customized rehabilitation or surgical treatment strategies. For example, optimal control solutions could identify new ways to minimize medial knee contact force for individuals with knee osteoarthritis or maximize gait speed and bilateral symmetry for individuals who have had a stroke or have Parkinson's disease. For education, "at risk" high school students from underrepresented groups will be exposed to ways that technology is being used to improve human health. In addition, musculoskeletal modeling researchers will be exposed to and have the chance to interact with the new technology through planned workshops at national and international conferences, as well as through broad distribution via the web.