Industrial robots, though highly precise and capable, have a relatively high inertia. This severely limits how quickly and safely they can move to avoid unexpected collisions and high impact forces while operating in close proximity to humans and delicate equipment.Furthermore, the high mass of these robots results in a higher robotic payload in space applications. My research will focus on soft, pneumatically actuated robots that will use comparatively less payload (weighing ten times less than Robonaut 2) and be safer around people and equipment than traditional robots, even when moving at high speeds.

One important feature in robots capable of working around humans and mimicking human dexterity is the ability to use two or more arms. Many tasks such as lifting heavy/bulky objects or service and assembly are difficult, if not impossible, with only one arm. This problem has sparked research into multi-arm manipulation. My research will focus on coordinated, multi-arm manipulation using inflatable, pneumatically actuated robots. Coordinated manipulation tasks are defined as two or more robotic arms physically interacting with the same object. My hypothesis is that coordinated multi-arm manipulation can realistically and usefully be implemented with an inflatable, pneumatically actuated robot. My research goals are to implement coordinated multi-arm control for (1) impact tasks with rigid objects (like sweeping off a solar panel or assembly of construction materials that require impact for insertion) and (2) soft object manipulation tasks (like moving a tarp or a flexible solar array).

Accomplishing my research goals will require several steps. One difficulty with soft, robotic arms is that the dynamics and kinematics of the arm change regularly. This makes it difficult to accurately and repeatably reach a desired position. My first approach to this challenge will be to design a hybrid controller using model predictive control and servoing to close task space error. Once I can accurately command a single arm, my approach to coordinated multi-arm manipulation will be to design and implement an object level model predictive controller to accurately control both rigid and soft objects. With this design, I propose that each arm can be treated as a force/torque input on the object.

This research has many applications to NASA interests and programs. The NASA Technology Roadmap TA 4.3.5: Collaborative Manipulation states, “For collaborative manipulation, the required technical capability is to provide a teamed approach for multiple robots or teams of humans and robots working with objects, equipment, or samples.” This collaboration includes coordinated manipulation tasks where multiple robot manipulators are physically connected together in tasks like handling a common load. My graduate research directly impacts these goals. I will be researching and implementing control methods for coordinated multi-arm manipulation tasks with soft robots. This research will enable soft robots to work collaboratively with other robots (soft and rigid) on tasks in space. Furthermore, TA 4.3.5 lists robust safety system development as a goal. TA 4.7.5: Safety and Trust expands on this by setting the goal of having a crew “be able to work next to a robotic assistant, within a one-meter proximity in a controlled and safe manner, without being physically attached to it.” The soft robotic platforms I will be utilizing for my research are inherently safe for operation around humans and delicate equipment due to their inflatable structure and low inertia. The algorithms I develop for multi-arm manipulation will help these robots have performance on par with state of the art torque controlled robots to work more robustly and safely in space.