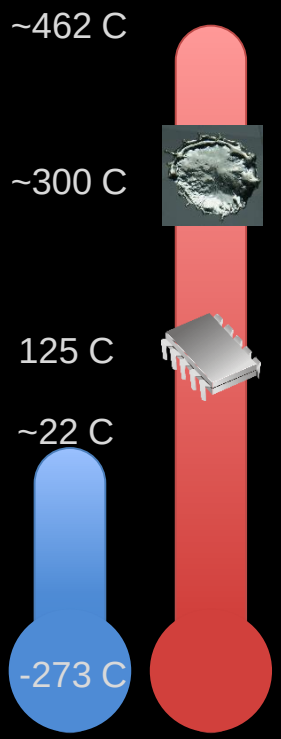

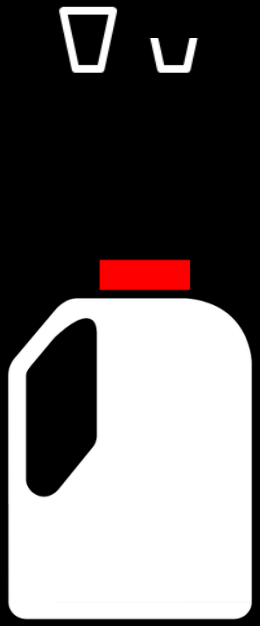

Image: Soviet Space Agency
Additional processing: Don P. Mitchell via wanderingspace.net

Background: Soviet Space Agency Additional processing: Don P. Mitchell via wanderingspace.net

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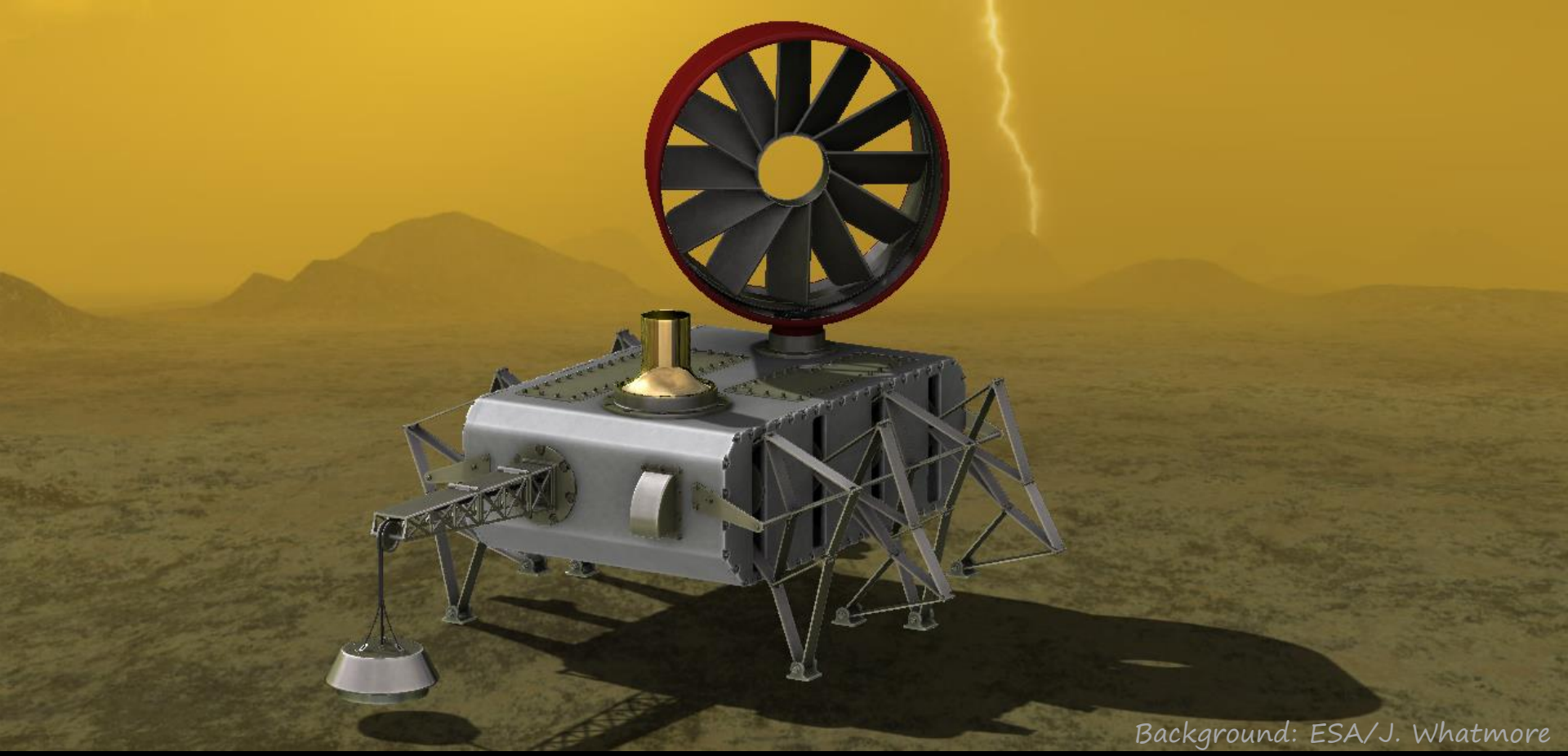


Automaton Rover for Extreme Environments (AREE)

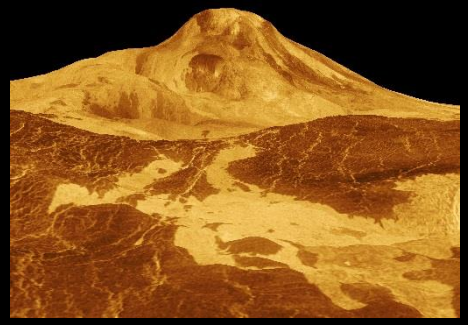
Jonathan Sauder, Evan Hilgemann, Jessie Kawata,
Katie Stack, Aaron Parness, Michael Johnson

May 24, 2016

Jet Propulsion Laboratory
California Institute of Technology

NASA Innovative Advanced Concepts

Why Automata on Venus?



Longitudinal Science

What are diurnal temperature fluctuations?

How do wind speed and pressure vary?

Is there seismic activity on Venus and to what extent?

What is the make up of the interior of the planet?

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An Inspiring Legacy

Automata have been demonstrated over centuries

The Writer:
Minutes 2:20 to 4:10
http://www.youtube.com/watch?v=bY_wfKVjuJM&t=2m20s

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An Inspiring Legacy

Automata have recently been revived through Theo's work

theo jansen, *strandbeest evolution*, 2013.

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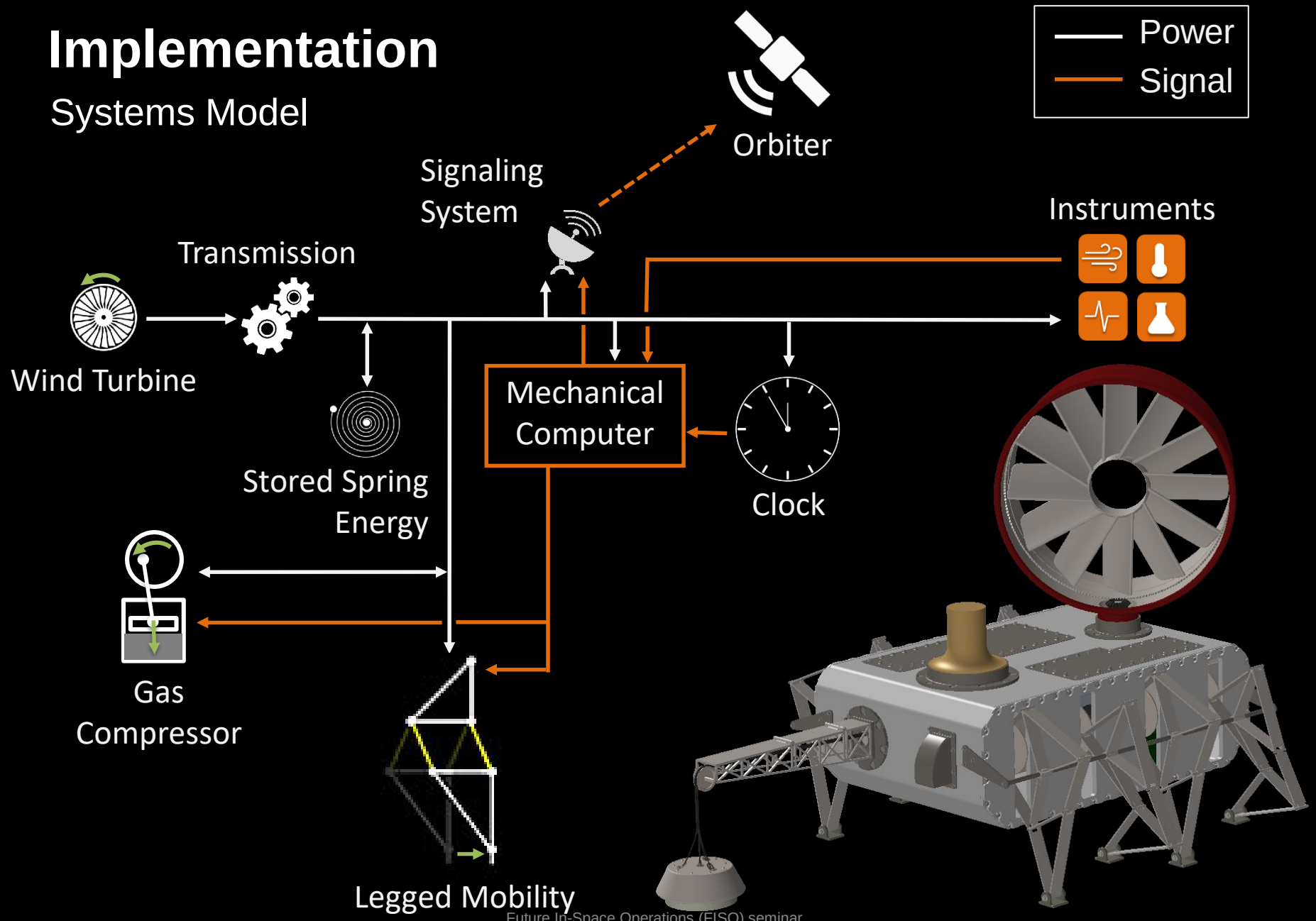
Implementation

Systems Model



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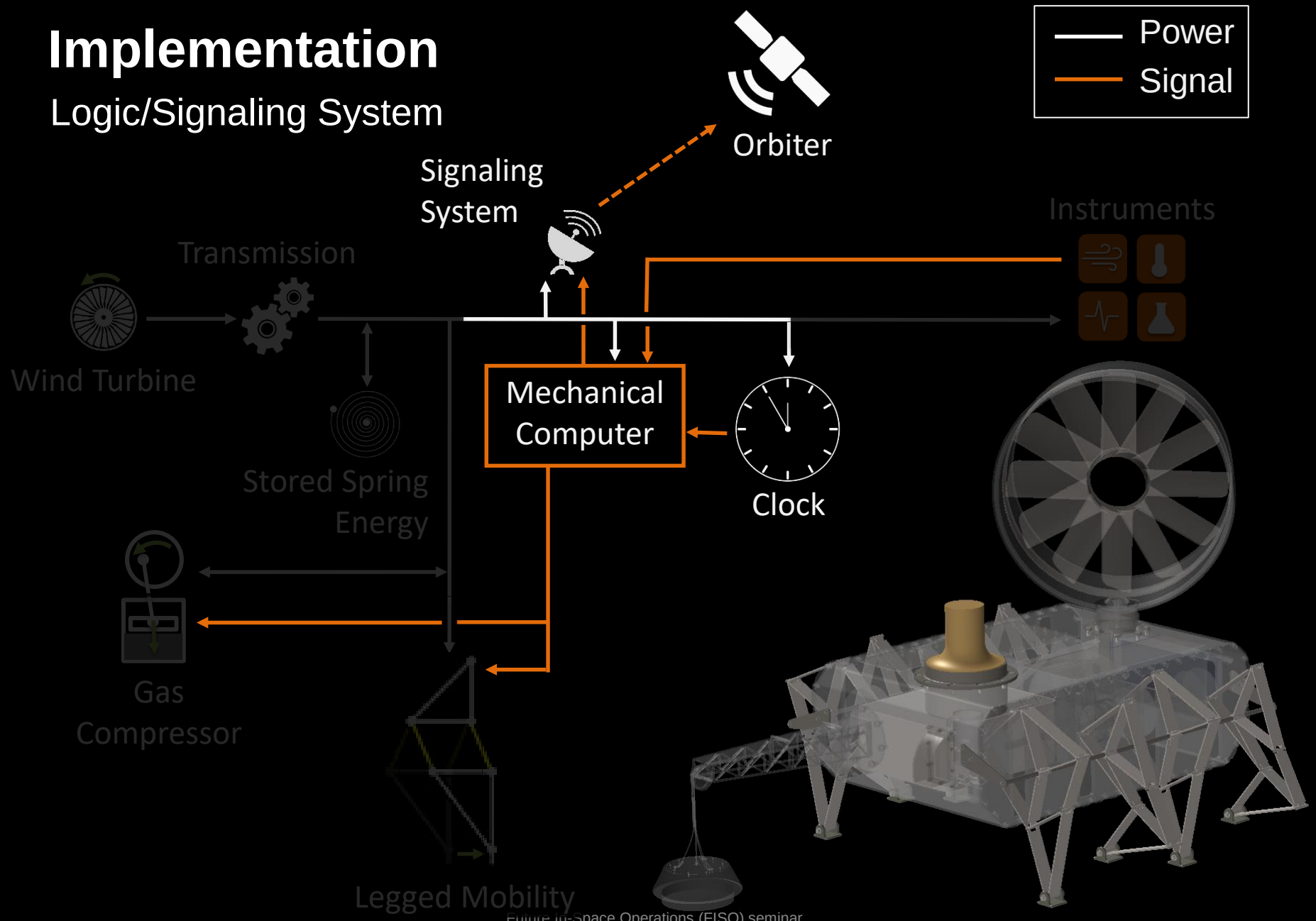
Implementation

Logic/Signaling System



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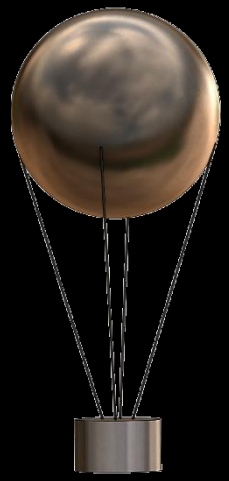
Signaling Trade Space

Records and Balloons



Vacuum Tube Transmitter

Image: Joe Haupt

RADAR Targets

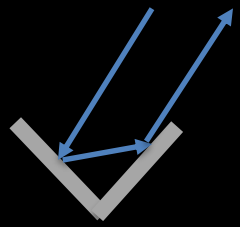


Image: Bin im Garten

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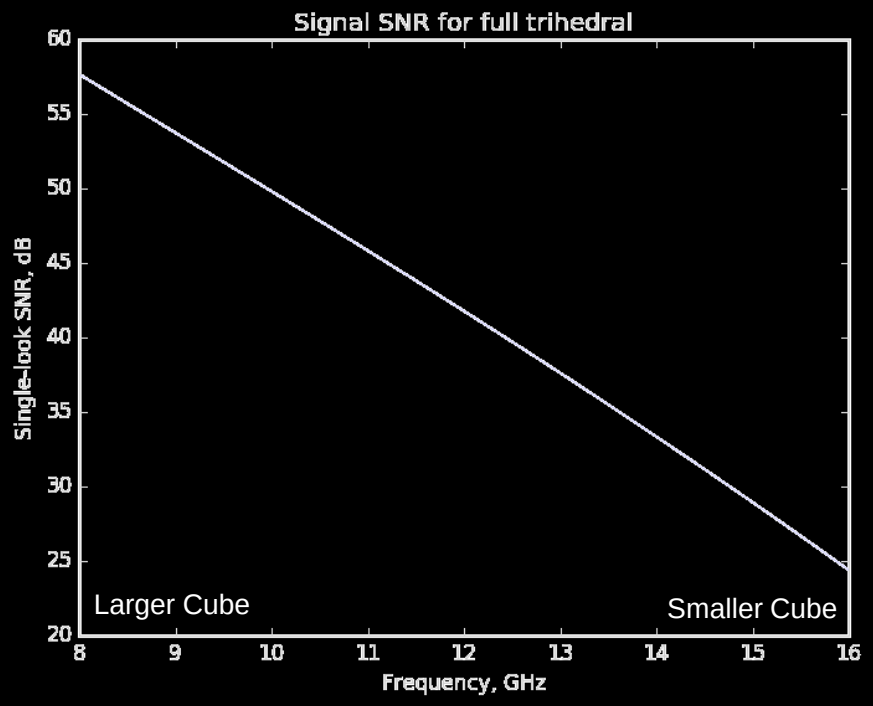
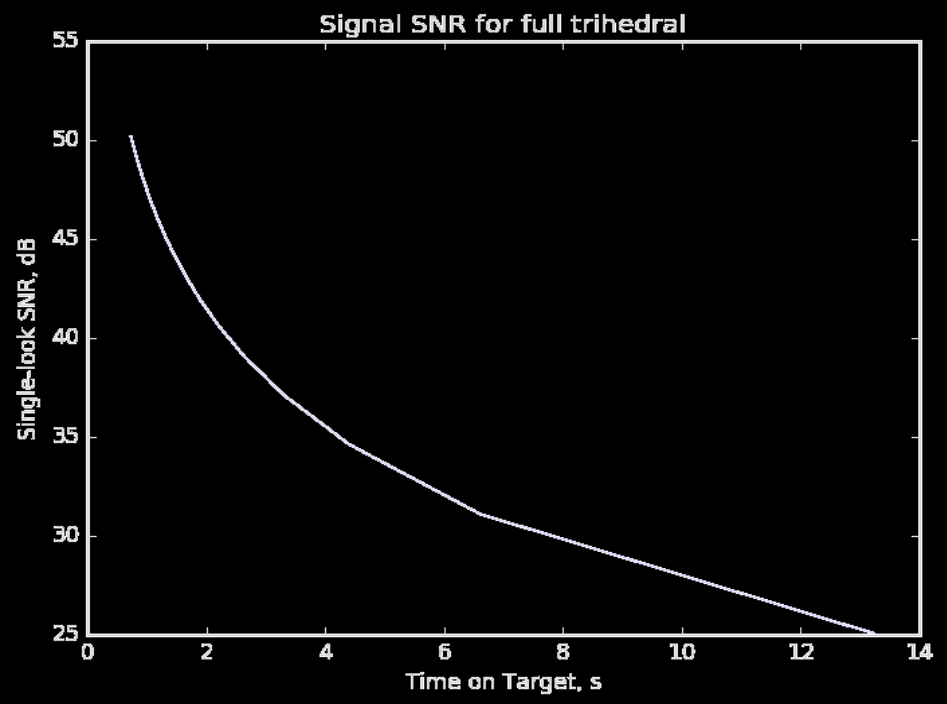
Signaling Using a RADAR Target

Varying Corner Cube Size (and freq.)



Varying Radar Antenna Size



	Records and Balloons	Vacuum Tube Radio	Radar Target	High Temperature Transceiver
Data Rate (bits/day)	10E4 bits	10E6 bit	10E3 bits	10E6 bits
Risk and Investment	Very High	Moderate/High	Low	Moderate

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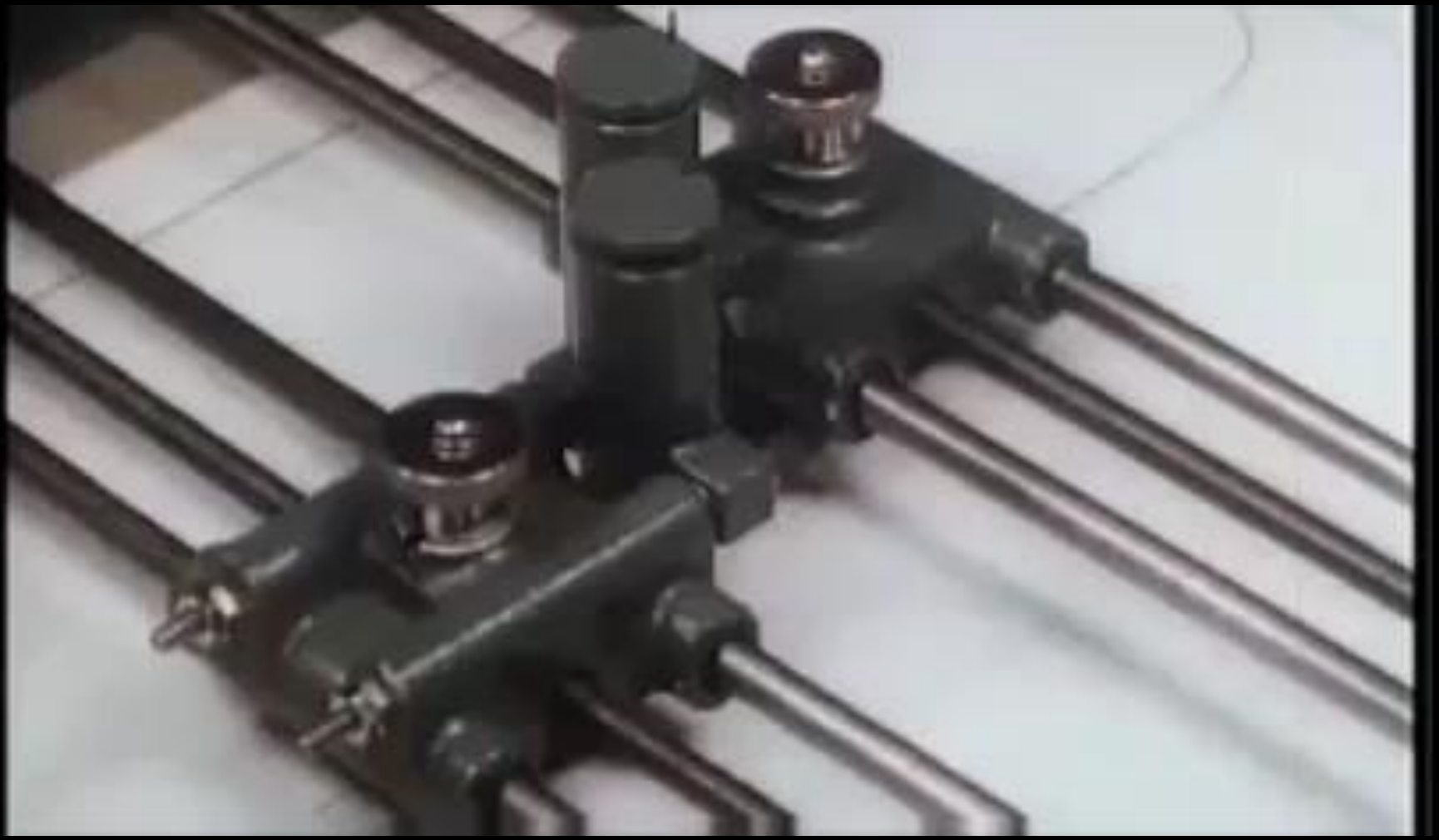
Mechanical Computing

A historical perspective



UCLA's 1948 Mechanical Computer. Dir. Popular Science, 1948, Prod. Gizmodo, *Vimeo*

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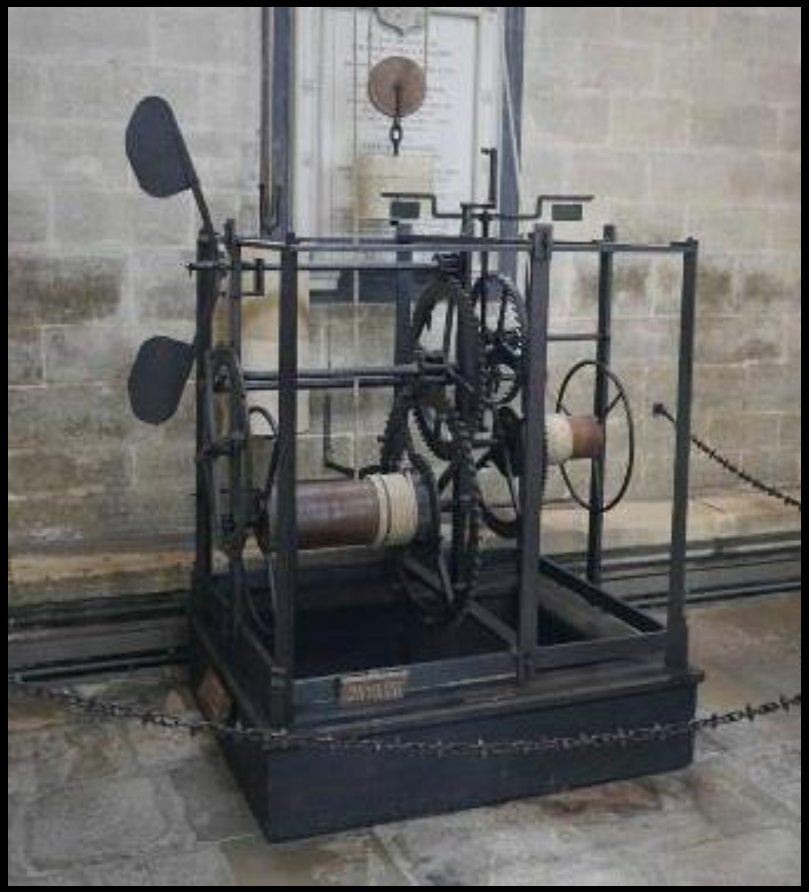
Other Examples

Clocks



Salisbury Cathedral Clock - 1380

H5 pocket watch – 1770s

https://www.tripadvisor.com/
http://www.thepirateking.com/

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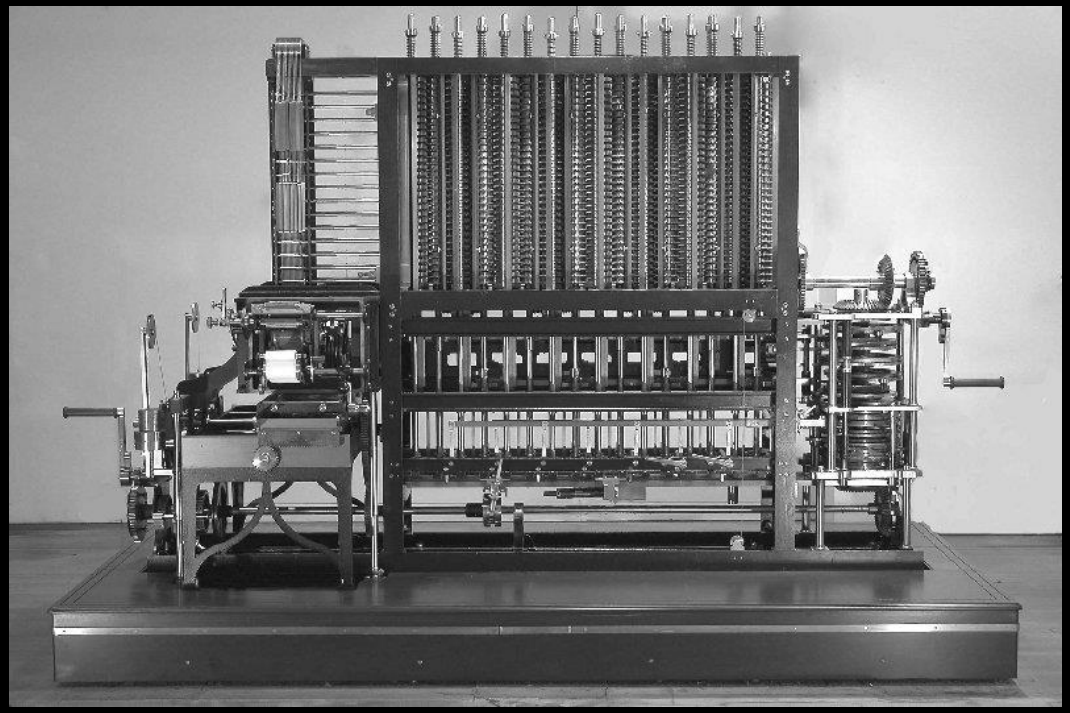
Other Examples

Analytic Engines, Arithmometer



http://www.computerconservationsociety.org
http://www.historyofinformation.com

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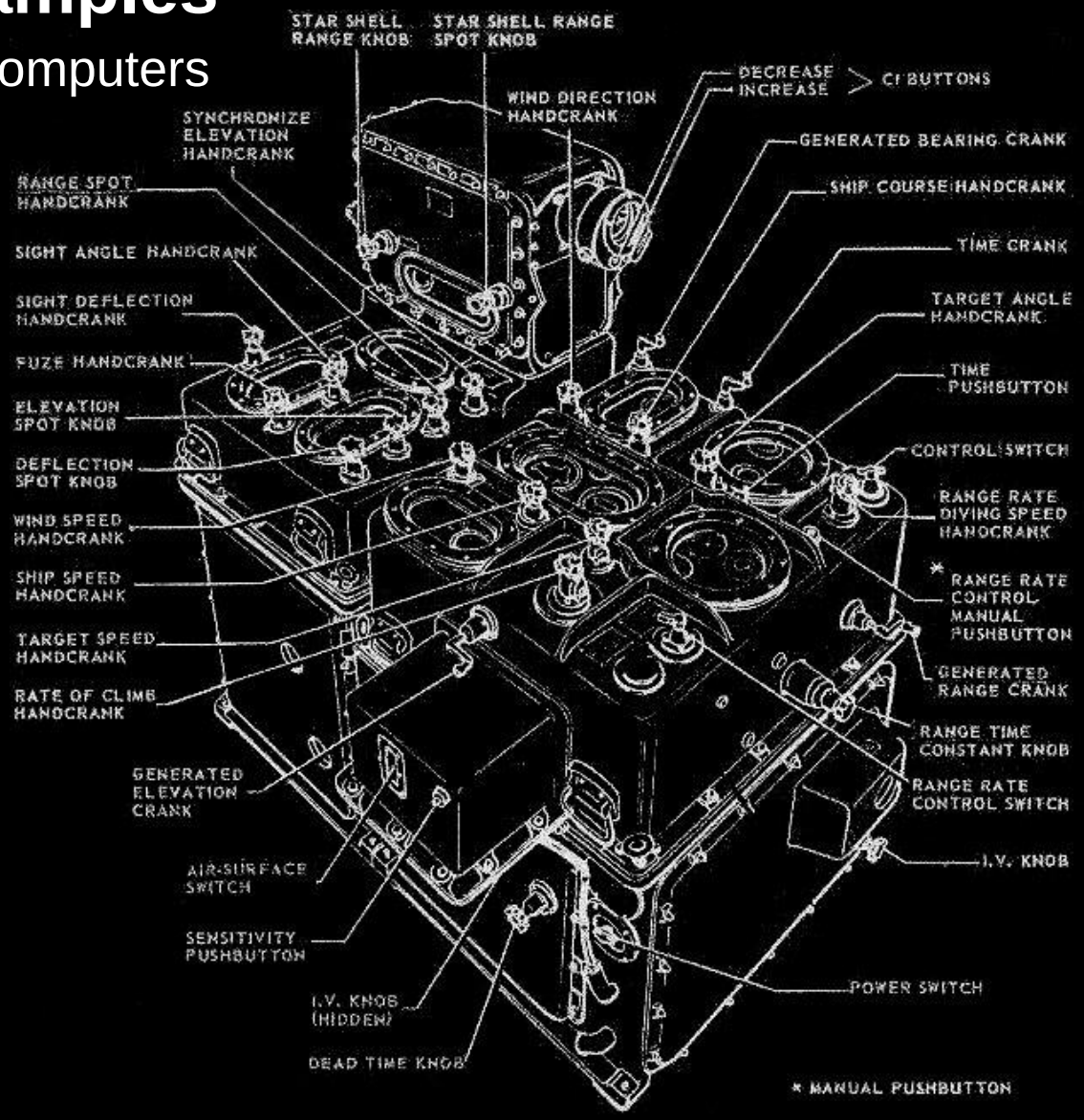
Other Examples

Fire Control Computers



https://en.wikipedia.org/

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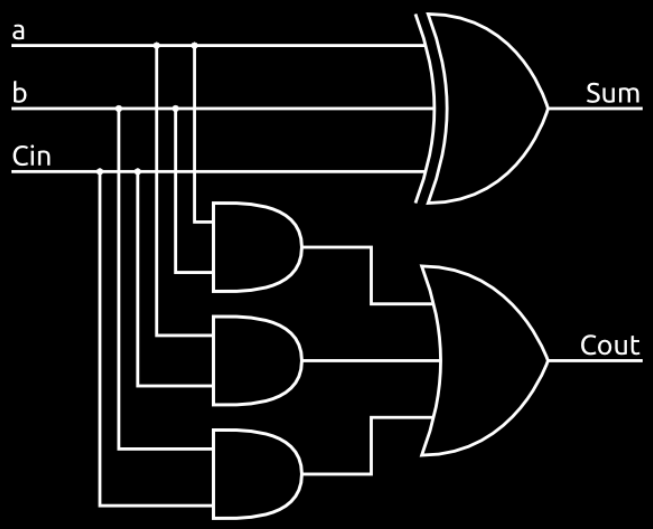
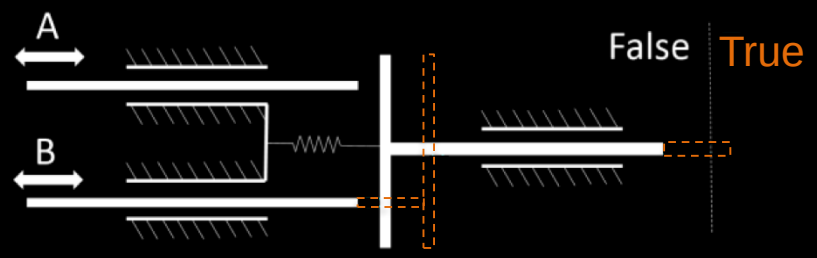
Binary Computing



Full Adder



Mechanical ‘OR’ gate

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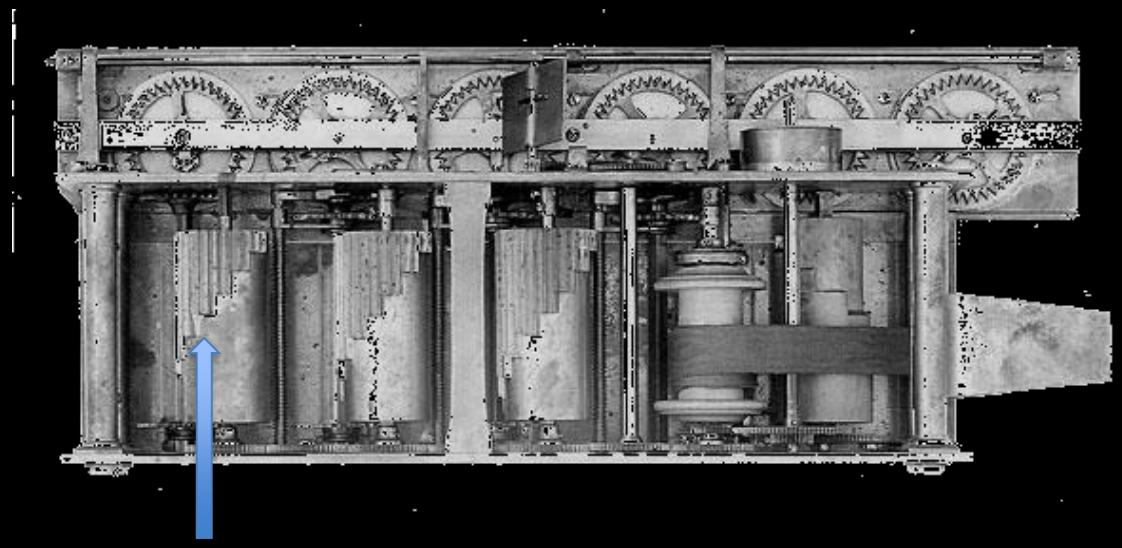
Digital Computing



Detents

Arithmometer cut-away

https://www.britannica.com

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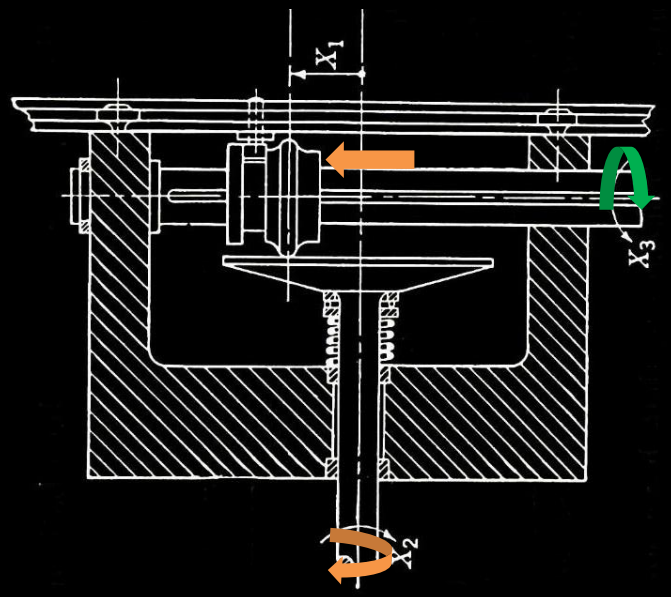
Analog Computing

Input
Output



Basic Mechanisms In Fire Control Computers Part 1, Dir. US Navy, 1953, Prod. Excelsior10000, 2011. *YouTube.*
A. Svoboda, "Computing Mechanisms and Linkages"

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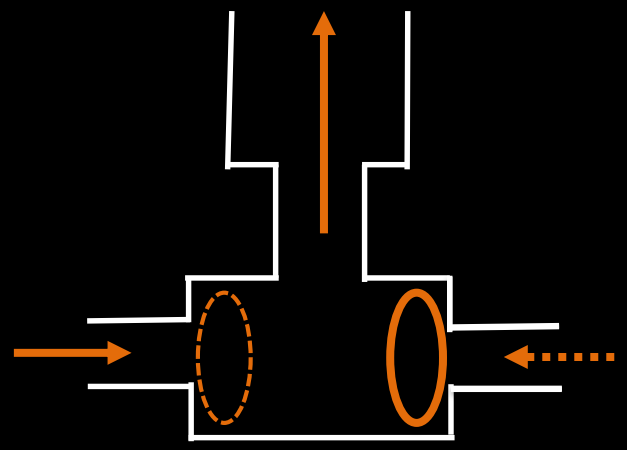
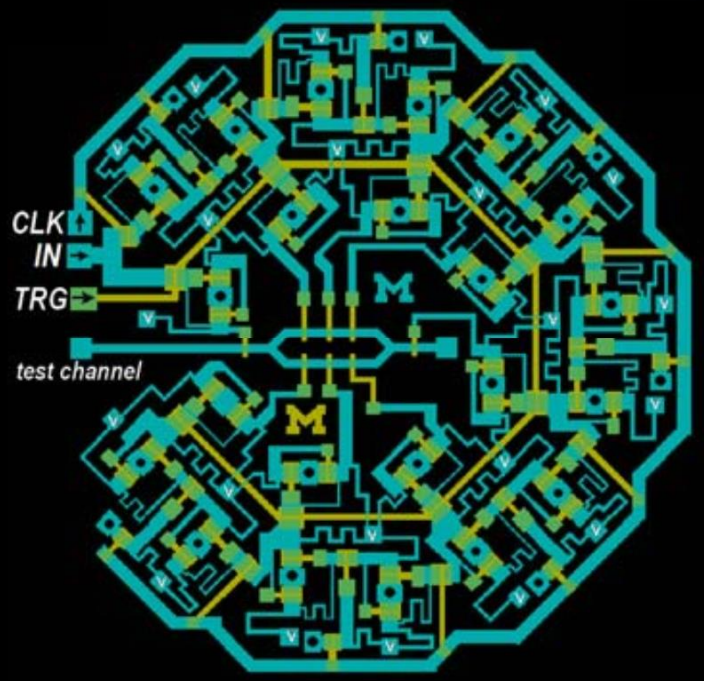
Pneumatic/Fluidic Logic

Advantage: can have gain



Pneumatic ‘OR’ Gate



8 bit pneumatic/fluidic processor

M. Rhee, Microfluidic pneumatic logic circuits…

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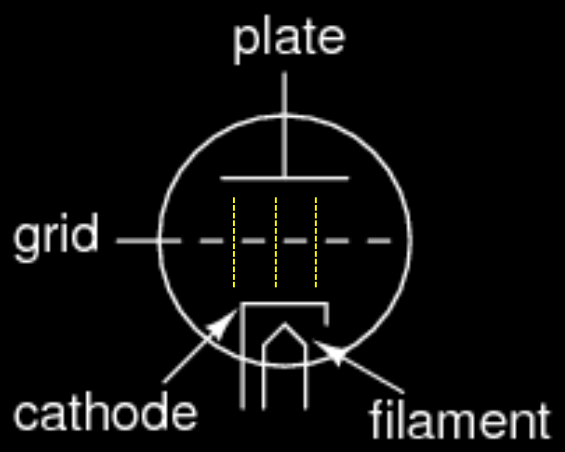
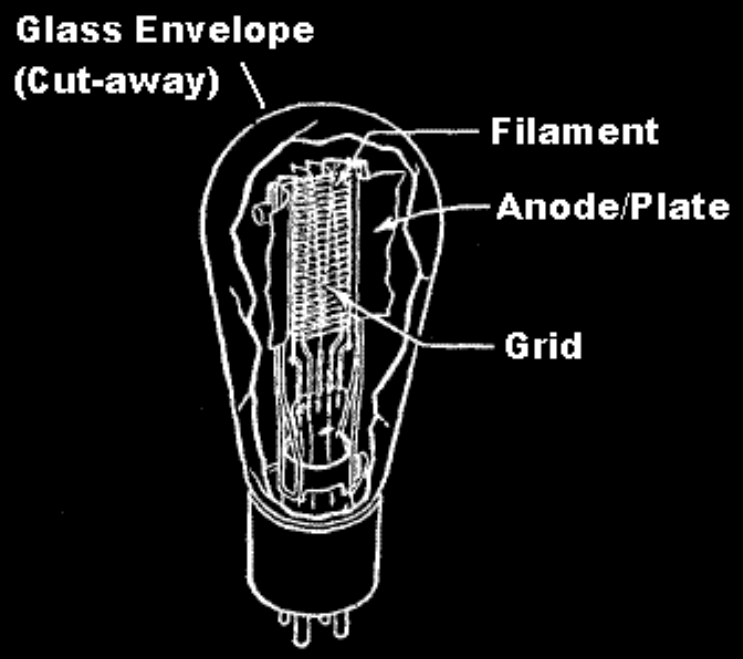
Vacuum Tubes

Inherently tolerant to high temps





http://www.qsl.net/m0ayf/VFD-Regen.html

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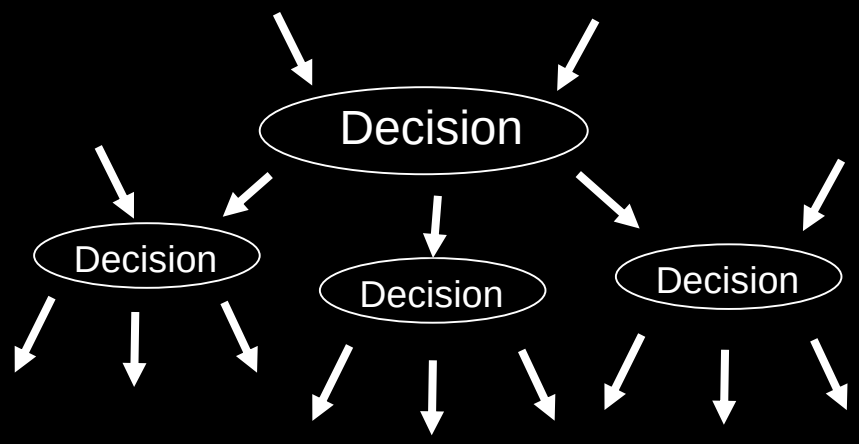
Computer Architecture

Traditional Centralized Model

Distributed Model

Many simple rules = complex behavior



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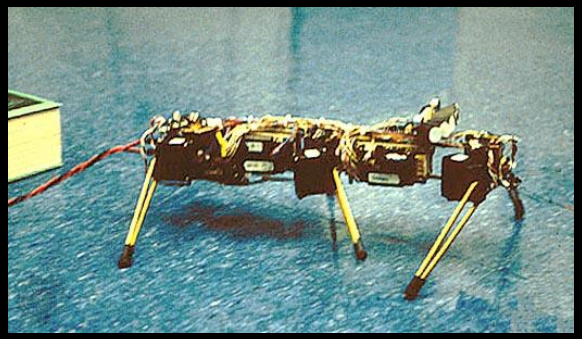
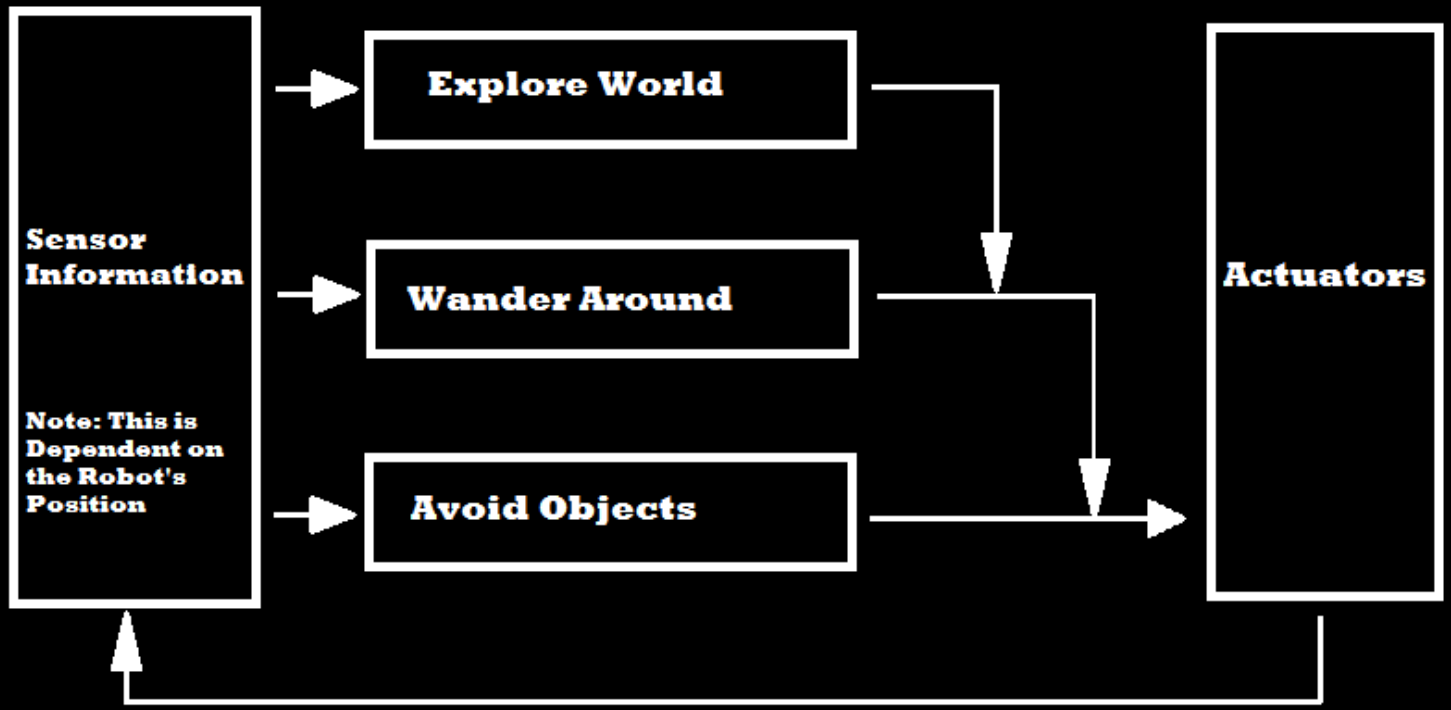
Computer Architecture

Example: Subsumption



Genghis Robot



Brooks, Rodney, Cambrian Intelligence: The Early History of the New AI.

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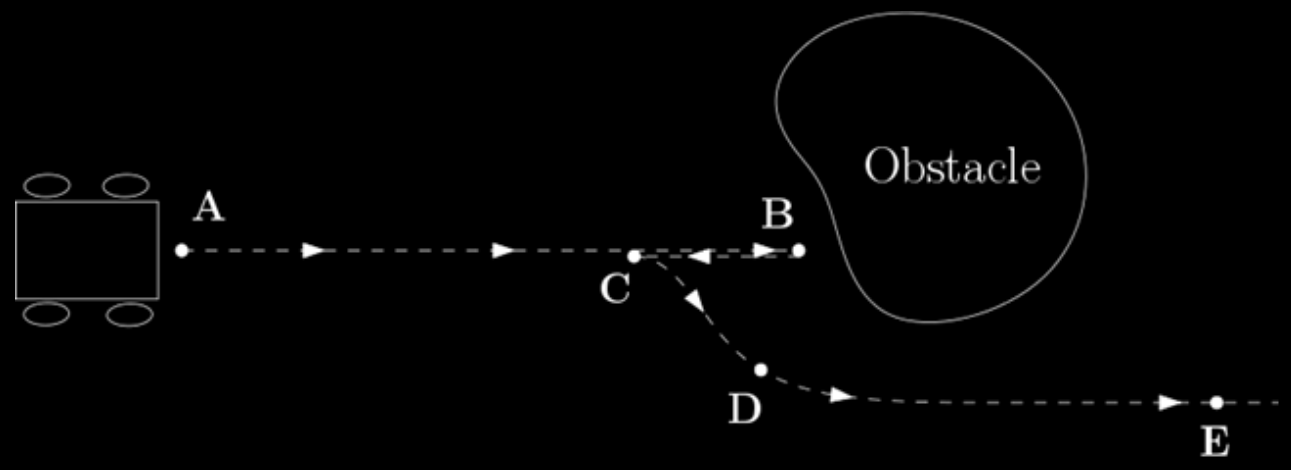
A Mobility Case Study

Obstacle Avoidance Goal



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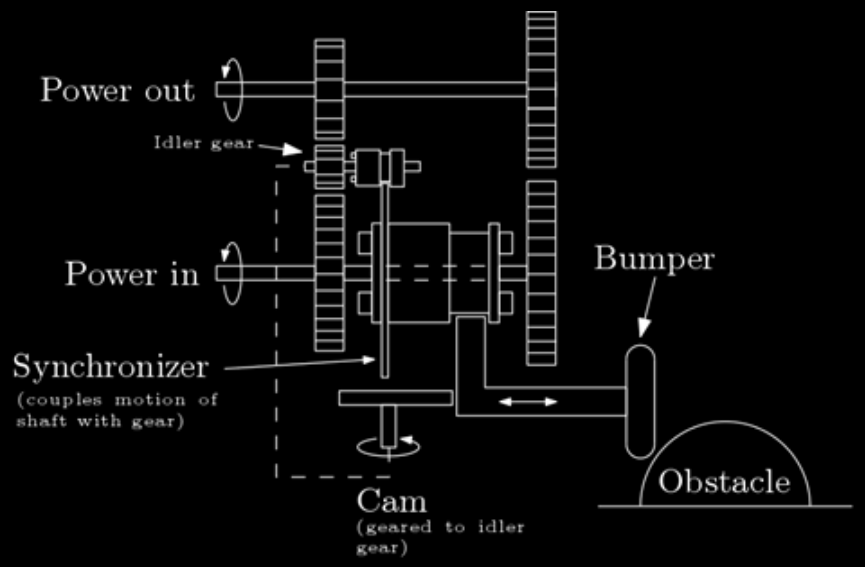
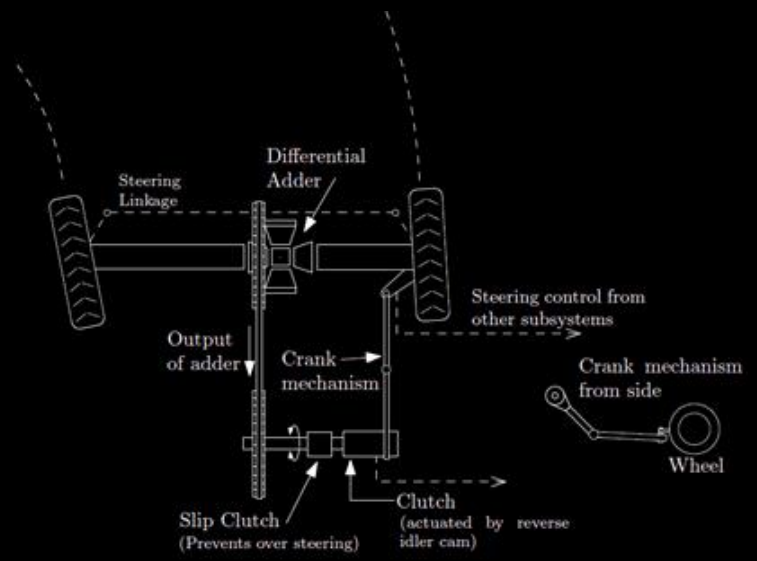
A Mobility Case Study

Obstacle Avoidance Mechanisms





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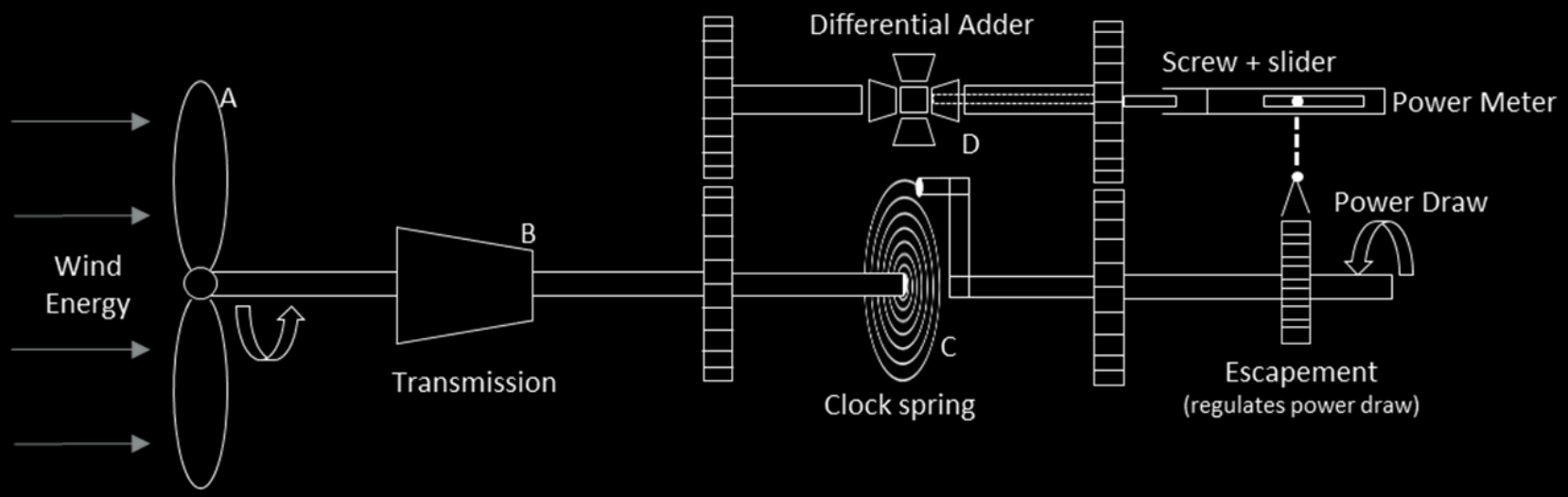
Mobility Case Study

When to Move



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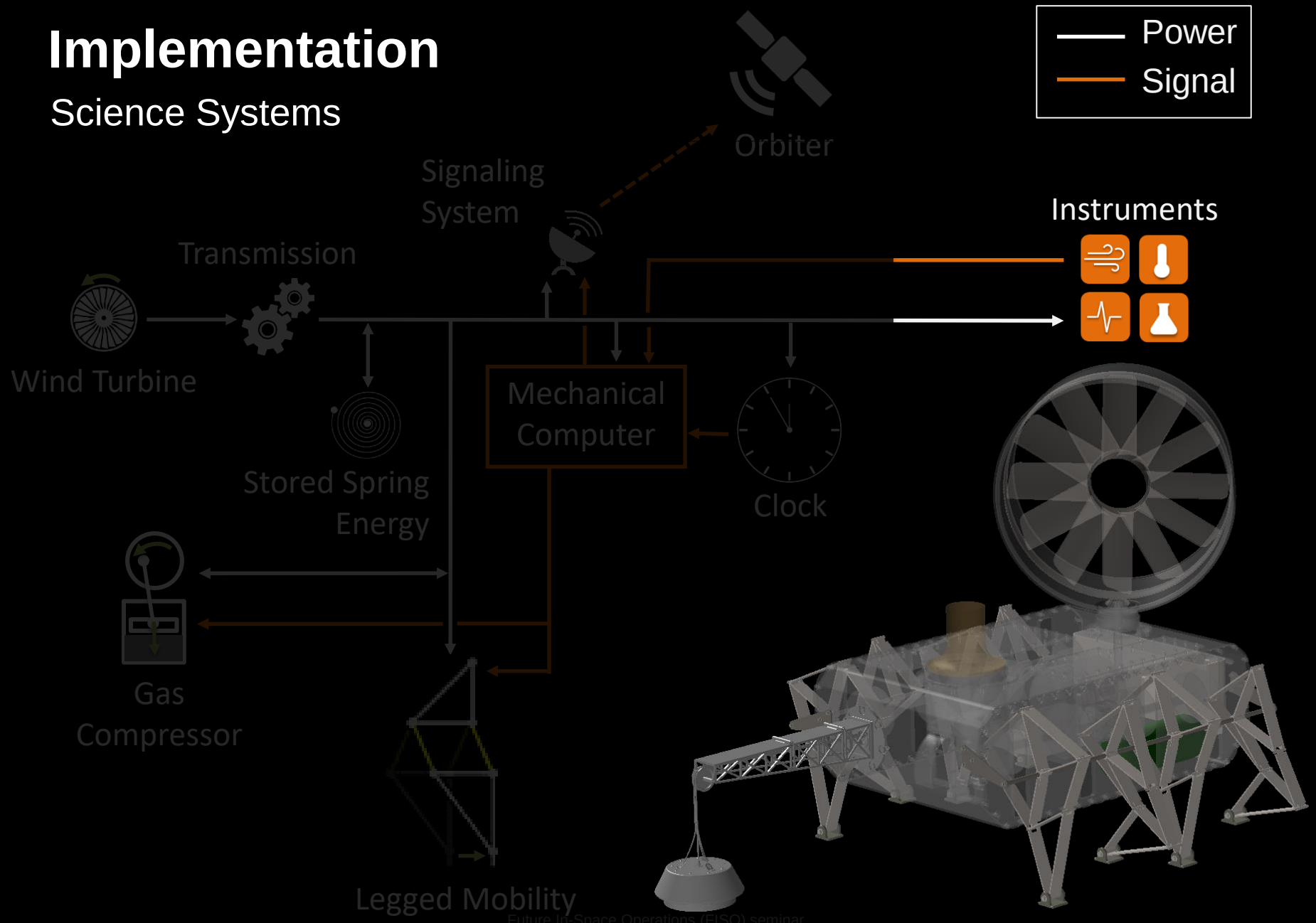
Implementation

Science Systems



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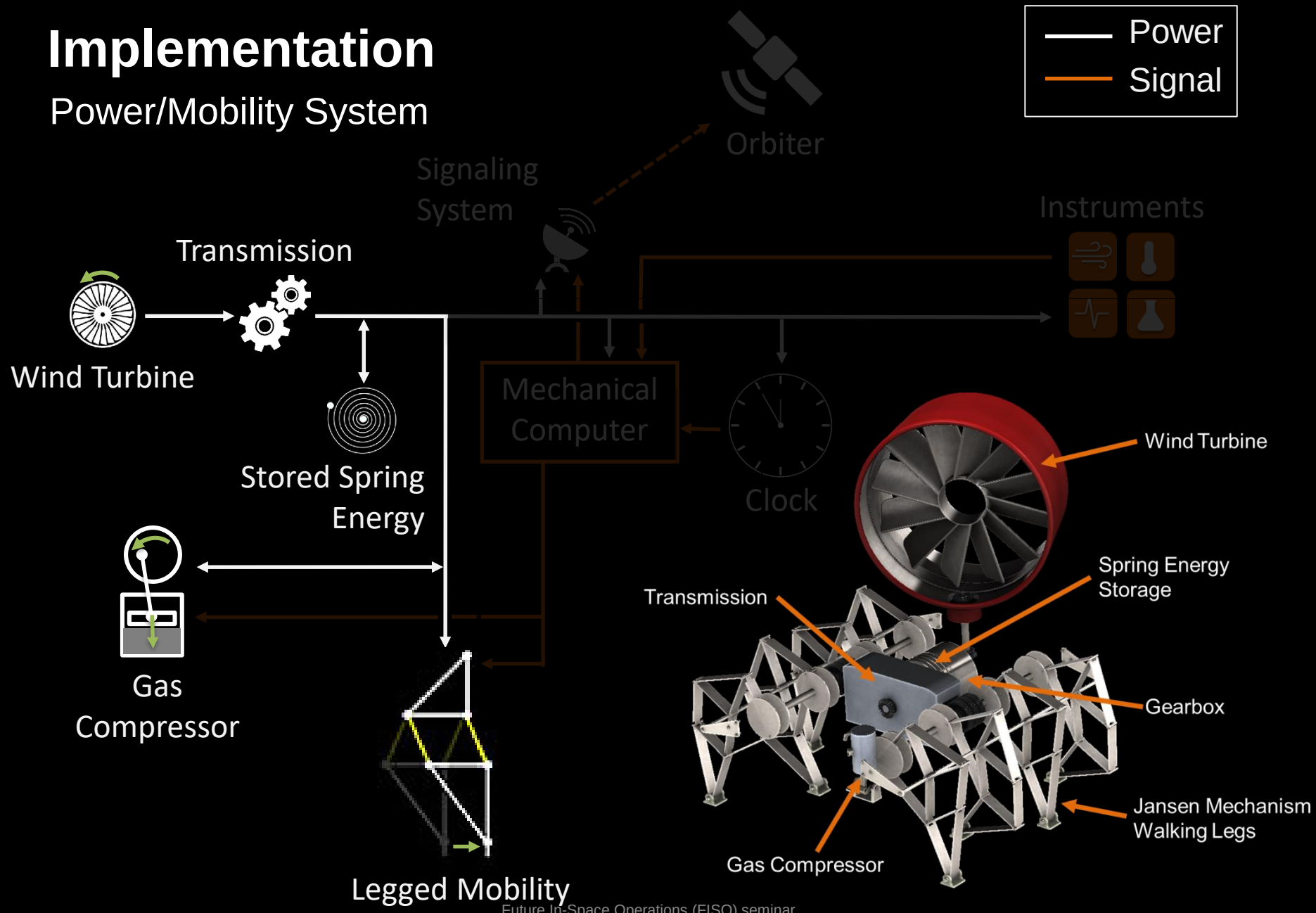
Implementation

Power/Mobility System



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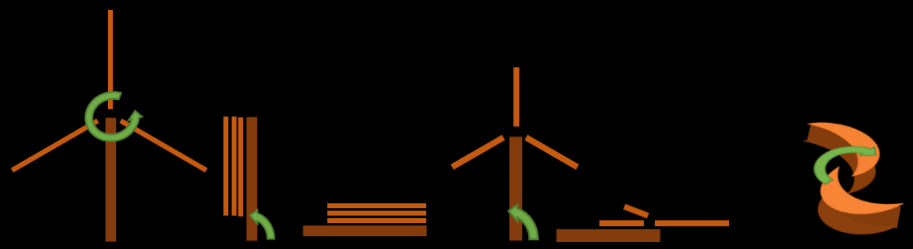
Energy Generation and Storage Comparisons



	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	10.27
Power Gen. Density (W/kg)	1.10	0.91	0.20	1.35	1.46
Risk & Investment	High	Moderate	Moderate	Very High	Low

	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

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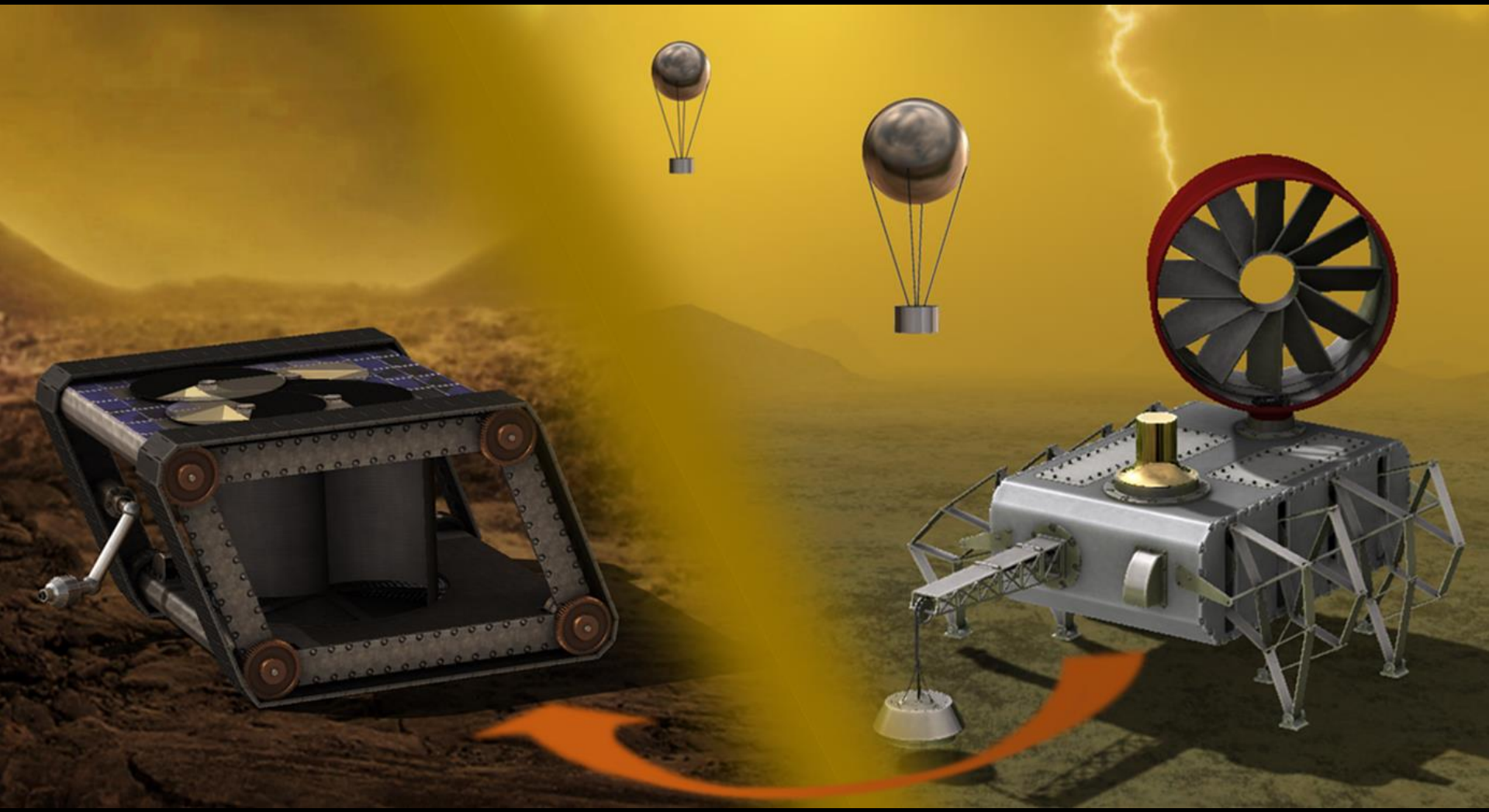

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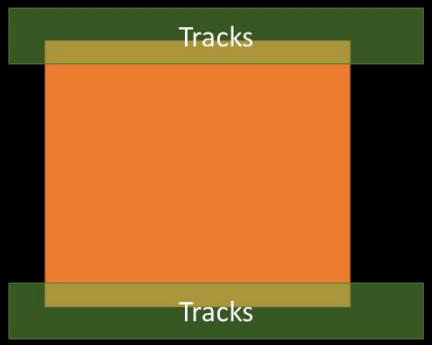
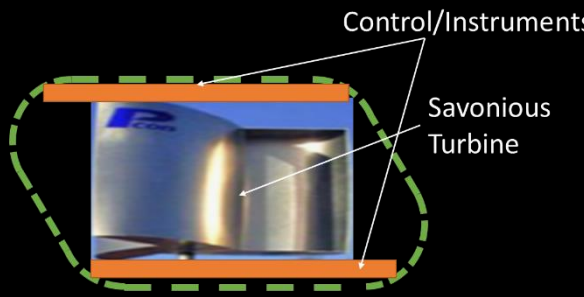
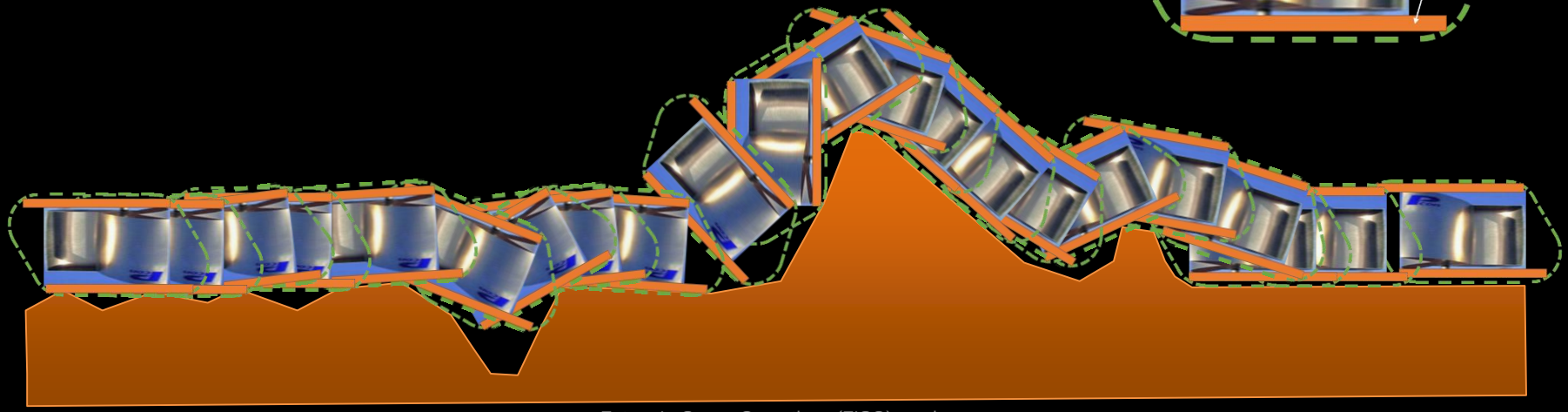
Locomotion System Design

Ability to Climb Large Objects and Operate Independently of Orientation







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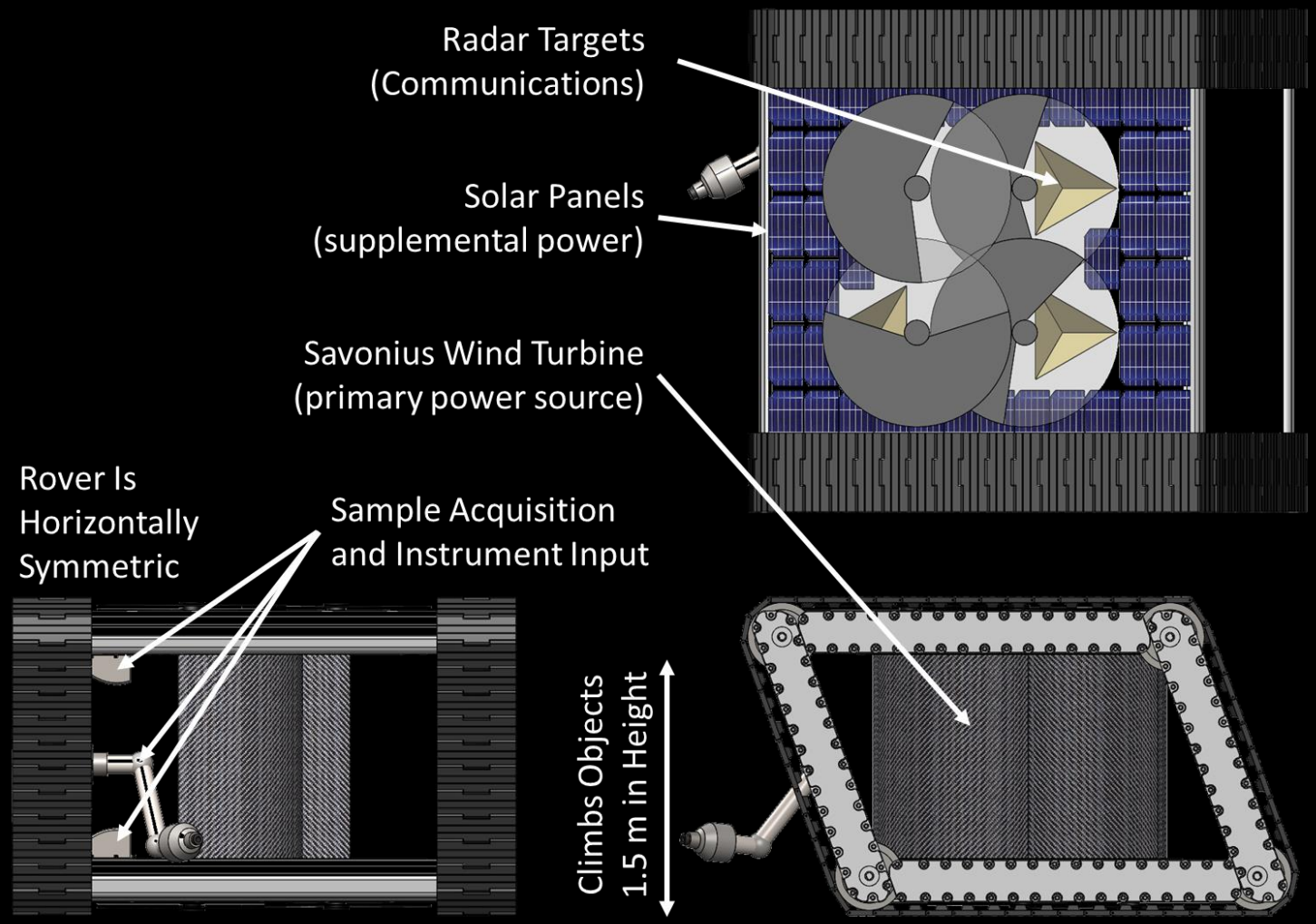
A Revised Automaton Concept



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JPL: Jeff Hall, Bernard Bienstock, Jan Martin, Scott Hensley, Simone Tanelli, Mike Pauken, Bruce Banerdt, Rosaly Lopes, Laura Kerber, James Cutts, Brian Wilcox, Arbi Karepetian, Brett Kennedy, Kim Aaron, Douglas Hofmann, Jessie Kawata, Kevin Baines, Sue Schmekar, Yuki Maruyama and Mohammad Mojarradi

Other: Theo Jansen (Strandbeest), Kyle Colton (Planet Labs), Nathanael Miller (LaRC), Charlie Manion (Oregon State), Ofir Atia (Art Center), Lori Nishikawa (Art Center)

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