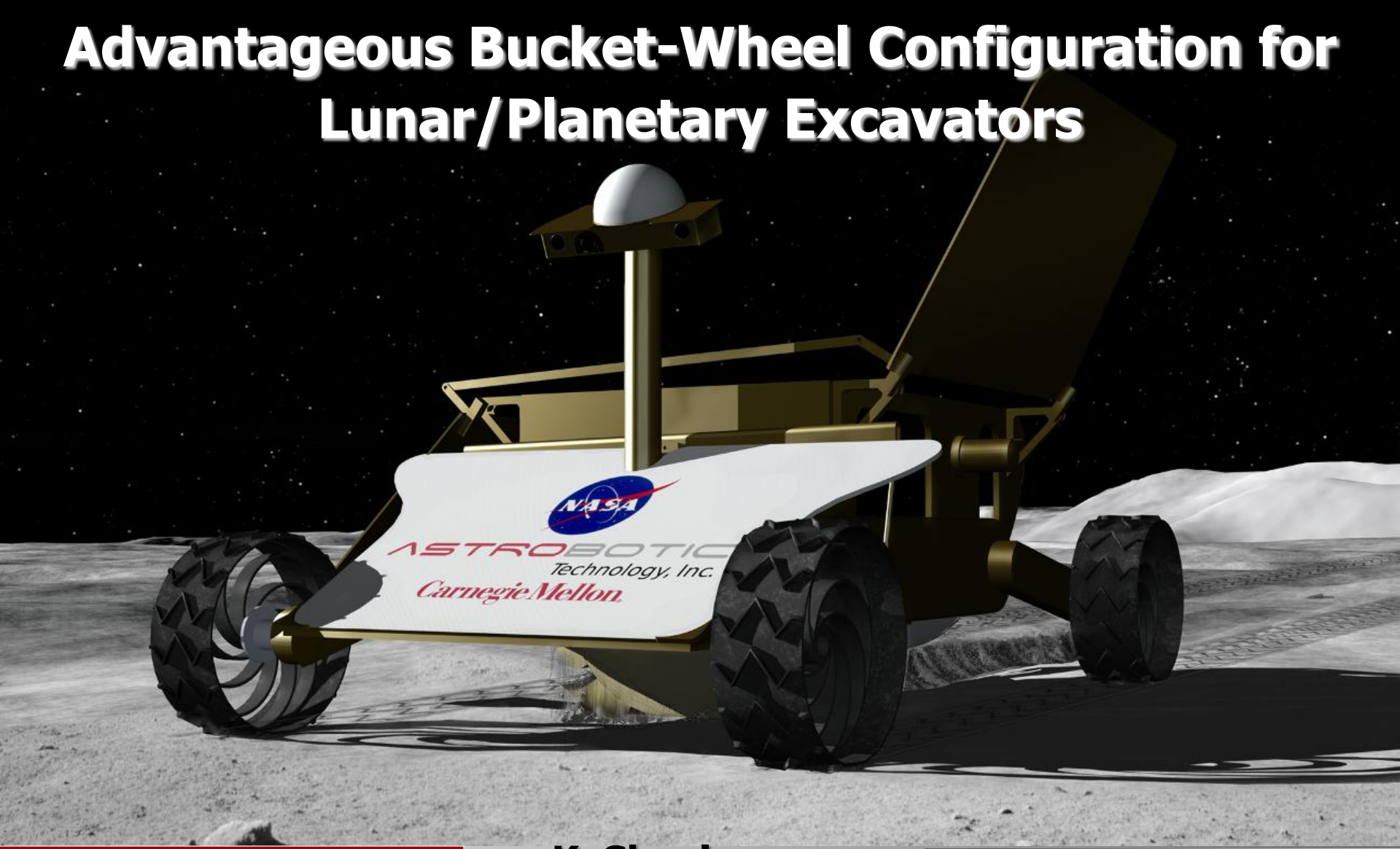
Advantageous Bucket-Wheel Configuration for Lunar/Planetary Excavators



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K. Skonieczny,
D. Wettergreen,
W. Whittaker

PTMSS 2011

June 21

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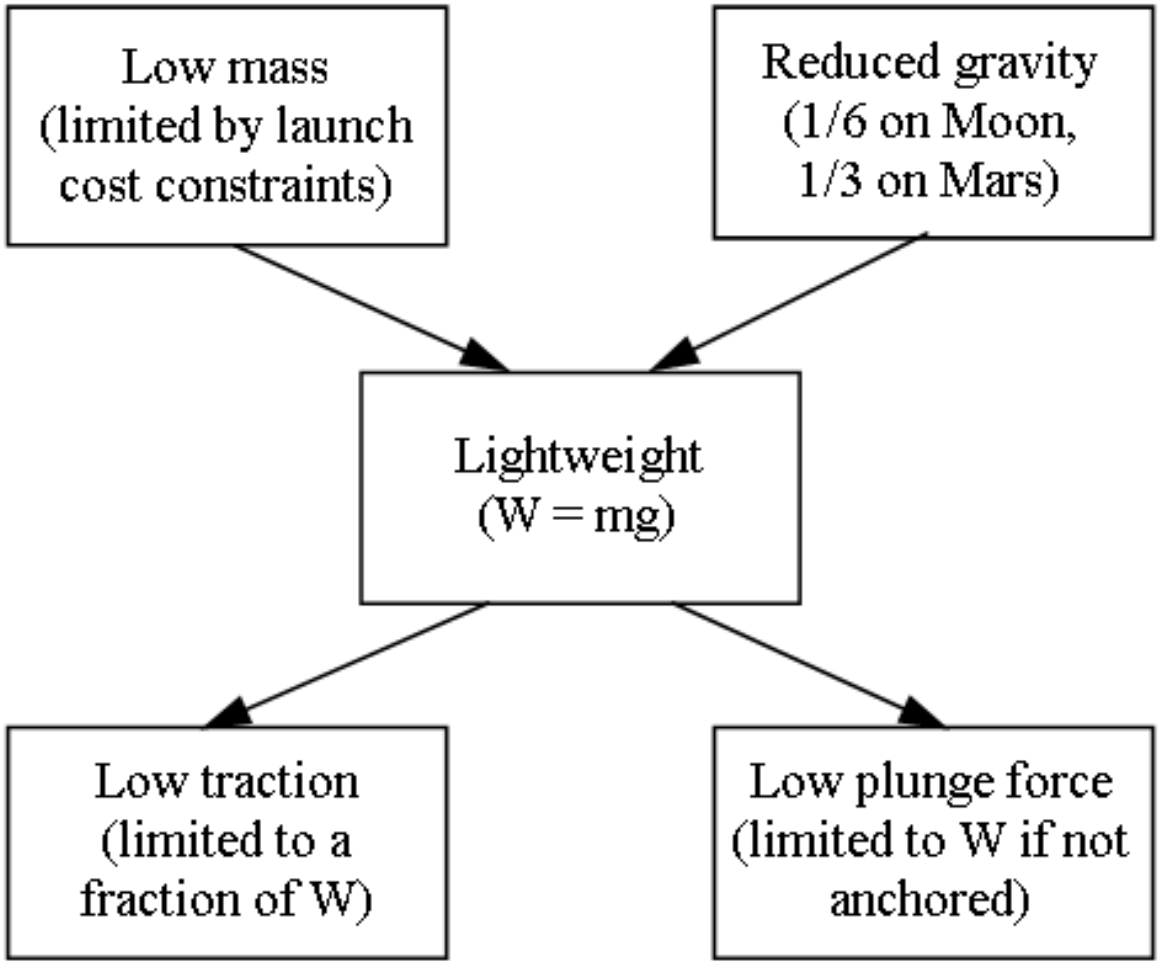
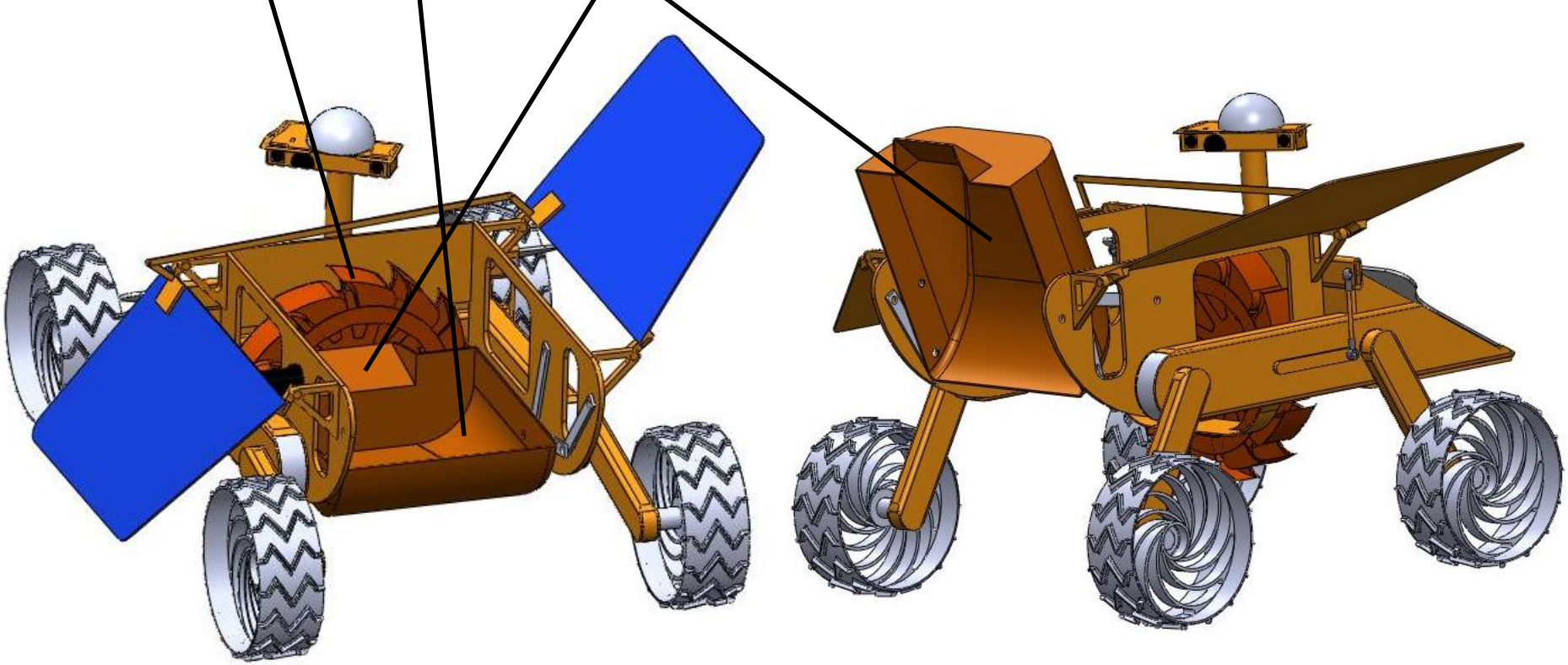
Lightweight excavators for regolith mining

Lightweight robotic excavators have limited traction and yet must nonetheless mine resources productively



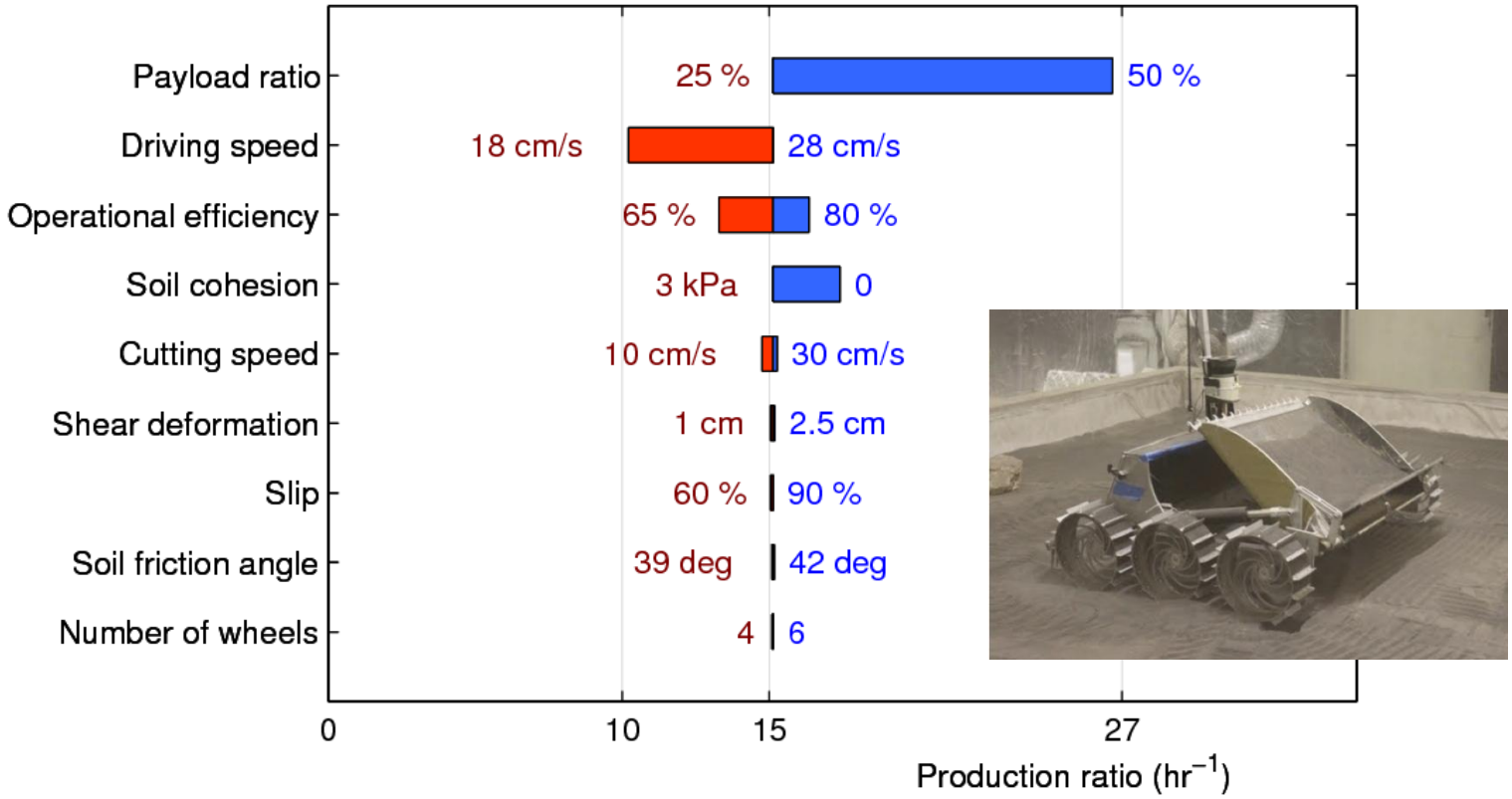
Lightweight robotic excavator configuration

- Dump-bed for high payload ratio
- Bucket-Wheel
  - Mounted transverse for direct transfer to dump-bed



Dump-bed for high payload ratio

Payload ratio and driving speed govern productivity for lightweight excavators, as shown in past work



Skonieczny, Wettergreen ,and Whittaker (2010) *Earth & Space*

Scarab configuration is centered around the tool

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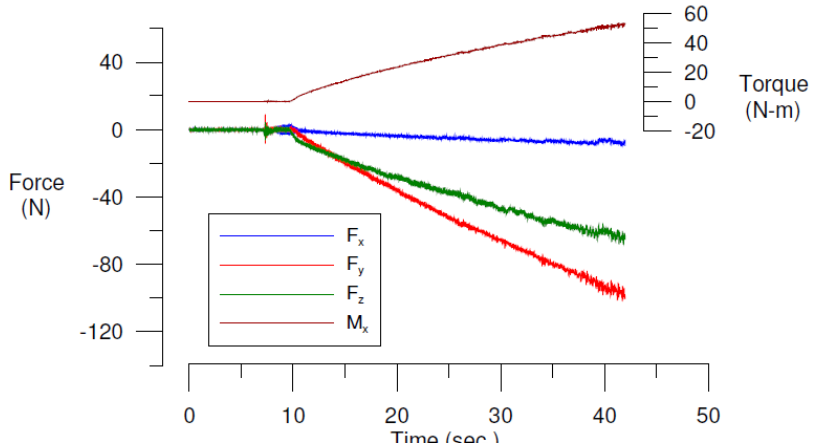
Discrete and continuous excavator configurations

Discrete excavators

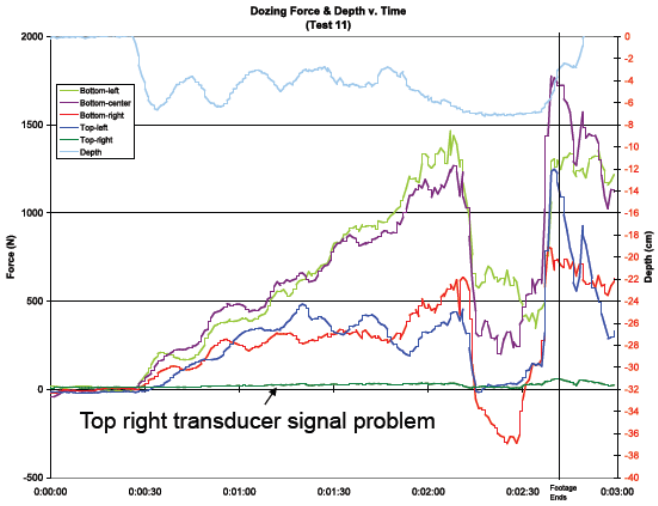
Continuous excavators

Discrete excavators experience rising resistance

Discrete excavators such as loader buckets and dozer blades undergo rising excavation resistance as soil accumulates

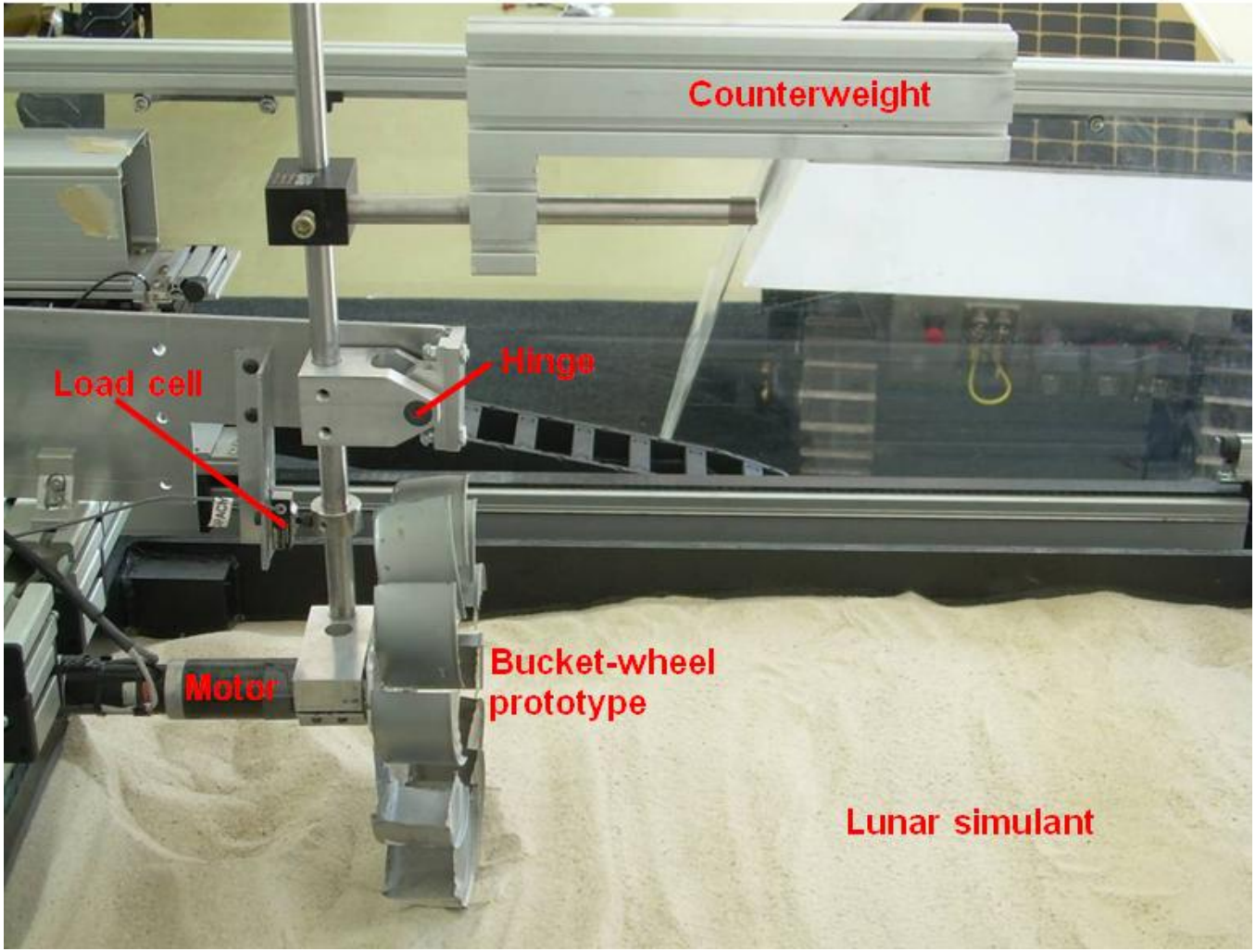


Agui and Wilkinson (2010) *Earth & Space*



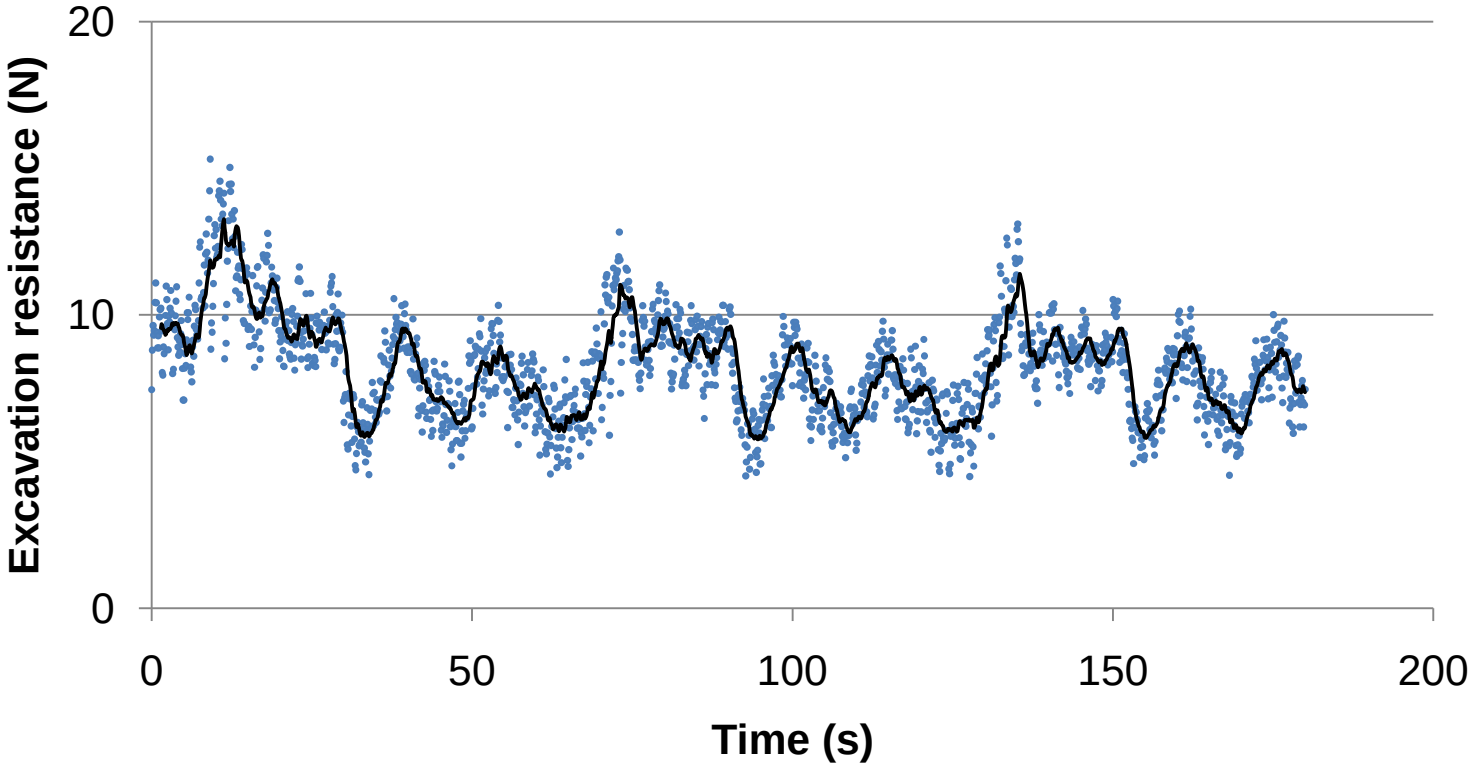
King, van Susante, and Mueller (2010) *PTMSS/SRR*

Measuring bucket-wheel excavation resistance



Bucket-wheel excavation resistance results

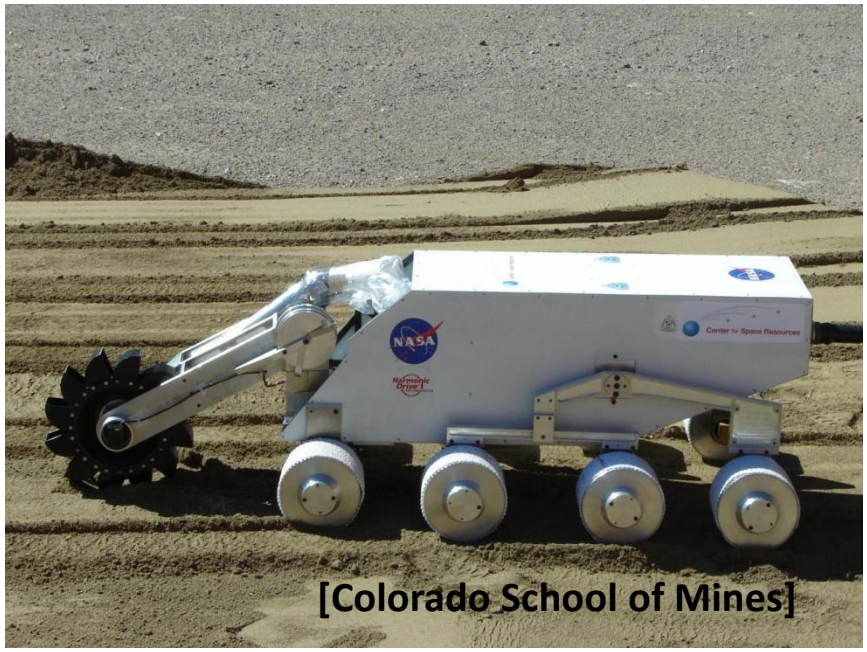
Excavation resistance does not rise as cutting progresses with a continuous excavator such as a bucket-wheel



Bucket-wheels and bucket-ladders

- **Bucket-wheel and bucket-ladder configurations have both been shown to be viable options for lightweight excavation**

- **Bucket-ladders have won favor due to inherent combination of regolith excavation and transfer**



[Colorado School of Mines]

Johnson and van Susante (2006) *SRR*

Johnson and King (2010) *J Terramechanics*

Bucket-ladders have proven very productive

A bucket-ladder won the Regolith Excavation Challenge and each of the Lunabotics competitions


[Paul's Robotics]

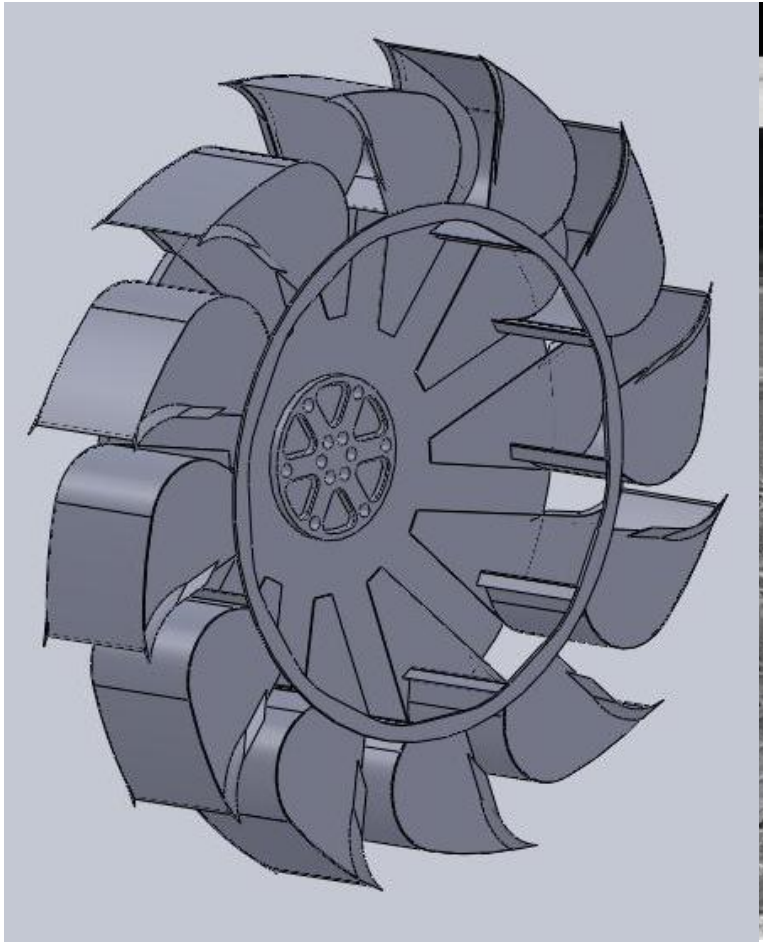

[Montana State University]

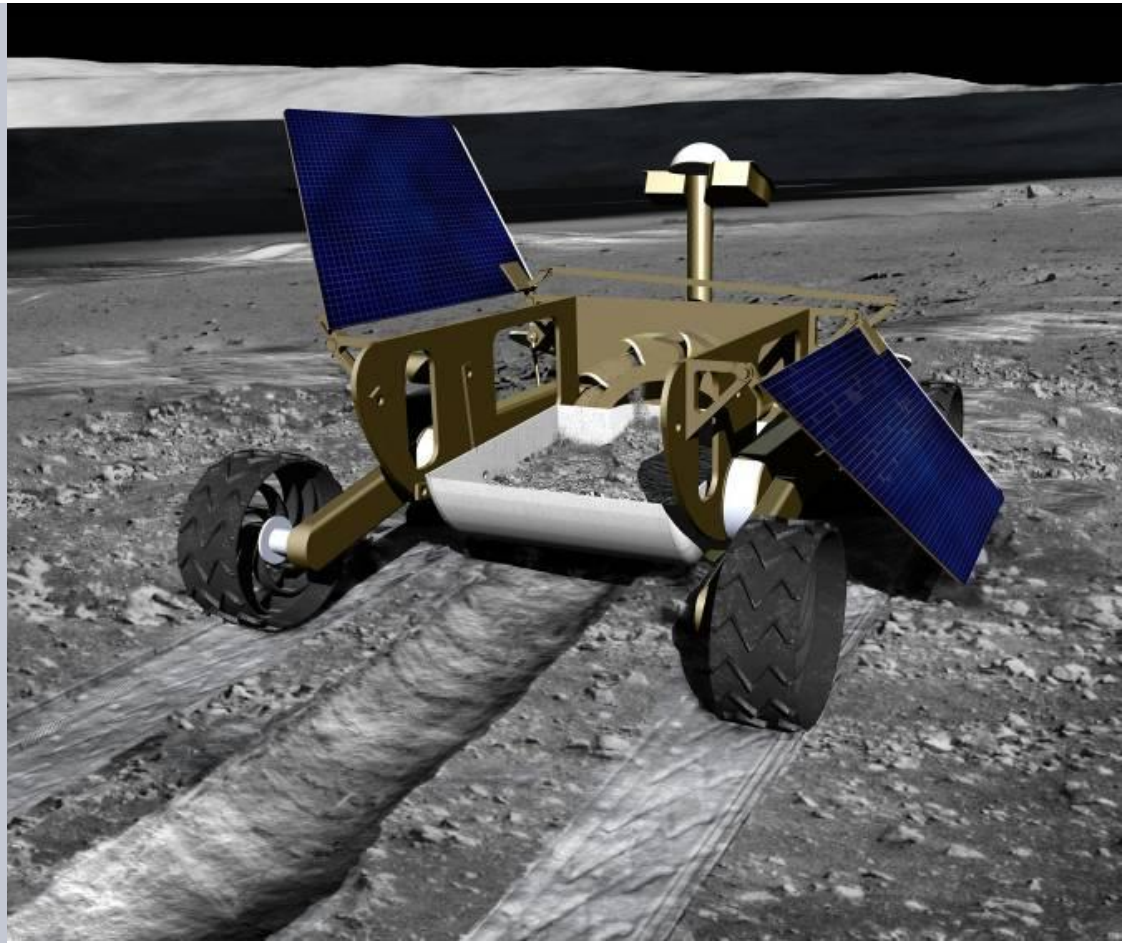

[Laurentian University]

Bucket-ladder designs to date all feature chains exposed directly to regolith and dust

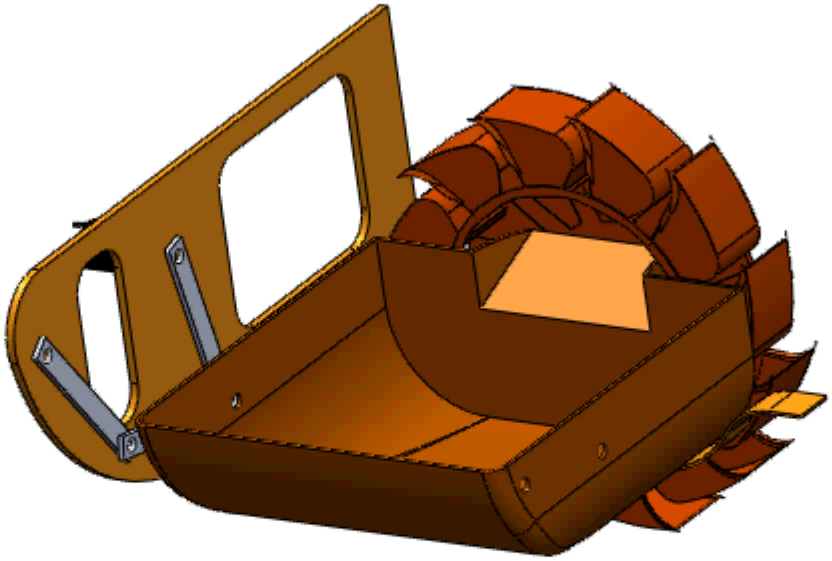
Transverse bucket-wheel configuration

A bucket-wheel is a single moving part and, mounted transverse, can transfer regolith directly into a dump-bed



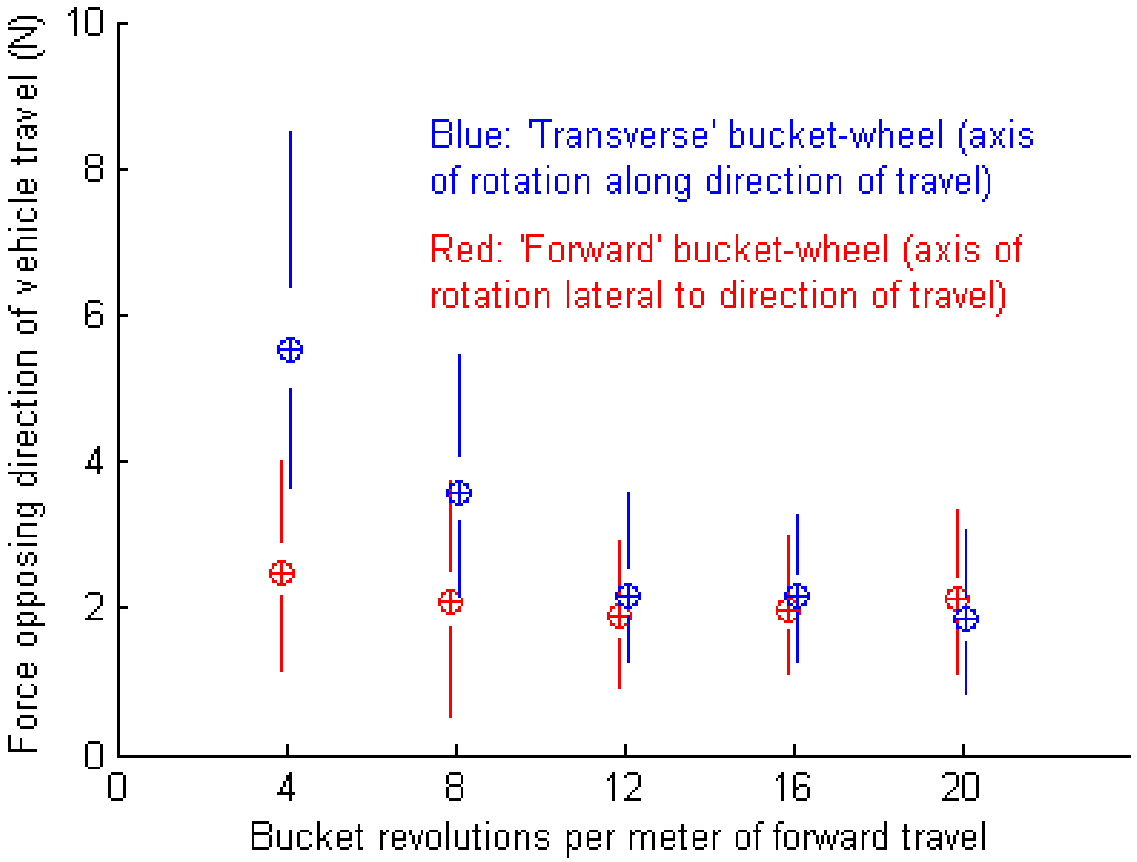


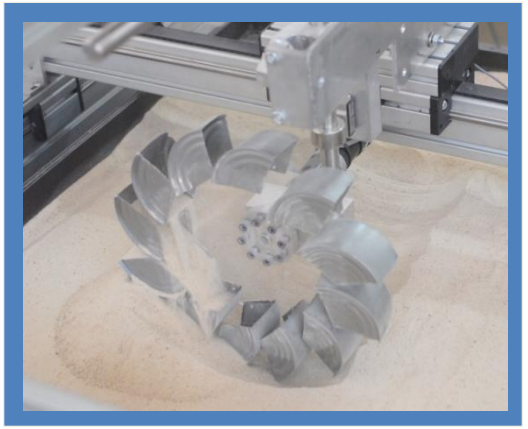
Bucket-wheel and dump-bed



Transverse vs. forward excavation resistance

Transverse bucket-wheels do not experience significantly higher excavation resistance as long as rotation speed is sufficient





Conclusions

- Continuous excavators, such as bucket wheels, exhibit bounded excavation resistance that enables sustained productivity even when weight-limited
- Mounting a bucket-wheel centrally and transverse to driving direction enables direct regolith transfer without the need for exposed chains or conveyors
- Bucket-wheel orientation does not significantly impact excavation resistance as long as rotation speeds are sufficient

Future work

- Additional testing with a 6-axis load cell will characterize side loads
- New bucket-wheels designs are being developed for transverse operation
- A prototype transverse bucket-wheel excavator is being developed

Astrobotic lunar missions

Astrobotic Technology Inc., partnered with Carnegie Mellon University, conducts research on critical lunar technologies

- **Regolith excavation, gravity offload, thermal analysis**

Astrobotic provides commercial space technologies for the Moon

- **Transmitting high-definition video of a tele-operated lunar surface trek to win the Google Lunar X-Prize**
- **Providing payload access to the lunar surface and unique data sets**

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Questions?

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