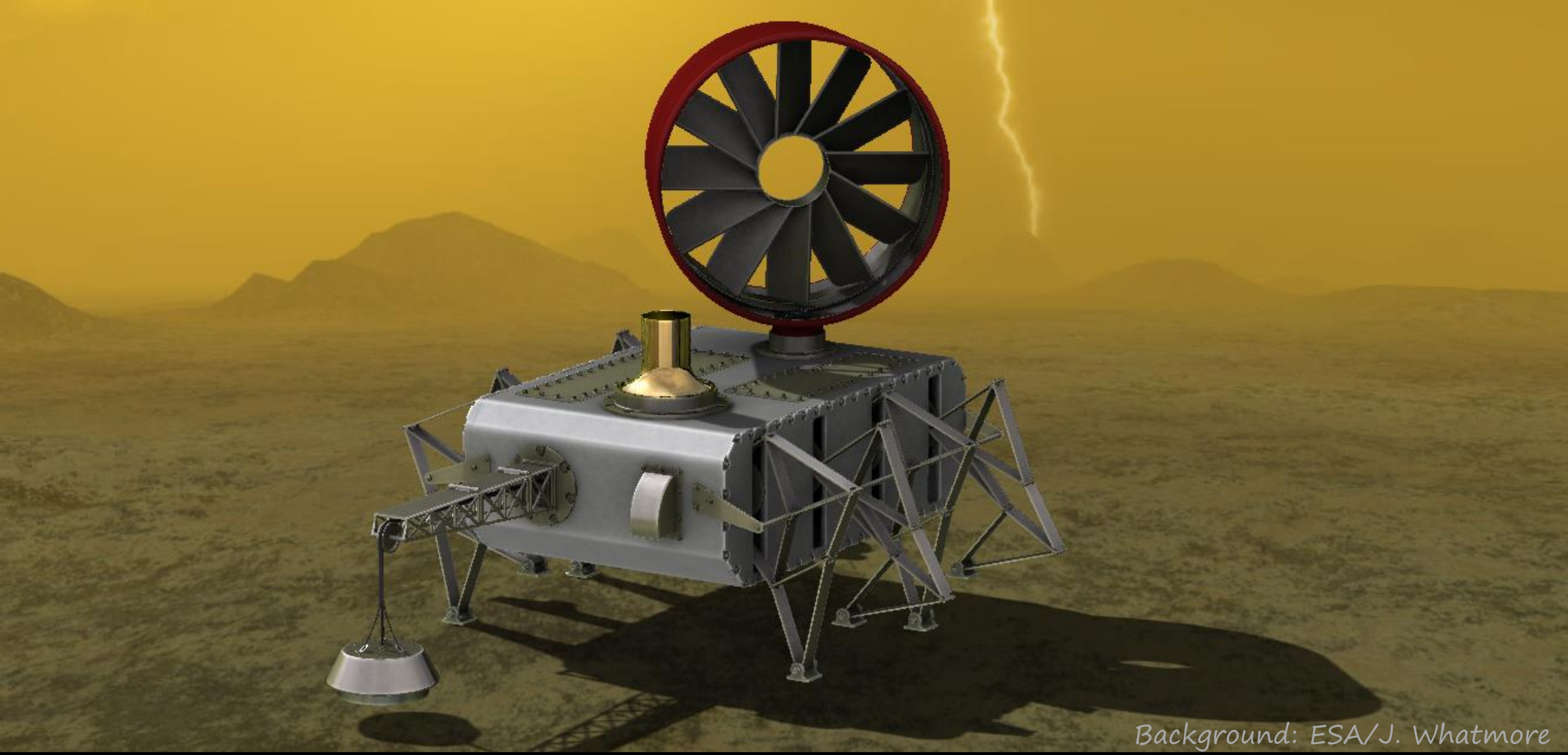


Automaton Rover for Extreme Environments (AREE): Rethinking An Approach to Rover Mobility

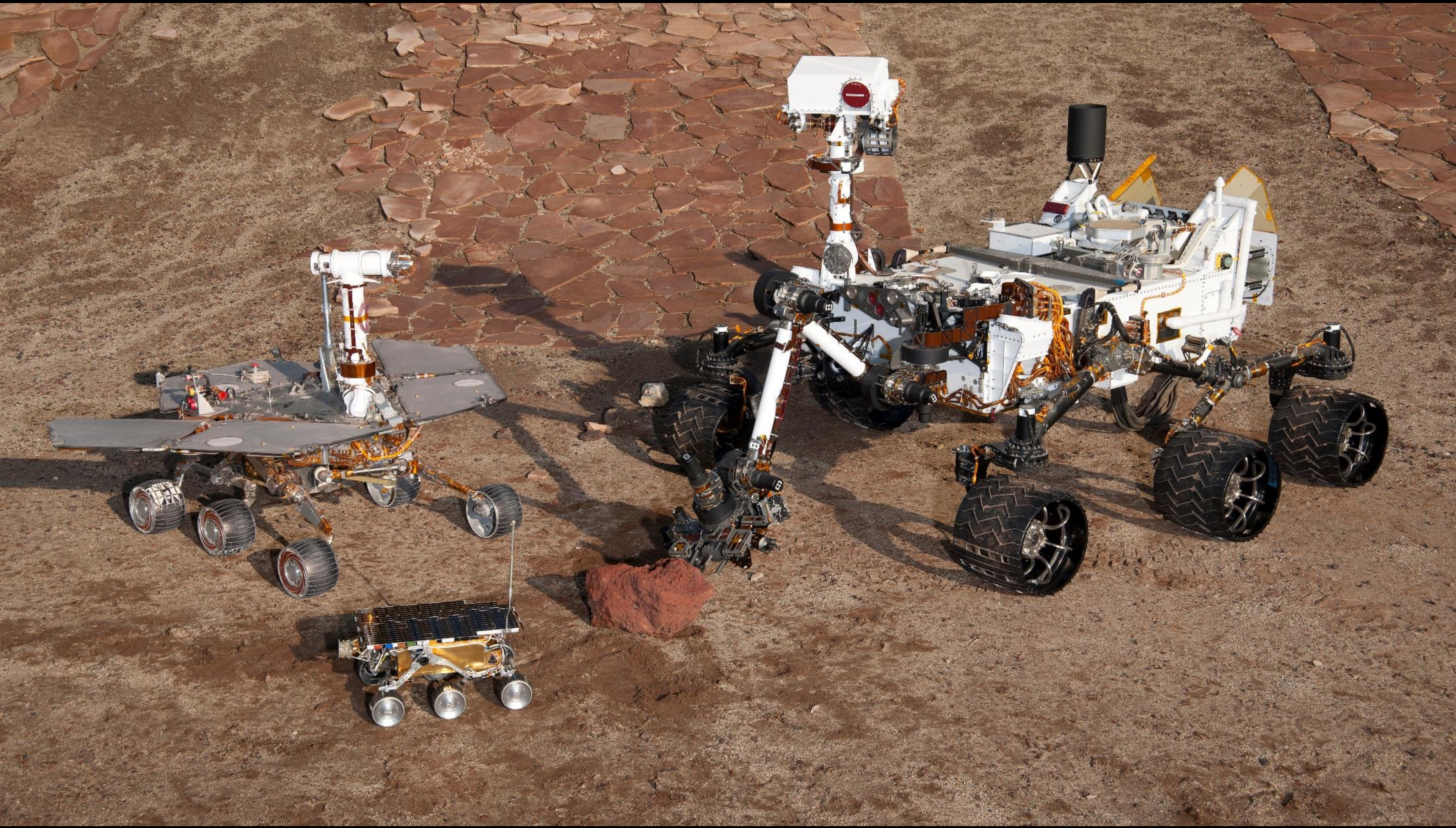
Jonathan Sauder, Evan Hilgemann, Jessie Kawata, Katie Stack, Aaron Parness, Michael Johnson

Nov. 14, 2017

Jet Propulsion Laboratory
California Institute of Technology

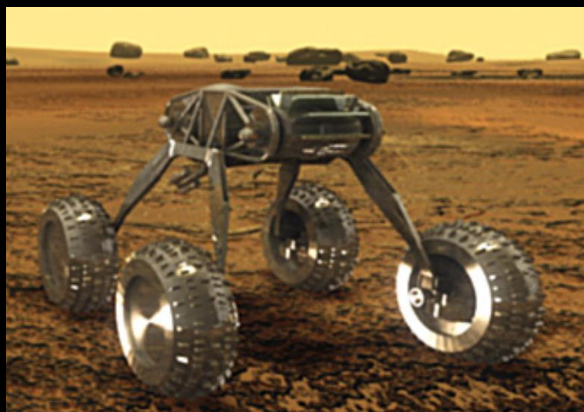
NASA Innovative Advanced Concepts

When we think of planetary surface rovers…

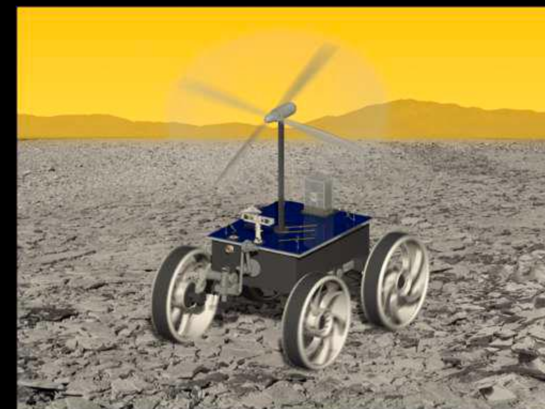


Prior Venus Rover Concepts

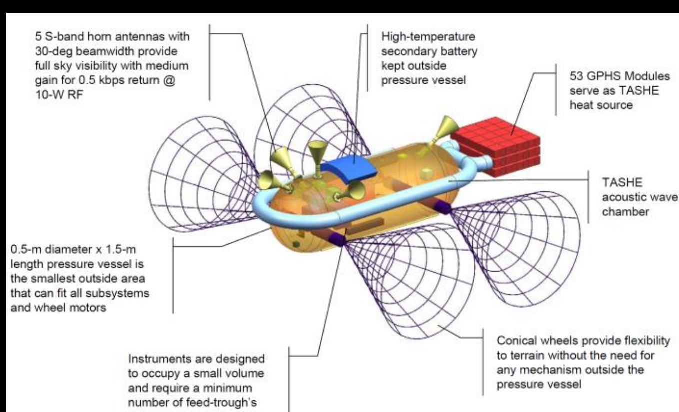
Require High Temperature Electronic or Cooling System Development



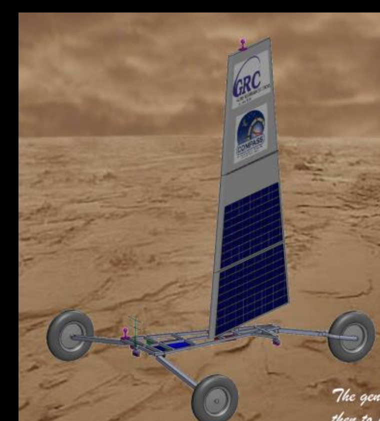
Landis et. al, NASA Glenn



Benigo et. al, NASA Glenn



Shirley et. al, NASA JPL



Landis et. al, NASA Glenn

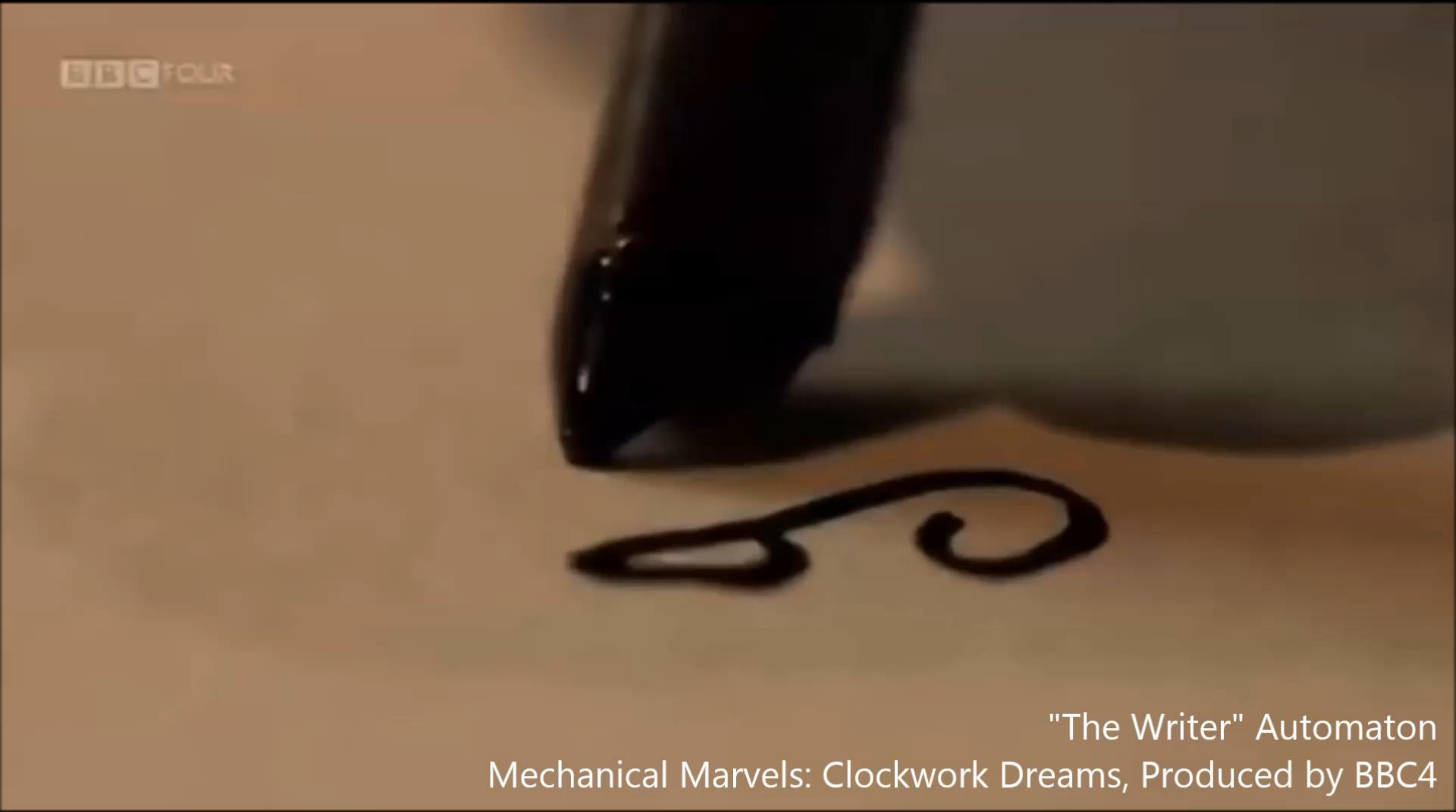
The Challenge: Current Capabilities

Current SiC and GaN are far from Mars Curiosity

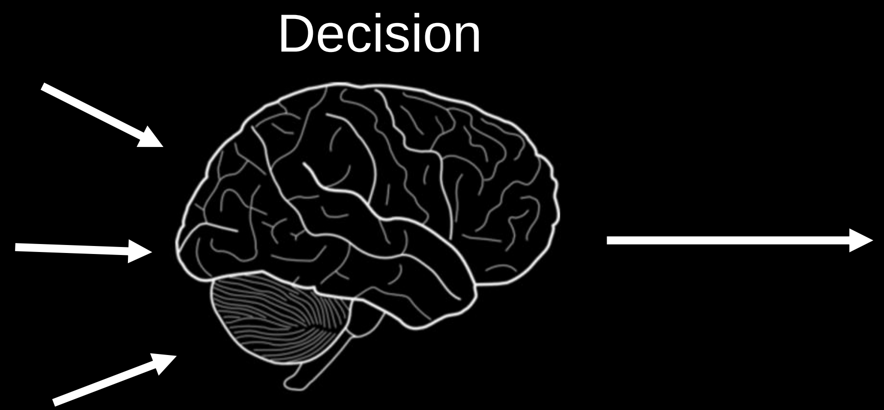
Venus rovers of the foreseeable future will have to be designed around limited electrical capabilities

An Alternate Approach: Automata

au·tom·a·ta *(n): a machine that performs a function according to a predetermined set of coded instructions* (i.e. mechanical robot)



Robotic Architecture



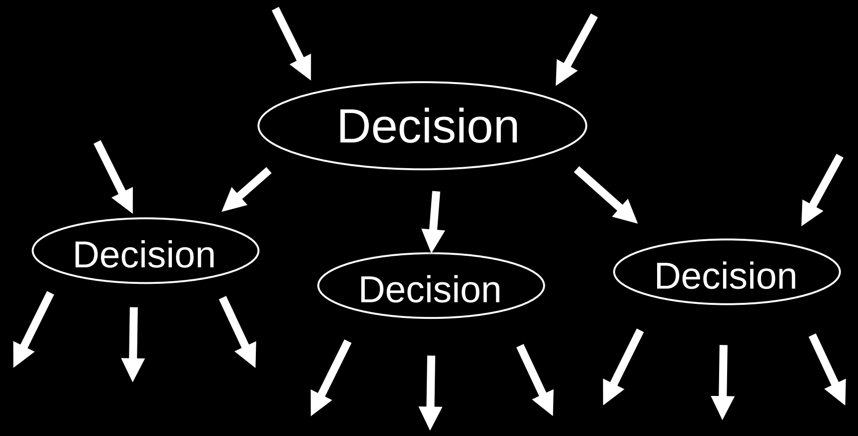
Traditional Centralized Model

Inputs into a complex, high performance core

Don't purely replicate electrical systems mechanically

Distributed Model

Many simple rules produces ability to adapt

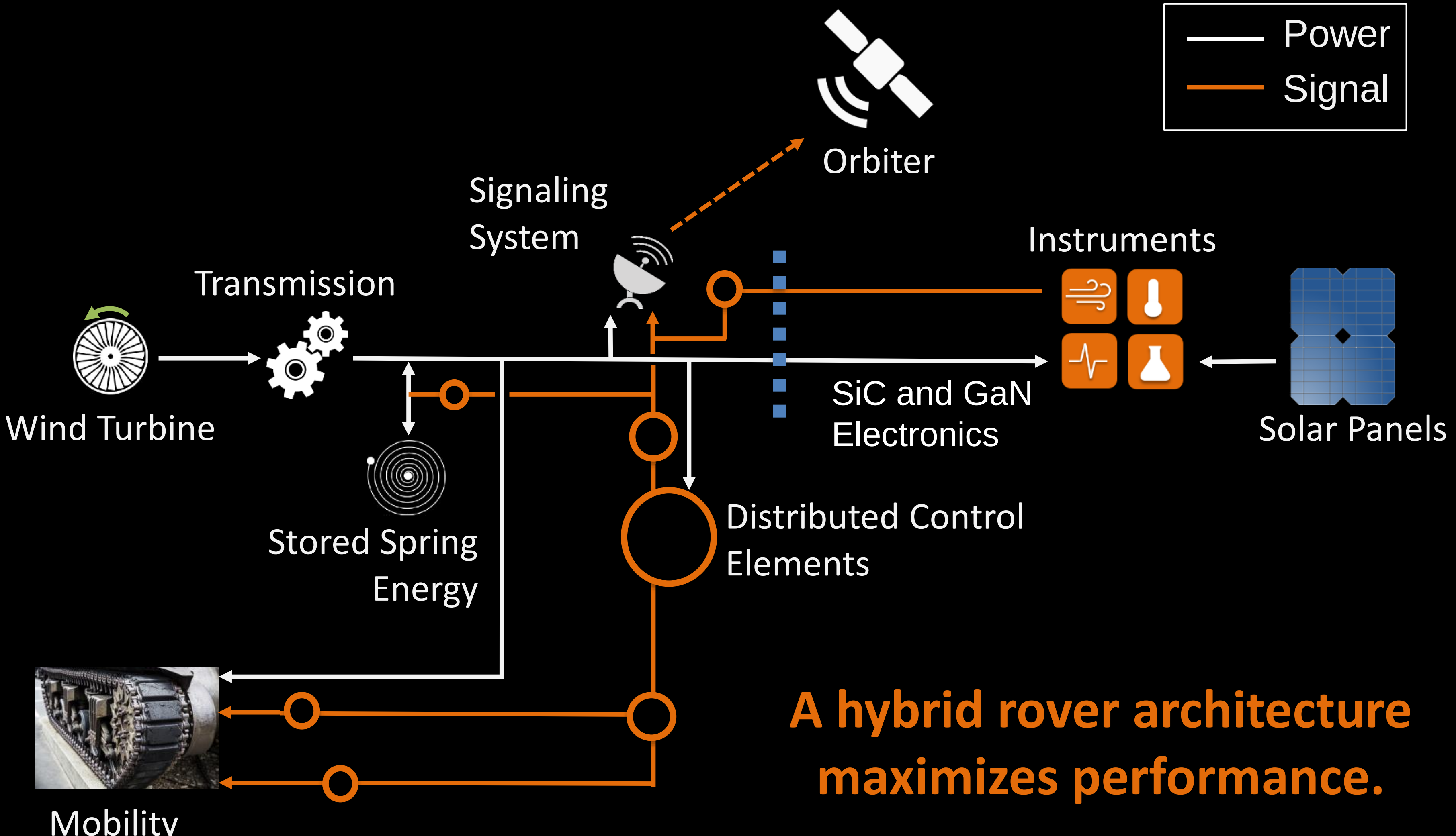


Brooks. Subsumpiton Architecture

Distributed, simple mechanisms → evolved, emergent behavior

Developed Concept

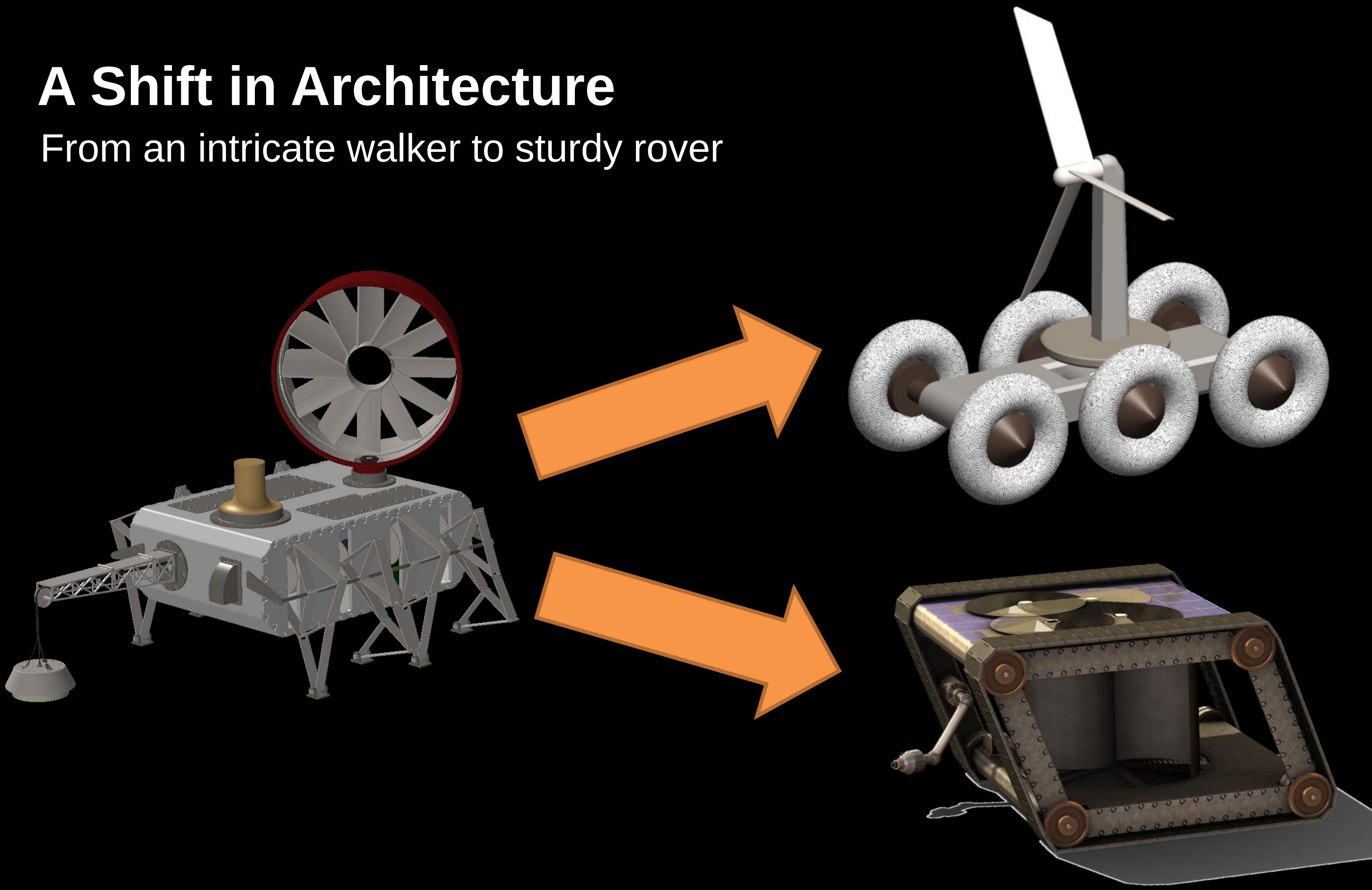
Mobile Platform for High Temperature Instruments



A hybrid rover architecture maximizes performance.

A Shift in Architecture

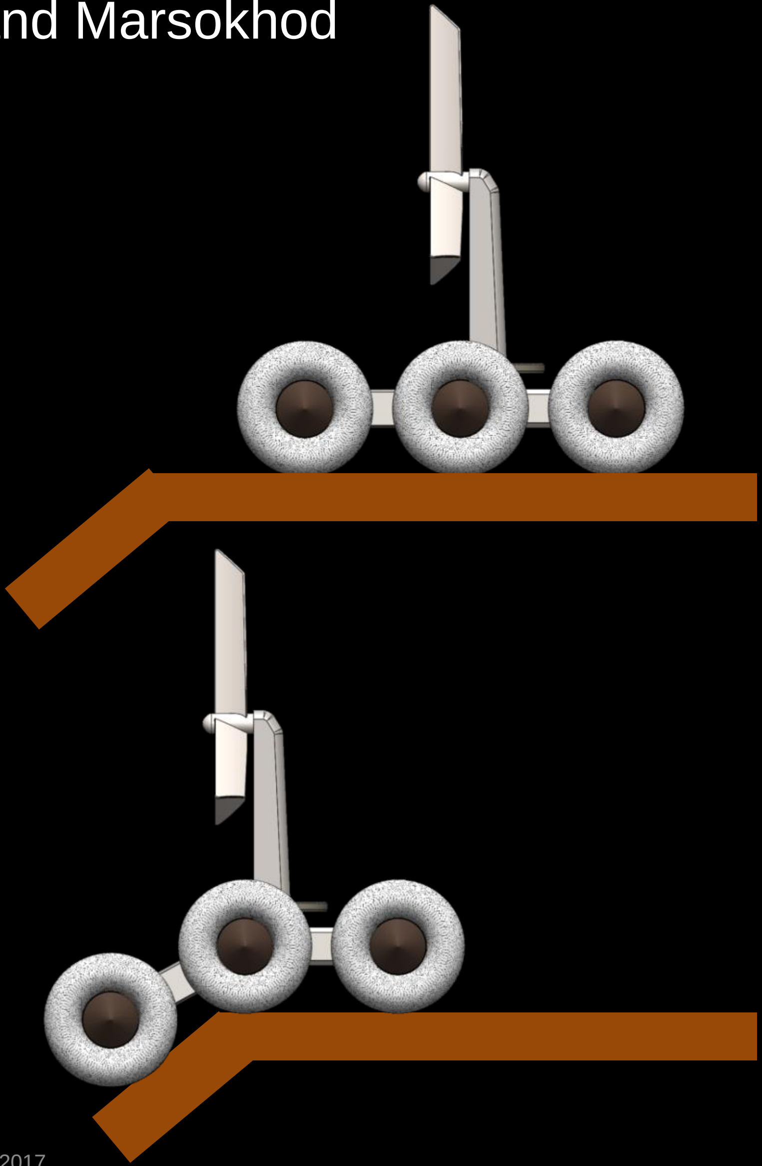
From an intricate walker to sturdy rover



Utilize mechanisms to reduce requirements on electronics

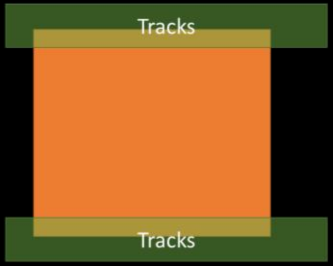
Locomotion System Design: Architecture 1

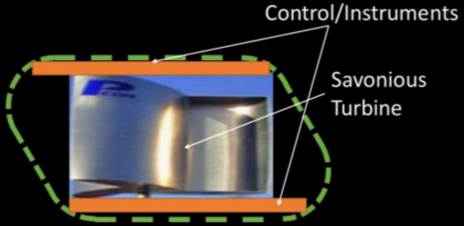
Draws from the Soviet Venerokhod and Marsokhod

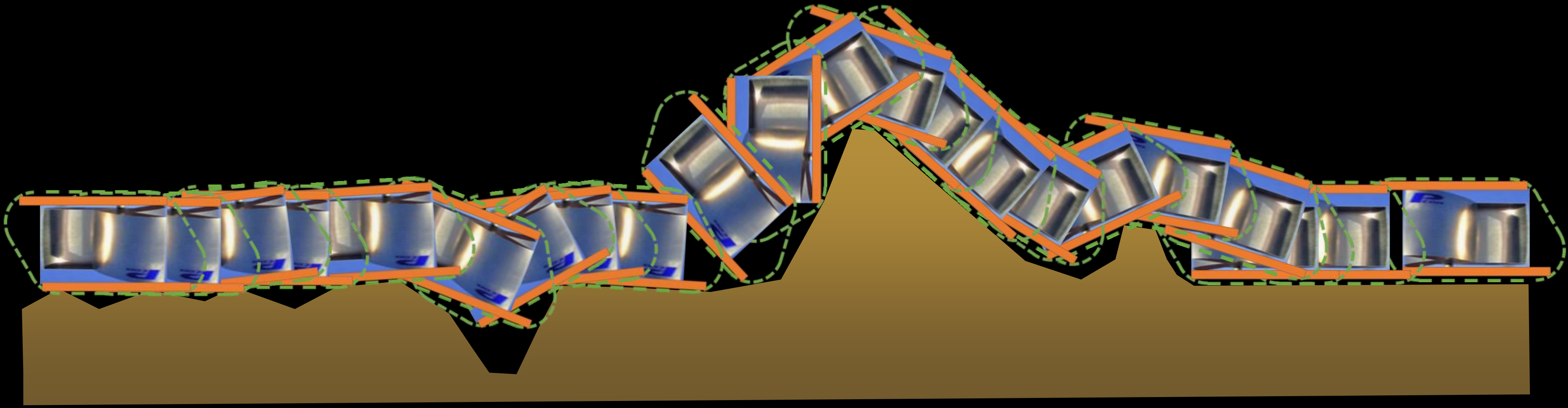


Locomotion System Design: Architecture 2

Ability to Climb Large Objects and Operate Independently of Orientation

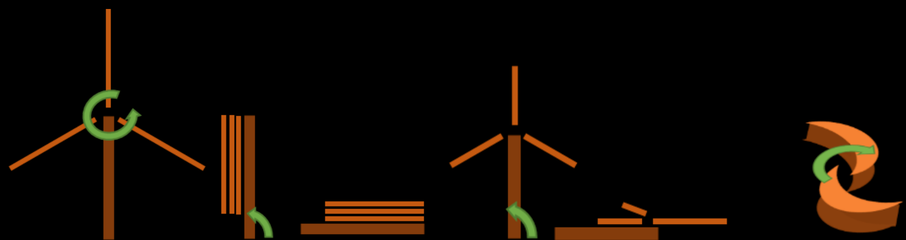






Robustness and resilience to reduce complexity

Energy Generation Trade



	2x Deployable Turbine 6.4m	Deployable Turbine 3.2m	Savonius Turbine	RTG	Solar (averaged over 58 Earth days)
Average Power (W)	114.85	28.71	3.18	25.70	6.13
Power Gen. Density (W/kg)	1.10	0.91	0.20	1.35	2.40
Risk & Investment	High	Moderate	Moderate	Very High	Low

Assumes a wind speed of 0.6 m/sec

Solar assumes 32 W/m^2 at peak with 3.1m of deployed area.

Energy Storage Trade

	NaS Battery	NaCl Battery	Metal Spring	Composite Spring	Gravity (3m tower)	Flywheel (in vacuum)	Compressed Atmosphere
Energy Density (W-h/kg)	220	143	0.09	0.75	0.01	10	15
Risk & Investment	Very High	High/ Moderate	Low	Low/ Moderate	Low	High	High/Moderate

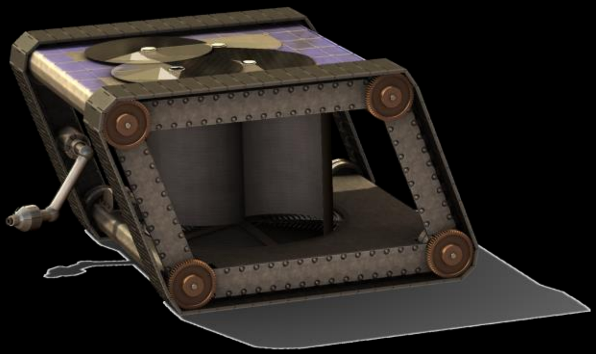
Mechanical System	Electrical System
Power Loss	Power Loss (86% more)
Frictional Loss	Frictional Loss Generator Efficiency (33%) Resistive Losses Motor Efficiency (43%)
Gearbox Requirements	Gearbox Requirements
25 RPM → 2 RPM 12.5:1 Gearbox	25 RPM → 3,000 RPM 1:120 Gearbox

Current Activities and Future Work

Of potential interest to the VEXAG community

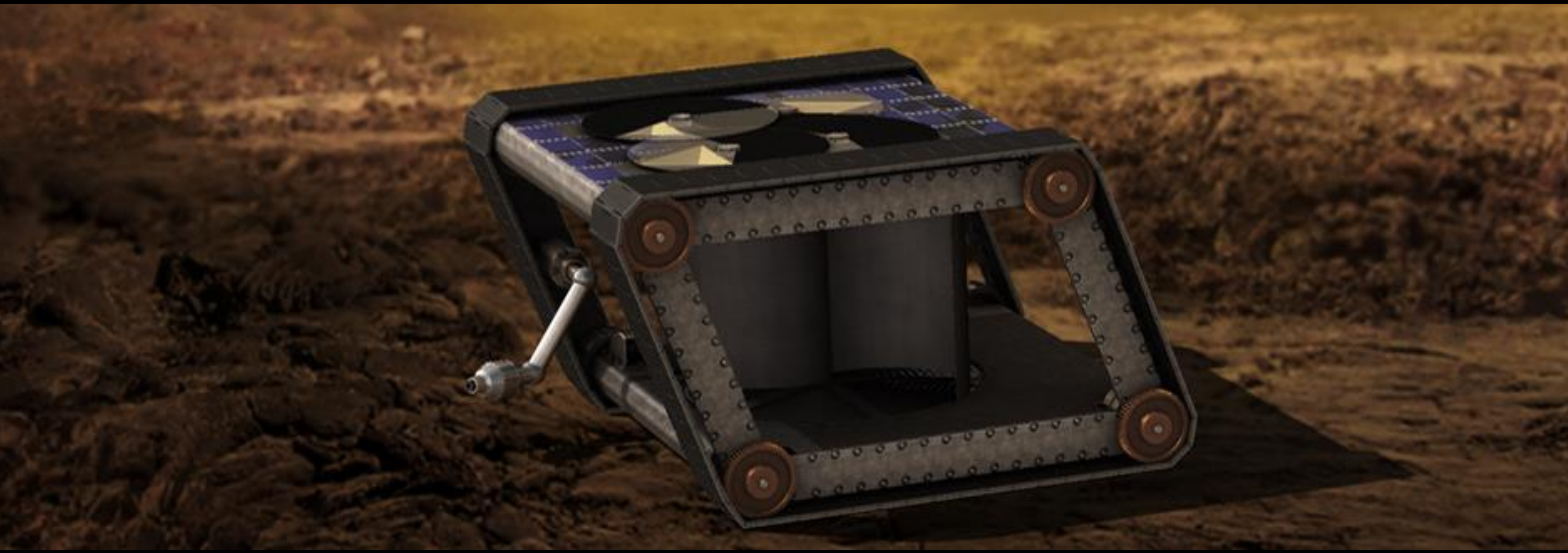
- High temperature mechanical clock
  - Prototype in Winter 2018
- RADAR Target Signaling System
  - Prototype in Spring 2018
- Wind Turbine Design for Venus and Test Methods
  - Prototype in Spring 2018 (University Teams)
- Mechanical to Electrical Interface
  - Prototype TBD
- Scale Model AREE Rover
  - Prototype in Spring 2019

AREE in Summary



Key Takeaways

- **AREE provides a mobile platform for high temperature instruments**
  - Utilizes mechanisms to reduce requirements on electrical systems
- **AREE Design Principles**
  - Distributed, simple mechanisms → evolved, emergent behavior
  - Robustness and resilience to reduce complexity
  - A hybrid rover architecture maximizes performance
- **AREE Trades on Mechanical Systems**
- **AREE Current Work**
  - High Temperature Clock
  - Wind turbine optimized for Venus



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