PROTOTYPE OF AN EXCAVATION ROVER FOR REGOLITH COLLECTION AND TRANSPORT

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ABSTRACT

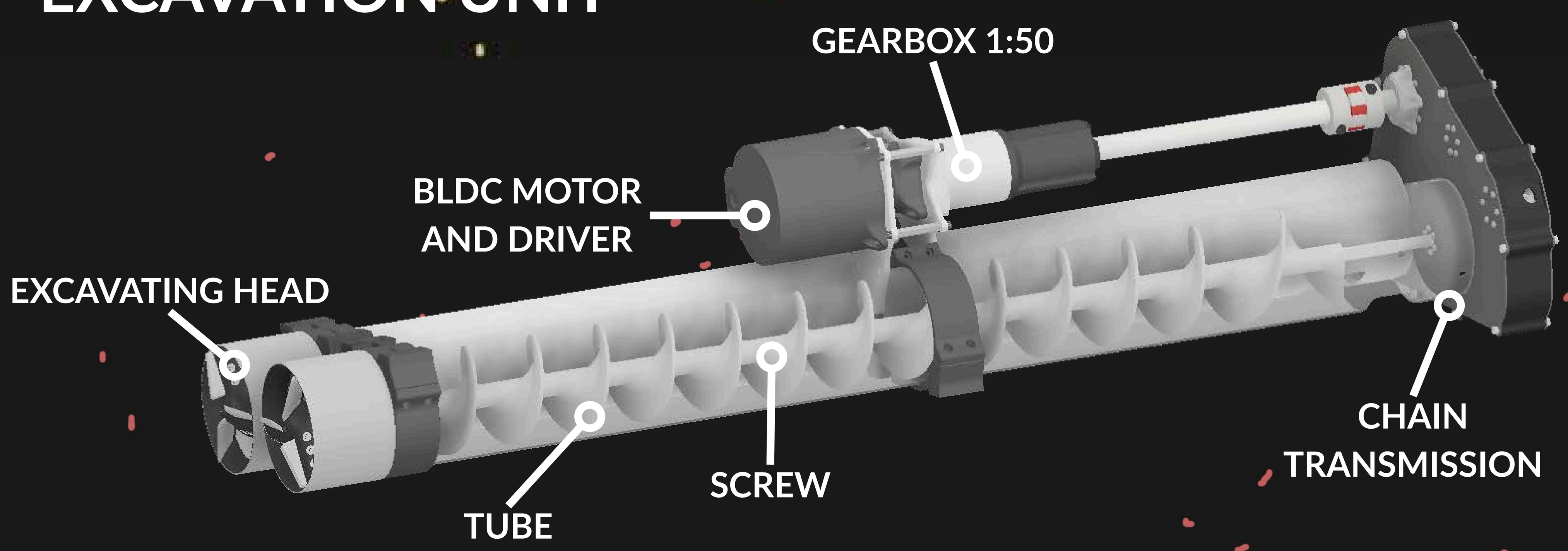
A lunar auger excavator was designed as a part of the DISTOBEE project for the ESA "The Second Space Resources Challenge". The rover's architecture is centered on a dual-screw mechanism designed to perform two critical functions: it serves as the primary excavation module and provides temporary on-board storage for collected material. The rover's structural assembly includes a frame, mobility subsystem, a tilt mechanism, and the excavation module.

The operational cycle is driven by rotating screws that convey regolith along the length of the tubes. During the digging phase, the module is tilted at a specific angle relative to the surface, allowing the excavating head to penetrate the lunar soil. Once the storage capacity is reached, the module is raised back to a horizontal position. By adjusting the system in such a way, resistance during the motion is reduced and the rover's overall stability is enhanced during transport across uneven, heavily cratered lunar terrain.

In order to conduct optimization experiments, a laboratory test stand filled with lunar regolith simulant was built. During the experiments, excavator throughput was measured as a function of the advance speed and auger rotational speed. Simultaneously, energy consumption and mechanical loads were tracked to refine the hardware's durability and energy efficiency. Beyond the excavation subsystem, the test stand offers the capabilities required to evaluate alternative drivetrain configurations and steerable wheel geometries in upcoming research phases.

DISTOBEE
AGH Lunar Resources Initiative

EXCAVATION UNIT



The excavation module collects and temporarily stores lunar regolith in two dedicated tubes that are equipped with excavating heads (Fig.1). The collection is achieved by internally rotating screws that convey the excavated regolith along the length of the tube toward an outlet. To balance the generated torque during digging, the heads and variable-pitch spiral screws rotate in opposite directions relative to each other. Power is supplied by a central drive unit that distributes torque to the drive shafts of both the screws and the excavating heads. During the excavation process, the digging module is tilted at a specific angle relative to the surface, allowing the excavating heads to dig into the lunar regolith. After the excavation cycle is completed, the module is raised back to a horizontal position.

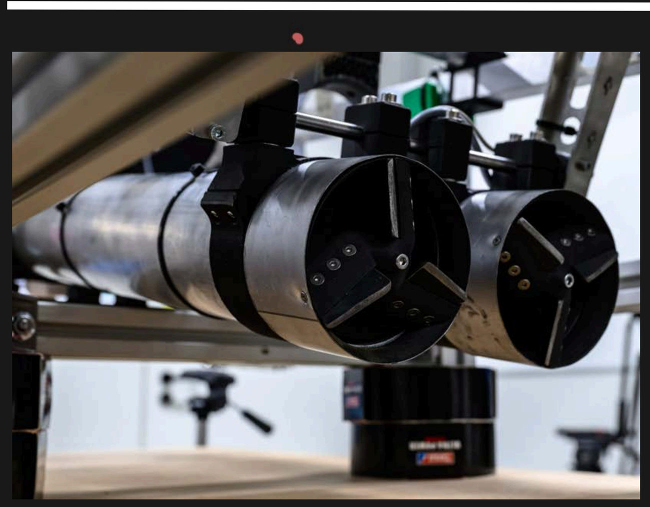


Fig.1 Excavating heads integrated into the rover's digging module

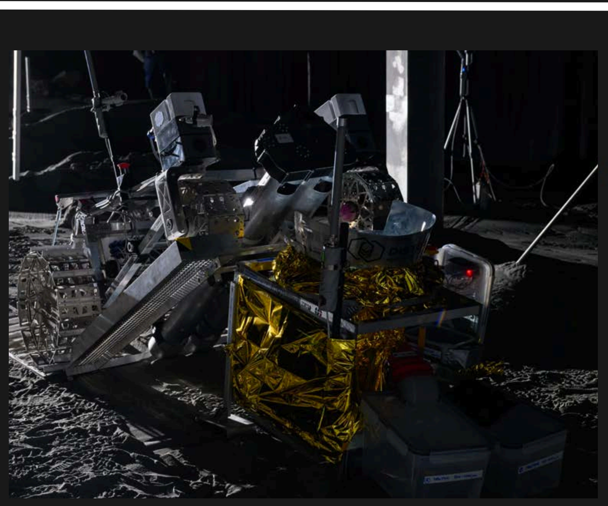


Fig.2 DISTOBEE system during ESA "2nd Space Resources Challenge"

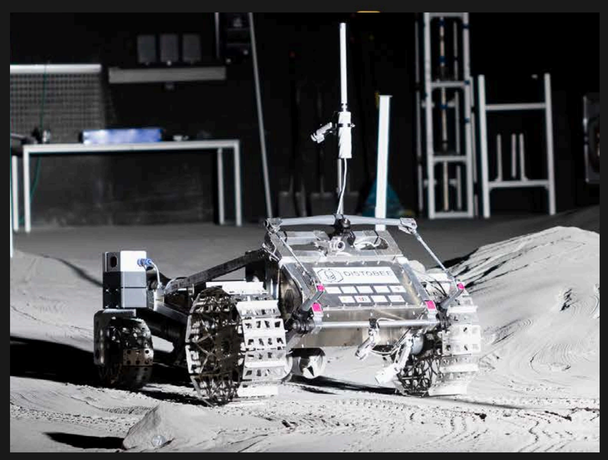


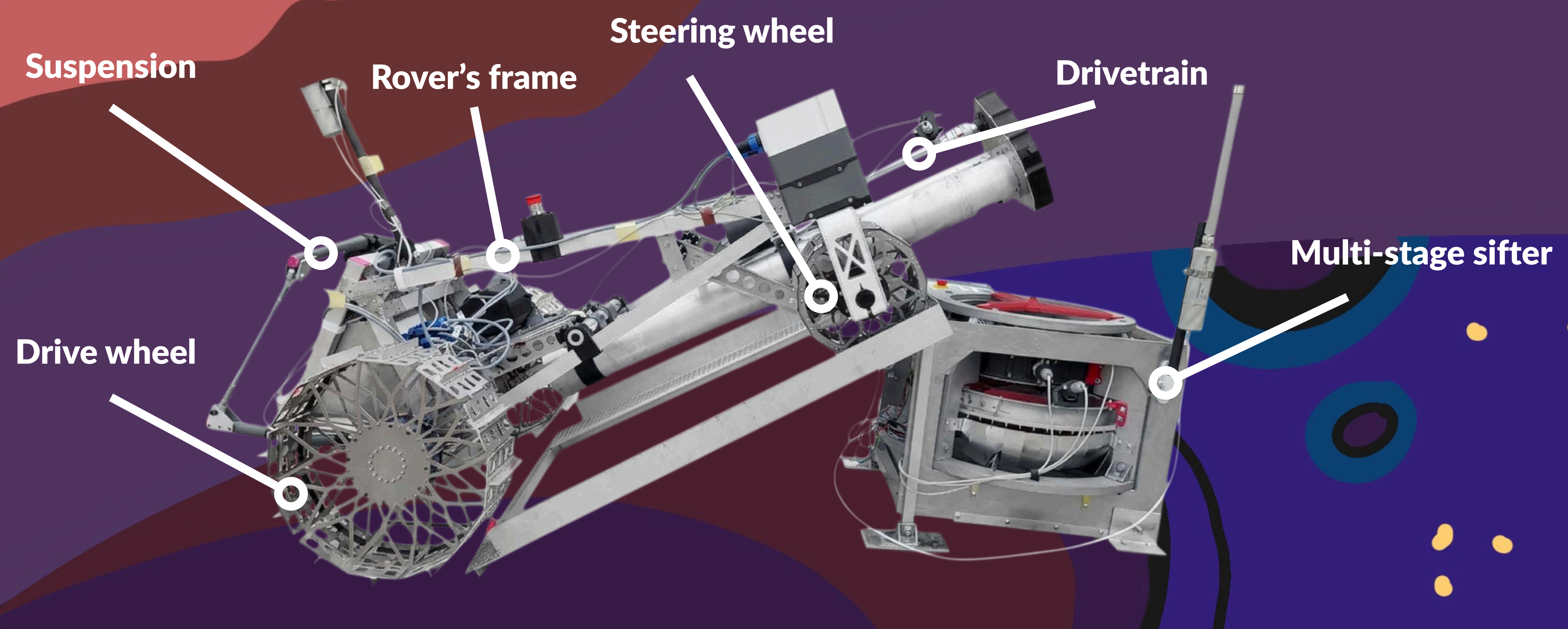
Fig. 3 Excavation rover during final field test at "LUNA" facility

FIELD TEST

The excavation rover prototype was tested during the finals of "The Second Space Resources Challenge" at the LUNA facility. The primary objective of this field test was to validate the operational capabilities of the excavation rover in a realistic environment and to evaluate the performance efficiency of its integrated subsystems. The test was successful, demonstrating stable structural integrity and high operational efficiency across most of the rover subsystems. The excavation module demonstrated outstanding operational efficiency - the rover successfully excavated, transported, and stored 7.6 kg of lunar regolith simulant during a single operational cycle. This achievement confirms the functional capacity of the designed excavation system, demonstrating stable operation and high efficiency of the rover's digging module. Despite this operational success, the test mission provided data that highlighted areas where the system could be improved. Future upgrades will focus on the rover's wheel geometry and traction. Additionally, optimizing the tilt mechanism's control software remains a priority.

EXPERIMENTS

The primary objective of the experiment was to characterize the performance of the excavation system and identify the optimal correlation between the rover's advance velocity and the auger's rotational speed. The key considered indicators were the resistive drag force, system power consumption, and the volumetric accumulation per unit length of the storage tube. Prior to each trial, the lunar regolith simulant was compacted with a roller to ensure material density uniformity. After initial testing, various parameter combinations were evaluated, crossing auger rotational speeds between 5 and 15 rpm with rover advance speeds from 10 to 25 mm/s.



RESULTS

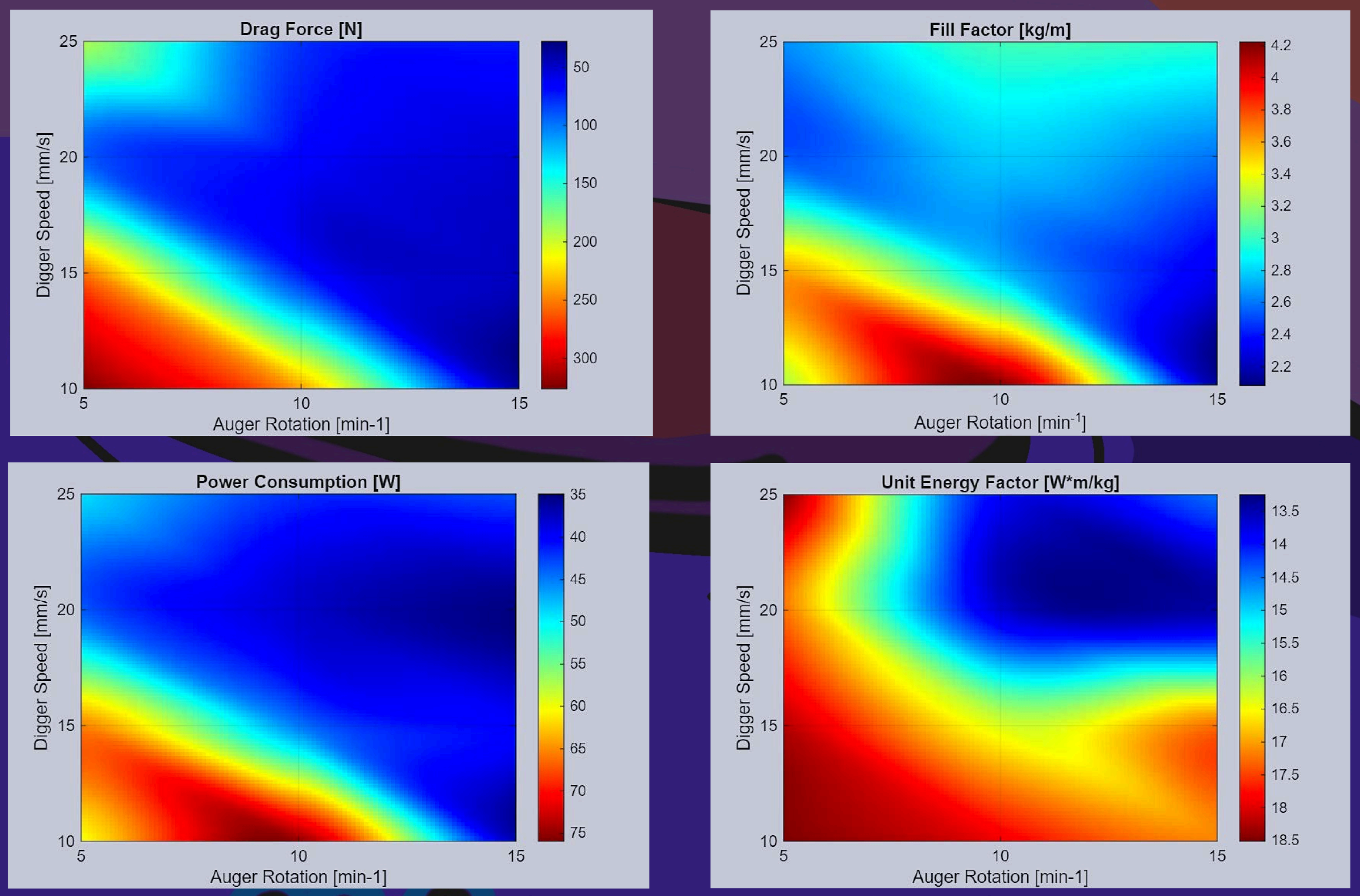


Fig.4 Heat map of regolith simulant excavation parameters determined during laboratory tests

CONCLUSION

Future research will optimize the screw-driven mechanism by analyzing how auger speeds and rover feed rates impact power demand and particle agglomeration across varying regolith densities. Additionally, next-phase developments will refine the rover's mobility subsystem, specifically wheel geometry, suspension, and tilt kinematics, while upgrading communication and vision subsystems.

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