Modular Tool for Robotic Construction on the Lunar Surface. N. D. Blas[1] and D.P Purcell[2], [1]Independant Researcher, 388 S. 4th Street, Tooele UT, 84074. Email: nathenblas@gmailcom, [2]Colorado School of Mines, 1310 Maple St. GRL 140, Golden, CO, 80401. Email: dpurcell@mines.edu.

Introduction: Robotic operations on the lunar surface will enable both national entities and private companies to begin construction of facilities such as landing pads [1], habitats, berms, and related infrastructure assets. Initial construction operations on the lunar surface will be primarily completed with the aid of robotic vehicles, equipped with tools such as bulldozer blades, excavation bits, and hauling bays. On Earth, analogous vehicles with similar equipment are often dedicated for only single purpose operations. Due to mass and volume limitations inherent for operations on the Moon, rovers will need to be multi-functional, capable of completing several construction operations as efficiently as possible. Modular tools and equipment will be essential for this task, specifically when considering the deployment of ground anchors into the lunar surface. Ground anchors (soil nails, helical piles [2]) will serve to secure building foundations, and function as re-useable construction supplies for both temporary and long-term facilities. The aim of this study is to provide proof of concept of a rover-based tool which can deploy ground anchors into the lunar surface with both rotational, and percussive mechanisms built into a single, compact device.

Design Features: The Yankee Screw Punch (YSP) (**Figure 1**, **Figure 2**) is a novel variation of a handheld tool known as a "Yankee Screwdriver" [3]. The YSP is designed to submerge a ground anchor in either terrestrial soil or lunar regolith. To accomplish this a threaded rod will apply a torsional force deploying the anchor into the ground. At the end of this motion a percussive force will work to seat the anchor in place. This will all be accomplished by exerting a force in a purely linear motion. As such the YSP exists in one of two states, extended, and compressed. When in use the YSP will start fully extended with both springs uncompressed. As force is applied to the tool the main tool head will see three full rotations. Once the YSP has been fully compressed an internal rod will release applying the percussive force. When fully extended and in an at rest state the YSP measures just under 620mm (24.4in). While compressed the YSP measures 495mm (19.48in). The main body, which takes up 445mm (17.7in) of the total length is 130mm x130mm (5.11in x 5.11in).

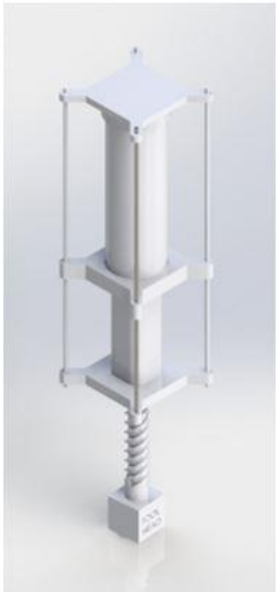

Figure 1: *Yankee Screw Punch fully assembled. Rendered in SOLIDWORKS 2020.*

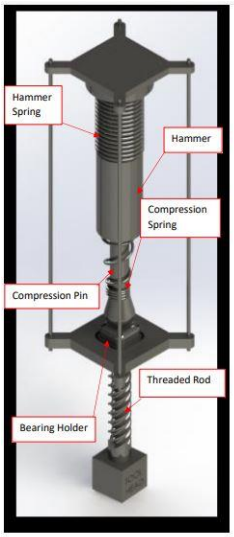

Figure 2: *Yankee Screw Punch with casing removed. All internal parts are shown and annotated. Rendered in SOLIDWORKS 2020.*

Lunar Application: Verification testing will take place with standalone, manually operated prototypes at standard terrestrial temperatures and pressures, however certain considerations must be made for the YSP operation on the lunar surface. For example, identification of viable rovers and lunar vehicles which the YSP could

be mounted too must be completed. The YSP mount must enable full range of linear travel along the threaded screw. Additionally, the percussive force imparted at the end of the toolhead stroke must not damage internal components, or cause damage to the parent vehicle. Dust mitigation in regolith environment is always an area of concern, and further work must be completed for a lunar-based prototype to ensure regolith does not infiltrate the YSP, causing mechanical damage or binding. Initial review of viable lunar vehicles indicates that the Astrolab Venturi Flex rover [4] (**Figure 3**) is a promising platform to which the YSP could be mounted.

Figure 3: *Astrolab Venturi "FLEX" Rover. Image Source: https://astrolab.space/mission1*

The FLEX rover has sufficient payload volume to accommodate the YSP on either the top-deck, or underslung payloads. Furthermore, the FLEX rover has sufficient mass to apply the downward force which would be required for ground anchor deployment into unconsolidated regolith. Other potential platforms include variants of the Lunar Terrain Vehicle (LTV), currently under competitive development by aerospace companies such as Lockheed Martin, and Northrop Grumman. [5], [6]

Future Work: Currently the YSP is being constructed using additively manufactured parts, alongside Commercial-Off-The-Shelf (COTS) hardware. This prototype will be used for testing and point of failure observation. The design is modular so any future upgrades can be implemented without a full rebuild. The prototype is estimated to be complete by the end of March and testing can begin in April. Prototype verification testing will be conducted in terrestrial soil and lunar regolith simulant. Testing will determine the appropriate parameters for the internal springs and material that can withstand the forces exerted and temperature fluctuations seen in a lunar setting. Other future work will include design and testing of a mounting apparatus.

Conclusion: Ongoing development of the YSP will iterate on existing technologies to provide a modular ground anchor deployment tool, which can be mounted on a variety of rover platforms. The YSP leverages rotational and translational movement of the rover platform aid in seating ground anchors during construction operations, without relying on an external powered interface which would otherwise be required. The YSO is currently in development, with the initial terrestrial testing already underway. Analog testing for YSP viability, including material selection, and hardware purchasing is expected to be completed during the Summer of 2024.

References:

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