Impact-Testing the Integrity of 6-Strut Tensegrities

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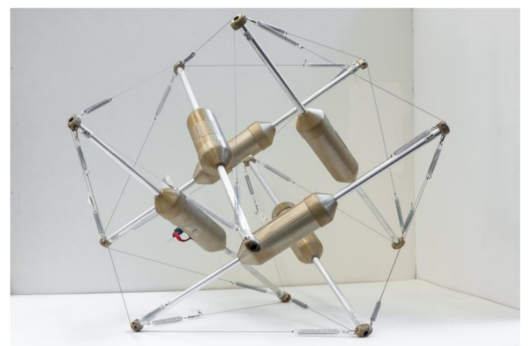
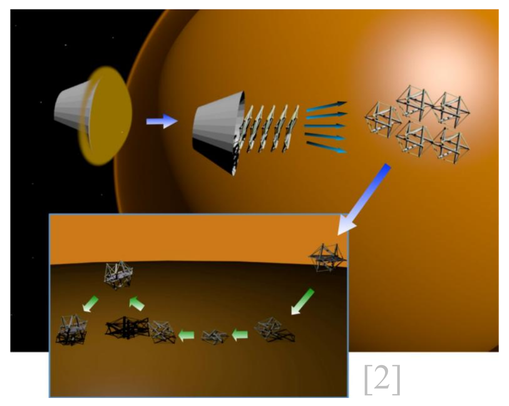
2015 Transfer-to-Excellence Research Experiences for Undergraduates Program (TTE REU Program)

Abstract – Tensegrity robots are a revolutionary generation of soft robotics, designed to operate safely and effectively alongside humans. For space exploration purposes, these robots have a much better chance at confident landing than traditional robots. Due to the natural compliance and structural force distribution properties of tensegrity structures[1], these robots are able to absorb significant forces upon impact[2], making them an effective replacement for traditional space rovers. Designing the first controlled drop test for tensegrity robots will further improve the framework of these structures and develop an optimized means of observation of their behavior upon impact, allowing for recognition of opportunities for improvements for subsequent versions of the robot. The current design focus of this study is on testing 6-rod tensegrity structures, but the design will be modular for developing and testing other tensegrity structures. Video analysis and motion tracking tools were used to perform detailed falling and impact analyses of the structure deformation and center of gravity during drop tests. By observing the results of the structural deformation per height drop upon different surfaces, scientists and engineers will be able to build a superior 6-strut tensegrity robot for planetary exploration.

Introduction

- "Tensegrity" = Tensional Integrity
- Flexible structures built from interconnected tensile cables and compressive rods[1]
- 6-strut, 24-cable tensegrity structure is sphere-like with geometry similar to an icosahedron (20 faces)





[2]

Why drop test?

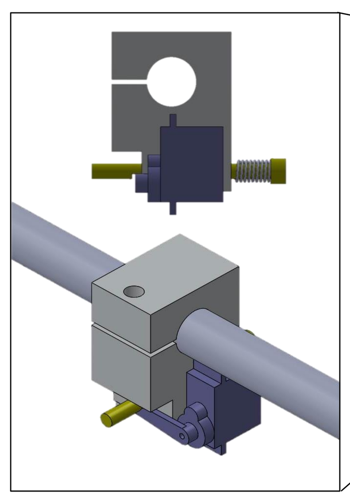
•Currently all drop tests performed on tensegrity robots have been freehanded; need controlled system to reliably analyze behavior

•Need to ensure a safe landing for planetary expedition purposes

•Results will be used to verify the tensegrity's structural integrity

Methods

- Height drops done in one-foot increments from one to five feet
- Robot orientation: dropped flat onto base triangle
- Video analysis tool Tracker used to analyze structural behavior upon impact; Motion capture system Vicon (attempted)
- Test structure is cost-efficient, repeatable, precise, and easy to operate

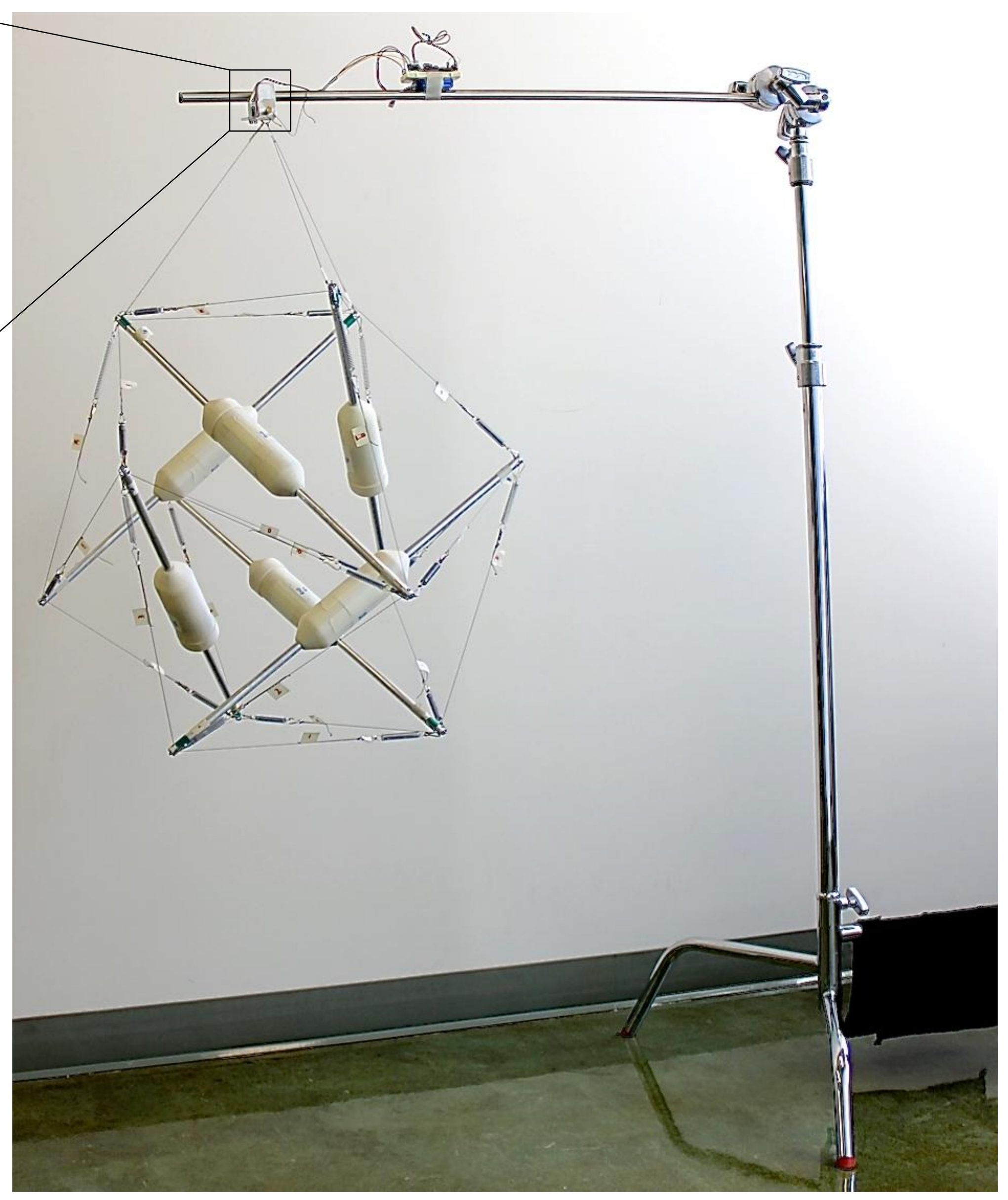


Quick-release mechanism built for reliable control and repeatability of drops:

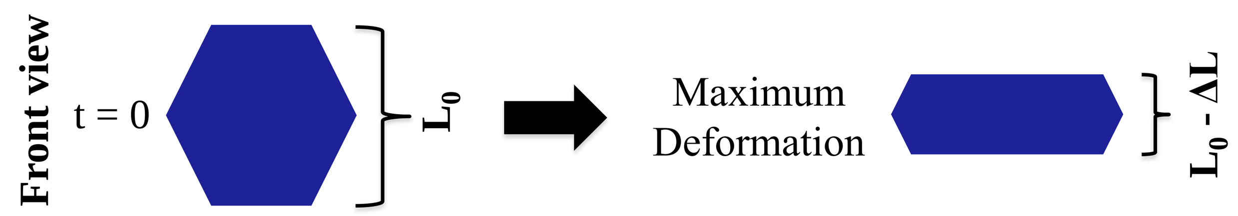
- Machined aluminum stock to clamp stand
- Spring-loaded brass pin
- Servo motor connected to launchpad and micro-controller

Test structure design:

- Portable, off-the-shelf light stand
- Easy to change heights
- Most reliable for minimal material needed



Data Analysis

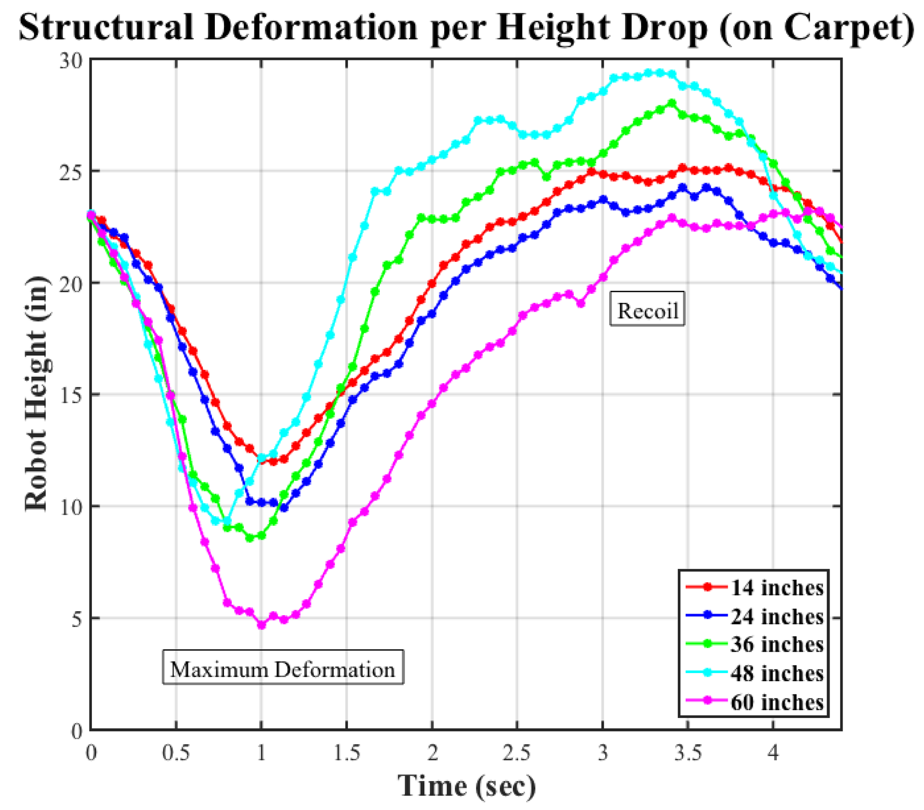


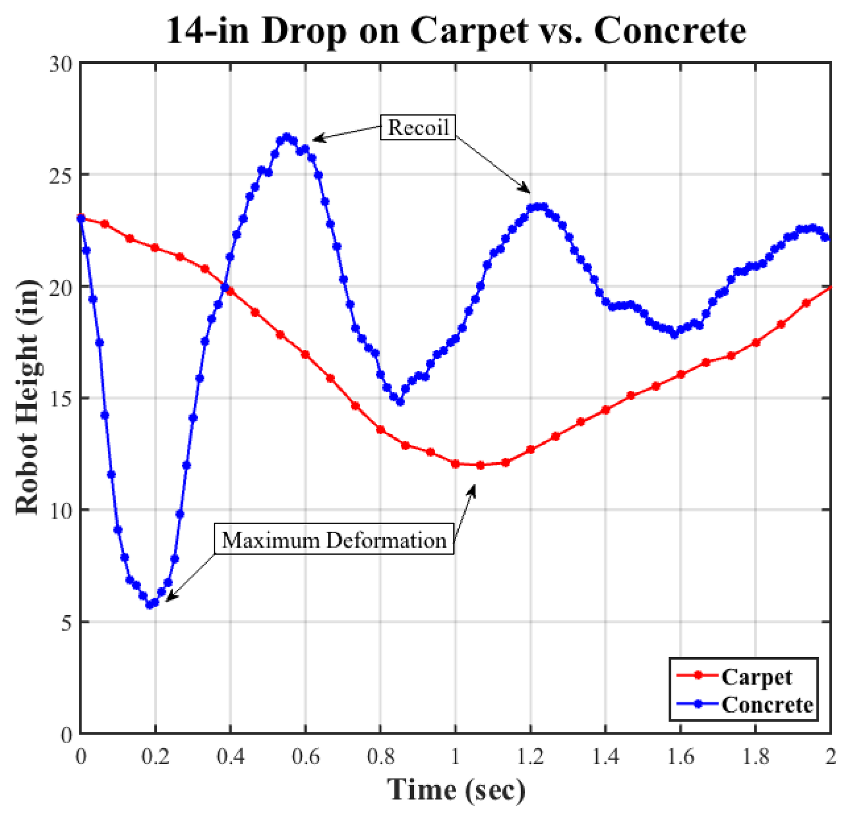
Initial trend followed:

•Increased drop height results in increased deformation and recoil in shorter period of time

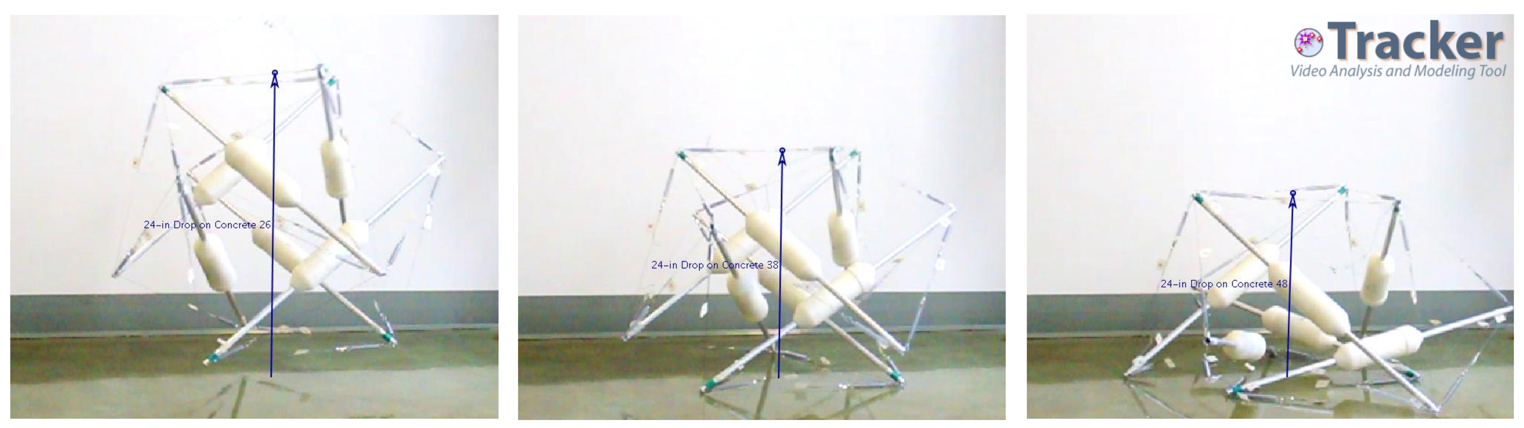
Exceptions:

•60" drop resulted in minimal recoil then deformed again; 14" drop had greater recoil than 24" drop; slightly larger deformation with 36" drop than 48"





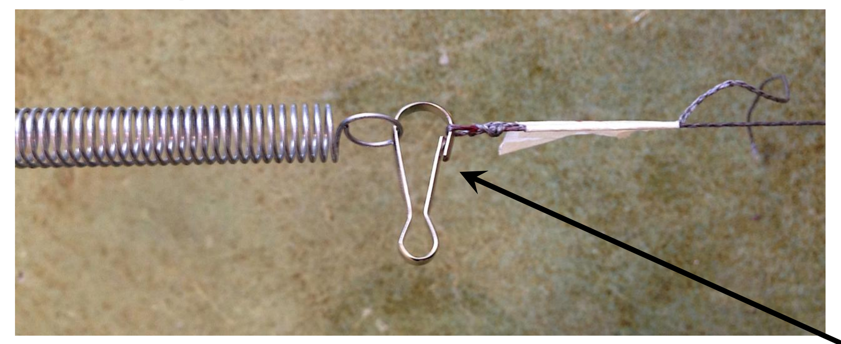
- Drop on concrete resulted in almost twice as much deformation six times faster than on carpet
- Increased deformation and recoil due to carpet's greater friction coefficient

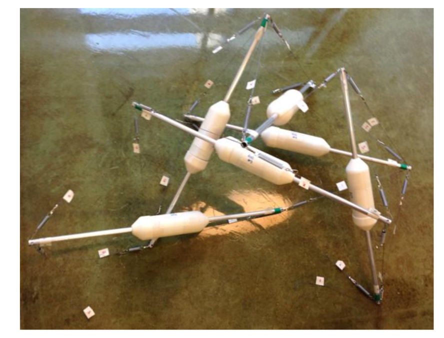


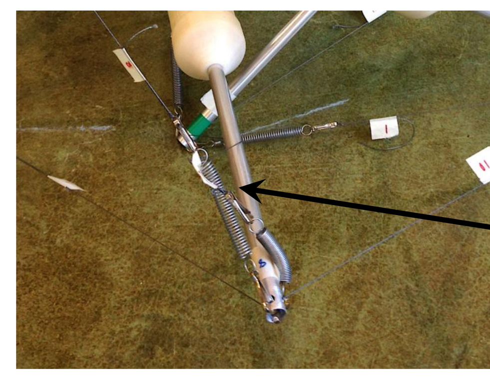
Results

- Endured approximately 100 drops with few visible minor damages
- Tests have proven structure to be robust as anticipated for heights tested
- Necessary improvements for protection of cables, springs, and nodes
- Drop tests help to understand how to build a tensegrity robot sufficient for deployment

Modes of Failure:







Clip openings cause springs and cables to detach upon impact

Cable lines get tangled in coils of springs

Future work:

- Create protective barriers
- Potential new methods of movement inspired by motion from tests
- Test different robot drop orientations
- Build new Vicon model to track center of gravity

Acknowledgements

I would like to graciously thank the following people for their invaluable support throughout this research experience: my mentor, Lee-Huang Chen; my Principal Investigator, Professor Alice Agogino; my lab partner, Kevin Li; the Berkeley Emergent Space Tensegrities Lab; the Transfer-to-Excellence Research Experiences for Undergraduates Program staff and my fellow interns; and the Mechanical Engineering Technical and Instructional Group.

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[2]V. SunSpiral and et al. *Tensegrity Based Probes for Planetary Exploration: Entry, Descent and Landing (EDL) and Surface Mobility Analysis.* [Online] Available: http://www.sunspiral.org/vytas/cv/tensegrity_based_probes.pdf

This work was supported by an Early Stage Innovations grant from NASA's Space Technology Research Grants Program.

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Support Information

This work was funded by National Science Foundation Award ECCS-0939514 & ECCS-1157089 & ECCS-1461157