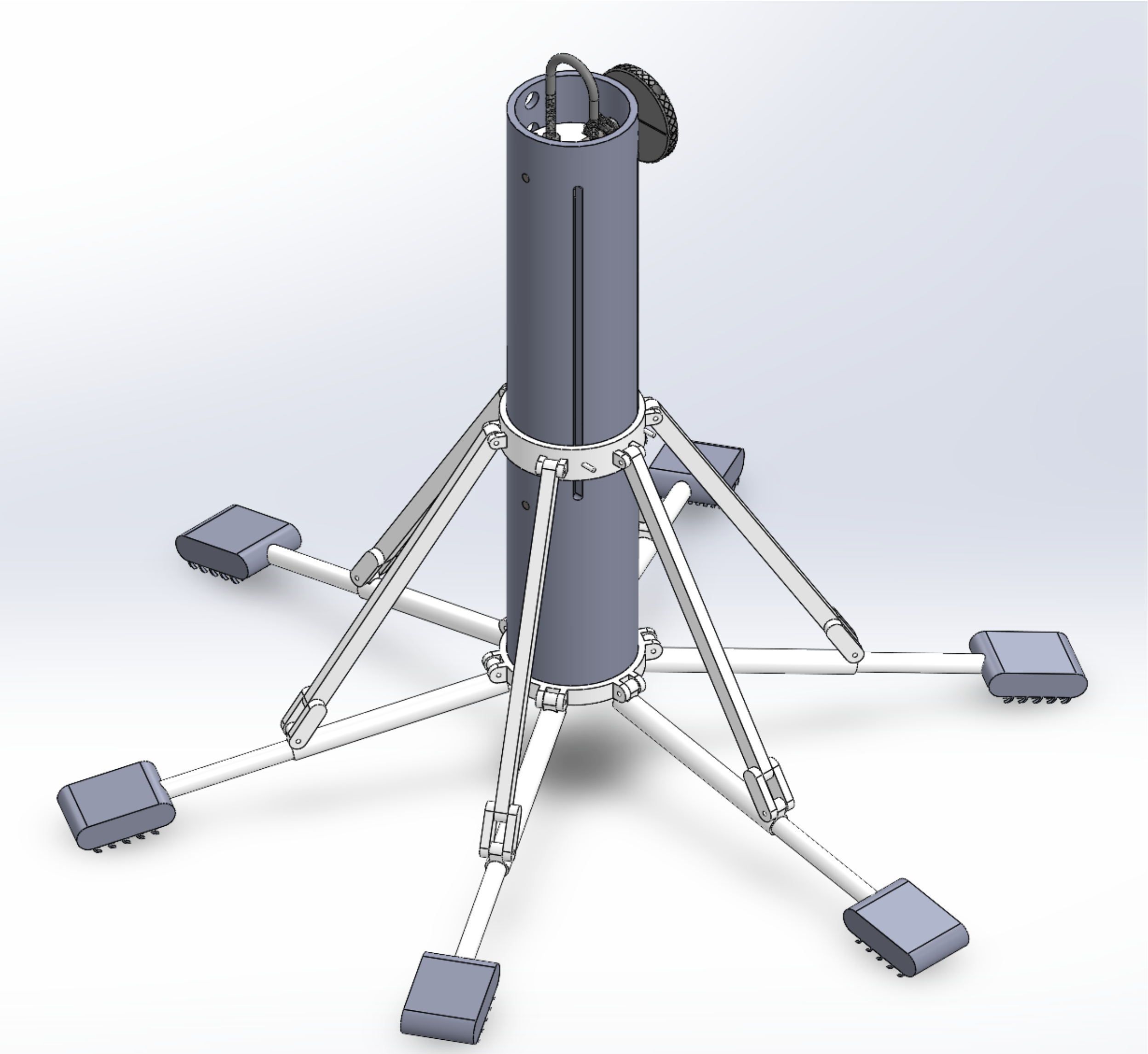
Title of Design:
RAD (Reusable Anchoring Device) Pack
Design Challenge Addressed:
Lunar Surface EVA Operations | Lunar Reusable Surface Anchoring Device

Team Name:
The Wolf's Paw



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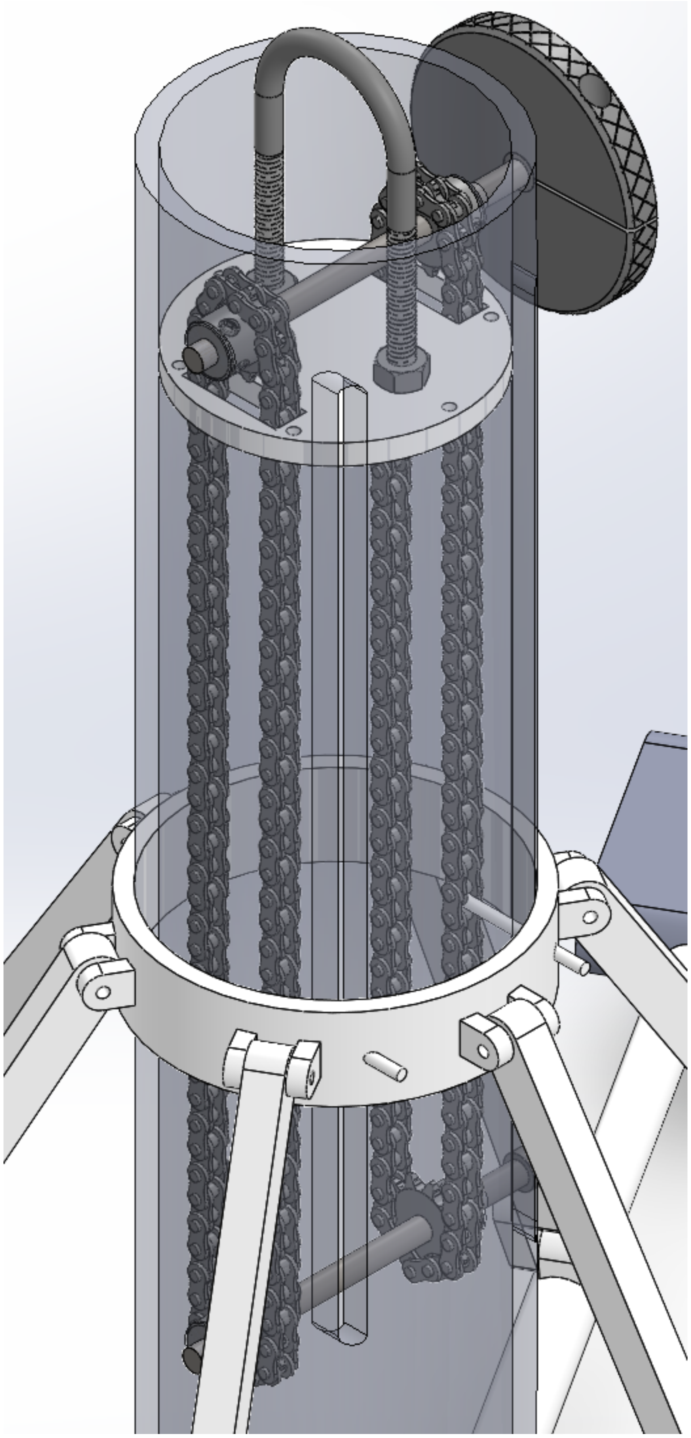
Abstract

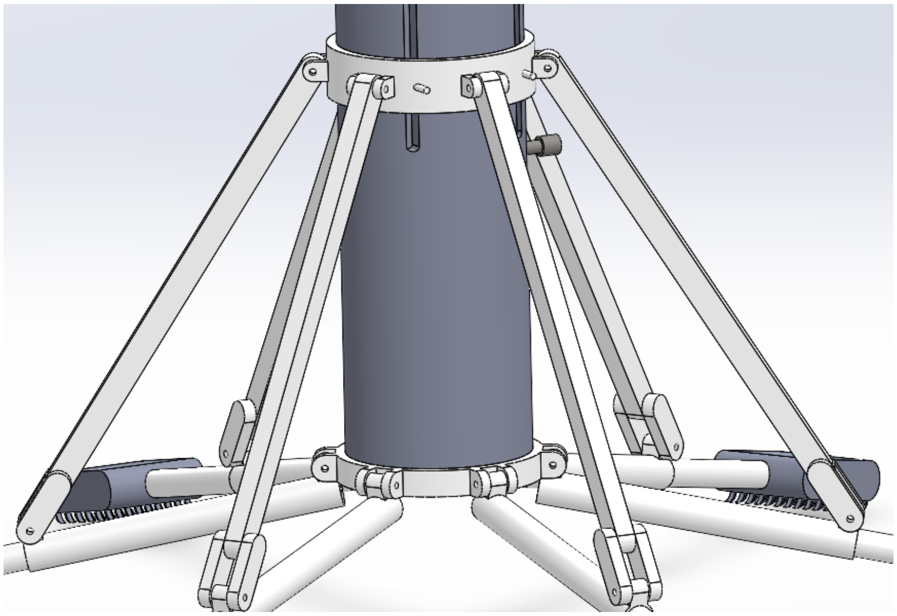
The design in the detailed proposal below entails a miocrospine device that is utilized to latch onto crevices in comets, rocks, or planet surfaces. The device is unique in that it is entirely human powered, and thus does not require any recharge time between uses, nor does it leach from the spacecraft resources. It will have an extremely low mass allowing for easy transport while maintaining structural integrity by using high strength polymers. To reach performance goals while meeting dimension requirements, a support system will be utilized to lower the arms. The cylindrical device will have six arms that are attached to the main body by way of joints and supports. The arms can be lowered and secured at customizable heights to adjust for varying rock surfaces. Each of these arms will utilize microspine technology to create friction with the desired surface to supply the desired gripping force. The microspines will be organized, metallic protrusions on the bottom of each arm angled towards the central axis of the device's cylindrical body. To create additional friction, a cable system will be implemented to pull each foot towards the body. Springs will be at each arm part A and B connection to allow for variable pressure on a heterogeneous surface. Each action will be able to be performed with limited dexterity and limited force to accommodate use during EVA functions. This device is extremely useful for microgravity anchoring scenarios by using a straightforward manual attachment process with a robust construction to operate successfully in high stress environments.

Design Description

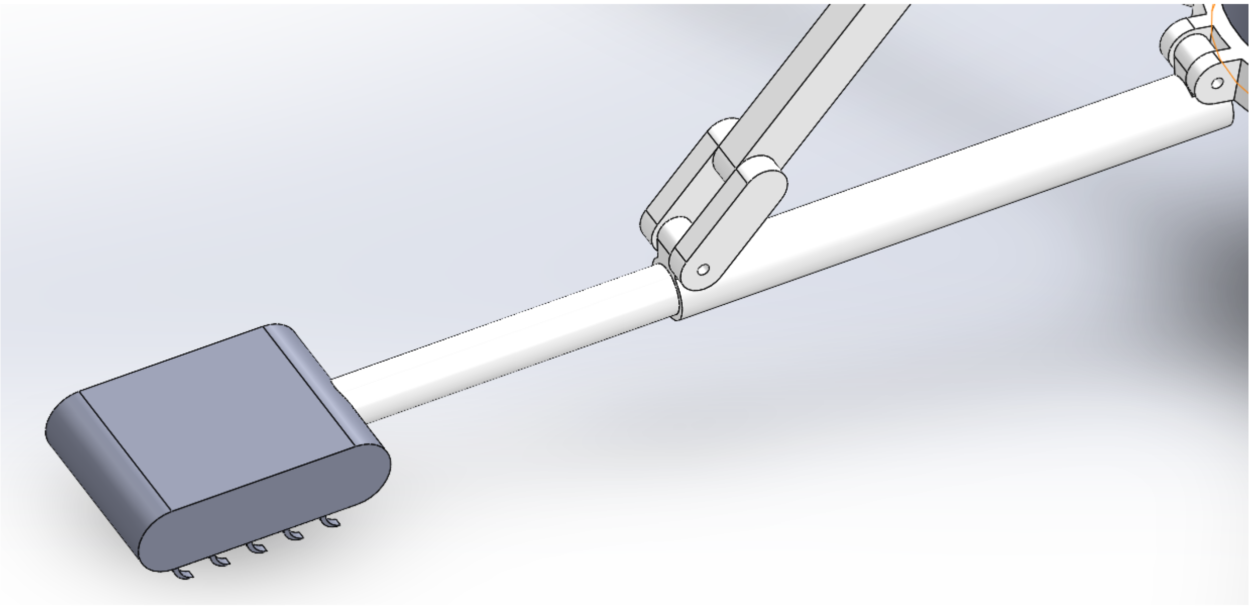
At the top of the body of our device an axle will run horizontally through the cylinder connecting two vertical gears that are inside. Connected to one end of the axle, outside of the body is a hand crank that will be used to turn the gears. The two top gears are connected to two gears at the bottom of the body by way of a two-belt system, so that when the two top gears are turned the two bottom ones also turn as the belt circles around them.



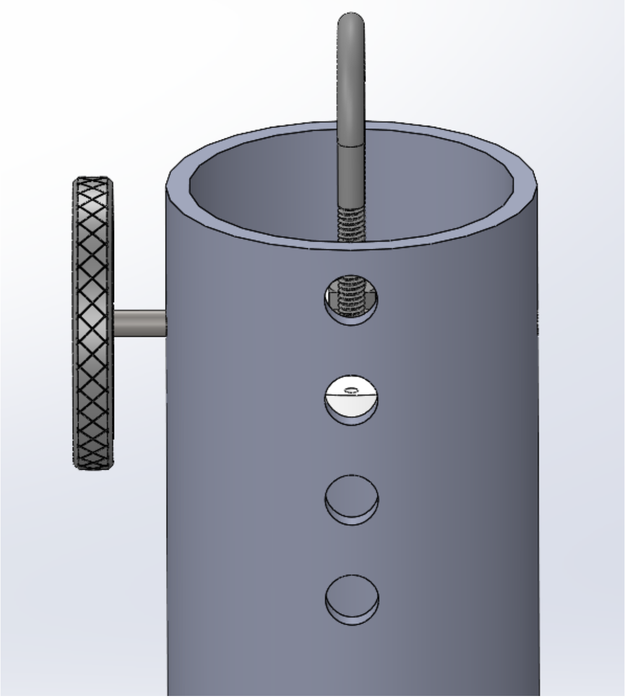
Around the body is a support bracket that is bolted to the belt on either side of the body. This support bracket will move up and down with the chain. There are slots cut out of the body following the path of the belt so the support bracket can be bolted to it. Attached to the support bracket are six supports (the bracket and supports are shown below).



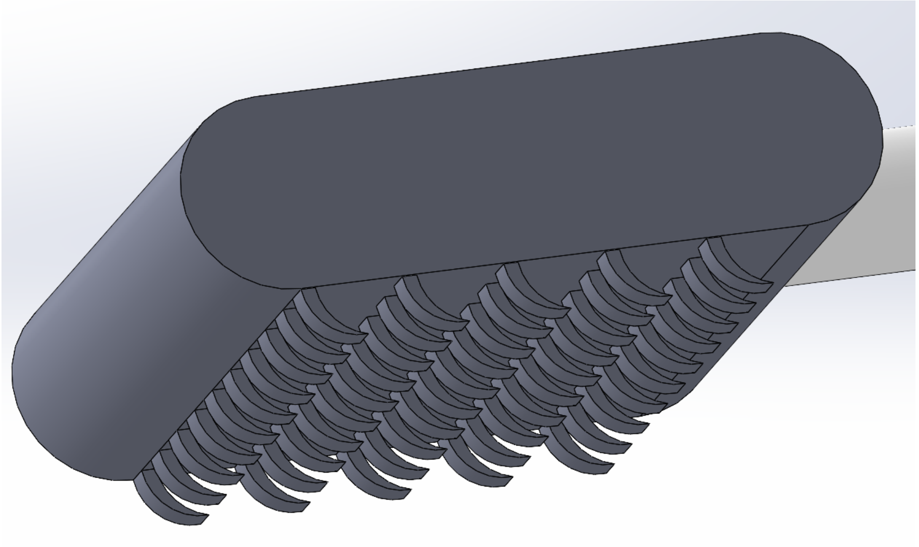
The supports are then attached to the arms with the spines on them. As the support bracket moves down the belt the supports will swing and push the arms down toward the rock surface. The shaft and belt system allows for better accuracy with the spine arm placement, wherever the arms need to be for the best grip on the rock they can be.



Each arm (depicted above) is composed of two parts. Part A will be connected to the body cylinder with hinges. Part B will slide into part A, and a spring will connect the two in order to force the arms into an outstretched resting position. A separate spring will be used for tensioning. This spring is attached to the end of part B on one side, and a chord on the other. The chord runs through the entire arm system, up through the body and attaches to the tensioning bracket. The tensioning bracket has a handle that is accessible at the top of the body. The resting position for the tensioning bracket will be down and thus the chords relaxed. When the anchor device is in position to grip the rock the handle will be pulled until desired tension is achieved and then twisted to be held in place. There is a spring powered pin in the tensioning bracket that the strings are attached to and holes in the body lined up vertically. As the handle and tensioning bracket are rotated, the pin will pop out into one of the holes (depicted below) to be locked in place so that the astronaut does not have to constantly apply tension.



Six arms will be attached to the bottom of the body, these arms will have the spine system on them. These arms will be attached to the bottom of the body with a hinge allowing it to move 180 degrees. Attaching the arms to the bracket will be a set of supports that are placed on the middle of the arms with another hinge. These arms will then attach to the bracket with yet another hinge. These hinges allow for all three angles of the triangle that is formed by the arms, supports, and the body to change. On the end of the arm is the spine system. The spines are curved hooks, angled towards the body.



Operations Plan

The device is stored in a cylinder with a six inch diameter. When ready for use, the device is to be pulled out of the cylinder by the handle at the top. At this time the device will be in its compact state. In this state, all of the device's arms are pulled upright and inwards, toward its main body. To begin the arms angling down and moving out, the user will spin the hand crank on the side of the device. This hand crank will lower the six arms down into their ready positions. At this point the arms will be at least a 90 degree angle between the main body of the device and the arms. From here, the user will position the device so that the main body is normal to the rock that it is to be attached to. After this, the user may need to turn the crank a little more so that the arms of the device are parallel to the rocks surface. Once the arms are parallel the user can lower the device so that the arms are making contact with the surface of the rock. The user will then pull the handle on top of the device to pull the microspines in toward the main body of the device. This action will latch the microspines to any crevasses in the rock. When the user is satisfied with the tension being created by the microspines on the rock, they will twist the handle so that the pin inside pops out of a small hole on the body of the device, locking the tensioning bracket, and therefore the spines in place. From here, to test the device, a ten pound force will be applied to the handle at the top of the body for one full minute. If the device holds, the user will cease applying the force to the device. Then, to reset the device, they will push the pin holding the handle until they are able to twist the handle back to its original position. The handle will then be pushed in and all the tension on the inner chords will be released, thus releasing the microspines from their holds. Finally, the user can turn the crank on the side of the body of the device in the opposite direction as before; until the arms are returned to the side of the body and the device is in its compact state. We will repeat the process above for multiple different rock surfaces to test the device's ability to attach to varying rock types. If we are successful with the ten pound force, we will add more force to the testing process to find a maximum load possible by our device for each rock type.

Safety

The microspine design employed in this device uses small, sharp spines to grip onto the surface of a rock due to normal forces between the spine and the rock surface. These spines, while they are sharp, are very little and are stored within the body of the mechanism, thus reducing the likelihood of the spines puncturing or scratching any portion of the space suit. The entirety of the device is stored within a solid metal casing, therefore the inner mechanisms pose no safety threat to the astronaut during the handling and operation of the device. The pin that protrudes from the casing could pose the risk of pinching, however, it will be rounded on the end in such a way that it is less likely to pinch and tear any fabric, and instead the surface should slide along as the pin is pushed. The cranks should be relatively safe for use, as well as all of the gears connecting the cranks that are stored within the outer casing. The device is also spring-loaded and tension-based, so there is always the risk of breakage within the device. This risk is reduced by the use of low-stiffness springs to lessen the force they exert on the internal strings, and by avoiding sudden movements that would exert a sizable force over a short period of time. If the strings are to break, the device should be slowly and carefully extracted, and then put away. Because there is no use of chemicals to operate the device, nor anchor it onto the surface, concerns surrounding reaction of the skin or the suit are virtually non-existent.

Despite these measures taken to alleviate risks, there is still concern pertaining to user error, ergo the astronauts should be properly educated on the usage of the device to minimize the likelihood of damage caused to the astronaut's suit or the anchoring device itself. This is outlined in the operations plans, but safety precautions performed during the use of this device will be further discussed here. First, before the device is used by the astronaut, the gears should be tested outside of the space suit to ensure everything is working accordingly. When in use, the device should be held such that the handle is always facing the user. As the device is being unfurled and the arms extended, one hand should remain on the body and one hand should remain on the handle at all times until the device is ready to be detached from the surface. During testing, this device should be subjected to multiple trials to properly demonstrate the durability of the internal tension mechanism. Additionally, the tensile strength of these mechanisms will be determined and adjusted such that they are significantly stronger than they need to be in order to avoid breakage. Furthermore, the pin should be tested by a gloved hand to determine if there is any pinching before actual use of the device.

Technical References

Asbeck, Alan T., et al. “Scaling Hard Vertical Surfaces with Compliant Microspine Arrays.” The International Journal of Robotics Research, vol. 25, 12, Dec. 2006, p. 1165–1179, https://journals.sagepub.com/doi/abs/10.1177/0278364906072511?casa_token=p-1Xs38_3s8AAAAA:1JgBLWh-3UKJv_dSU-8lUSnIG7UPKb4qY6XQKJGjukBO-CXCRkbxCqpFhoDiT3Z1gwjnSxzT7yI_Mw.

Asbeck, Alan T., et al. *Climbing Walls with Microspines*. Nov. 2004, p. 1–3, https://www.semanticscholar.org/paper/Climbing-Walls-with-Microspines-Asbeck-Kim/9dbd3a244cfb05c1d5527a7baca83c2414253d15.

Ezekiel G. Merriam, Andrew B. Berg, Andrew Willig, Aaron Parness, Tim Frey, and Larry L. Howell. “Microspine Gripping Mechanism for Asteroid Capture.” 43rd Aerospace Mechanisms Symposium, May 4, 2016, 401-414, https://ntrs.nasa.gov/citations/20160008148.

Spenko, Matthew. “Making Contact: A Review of Robotic Attachment Mechanisms for Extraterrestrial Applications.” *Advanced Intelligent Systems*, July 2021, p. 1–11, https://onlinelibrary.wiley.com/doi/full/10.1002/aisy.202100063.

Stem Engagement Section

SEDS@NCSU MicroG-NeXT team has the following objectives for STEM Outreach:
Educate community members on the current goals of space exploration and the current research being developed
Educating the local students on moon geology as an immersive enhancement to curriculum science geology lessons.
Connecting and encouraging youth to develop interests in space exploration.

The target audience for the outreach engagement are 9-12th grade high school students from Wake STEM Early College High School located in Raleigh, NC. Wake STEM Early High School students are an excellent target audience due to their passion for the sciences. SEDS@NCSU plans on implementing the program called “Model Lunar Anchor”. The activity can be divided into two sub-activities and a big overarching one. Each sub-activity will focus on teaching a lesson connected to the high school science curriculum and the Lunar Anchoring Device. The first sub-activity will be about the moon's geology. The high school geology curriculum will be incorporated. Samples of rocks (Basalt, Anorthosite, Breccia) will be brought to teach the students about the different rock types here on earth and connect them to the rocks that can be discovered on the moon. The next sub-activity will be a lesson on “micro-spines”. The “micro-spines” activity will be simulated using foam and toothpicks to teach the students about micro-spines. The rocks from the geology lesson will be used to describe how friction works on different surfaces. This activity will be incorporated into a general lesson on friction to connect with the high school physics curriculum. After the two-sub activities, a big activity will be implemented as a culmination of the smaller activities. The big overarching activity will be a modeling project where students will simulate creating their own lunar anchoring device. The activity will be turned into a small competition where the student group who made the “best” (will be judged via a rubric on completion and performance) will receive a ribbon of recognition. The materials that will be used are cheap and easy to find materials such as straws and toilet paper tubes to create the body and using foam and toothpicks for the microspines. Students will be given 30 minutes to complete the project and will then compete. The devices they created will be judged on whether the devices can deploy the legs successfully and how much weight of clay it can hold before breaking. Since we are teaching high school level science we will be altering language used in teaching that can be understood by high school students. Any language or terms that are unfamiliar to the students will be accommodated by the SEDS@NCSU team. SEDS@NCSU has three social media accounts, a twitter, an instagram and a linkedin. We will be using these social media platforms to advertise our plan at hosting an event at Wake STEM Early High. The platforms will be used to share pictures to raise awareness in the community about the event.

Administrative Section

A. Mentor Request

Our team is not currently collaborating on our project with any technical point of contact at NASA. We look forward to being paired with a NASA engineer or scientist should we be selected to continue with this project.

B. Institutional Letter of Endorsement

We have requested a letter of endorsement from the Department Heads in the College of Engineering, and are awaiting response from them. We shall forward the Letter of Endorsement as soon as we receive it.

C. Statement of Supervising Faculty

We do not have a supervising faculty member. Our student team has worked diligently and tirelessly to make this proposal a reality without the guidance of any faculty member.

D. Statement of Rights of Use

As a team member for a proposal entitled "RAD (Reusable Anchoring Device) Pack" proposed by a team of undergraduate students from North Carolina State University, I will and hereby do grant the U.S. Government a royalty-free, nonexclusive and irrevocable license to use, reproduce, distribute (including distribution by transmission) to the public, perform publicly, prepare derivative works, and display publicly, any data contained in this proposal in whole or in part and in any manner for Federal purposes and to have or permit others to do so for Federal purposes only.

As a team member for a proposal entitled "RAD (Reusable Anchoring Device) Pack" proposed by a team of undergraduate students from North Carolina State University/college, I will and hereby do grant the U.S. Government a nonexclusive, non transferable, irrevocable, paid-up license to practice or have practiced for or on behalf of the United States an invention described or made part of this proposal throughout the world.

Signed:

Flynn Cruse, Thushan Fernando, Paige Ray, Daryl Harp Jr., Edward Hurley, Ajay Pandya, Alan Ferris, Brady Jones, Bridget Dale, Emily Dettmer, Erik Garcia, Erik St.Clair, Evan Corkery, Hailey Bruce, Jackie Liu, Jarrad Harland, Kierra Shook, Maia Schreiber, Robbie Leske, Sadie McCarthy, Sebastian Perna, Stephanie Ortiz.

E. Funding and Budget Statement

Items	**Costs**
Materials & Supplies	
3D Filament	$50.00
Steel hooks for Microspines	$50.00
Belts	$10.00
Gears & Pins	$10.00

Manufacturing Costs	None - university provided tooling.
Travel (for 10 people, though could be adjusted as needed)	
Flights	$8,000
Hotel	$15,000
Ground Transportation	$750
Food	$1,500
Miscellaneous	$500
Total	**$25,870**

Potential sources of funding: North Carolina State University's Engineer Your Experience (EYE) Fund, Student Government, SEDS USA.