Modular Tool for Robotic Construction on the Lunar Surface

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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:

The Yankee Screw Punch (YSP) (**Figure 1**) 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).

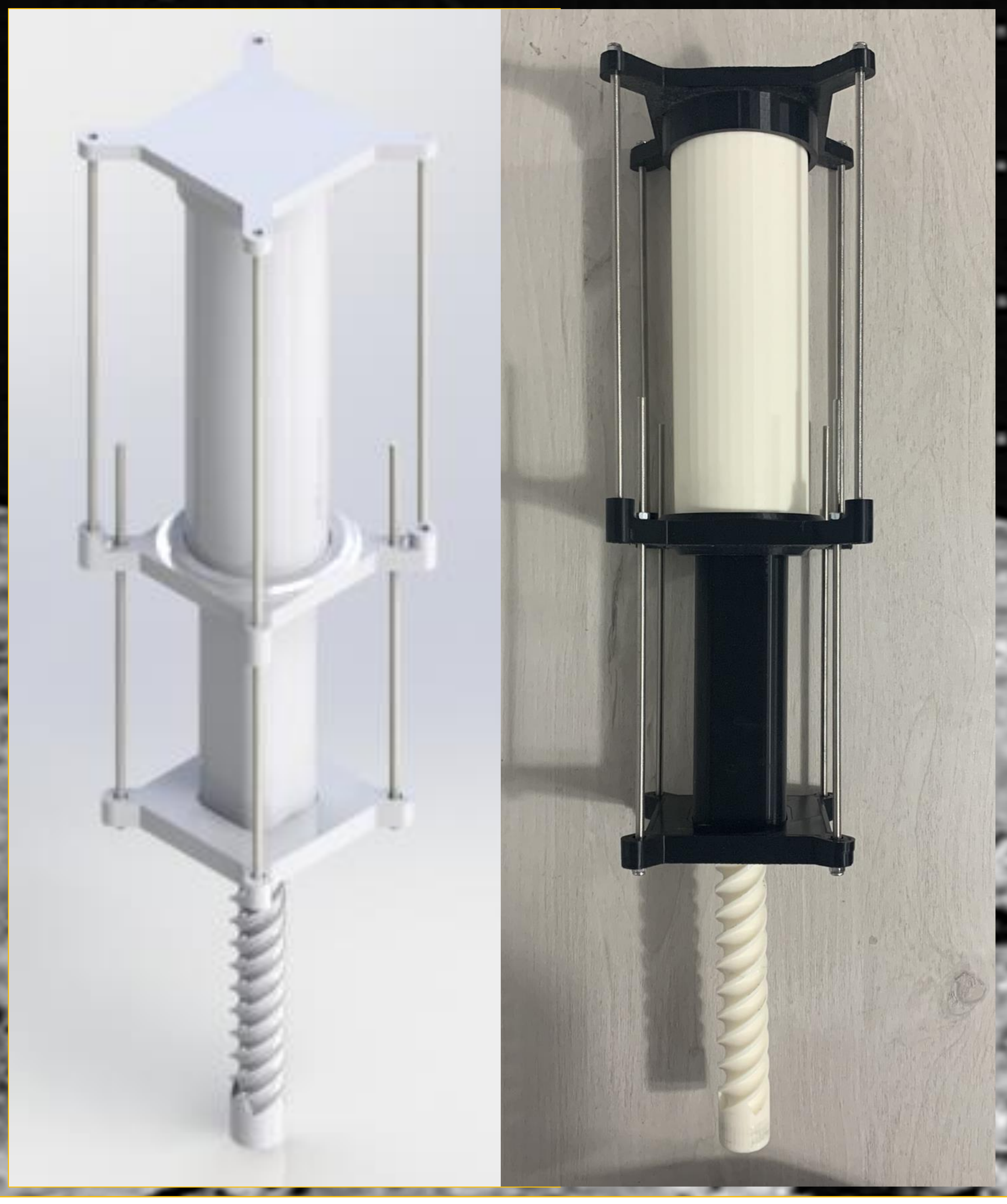


Figure 1: Yankee Screw Punch fully assembled. Rendered in SOLIDWORKS 2020 (left), and fully assembled prototype (right).

Figure 7: Astrolab Venturi "FLEX" Rover. Image Source: https://astrolab.space/mission1

Testing:

Functionality testing of the YSP included evaluation of Tool-Head performance in a variety of mediums, such as commonly available terrestrial soils. Mediums tested include sand, topsoil, and a mixture of topsoil with angular debris. Further testing will include testing in relevant highland, or mare simulants as required, such as Lunar regolith simulant (CSM-LHT) (**Figure 6)** . Initial testing identified potential modes of failure during operation. Specifically, the threaded rod material, prototyped out of polyethylene terephthalate glycol(PETG), proved to have insufficient strength, and the threaded rod fractured along the print layer lines**(Figure 5).** New iterations of the YSP Threaded Rod are being developed to increase strength, reduced mass and appropriate material selection. Further testing is planned to identify the force needed and the optimal positioning to successfully deploy a piece of hardware. As further hardware will be needed, such as Tool Heads and Mounting Systems, they will require their own testing.

Figure 5 : Part Failure cause by initial testing.

Figure 6: Initial Testing Beds, 3 different terrestrial soil

Lunar Application:

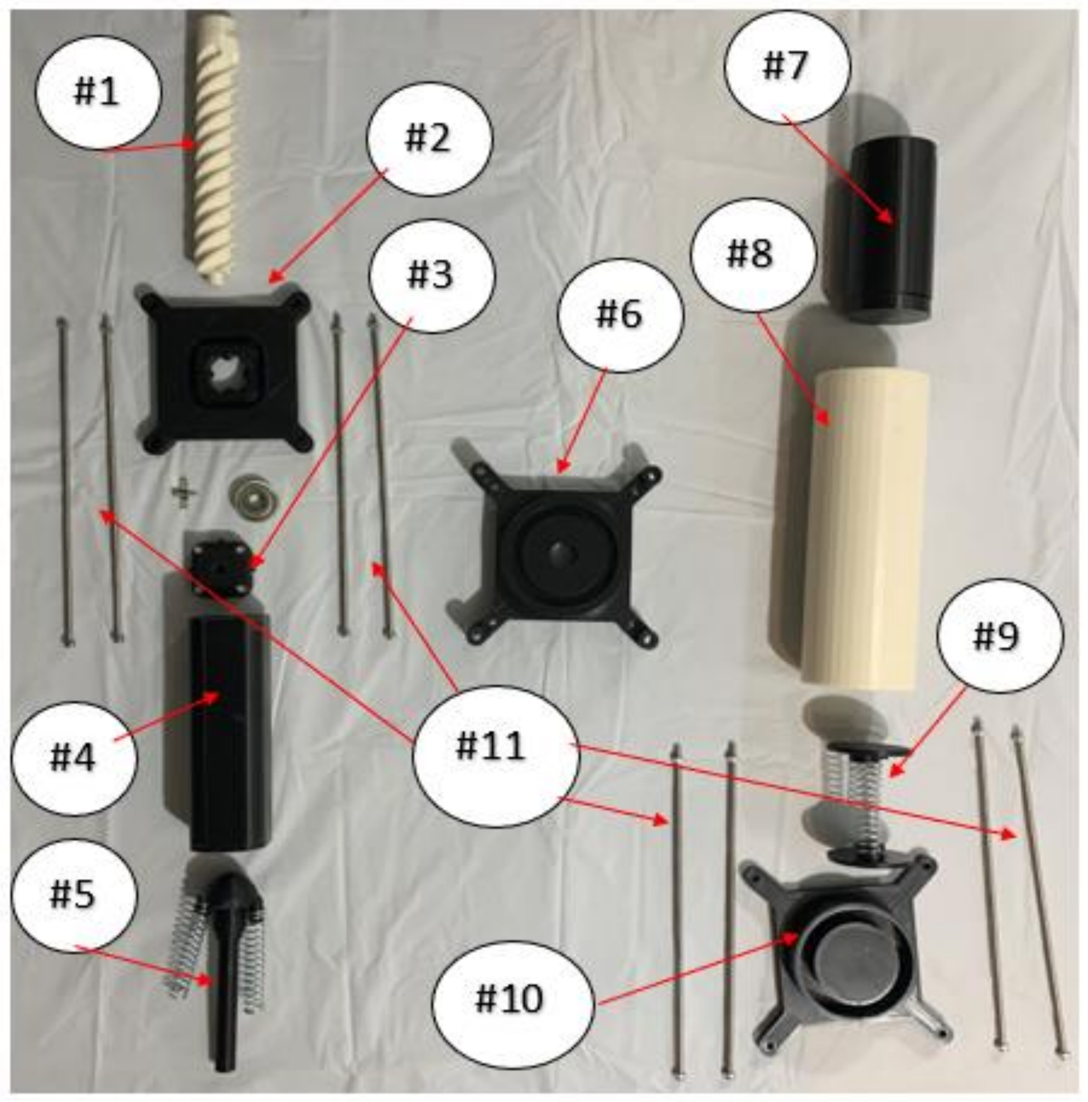
Verification testing will take place with standalone, manually operated prototypes at standard terrestrial temperatures and pressures, however certain considerations must be made for the YSP operation on the lunar surface. For example, identification of viable rovers and lunar vehicles which the YSP could be mounted upon 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 7**) is a promising platform to which the YSP could be mounted. The Astrolab Venturi rover is a proven prototype[7], capable of manipulating the YSP with either a robotic arm or enabling YSP operation via its “squatting” capabilities.

Figure 2: Tool Head Design Revision 1.

Figure 3: Tool Head Design Revision 2.

Future Work:

Future work on the Yankee Screw Punch will start with further testing to help refine the design and to improve performance. As mentioned in the Lunar Application Section, Temperature and Pressure fluctuations will need to be accounted for, especially when it comes the internal springs. Currently as seen in (**Figure 4)** Commercial-Off-The-Shelf (COTS) springs are being used, while further spring design is being implemented to keep constant dimensions and force while under the Lunar fluctuations. Additional work will also include the design and construction of attachments for both the Tool Head and Mounting System. Currently two Tool Heads have been designed . One has been constructed and is ready for testing. The second is awaiting construction. Lastly, research is needed to determine the range of anchor dimensions (Anchor length, shaft width, bearing plate diameter) that the YSP can deploy, either as a stand-alone tool, or with the aid of related robotic manipulators.



BOM

Part Number	Part Name	Quantity
#1	Threaded Rod	1
#2	Base plate	1
#3	Bearing Holder + Bearing Assembly	1
#4	Pin Casing	1
#5	Pin +Springs	1
#6	Midsection plate	1
#7	Hammer	1
#8	Hammer casing	1
#9	Hammer spring pack	1
#10	Cap	1
#11	Assembly screw packs	4

Figure 4 : YSP Exploded view with BOM.

References:

[1] Burns B, Coto M, Davis N, et al. Lunar In-Situ Landing/Launch Environment (LILL-E) Pad. In: NASA’s Big Idea Challenge; 2021. Available from: https://bigidea.nianet.org/wp-content/uploads/Colorado-School-of-Mines-Final-Technical-Paper-2021-BIG-Idea.pdf [Last accessed March 20, 2024]. [2] H.A. Perko, *Helical Piles: A Practical Guide to Design and Installation*, Hoboken, NJ: John Wiley & Sons, 2009.

[3] Zachry T. Furbish and The Forest City Screwdriver Co.: The Roots of “Yankee” Screwdrivers, 2003: The Chronicle of the Early American Industries Association, Inc., v. 56, no. 4.

[4] FLEX Payload Interface Guice, Astrolab Venturi, Version 2.0, November 2022.

[5] MDA Joins Lockheed Martin and General Motors On Next Generation Lunar Rover Development". *mda. space*. April 5, 2022. Retrieved April 7, 2022.

[6] Northrop Grumman Announces Team for NASA's Next-Generation Lunar Terrain Vehicle". *news.northropgrumman.com*. November 16, 2021. Retrieved December 3, 2021.

[7] “NASA Selects Companies to Advance Moon Mobility for Artemis Missions”. https://www.nasa.gov/news-release/nasa-selects-companies-to-advance-moon-mobility-for-artemis-missions/, April 3rd, 2024. Retrieved May 22nd, 2024