UNDERGRADUATE AND GRADUATE STUDENTS
RESEARCH POSTER - JUDGE'S SCORE CARD*

**Subject to change*

Presenter's Name: ____
Judge's Initials: _____________ **OVERALL SCORE** ________

ABSTRACT

60 Possible Points	Points Possible	Points Earned
The extent, which the abstract conforms to the required formatting: Typed, single-spaced, 1-inch margins, Times New Roman, 10-12 pt Font	8	
The extent, which the abstract clearly summarizes the research project	22	
The extent, which the abstract clearly demonstrates Broader Impact	15	
The extent, which the abstract clearly demonstrates Intellectual Merit	15	
TOTAL SCORE	**60**	

POSTER

125 Possible Points	Points Possible	Points Earned
Clear and succinct Introduction	5	
Clear and succinct Background	5	
Clear and succinct Hypothesis/Intent	5	
Clear and succinct Problem Statement	5	
Clear and succinct Materials/Methods	5	
Clear and succinct Data and Results	5	
Tables, figures, graphs, and/or charts are clear, relevant and explain the project	5	
The extent to which the poster demonstrates innovative research	5	
The extent to which the poster is presented in a professional manner	5	
The extent to which the research is laid-out in an orderly and concise manner that is readable and logical	20	
The extent to which the poster demonstrates Broader Impact – The extent to which the findings may be utilized for society	15	
The extent to which the poster demonstrates Intellectual Merit	15	
The extent to which the presenter articulates knowledge of research	20	
The extent to which the presenter acknowledges questions thoroughly	10	
TOTAL SCORE	**125**	

SAMPLE WINNING ABSTRACT

A Physics-Based Simulation Study of Tensegrity Damping Strategies for Controlled Hopping on Small Solar System Bodies

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In the last 10 years, space agencies have developed an increasing interest in exploring asteroids and comets. These small bodies may provide clues regarding the origin of our solar system and how life originated on Earth. However, most efforts to explore these bodies have been unsuccessful. For example, ESA's Rosseta mission demonstrated the complexity of landing a rover in microgravity when its lander Philae failed to grasp onto comet 67P/Churyumov–Gerasimenko. The total cost of the mission was 1.6 billion Euro and the time from launch to attempted landing was almost 11 years. After touching the comet's surface, Philae bounced multiple times on the comet's surface to an off-nominal configuration.

The intention of the project is to investigate the feasibility via dynamic simulation of a hybrid rover. The concept combines an internally actuated rover denominated *Hedgehog* and *Tensegrity* robotic structures for exploration of asteroids and comets. The combination of Hedgehog which is a flywheel propelled cube-like robot, with Tensegrity structures provides controlled mobility in microgravity. Hedgehog uses the principle of conservation of momentum when spinning three internal flywheels and applying a brake transferring the flywheel momentum to the rover. The Tensegrity exoskeleton enhances the ability to absorb and dissipate large amounts of impact energy allowing controlled landing of the rover.

The geometry of Tensegrity structures allows for the exoskeleton of the rover to be mechanically stable as stress is applied. Impact and collisions may deform the rover, but the Tensegrity properties enable the rover to return to its original shape. We predict that combining Hedgehog with a Tensegrity structure will allow for more reliable mobility than using Hedgehog by itself. The innovative concept exploits the benefits of Tensegrity structures while transferring the mobility task to its payload –Hedgehog– and uses the Tensegrity structure as a landing exoskeleton capable of absorbing impact after landing.

To evaluate the performance of the hybrid rover in microgravity, the open-source NASA Tensegrity Robotics Toolkit (NTRT) simulation environment proved to be an effective solution. This platform is based on the Bullet physics engine and implemented in C++ allowing for modeling simulation and control of Tensegrity robots. The team, composed of two underrepresented engineering students without background in programming, built the Tensegrity Hedgehog rover in the NTRT supported by Stanford faculty. Tensegrity structures and NTRT are highly inexpensive teachable tools to bring to classrooms and broaden the participation of minority students in the field of space robotics.

The testing strategy consisted of placing Hedgehog inside a basic 6-bar Tensegrity structure without active dampening at 0.0057 m/s^2 which represents Phobos' gravity. After comparing a Hedgehog Tensegrity 6-bar model against a 12-bar model, simple drop tests simulations confirmed the use of more bars enabled greater absorption of impact energy. The rover design changed to a 12-bar cube Tensegrity configuration with 24 internal cables from center of the six faces of Hedgehog. Internal cable connections allowed Hedgehog to transfer all its momentum from its chassis to the Tensegrity exoskeleton via 24 pre-tensioned cables. Later tests consisted in dropping the hybrid rover perpendicular to a flat surface at an altitude of 24 m. The rover's velocity profile changed from 0 m/s in former tests to 5 m/s with an overall mass of 10 kg.

After landing, the rover left the comet's surface at a faster rate than using Hedgehog by itself. These preliminary results simply showed the Tensegrity cannot passively provide the required dampening. Therefore, future work will include active dampening mechanisms within the Tensegrity structure to absorb the impact energy upon landing. Additionally, implementation of Tensegrity external cable controllers (actuators), flexible rigid bars, and multibody mobility in NTRT would likely enhance dampening of the hybrid rover. Finally, experimentation through a collaboration between Stanford University and NASA Johnson Space Center sharing microgravity tests beds will yield data to accurately assess the feasibility of using Tensegrity structures and Hedgehog. In conclusion, NTRT provides a realistic simulation environment for Hedgehog Tensegrity Hybrid robots. Further simulations efforts will demonstrate if the hybrid rover is an effective method for exploration of small solar system bodies.

Besides the high scientific value of exploring asteroids, the knowledge acquired from deploying autonomous robots in small bodies contributes to the development of smarter robots for Earth applications. The expertise of exploring space will help develop Earth robots capable of exploring nuclear accident sites such as Fukushima and perform specialized tasks to shut down the reactor. Additionally, these robots could be deployed in hazardous areas such as Houston after a hurricane, and Mexico after an earthquake to autonomously identify survivors.