DISTOBEE

MOBILE TUBE EXCAVATOR AND BRUSH ASSISTED MECHANICAL SIFTER IN THE DISTOBEE SYSTEM FOR LUNAR SURFACE OPERATIONS

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Context and Motivation

- Sustainable lunar exploration requires local resource utilization
- Lunar regolith as a primary resource for:
  - construction materials
  - oxygen and metal extraction
- Need for **robust, autonomous excavation and processing systems**
- DISTOBEE system was developed for the **2nd ESA Space Resources Challenge** *"Collection and Processing of Lunar Regolith"*

Design Assumptions and Operating Parameters

- Design of a fully integrated ISRU system demonstrator
- Mission requirements:
  - Collection and processing of **15 kg** of lunar regolith
  - Operational time limit: **150 minutes**
  - Energy budget: **300 Wh**
  - Maximum system mass: **60 kg**
  - Particle size separation into:
    - **500–1000 µm**
    - **100–500 µm**
    - **< 100 µm**
- Key design drivers:
  - Mechanical **simplicity**
  - Operational **reliability**
  - Compatibility with lunar environment and operations

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System Architecture

- **DISTOBEE** consists of two main subsystems:
  - Mobile excavation rover with storage capability
  - Stationary multi-stage screening unit
- Designed as a **modular and scalable architecture**

DIgging	**STO**ring	**BE**nificiation
Mobile tube excavator using dual-screw mechanism	Regolith storage in internal tubes for transport	Stationary multistage mechanical screening

referring to the work of a swarm of bees, modeling their organization, diligence, and teamwork.

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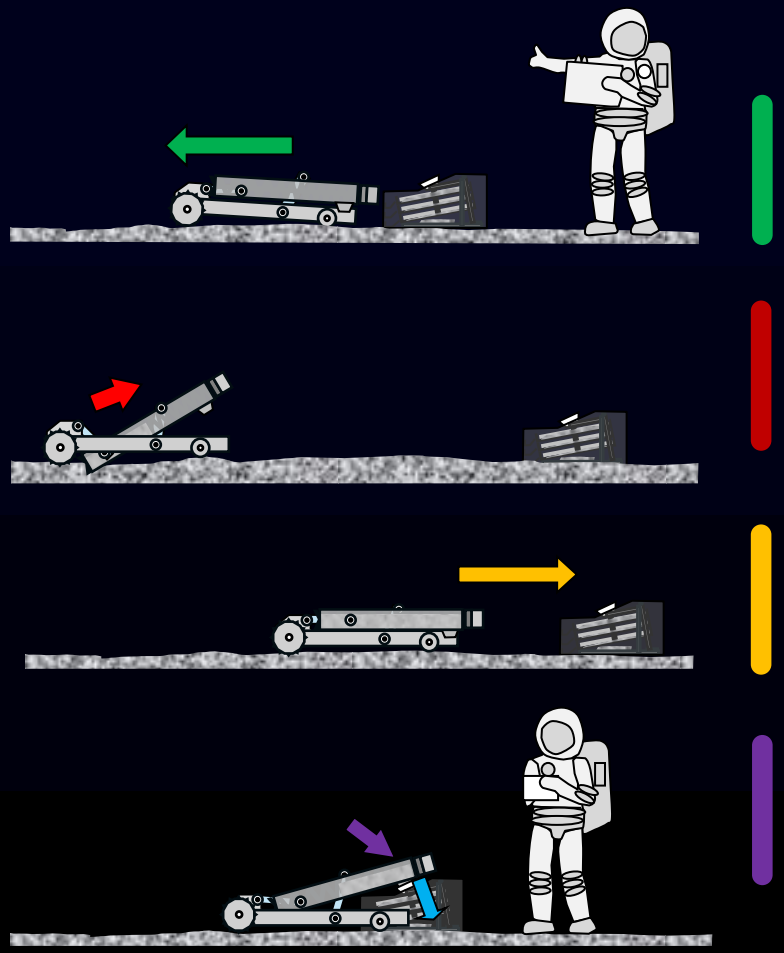
Operational Concept



1. Mobility and site approach

- The mobile platform traverses the lunar surface following a predefined mission plan, autonomously navigating and avoiding obstacles within the operational area.

2. Regolith excavation and storage

- The screw-based excavation mechanism collects lunar regolith and conveys it into an integrated storage tube. The filling process is continuously monitored using onboard sensors to assess storage capacity.

3. Transport to processing unit

- Once the maximum storage capacity is reached, the excavation rover relocates to the designated unloading and processing station.

4. Unloading and beneficiation

- Stored regolith is discharged directly from the storage tubes into the multi-stage screening unit, where mechanical particle size separation is performed.

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System devices

Digger with Tubular Excavation and Storage Devices

Multi-deck **Screening Unit**

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Excavation Rover Concept

- Mobile platform dedicated to regolith collection
- Equipped with a **dual-screw excavation mechanism**
- Functions:

1. digging regolith
2. loading into pipes
3. storage in accumulation tubes
4. haulage
5. unloading and feeding into the screener

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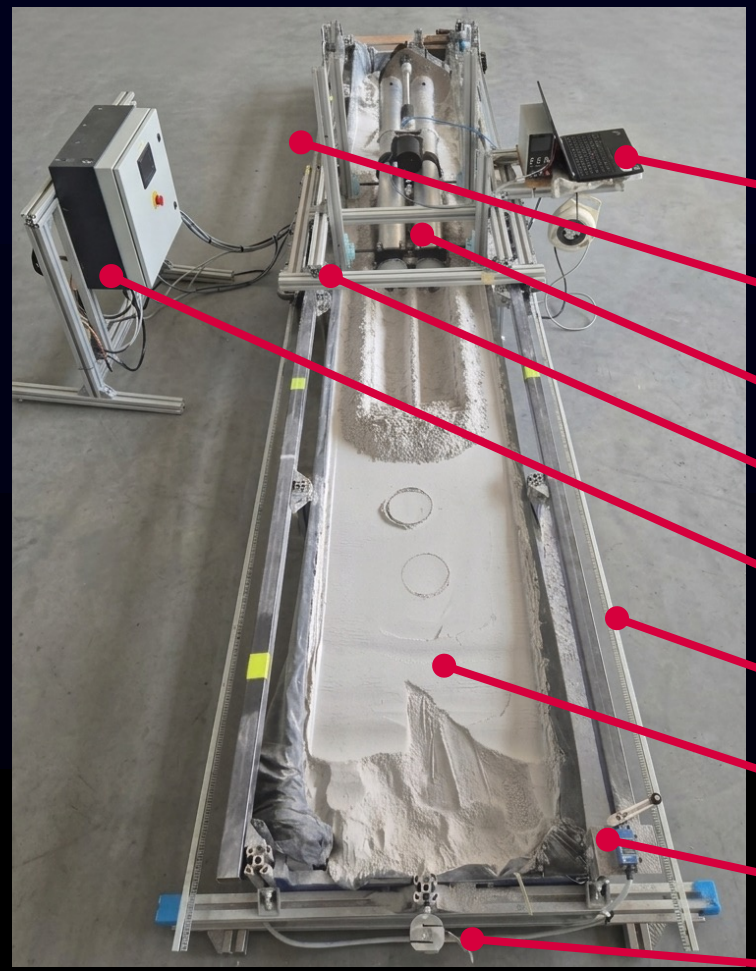
Laboratory test rig



Laboratory test rig for **excavation resistance** and **traction properties of drive wheels:**

- Computer
- Drive system
- Tested excavation and storage tube assembly
- Mobile mounting platform
- Control box
- Drive belts
- Trough filled with regolith symulant
- Test rig frame – linear guide rails
- Strain-gauge measurement system

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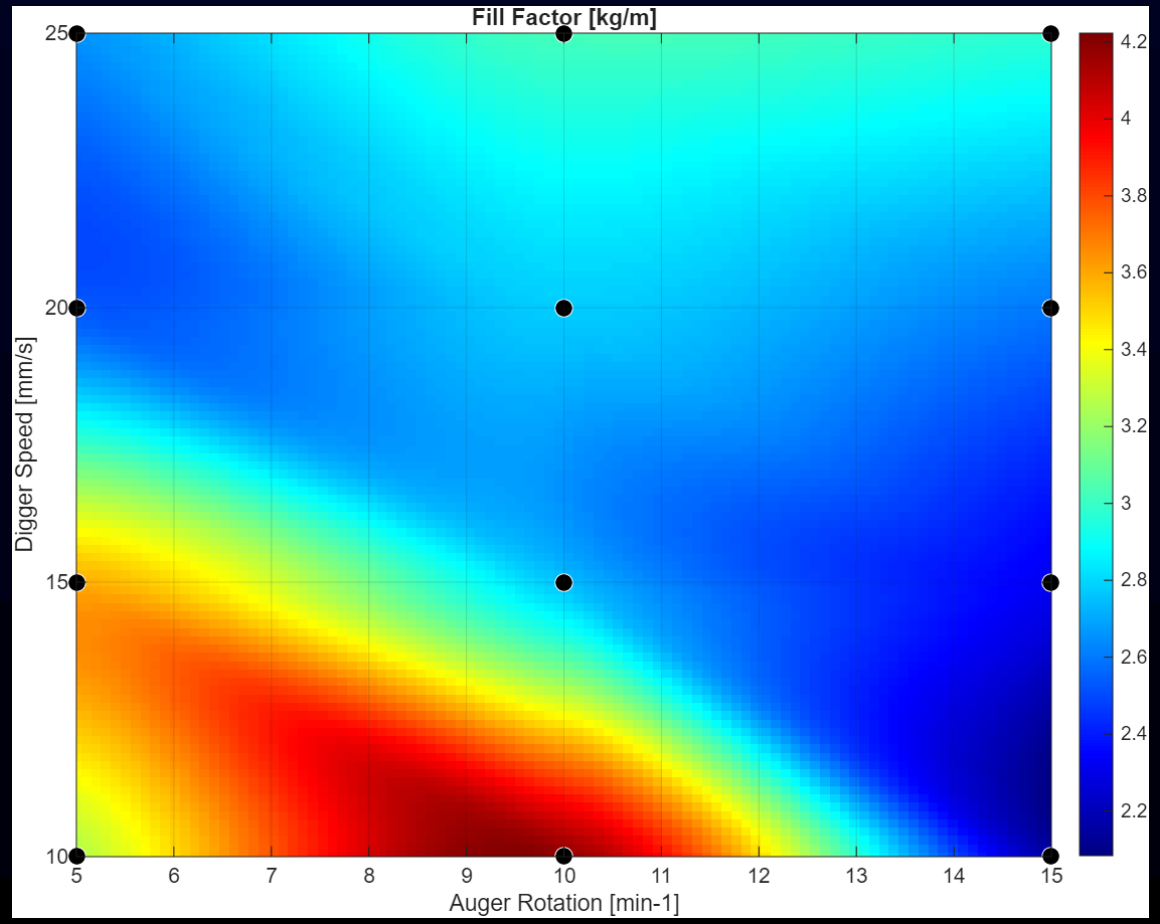
Laboratory tests



Heat map showing unit tube loading as a function of forward velocity and screw rotational speed, indicating optimal operational ranges for efficient regolith excavation and transport.

Multi Stage Screener: System Architecture

- Stationary, multi stage screening unit designed for mechanical regolith beneficiation
- Three coaxial screening decks with decreasing mesh sizes:
  - 1000 µm
  - 500 µm
  - 100 µm
- Each screening stage equipped with:
  - an independent vibration system
  - rotating brush assisted arms for active material handling
- All screens mounted at a fixed inclination angle to support gravitational material flow
- Dedicated camera system for each deck enabling continuous process monitoring

Operational Principle

- The screener operates in a cyclic mode

1. After loading, the first phase is the screening process:
    - brush equipped arms transport and distribute material across the screen surfaces
    - vibration enhances particle stratification and separation efficiency
2. After completion of screening:
    - the arms reverse their direction of rotation
    - retained material is discharged into external collection containers

- Each screening level is independently monitored using onboard cameras
- The inclined configuration of all decks ensures controlled and continuous material discharge

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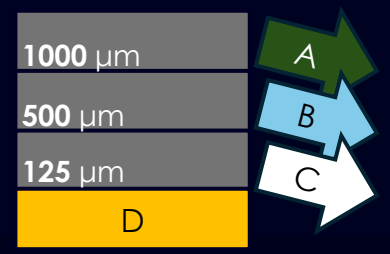
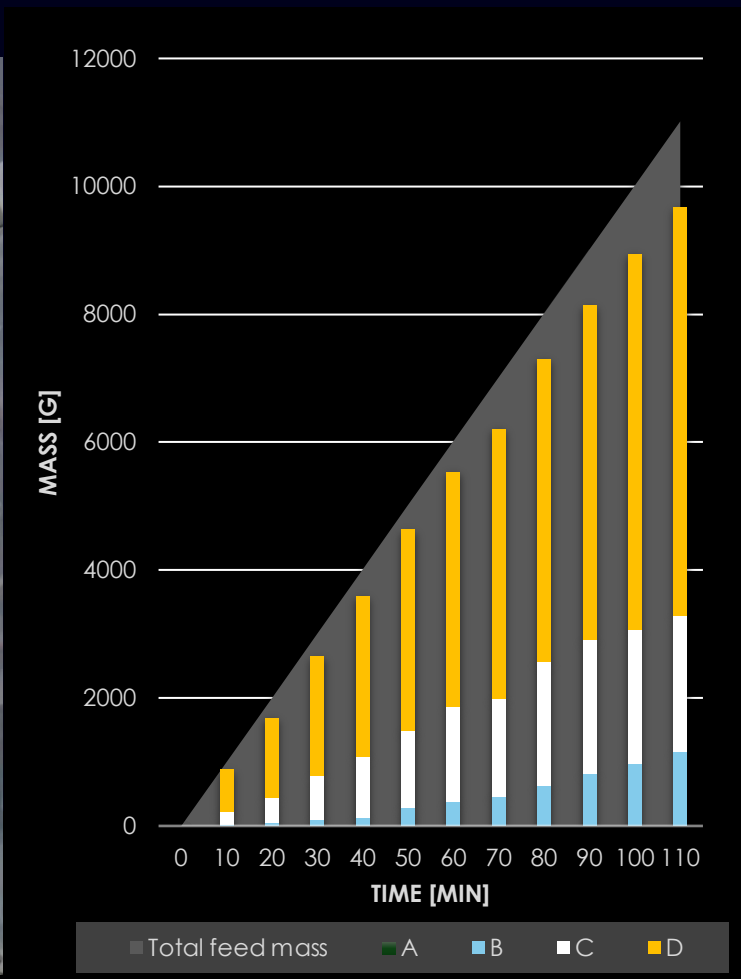
Laboratory tests





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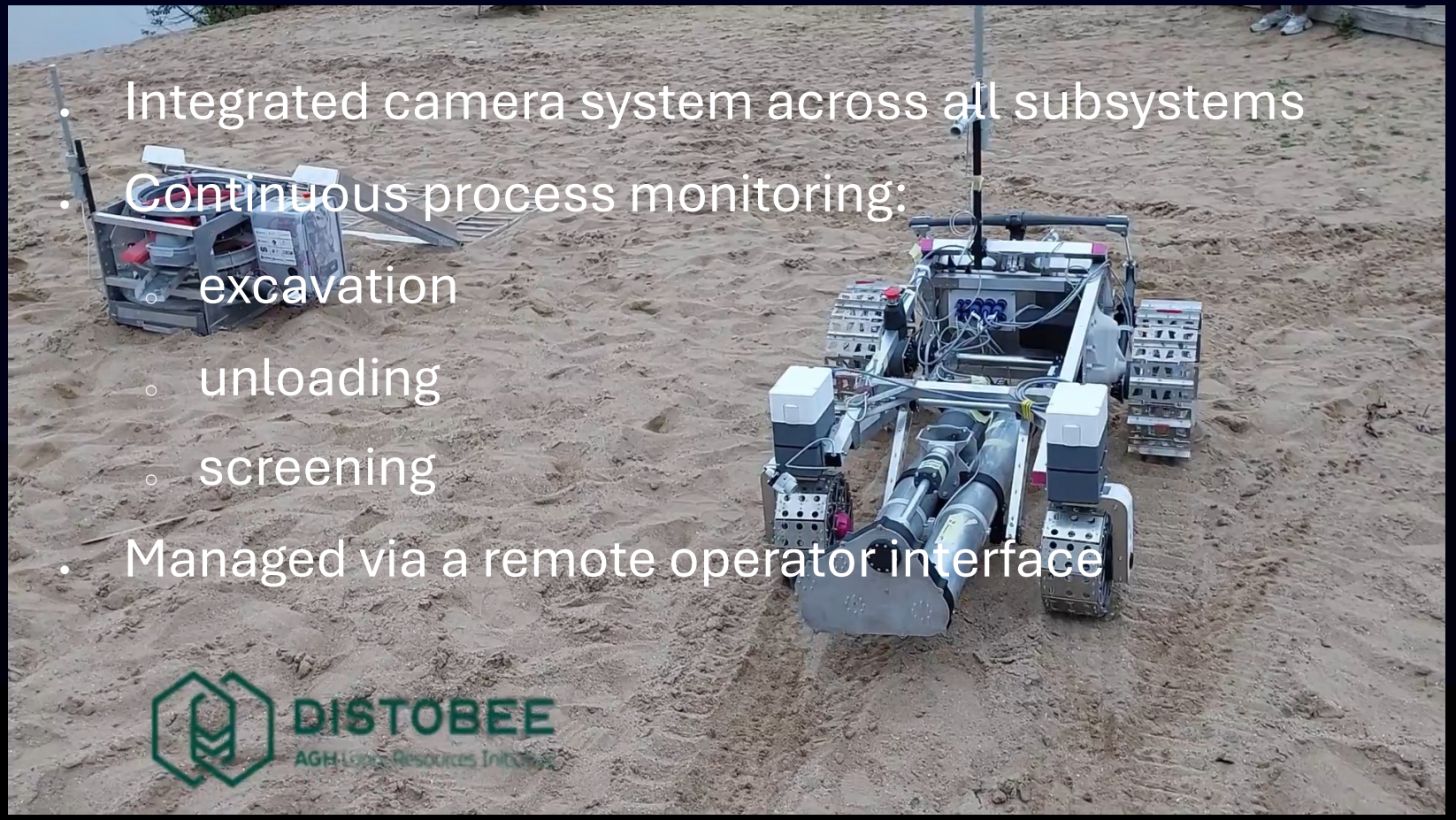
First field test - Monitoring and Control

- Integrated camera system across all subsystems
- Continuous process monitoring:
  - excavation
  - unloading
  - screening
- Managed via a remote operator interface



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The LUNA field test

1. Stable and reliable rover mobility on challenging terrain

2. Highly efficient excavation and storage tube loading performance

3. A critical software issue in the tube tilt subsystem limited full system operation, including the multi-deck sifter

Core excavation and mobility subsystems fully validated during LUNA tests

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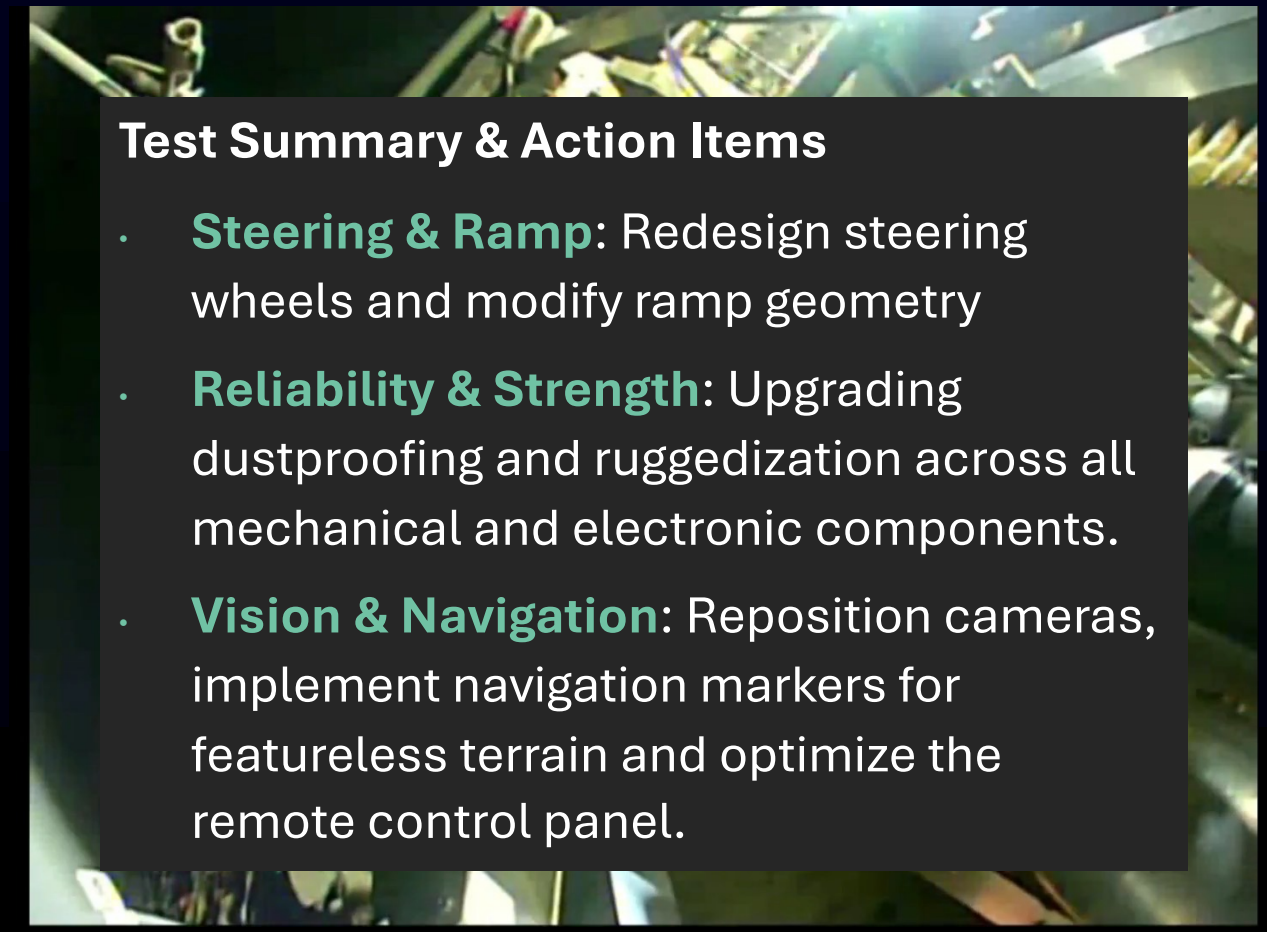
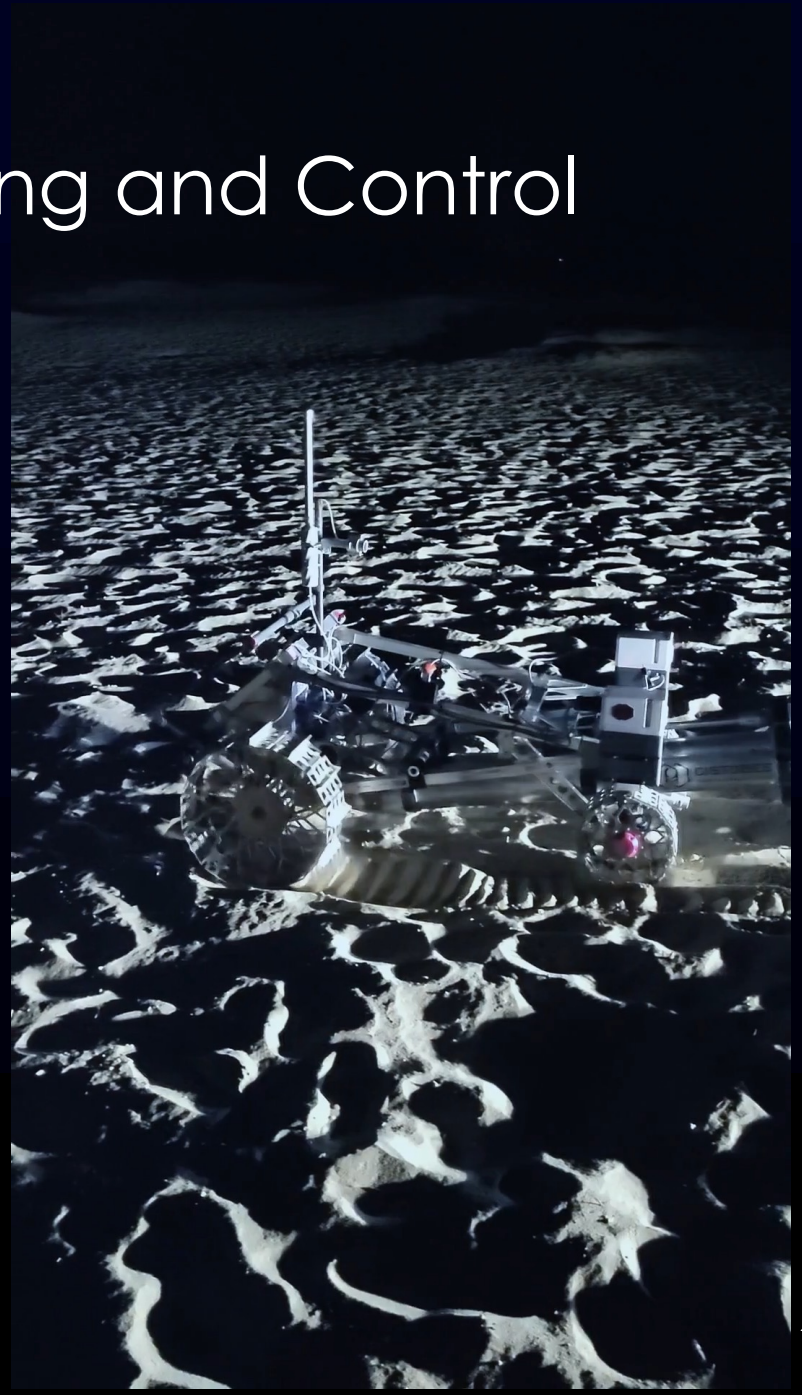
Desert field test – Mobility, Monitoring and Control



Test Summary & Action Items

- **Steering & Ramp**: Redesign steering wheels and modify ramp geometry
- **Reliability & Strength**: Upgrading dustproofing and ruggedization across all mechanical and electronic components.
- **Vision & Navigation**: Reposition cameras, implement navigation markers for featureless terrain and optimize the remote control panel.



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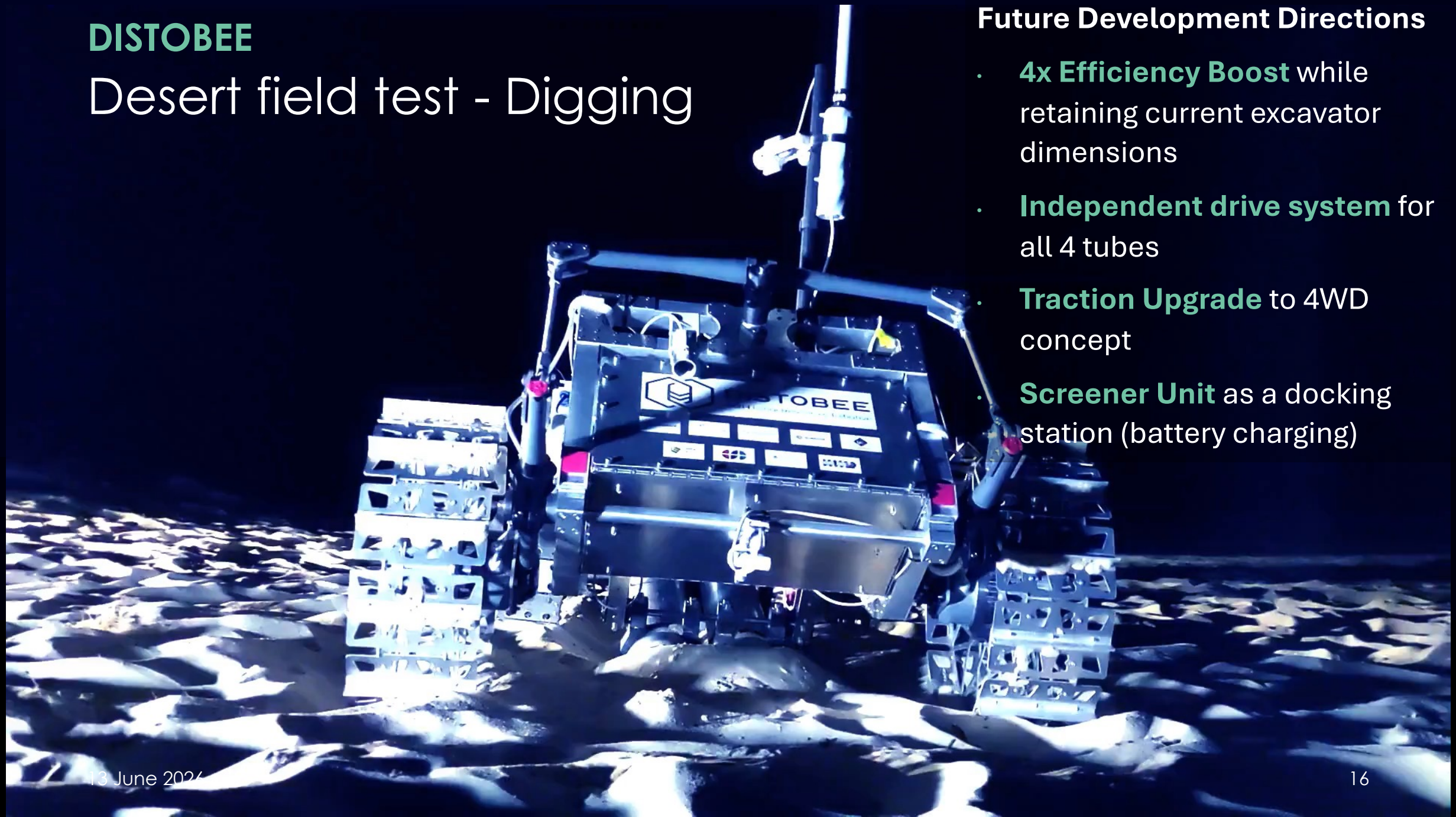
Desert field test - Digging



Future Development Directions

- **4x Efficiency Boost** while retaining current excavator dimensions
- **Independent drive system** for all 4 tubes
- **Traction Upgrade** to 4WD concept
- **Screener Unit** as a docking station (battery charging)

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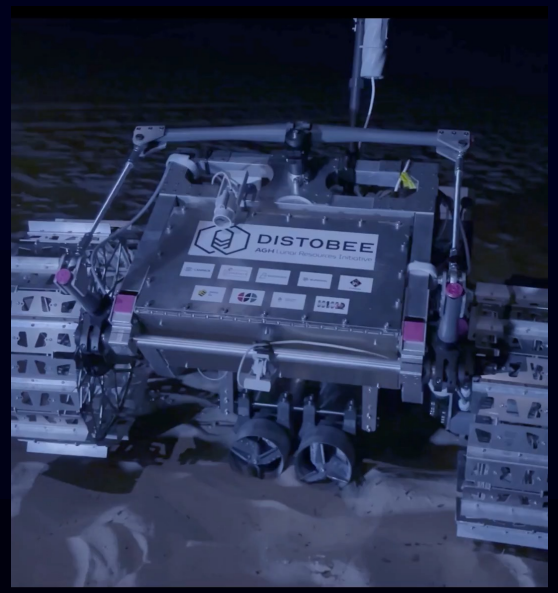
Summary and Conclusions

- **DISTOBEE** demonstrated a fully integrated and remotely monitored ISRU system, meeting performance targets for regolith collection efficiency and energy use.
- The system was optimized through laboratory testing at AGH University of Krakow and validated during field trials at the LUNA facility.
- All tests highlighted the critical importance of reliability and redundancy in key subsystems.
- Overall, **DISTOBEE** represents a promising approach to future lunar regolith excavation and beneficiation for ISRU.

Thank you!



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