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CURB MOUNTING, VERTICAL MOBILITY, AND INVERTED MOBILITY ON ROUGH SURFACES USING MICROSPINE-ENABLED ROBOTS

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California Institute of Technology

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Three Robots

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D.R.O.P.

-made by JPL

Scout

- made by ReconRobotics
- wheels made by JPL

LEMUR

- made by JPL

RECON ROBOTICS™

D.R.O.P. The Durable Reconnaissance and Observation Platform

Microspine Background

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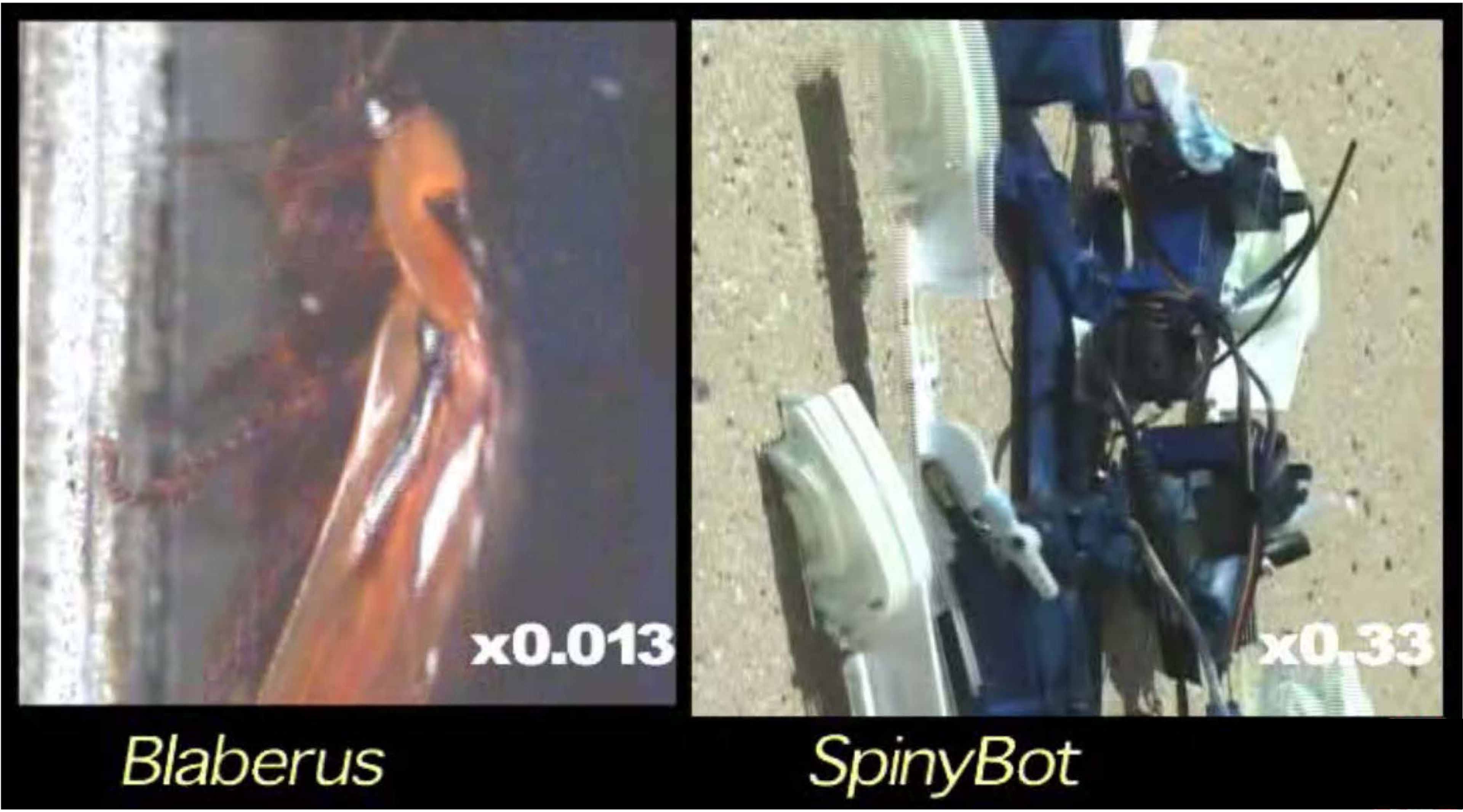

Inspired by the directional spiny features found on insects.
collaboration between R. Full (Berkeley) & M. Cutkosksy (Stanford) research groups

Microspine Applications

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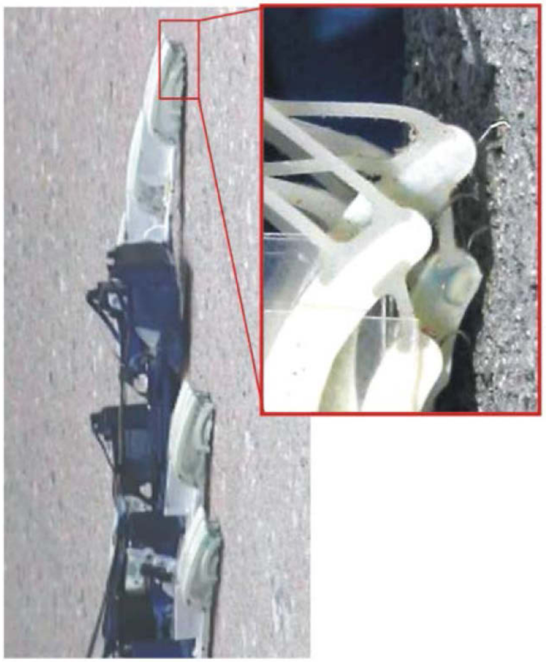
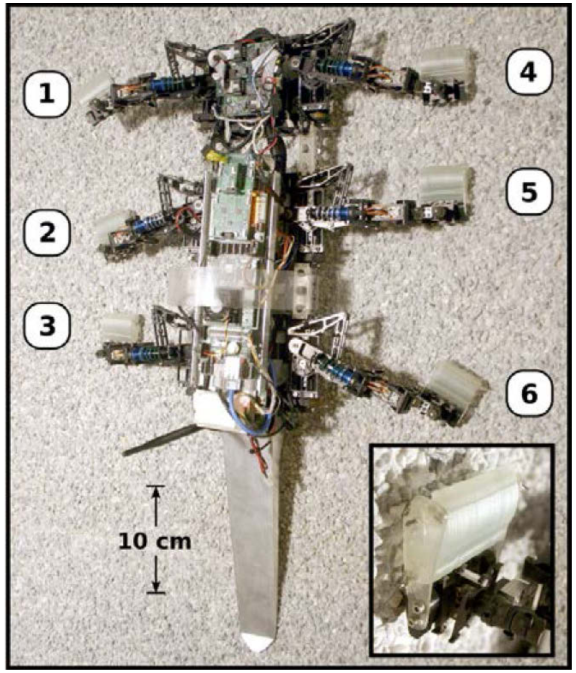
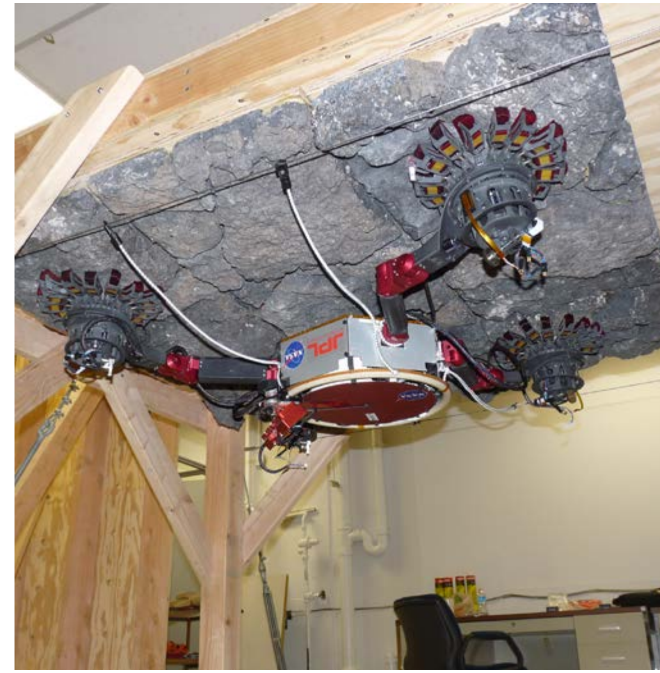


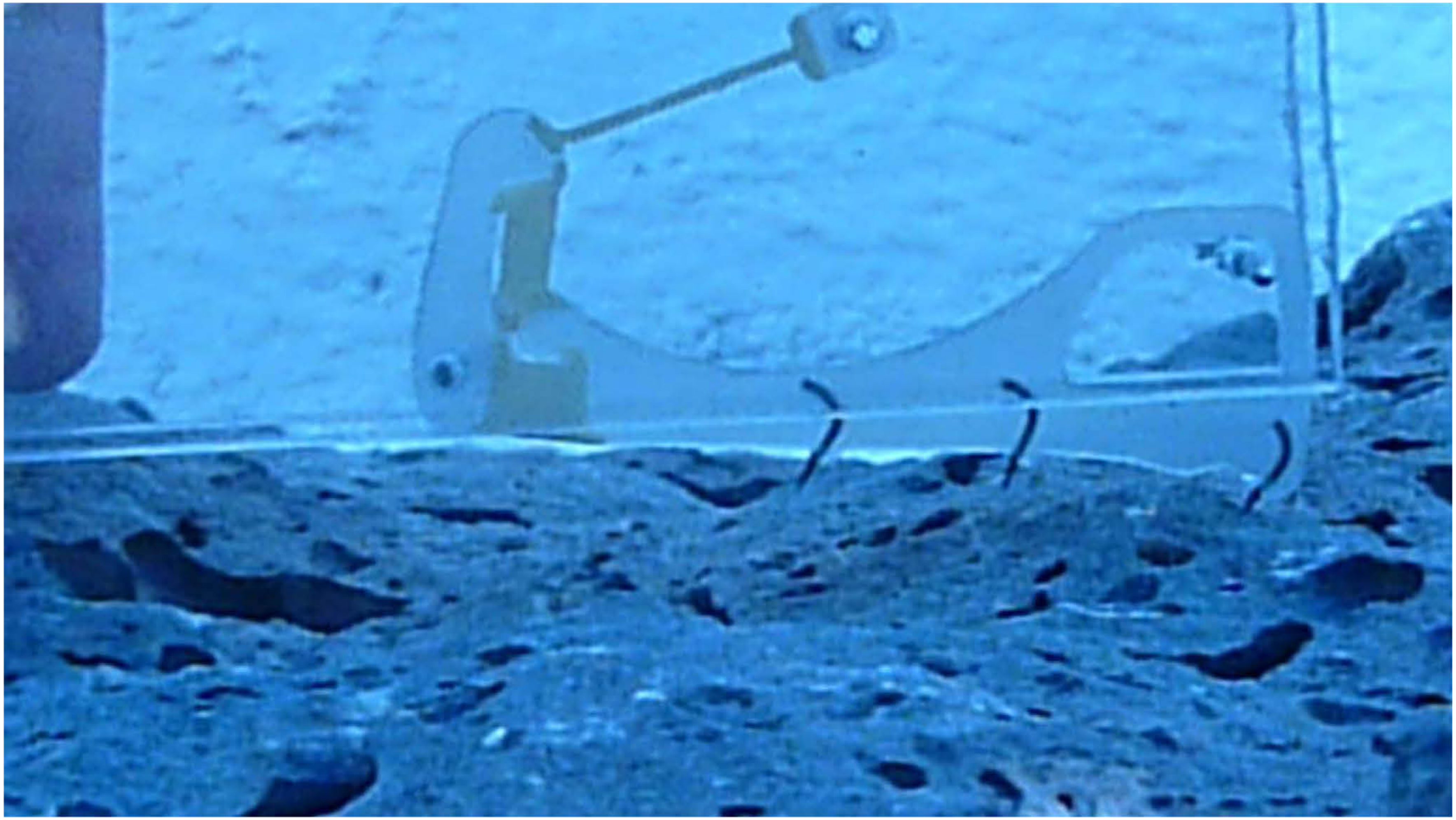




<u>CLOCKWISE FROM UPPER LEFT:</u>

Spinybot II, Asbeck et al, IJRR, 2006
RiSE, Spenko et al, JOFR, 2008
LEMUR, Parness et al, ICRA, 2012
Airplane, Lussier-Desbiens et al, IJRR, 2011
Human Climb, Parness, Discovery Channel, 2009

Linear Implementation



Opportunistically grip surface roughness

Linear Implementation

Distribute loads between many independent contacts

Limitations

- Speed
  - Spinybot II (2.3 cm/s)
  - RiSE (4 cm/s)
- Transition Ability
- Complexity of Controls

Boston Dynamics, 2007

Linear to Rotary

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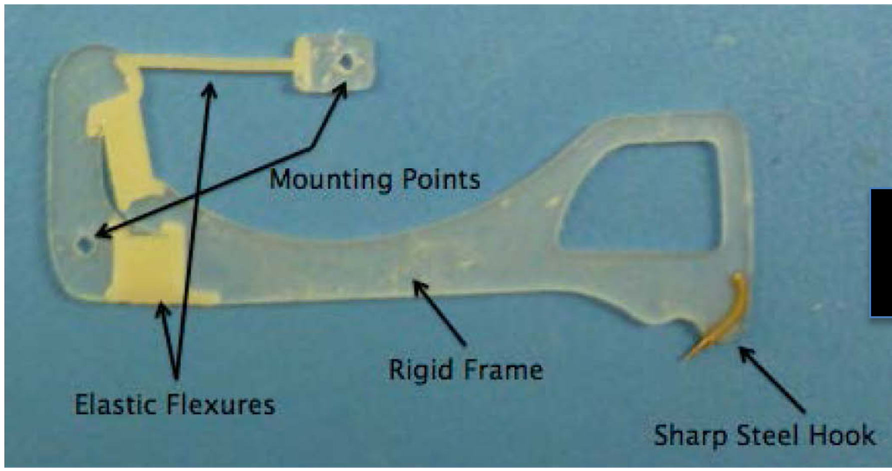

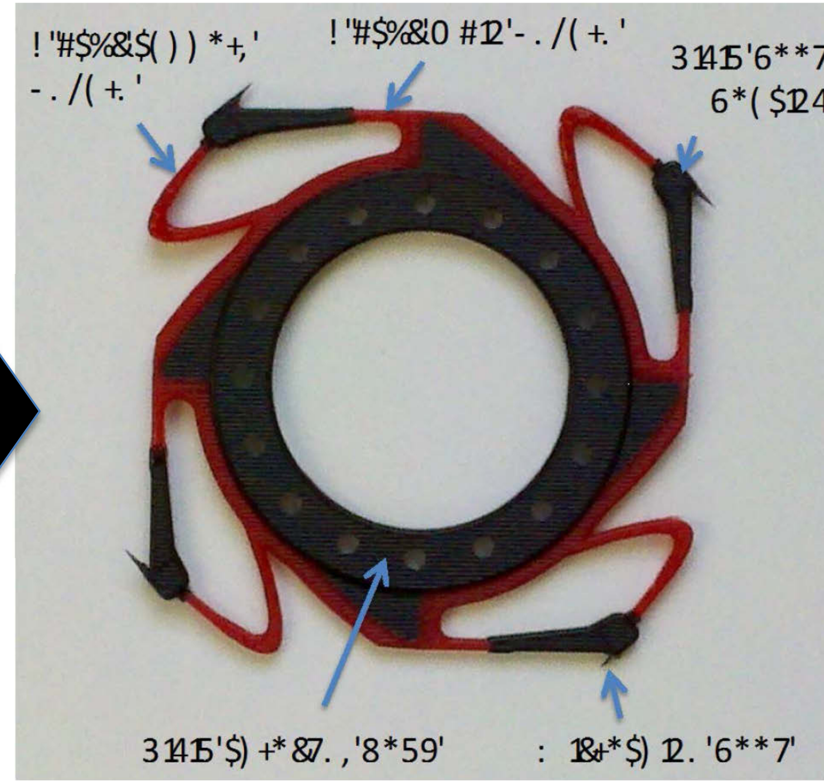

Rotary Microspine Performance on DROP robot prototype

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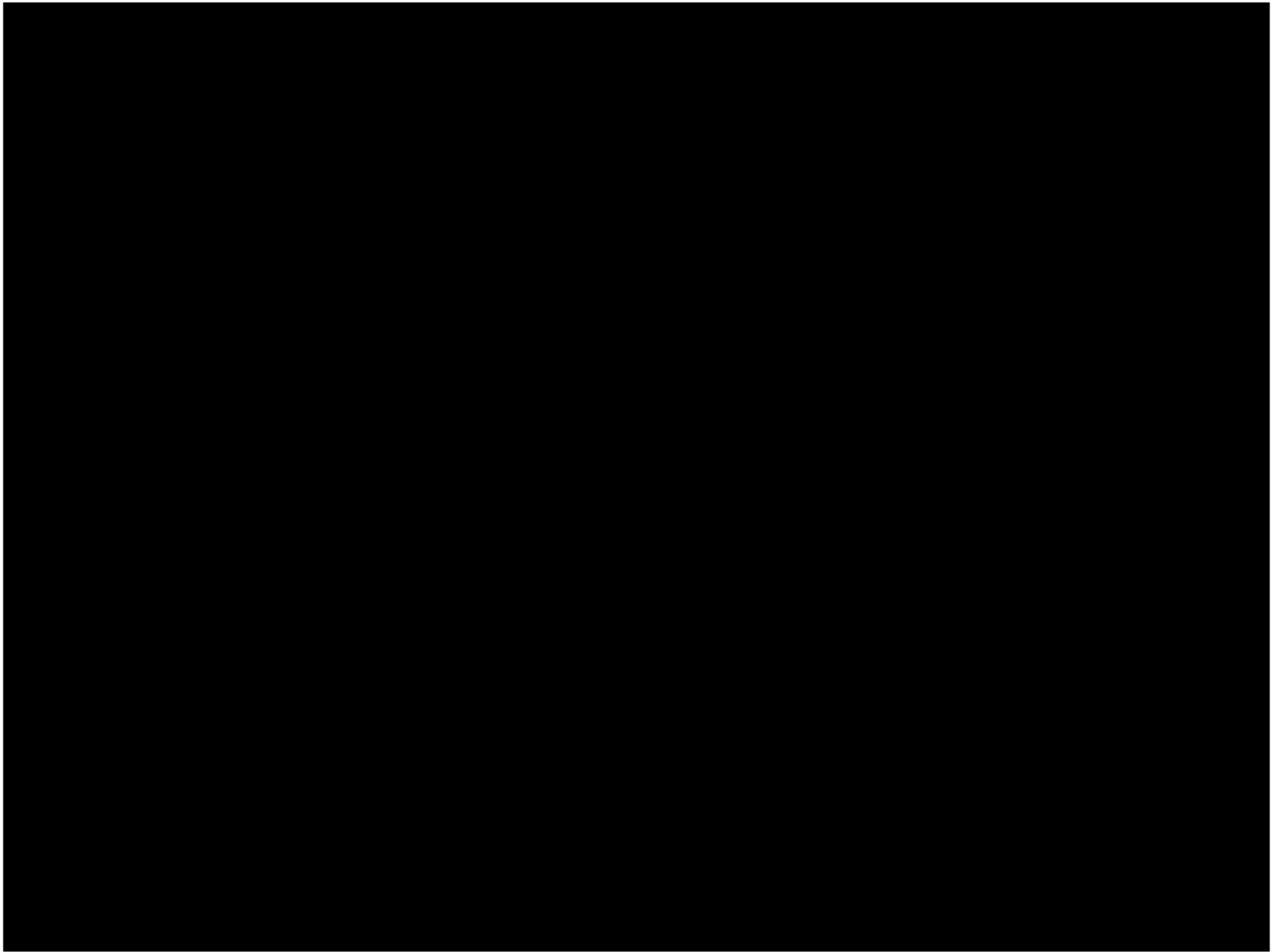
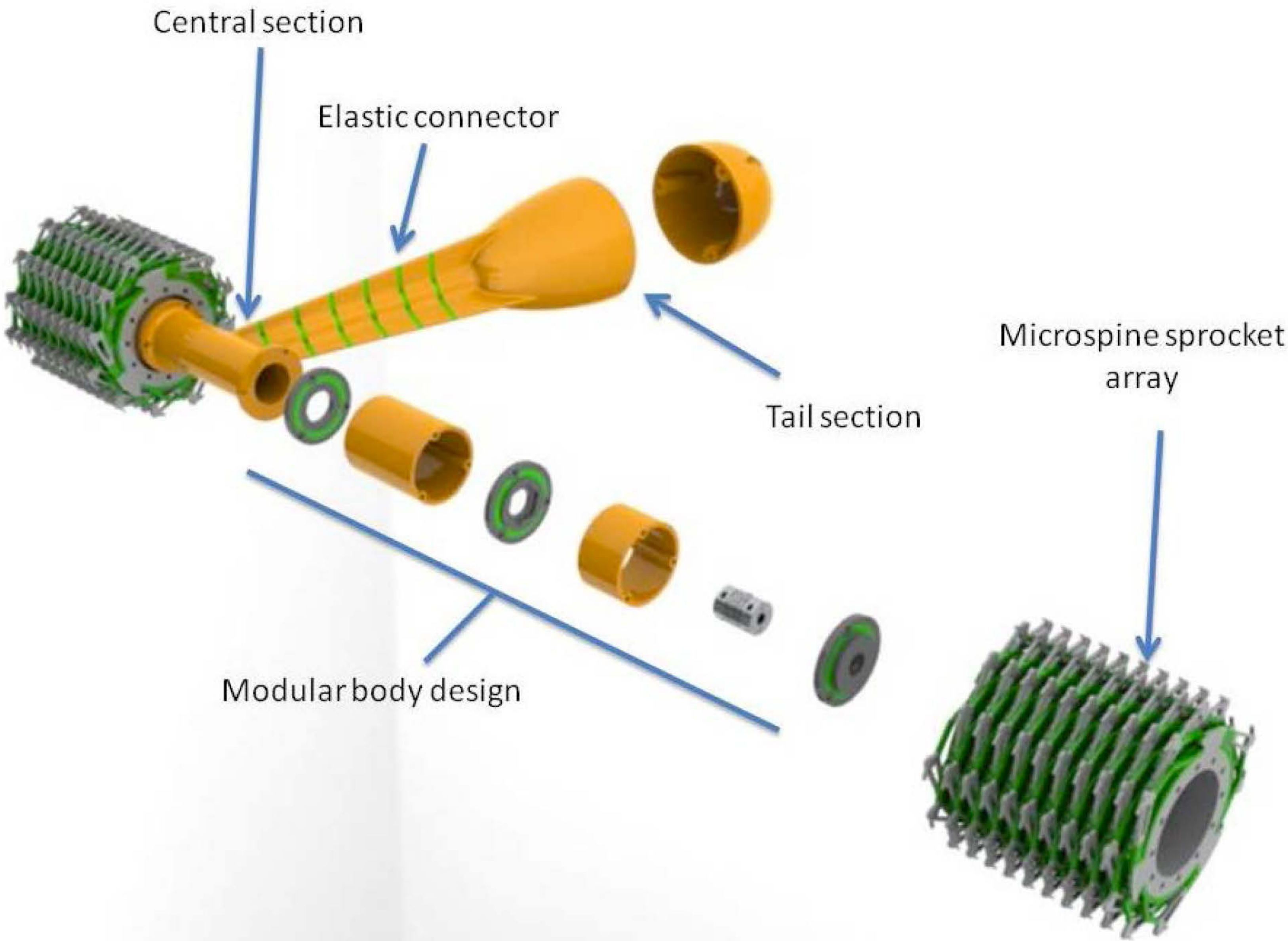


Body Design


Central section
Elastic connector
Microspine sprocket array
Tail section
Modular body design

FBD Analysis

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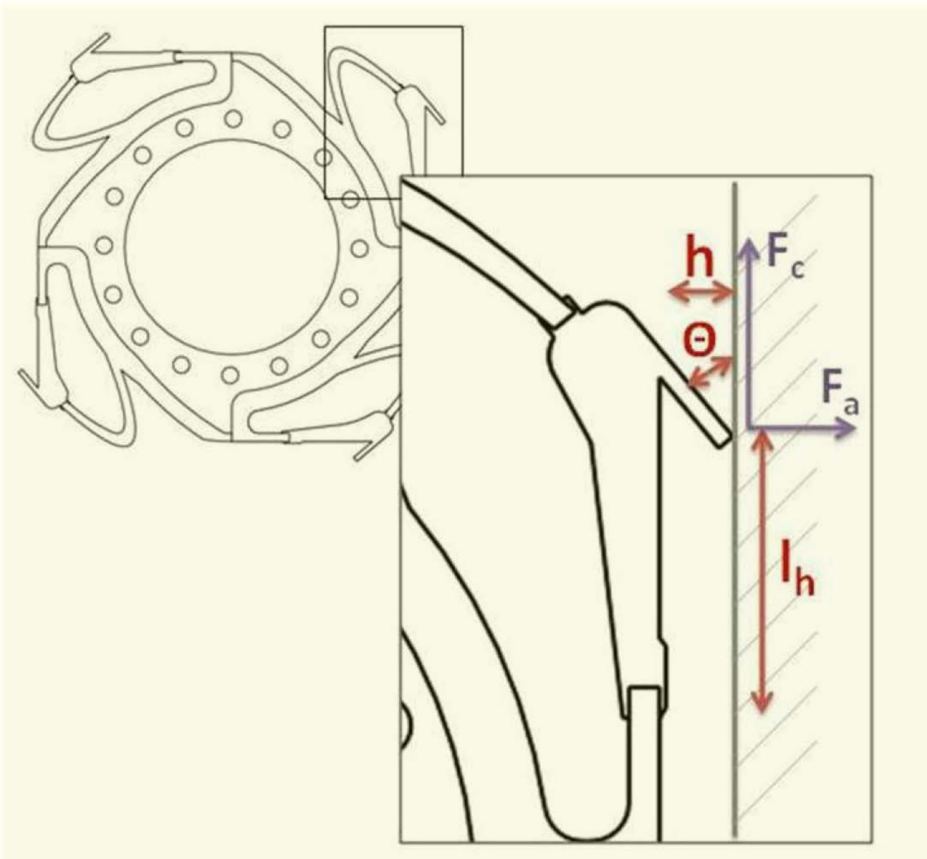

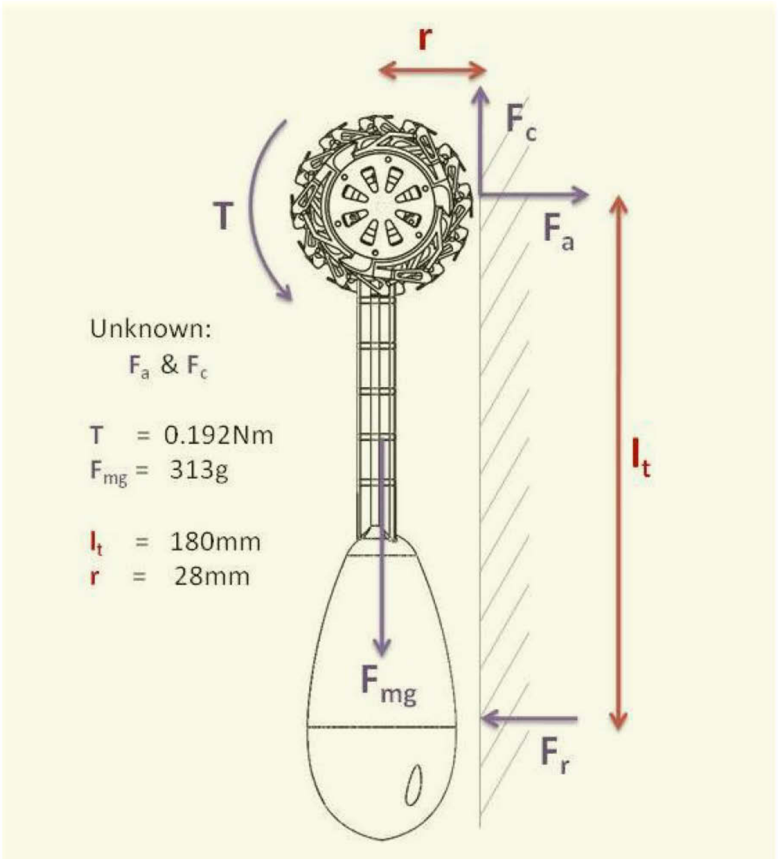

Constraints: $F_{a;max} \geq F_r$ and $F_c > F_{mg}$

Expansion Reveals Design Parameters: $F_{a;max} \geq ([F_{mg} * r + T] / l_t)$

Altering hook angle and flexure length play key role in engagement probability and release forces

Can alter radius of microspine wheel and length of tail

Use of ReconRobotics Scout

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Tactical Network Testbed

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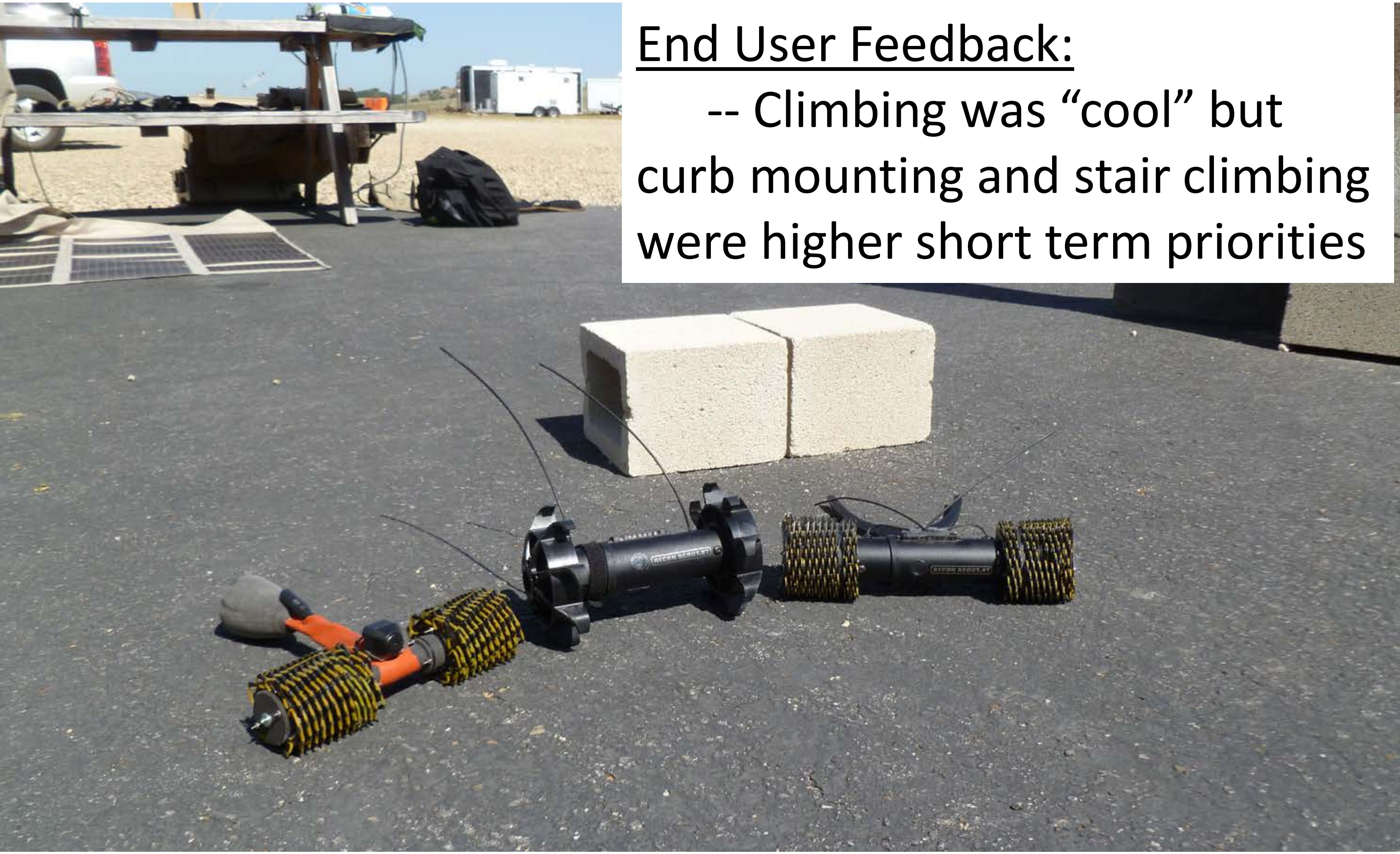

End User Feedback:

-- Climbing was "cool" but curb mounting and stair climbing were higher short term priorities

Curb and Stair Results

- Microspine wheels fabricated for ReconRobotics Scout platform
- Platform showed ability to mount curbs >4x wheel diameter
- Two tails tested (swallow, shown in picture, and straight)
- Stair climbing of 90 degree concrete stairs demonstrated

Video Results

Key Takeaway

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We present the extension of Microspine Technology from a linear to rotary implementation

The resulting robot prototypes can:

- Mount curbs with >4x wheel diameter
- Climb stairs with 90° cast faces
- Maneuver on flat ground at 45 cm/s
- Turn in place
- Transition between flat and vertical surfaces
- Climb walls at 20 cm/s

LEMUR Gravity-Independent Mobility Platform

Using Linear Microspines for Omni-Directional Anchors

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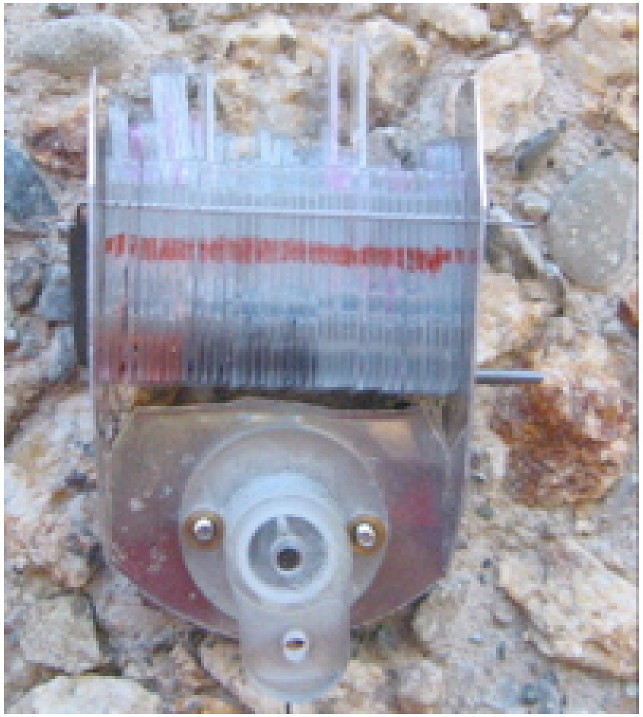
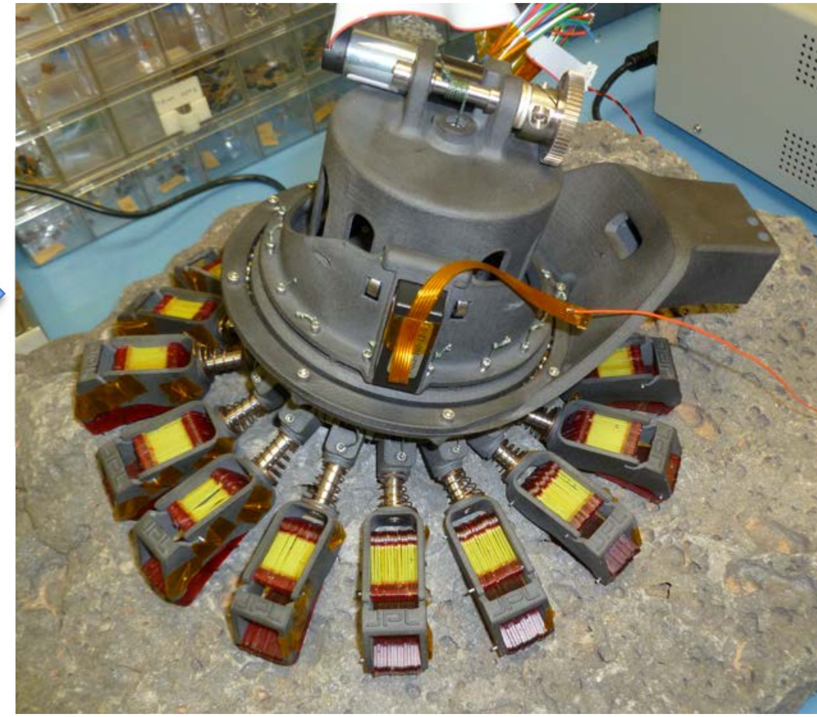


RiSE Foot
Spenko et al., JOFR, 2008



LEMUR Foot
Parness et al., ICRA, 2012

1. *Hierarchical compliance to allow gripping rocks*
2. *Radial config to allow resisting forces in all directions*

How to Grab Rocks?

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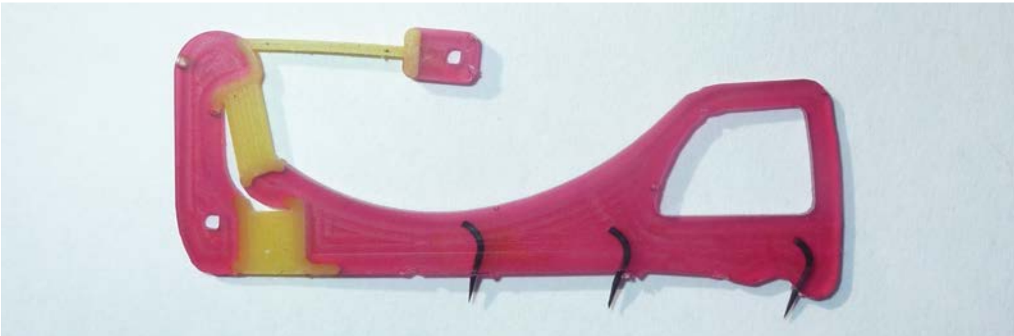
A hierarchical solution forms at multiple length scales.



mm-scale

cm-scale

10 cm-scale

Rock-Gripping in Action

Rock-Gripping in Action

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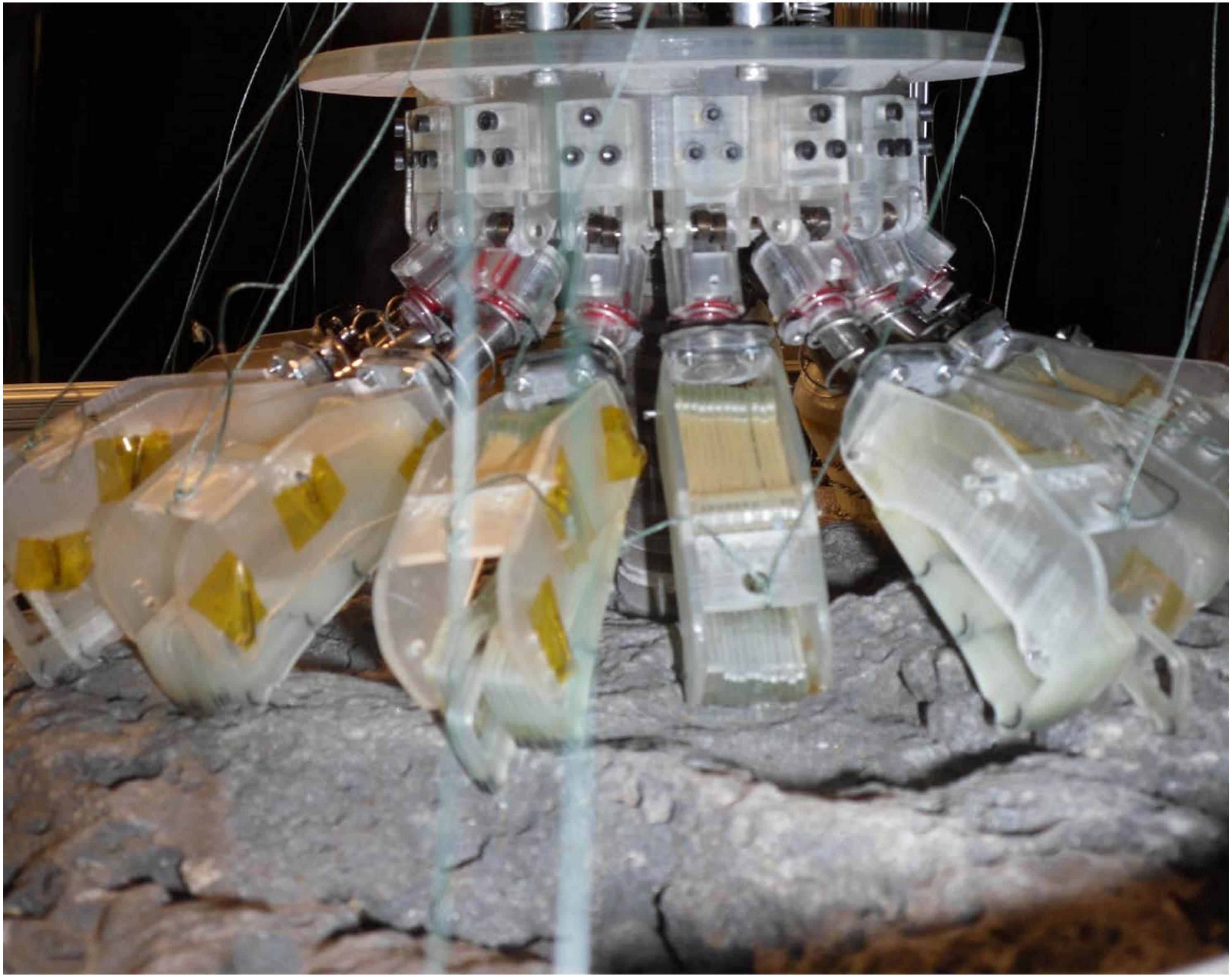

Rock-Gripping in Action

Robotic Ankle

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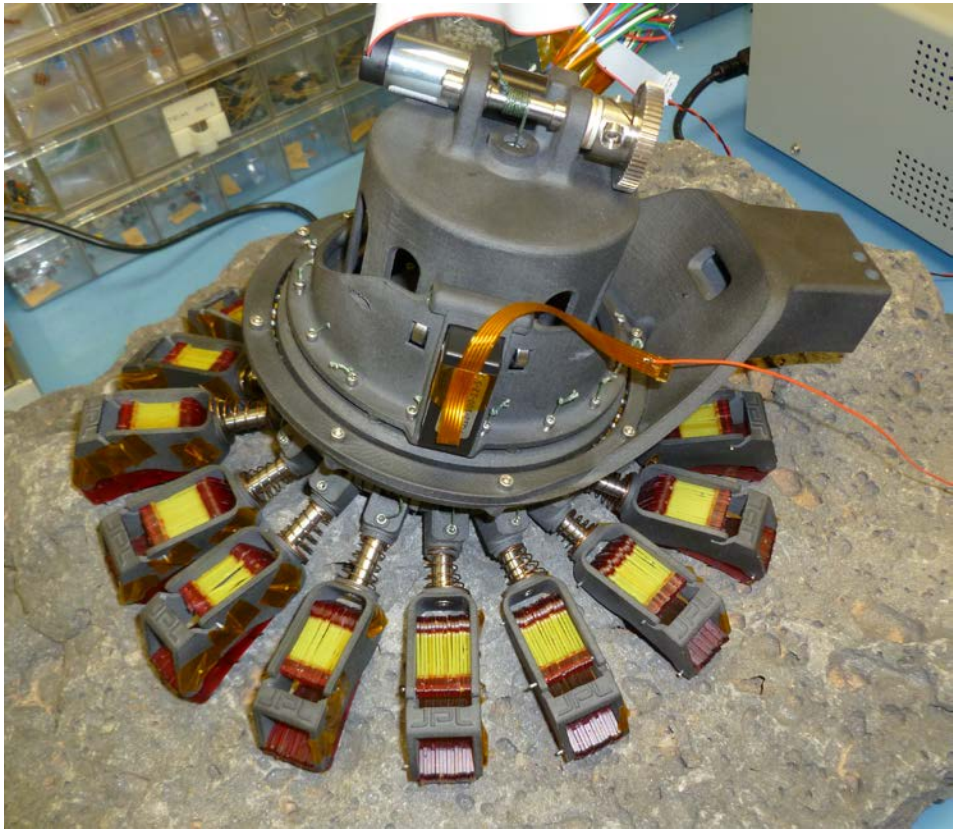

1.05 kg, 256 toes, >750 hooks
Silverlite X-bearing, 2 active DOF,
Cable routing, Mechanical
connects, Optical limit switches

ANCHOR STRENGTH
185N in Normal (42lbf)
155N in Shear (35 lbf)
155N @ 45° (35lbf)

Sample Acquisition

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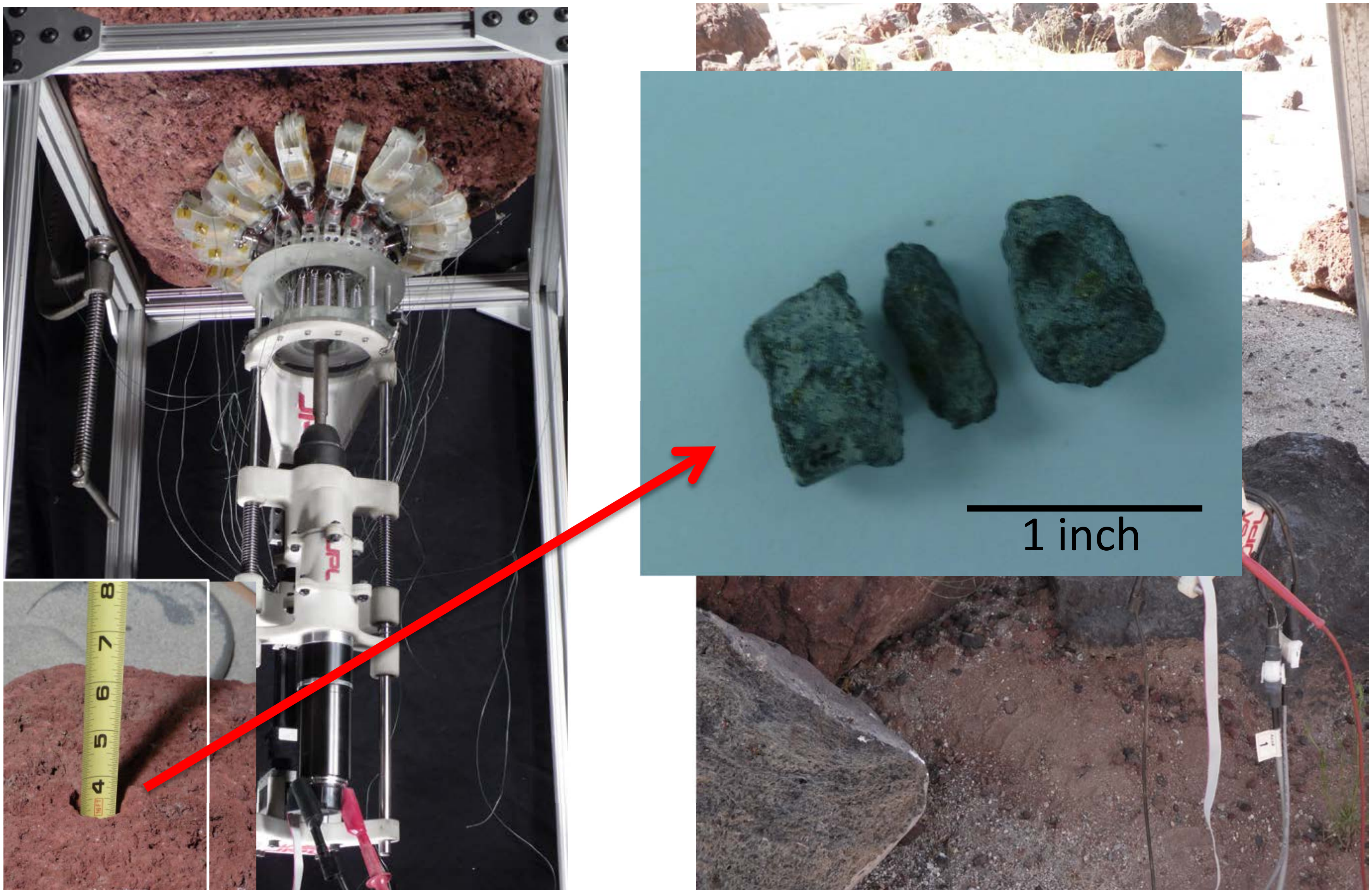

Latest Work

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Movie

Future Work – Exploring Earth's Lava Tubes and Caves

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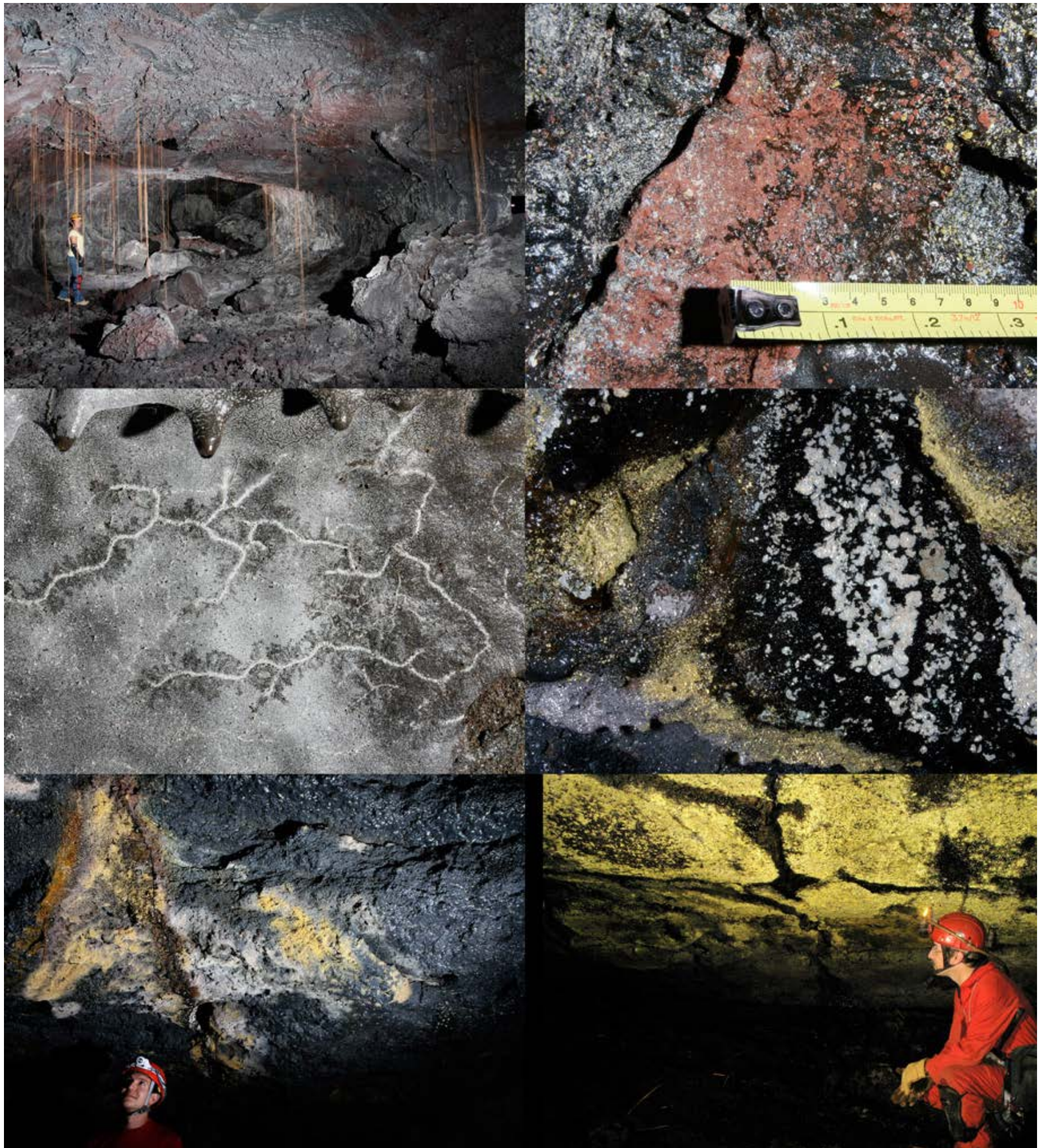

Two Classes of Microspine Robots were Presented

Durable Soldier Portable Robots

Microspines enable improved mobility including

- Vertical walls
- Curbs
- Stairs

Vehicle Portable Legged Robots

Microspines enable gravity independent ops

- Roof Awnings
- Cave ceilings
- 180 degree transitions

Thank You

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QUESTIONS

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