Point Designs of Mobility Systems for Meso-Scale Rovers

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One of the advantages of using small rovers for exploration is the potential for the creation of point designs. Even the most capable rover designed for general use will be incapable of performing certain tasks or traversing certain terrain. This presentation outlines four different conceptual designs and their niches in exploration.

<u>Pixel Popper</u>

Sometimes quantity of data may be more important than the quality of data. In particular, an experiment may return a “yes/no” response but must be carried out many times over a large area. In this case, a small rover with a large range but coarse navigation may be the answer. The Pixel Popper could be one solution. Carrying a payload of a single camera, the science experiment, and a transmitter, the rover could hop from location to location, sending back its simple answer whenever it landed. Because there are four piston legs, some crude steering can be accomplished by differentially firing them. By designing a low center of gravity, the rover should tend to land on its feet. If it does end up on its back, it could flip by having one piston capable of firing toward the top.

<u>Worm</u>

Areas currently inaccessible to rovers are small cracks in rock and any soil more than a few inches below the surface. A worm-like mechanism may be able to bring those regions to light. In basic form, the worm rover is a collection of identical mechanical units connected in series. Each unit consists of a telescoping payload/actuation module, which runs down the middle of the unit, and two hinged plate mechanisms, which flank the payload section. When a unit is moving forward (i.e., extension of the payload module), these plates fold against the body, streamlining the section. However, during contraction, the plates are forced away from the body, forming an anchor against backward motion.

<u>Yo-Yo</u>

An important scientific experiment that cannot be carried out by current rovers is the determination of cliff wall stratigraphy. Ideally, the rover would rappel down the cliff face, taking spectroscopic data as it went. The Yo-Yo design may be capable of achieving such motion. By firing a piton into a likely rock at the top of the cliff, it could move down the cliff face by playing out the line attached to the anchor. It would be particularly interesting to chemically create the line as the rover moved (artificial spinnerets). If gravity is insufficient to roll the rover, motors will take over, driving the "wheels" for brief periods. Instrumentation can be housed in the non-rotating pods beside the wheels.

Striding Hexapod

One of the limitations of current rovers is the inability to change gears. The same effective gear ratio is used whether speed or torque (force) is at a premium. By creating a hexapod with a variable length final leg segment (tibia), the stride length and effective lever arm of the leg to the body could be changed to suit the terrain. This design would be mechanically analogous to changing the ratio of the gear train.

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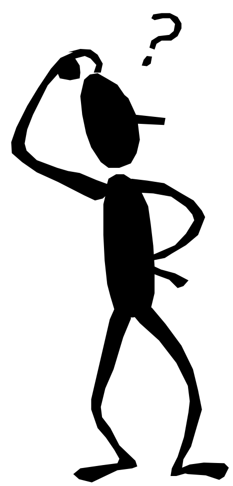
Outline

- Justification
- Pixel Popper (Grasshopper)
  - Scenario
  - Possible design
- Yo-Yo (Spider)
- Differentiated Leg Hexapod (generalized insect)
- Worm

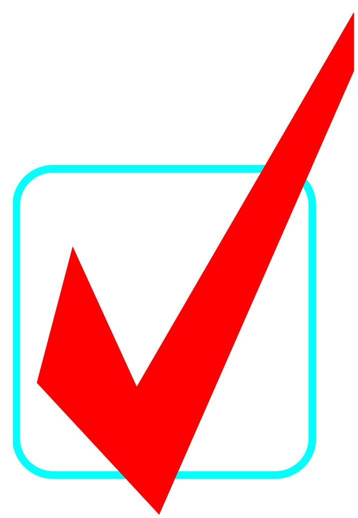
Why Point Designs?

- Low weight allows multiple rovers of different types
- General rovers incapable of certain tasks
- More efficiency performing certain tasks
- Lower cost?



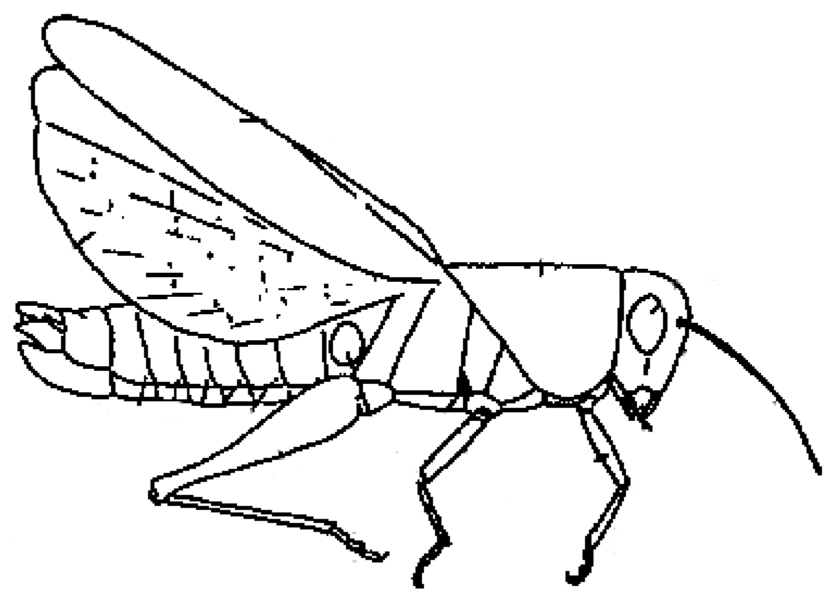
The Agent of "Yes/No" Science

- Some experiments may have a "digital" answer
- Quantity and speed of collection may be more important than detail and precision navigation
- Example: acid test for carbonates



Biological Inspiration

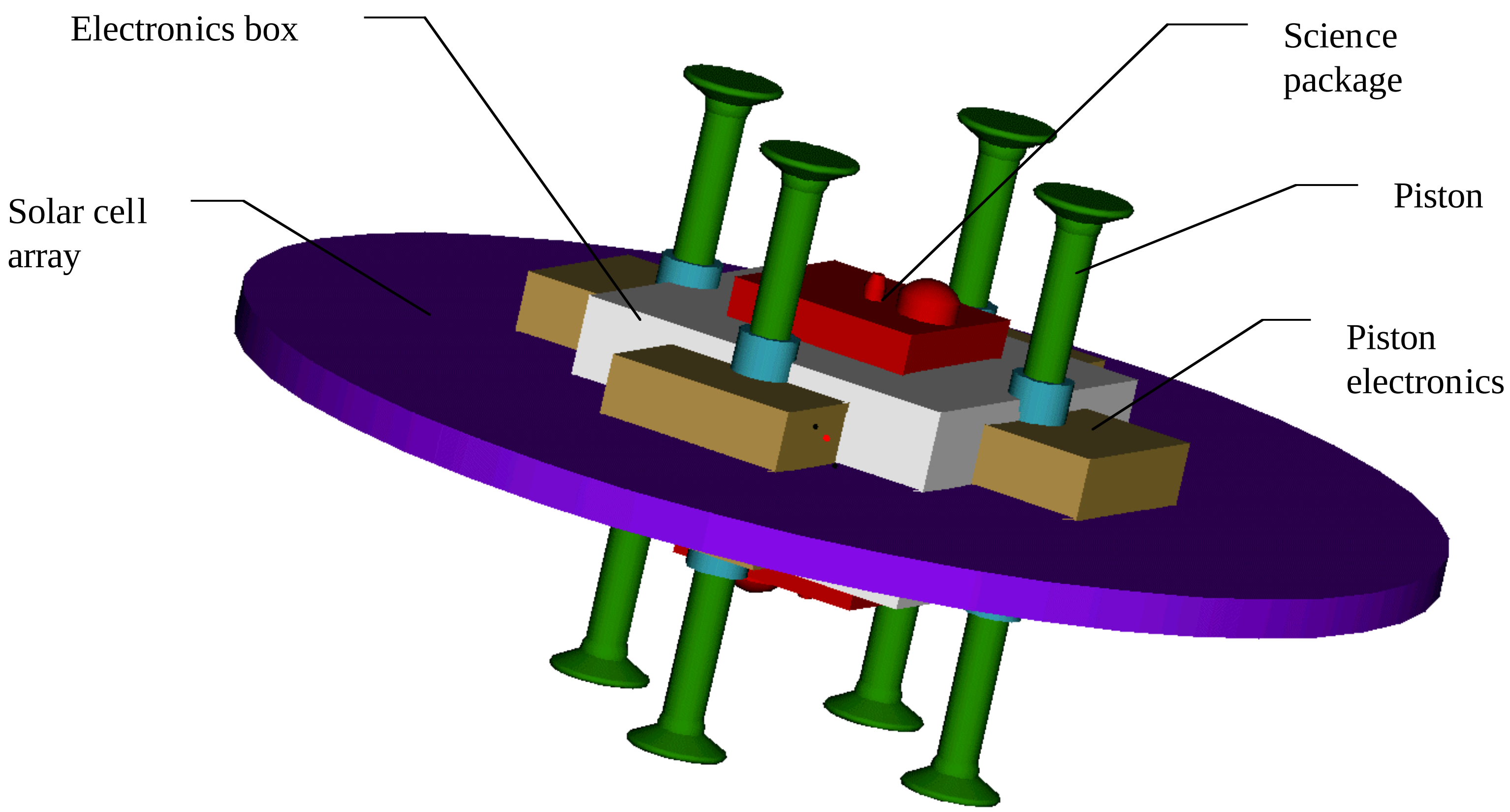
- Grasshopper
  - long range
  - minimal direction
  - short burst of activity



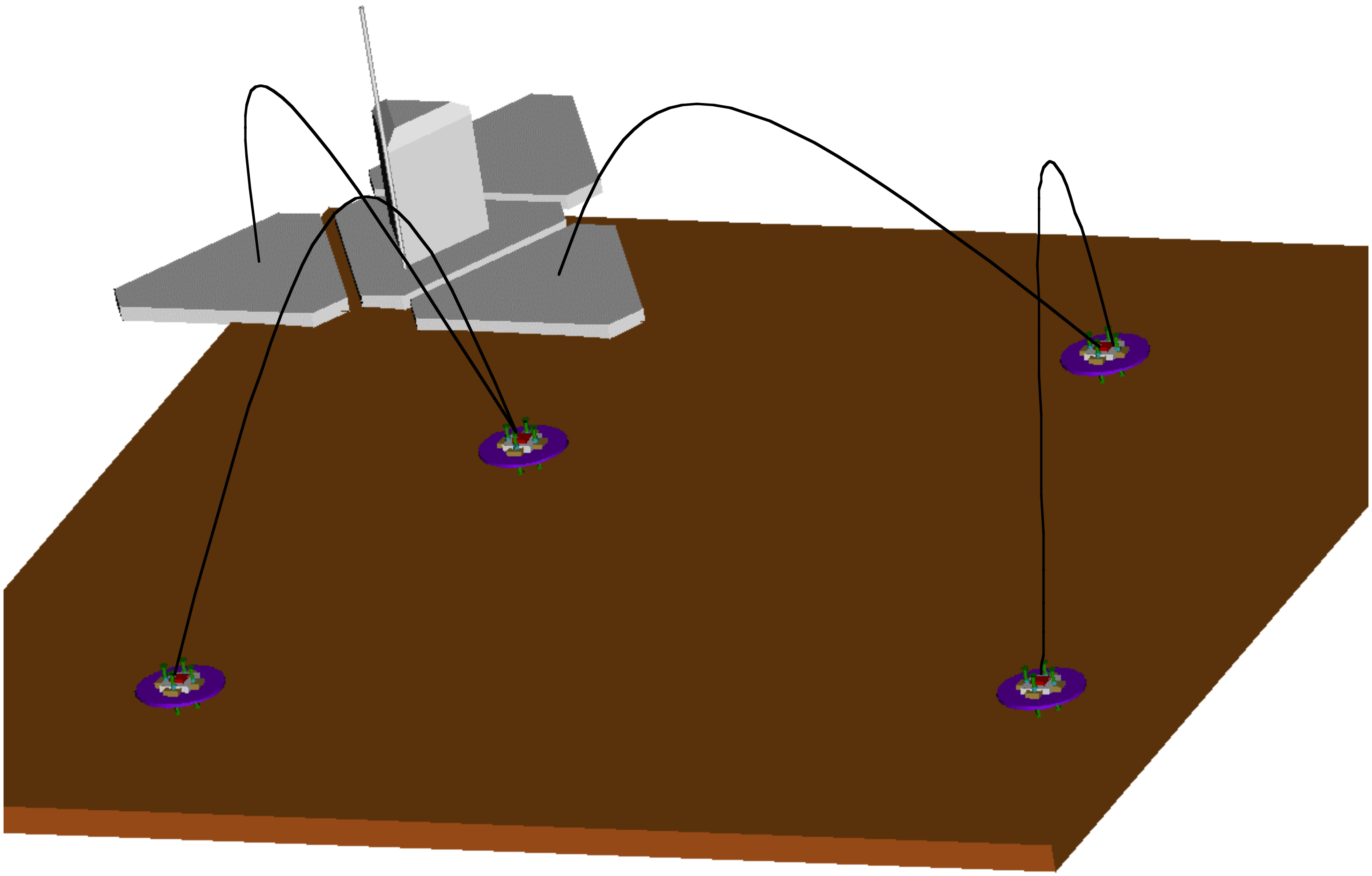
Conceptual design

- Eight pistons provide thrust and direction
- Closed H and O_2 fuel system under development by Wdowiak
  - current design capable of 1kJ energy release
- Symmetric (top/bottom) mobility and science
- Simple experiment package

Pixel Popper

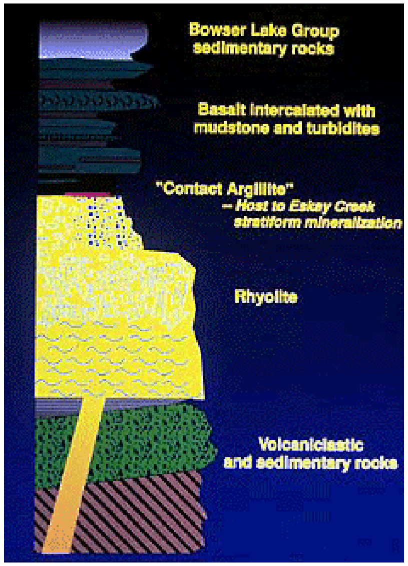


Operational Schematic



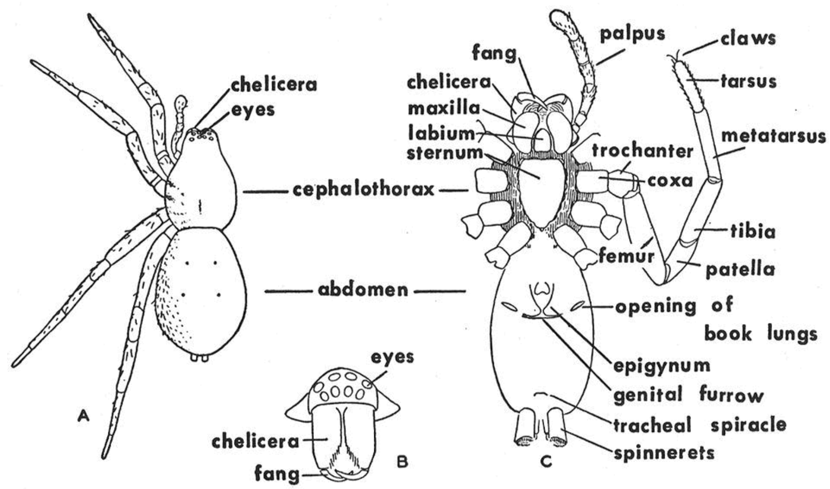
Stratigraphy

- Stratigraphy of cliff faces produces high knowledge return
- Requires a spectrometer
- Cliff crawling presents a distinct mobility problem



Biological Inspiration

- Spider
  - bi-modal mobility
  - could use cable spinnerets
  - cable provides safety, as well as mobility
  - instead of cable, spinnerets could extrude a recyclable, low-temp polymer

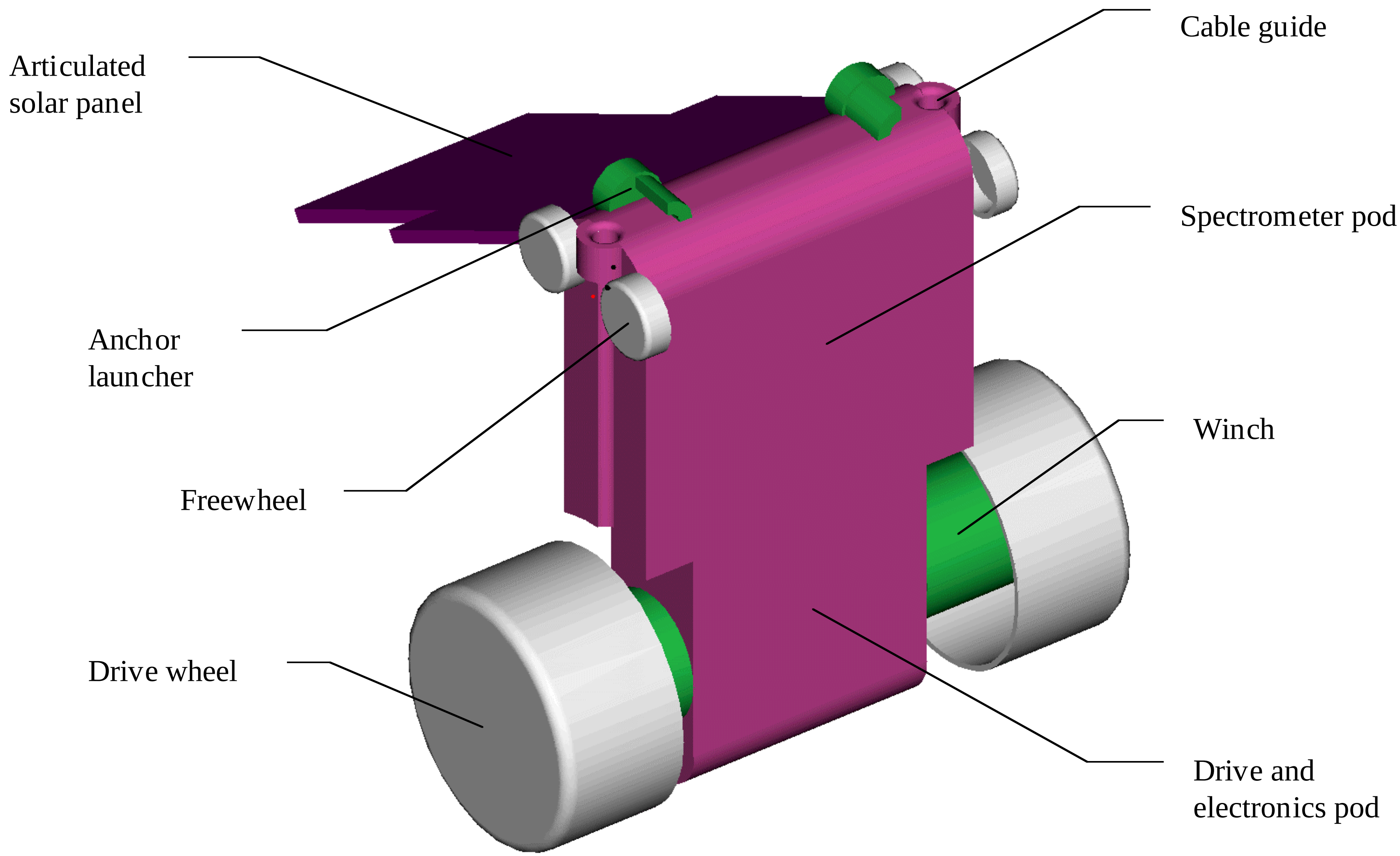


TEXT FIG. 1.—EXTERNAL ANATOMY OF A SPIDER
A. Dorsal view. B. Frontal view of face and chelicerae. C. Ventral view, most legs omitted.

Conceptual design

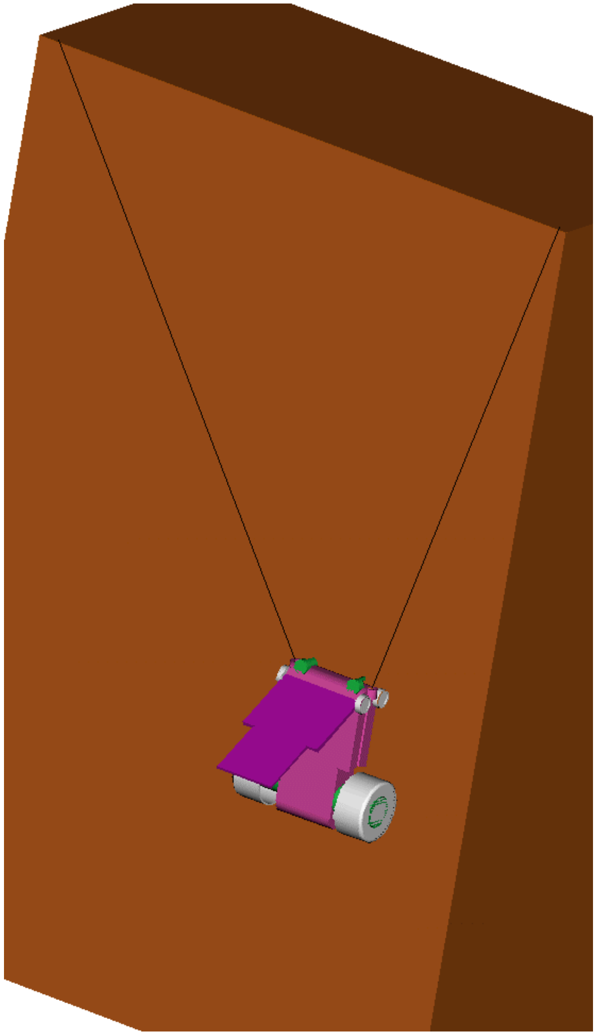
- Limited horizontal mobility provided by large wheels and freewheels
- Offset spectrometer provided reaction torque for horizontal movement
- Vertical mobility provided by a twin cable-winch system
  - off-axis guides allow for 2 DOF (xy, xè, or yè)
- Clutched gearbox enables one motor to drive a wheel and/or a winch

Yo-Yo Rover



Articulated solar panel
Cable guide
Spectrometer pod
Anchor launcher
Winch
Freewheel
Drive wheel
Drive and electronics pod

Operational Schematic

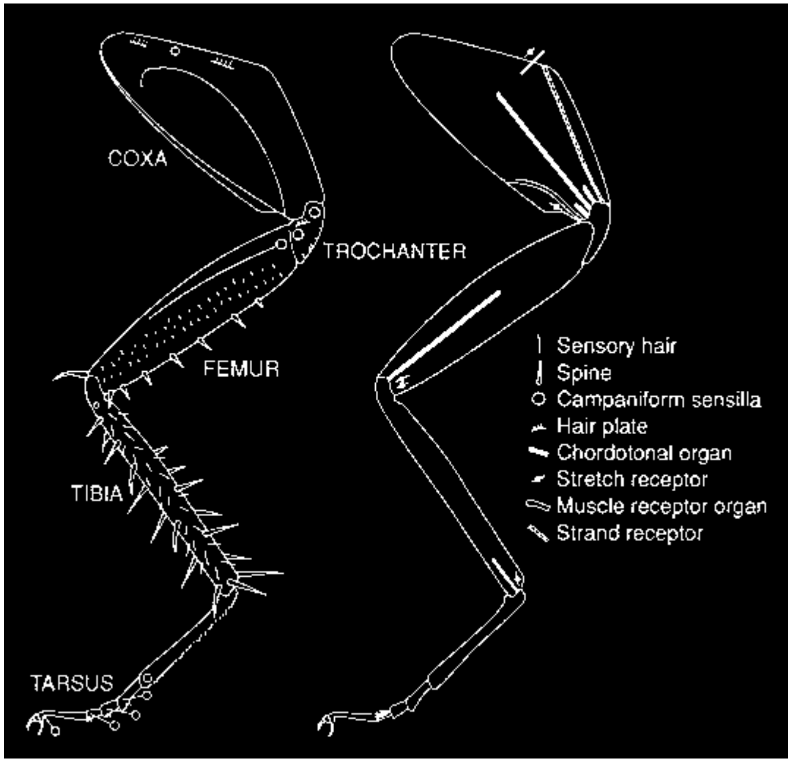


Sample manipulation or differential probing

- Highest return on mass of manipulators due to dual use (mobility and manipulation)
- Manipulators may be used to prepare specimen (abrading, etc…)
- Sonic, electrical, and heating experiments may require probes inserted at a distance from one another

Biological Inspiration

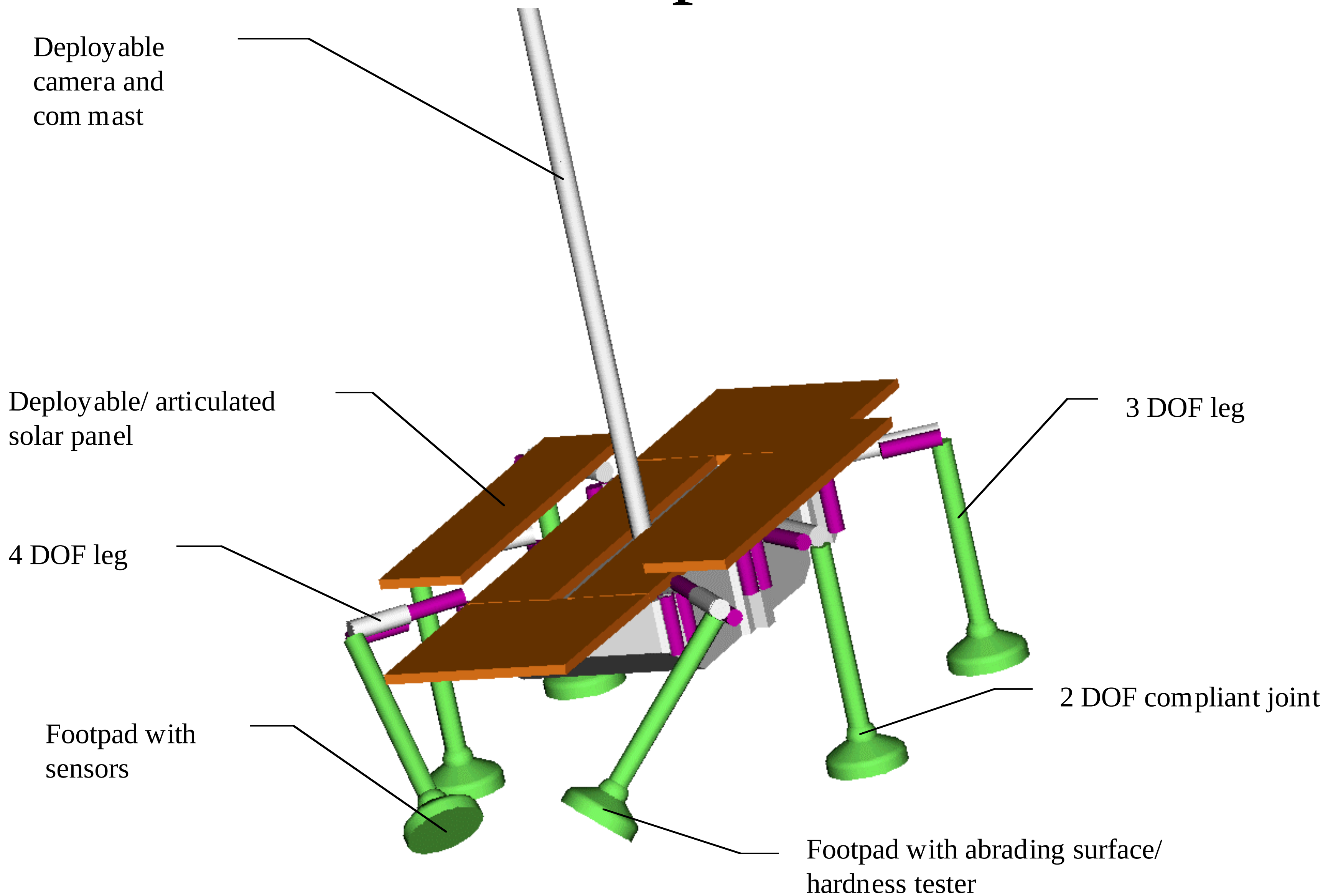
- Generalized insect
  - differentiated leg design
    - front legs used for manipulation as well as mobility
  - sensors placed on legs
    - contact sensors (spines and sensory hairs)
    - strain gauges (campaniform sensilla)
    - chemoreceptors
- Structures for storing mechanical energy



Conceptual design

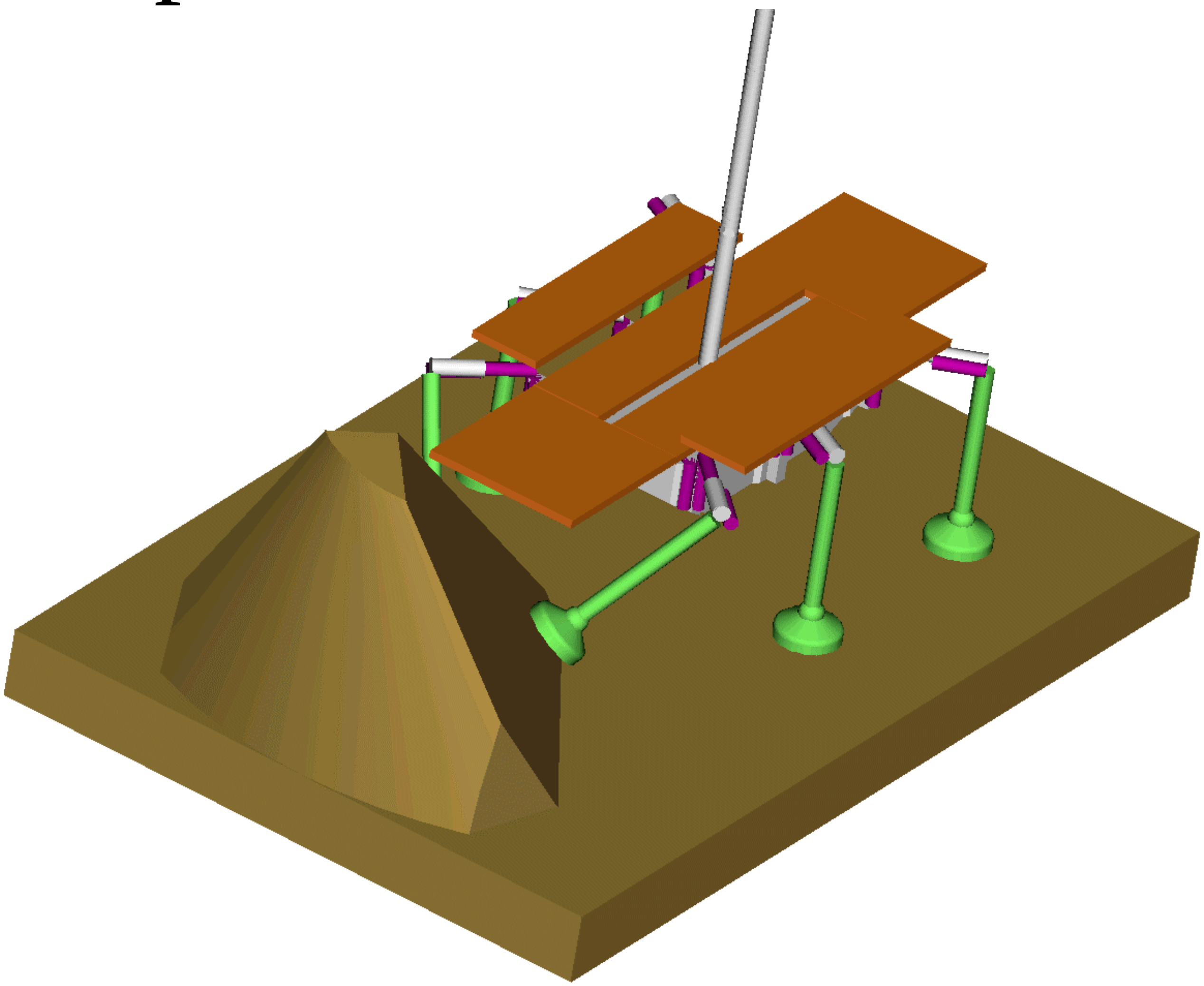
- 4 DOF front legs
- 3 DOF mid and rear legs
- probes integrated into foot pads
- mobility sensors built into legs
- spring-loaded joint/s to store energy and offset resting mass

Hexapod



Deployable
camera and
com mast
Deployable/ articulated
solar panel
4 DOF leg
3 DOF leg
2 DOF compliant joint
Footpad with
sensors
Footpad with abrading surface/
hardness tester

Operational Schematic



Crack Crawling and Shallow Digging

- Important information hidden away from elements
- Regions inaccessible to conventional rovers

Biological Inspiration

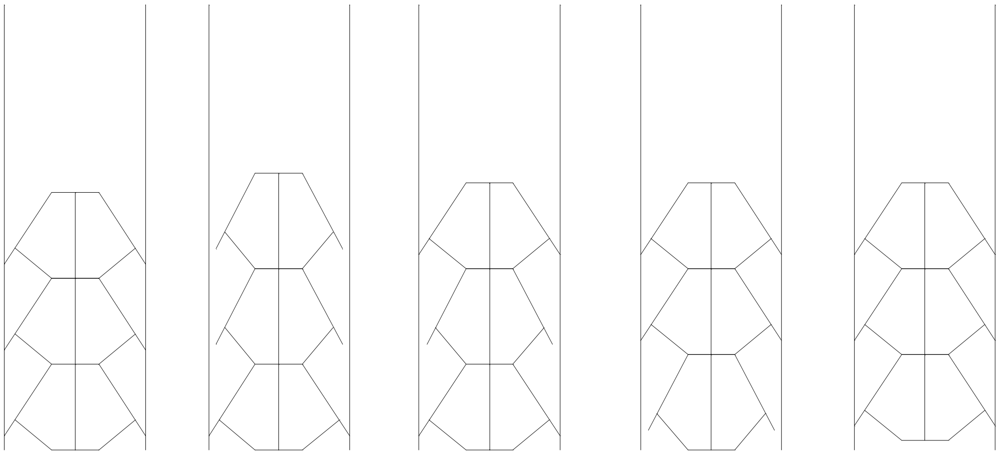
- Earthworm and *Amphisbaenia*
  - peristaltic motion
  - adaptable body configurations
  - highly modular mobility units

Conceptual design

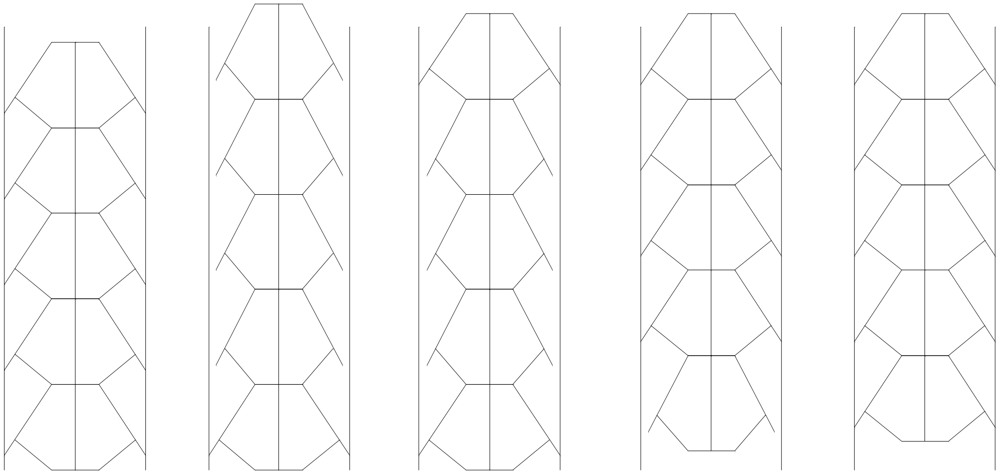
- Modular construction
- Linked linear motion and radial expansion
- SMA or EAP (**E**lectrically **A**ctivated **P**olymers) linear actuators in modules
- SMA or EAP bending actuators as collars between modules
- Tethered comm and power
  - possibly computation as well?

Peristaltic Motion

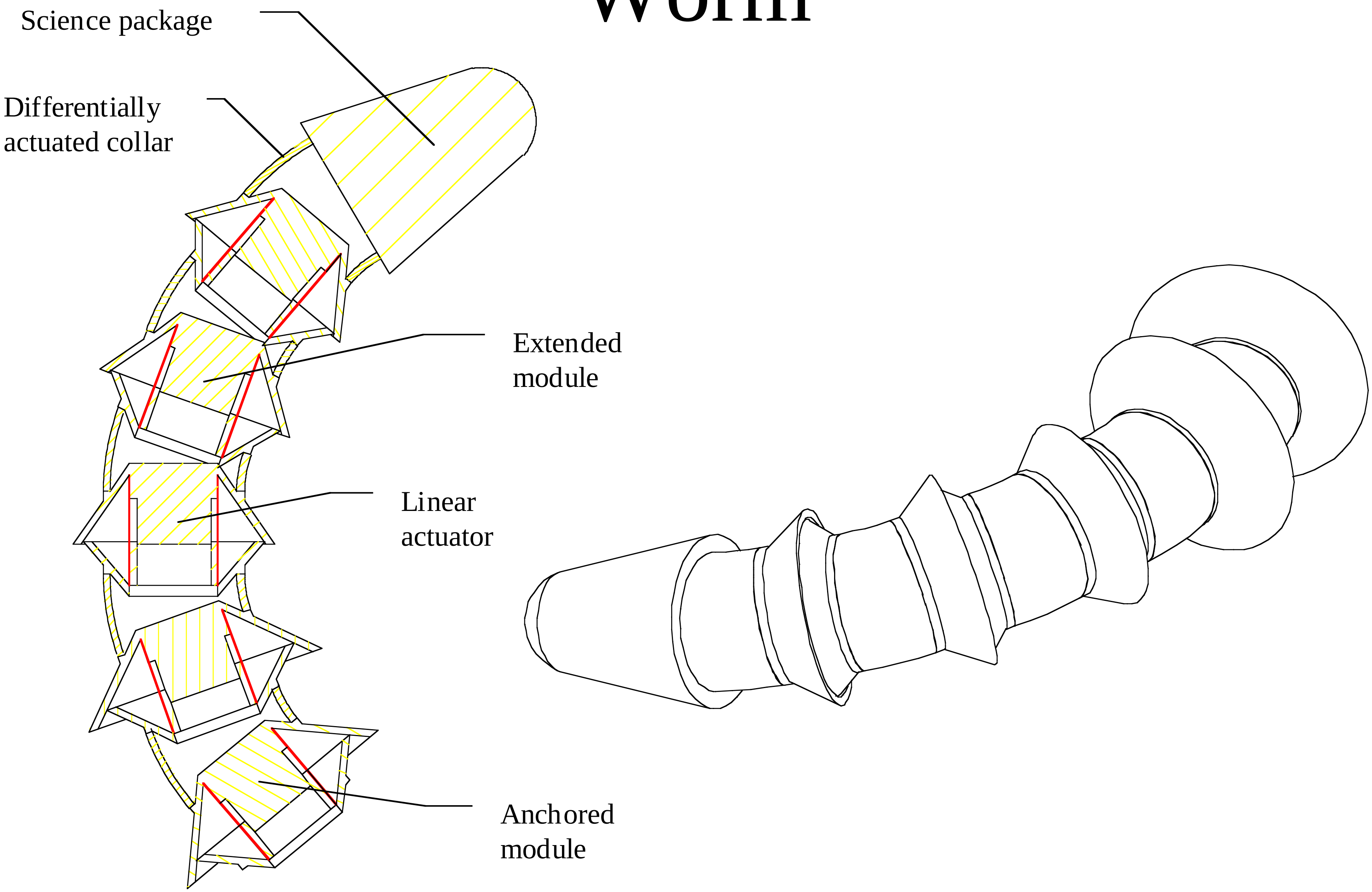
Three Segment Motion (minimum possible)



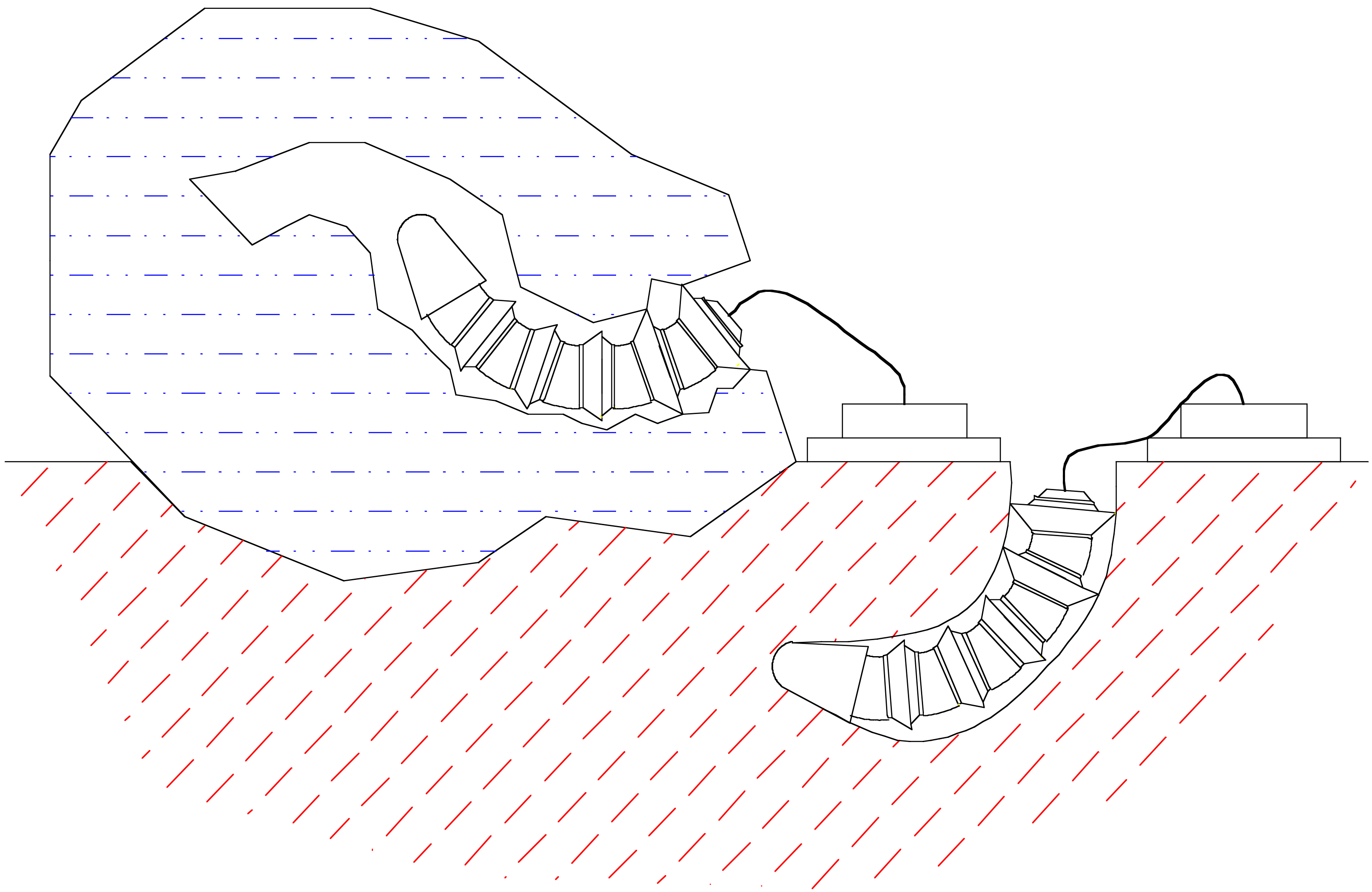
Five Segment Motion



Worm


Science package
Differentially actuated collar
Extended module
Linear actuator
Anchored module

Operational Schematic



Conclusion