Introduction to Rover Design

- Lecture #17 – October 24, 2023
- A few loose ends
- Steering systems
- Suspension systems
- Wheel-soil interactions

Errata

- On page 22 of the Reliability lecture, the second equation should be

$$\frac{n(n-1)}{2}R^{n-2}(1-R)^2 + nR^{n-1}(1-R) + R^n + C = 1$$

$$\Uparrow$$

$$not\ (1-R^2)!$$

- The slides have been updated on my web site – redownload to get the corrected version

RASC-AL Projects Update

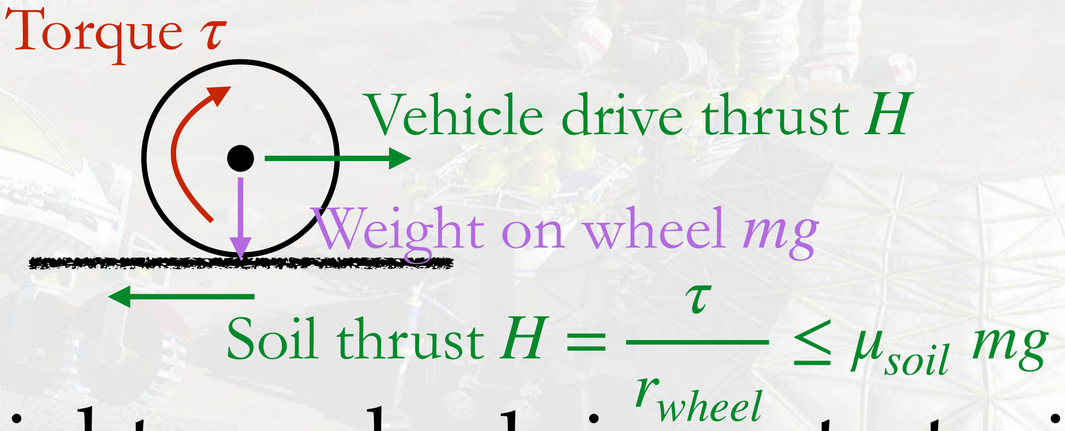
- I submitted (pretty much) all of the questions you submitted to me about the RASC-AL projects
- You can listen to the answers tomorrow in a 90-minute livestream 2:00-3:30 EDT – Teams meeting link posted on your Teams sites
- They will also post written answers after the meeting on the RASC-AL web site if you can't make the livestream

Midterm Exam – Thursday, 10/26

- Closed books, closed notes – you can have one (1) 8.5”x11” piece of paper (both sides) for formulas, notes, etc.
- BRING A CALCULATOR! It must be non-Internet enabled, i.e., not an app on your phone but a real calculator (remember Akin’s Law #1!)
- A copy of a previous midterm (with solutions) has been posted on my web site to give you an idea of what it might look like

Rover Design 101

- Mobility is based on transferring wheel torque into soil thrust to propel the vehicle
- The details of how that happens comprises the field of **terramechanics** – more on that later
- For now,

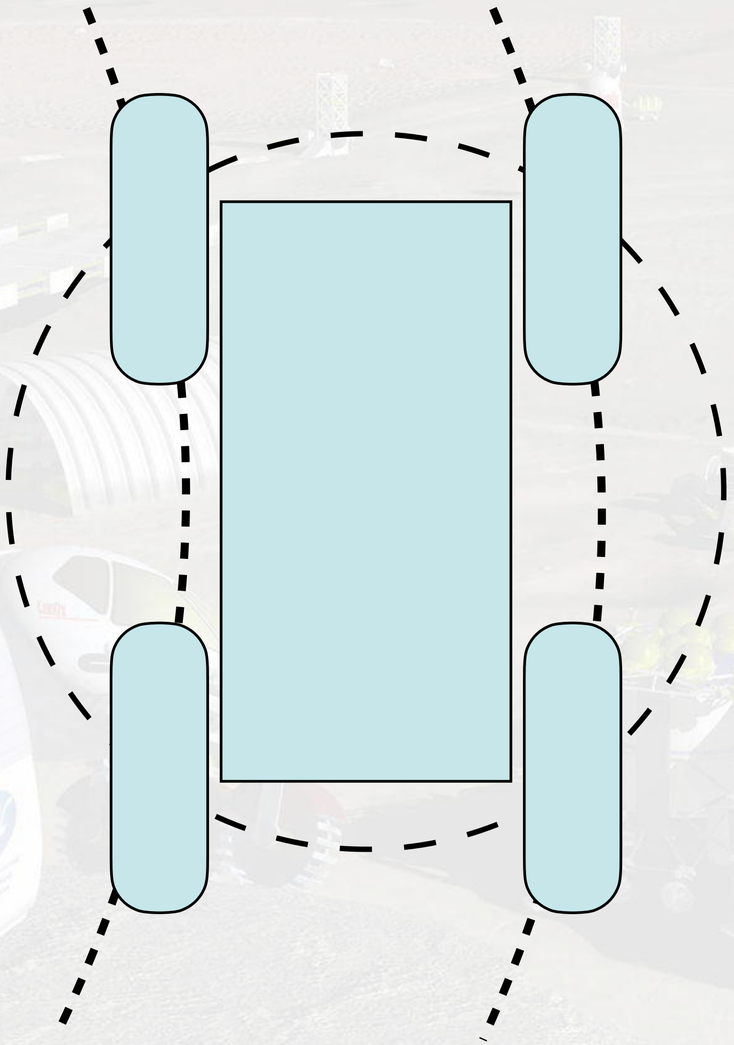


- So the key is keeping weight on wheels in contact with soil

Suspension ⟺ Steering Systems

- Suspension systems adjust the "fit" of the wheels to the terrain
  - Load balancing over obstacles ≈ "static"
  - Relieve impact forces on vehicle and payload ≈ "dynamic"
  - Protect the vehicle from terrain impact damage
- Steering systems allow the vehicle heading to be altered to control traverse path, e.g.
  - Turning entire vehicle
  - Turning heading angle of wheels

Skid Steering (Skid-Slip Steering)



Rigid Suspension, Skid Steer

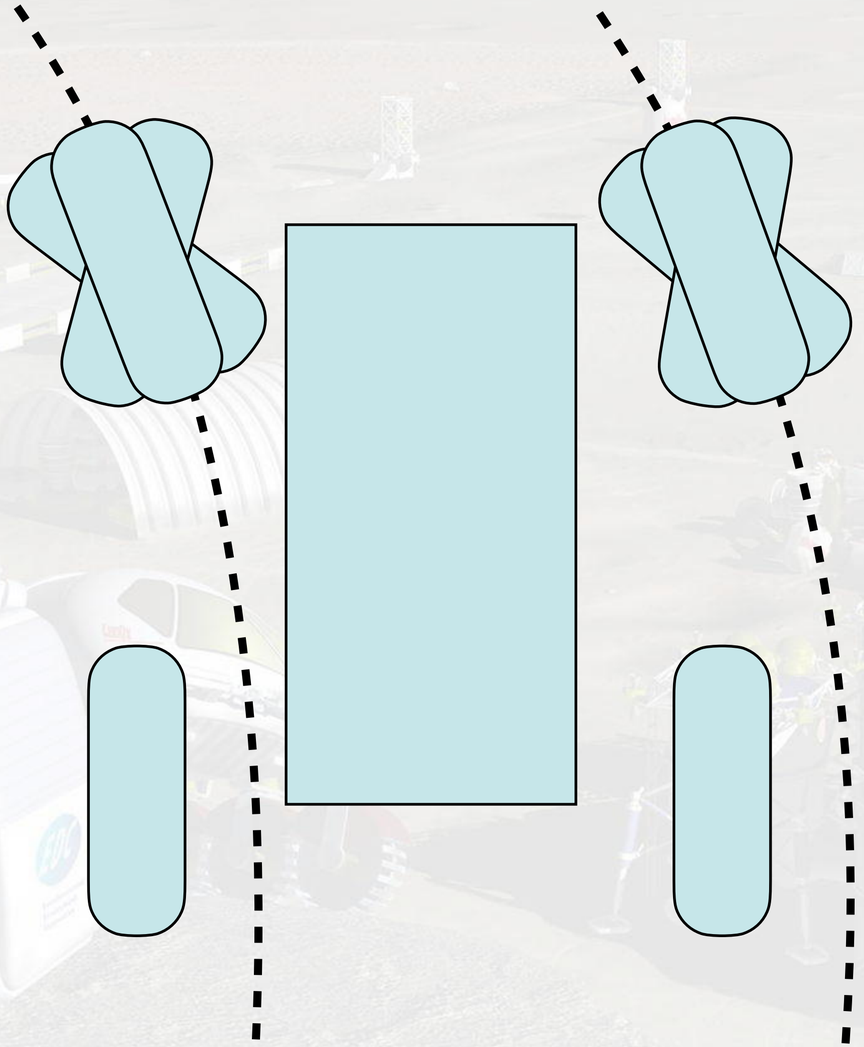
Electric Tractor, NASA Johnson Space Center

Electric Tractor Drive System

Rigid Suspension in Hilly Terrain

RAVEN (4-wheel configuration)

Differential Drive (Swiveling Wheels)



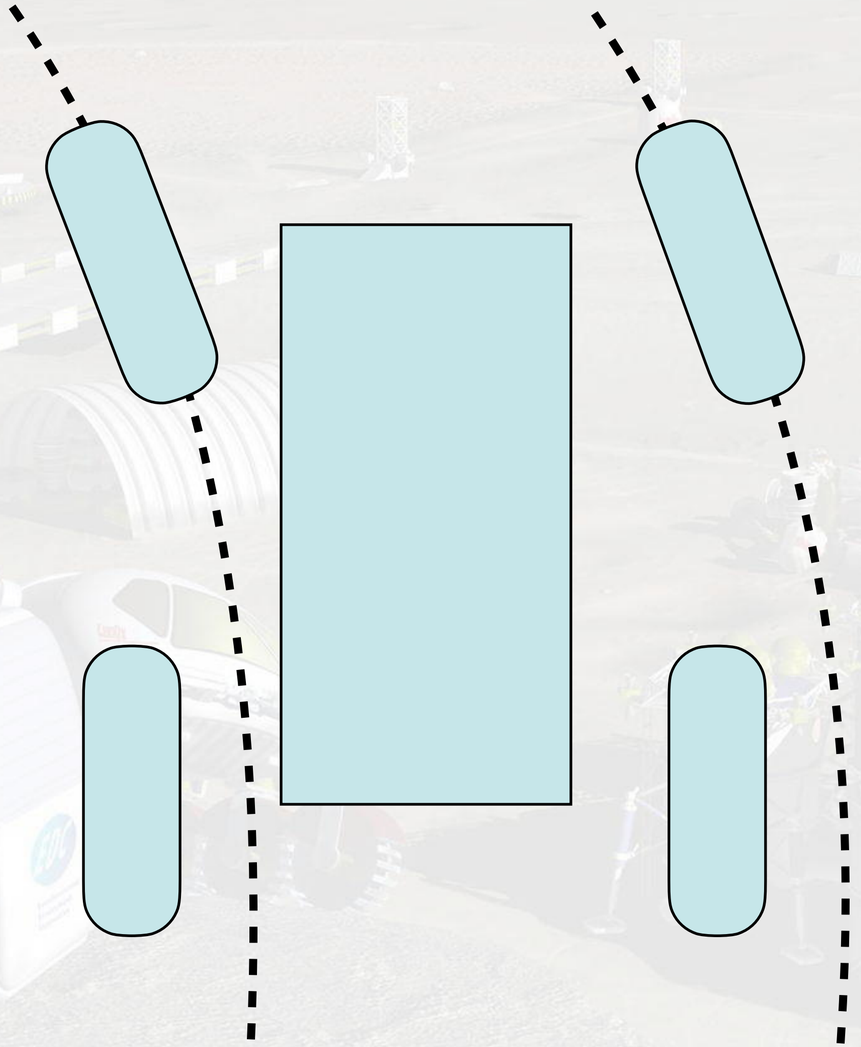
Laboratory Robot (CMU)

Laboratory Robot (CMU)

RAVEN (UMd/ASU)

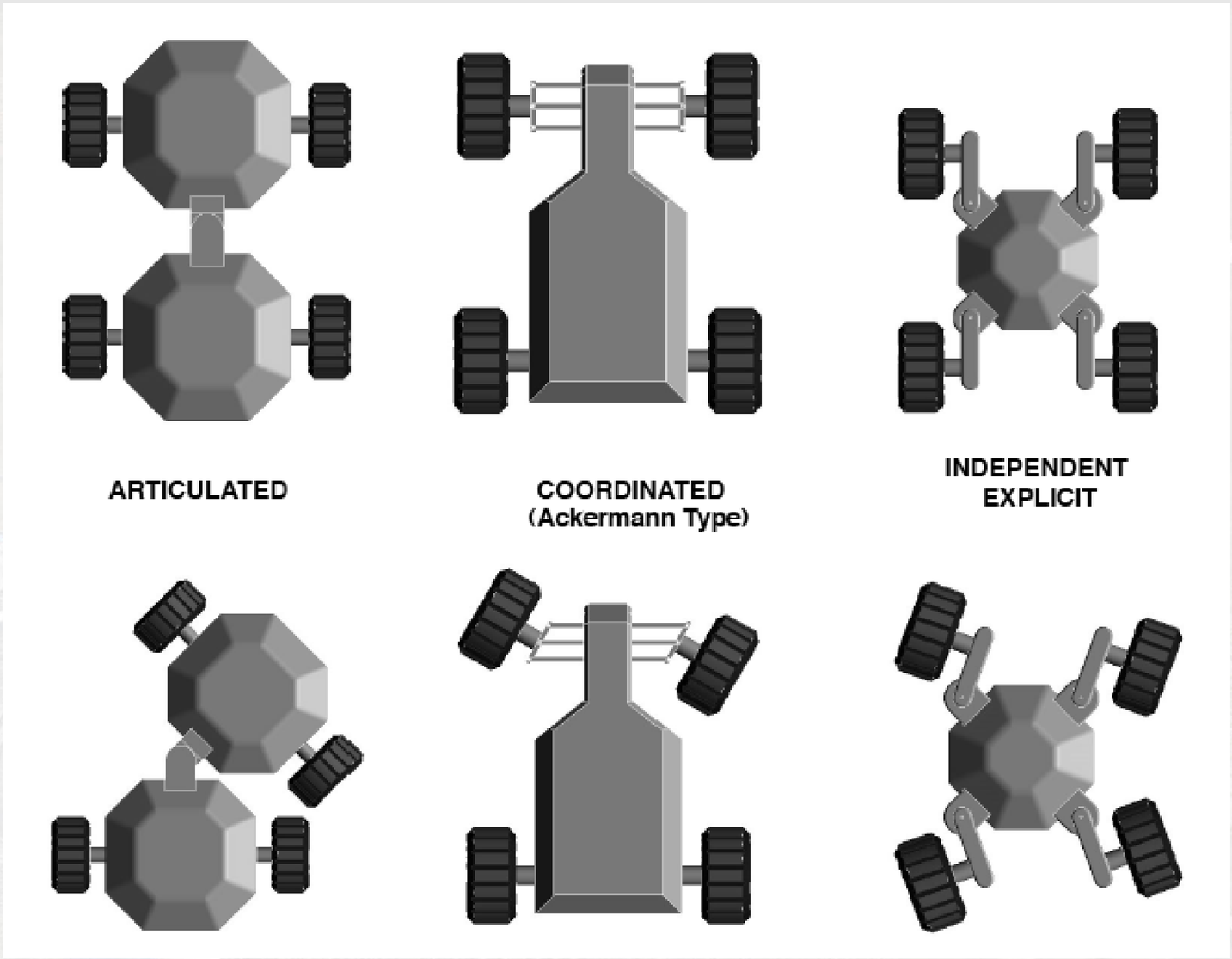
RAVEN in Field Trials

Ackermann Steering

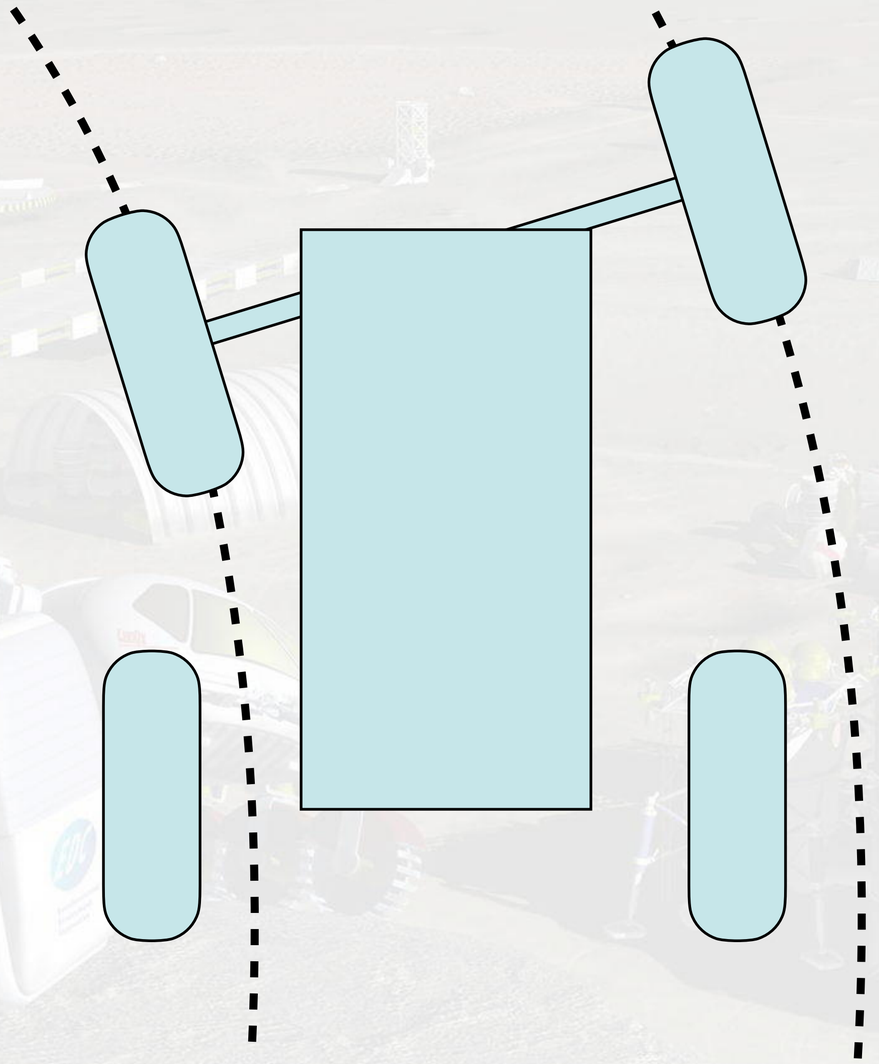


Tooth (JPL) - Ackerman Steering

Steering Schemes



Trailer Steering



Hyperion (CMU)

Hyperion (CMU) - Trailer Steering

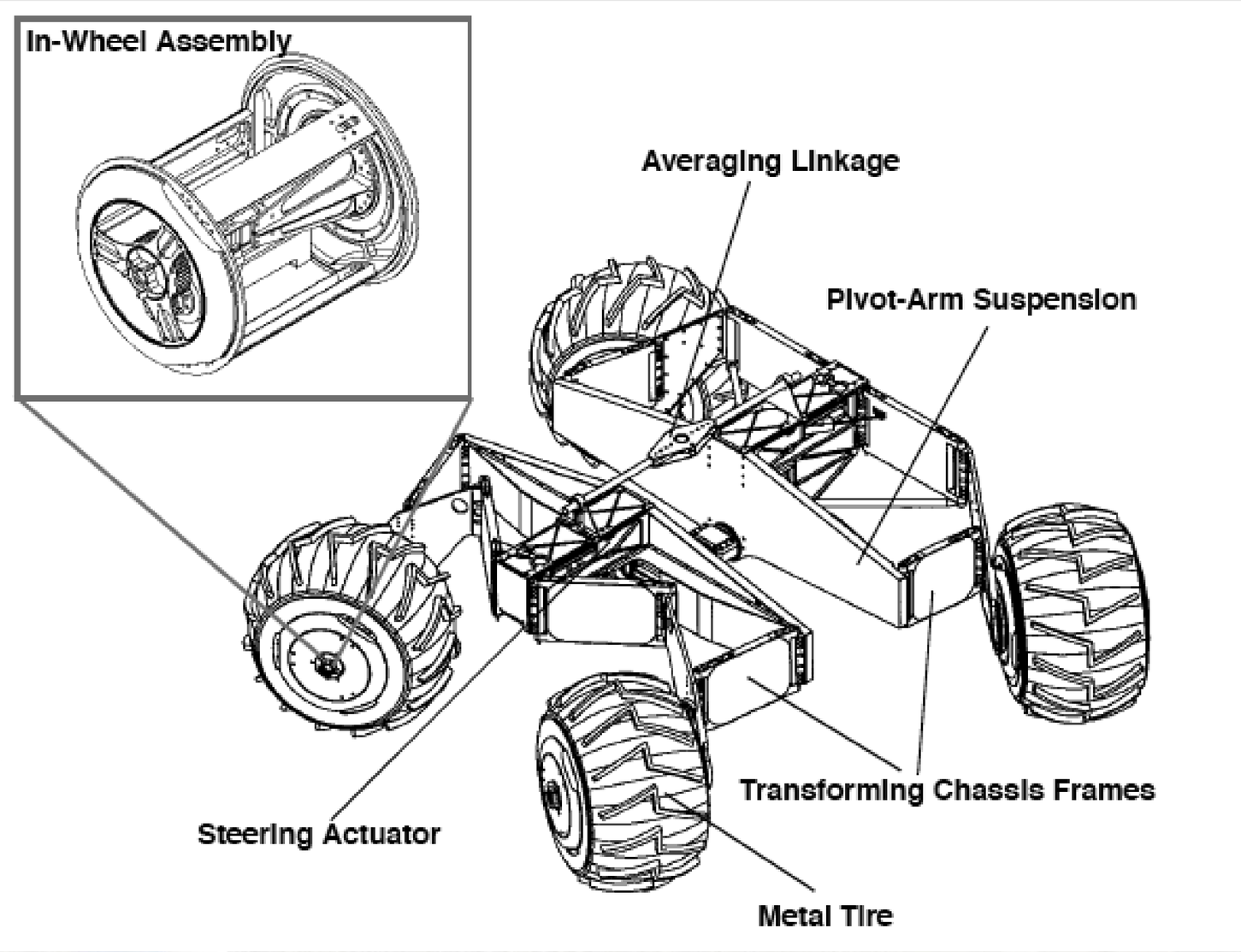
Independent Suspension (Towed Vehicle)

SCOUT Astronaut Support Rover (JSC)

SCOUT Suspension and Steering System

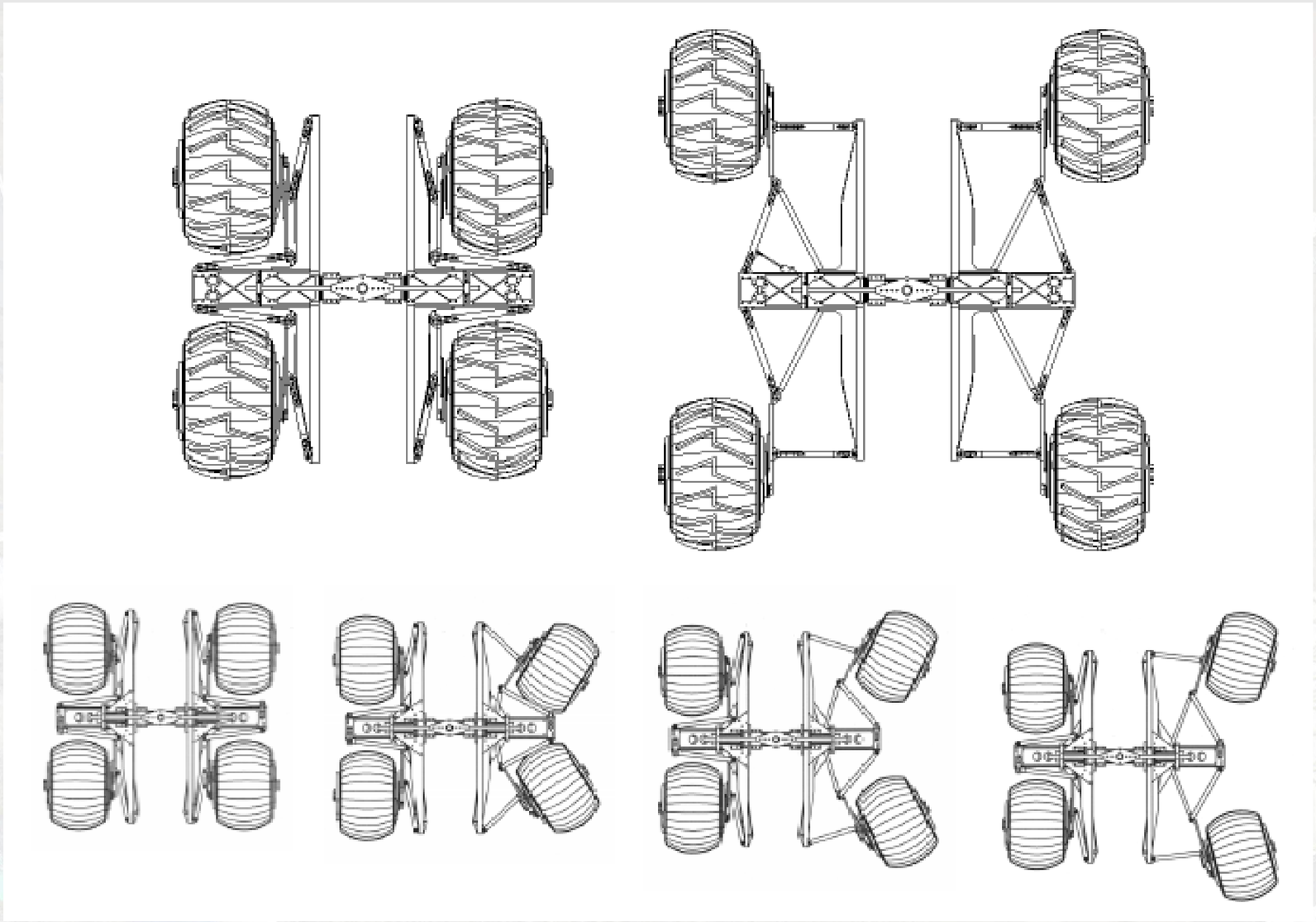
Articulating Suspension - Nomad (CMU)

Nomad Transforming Chassis



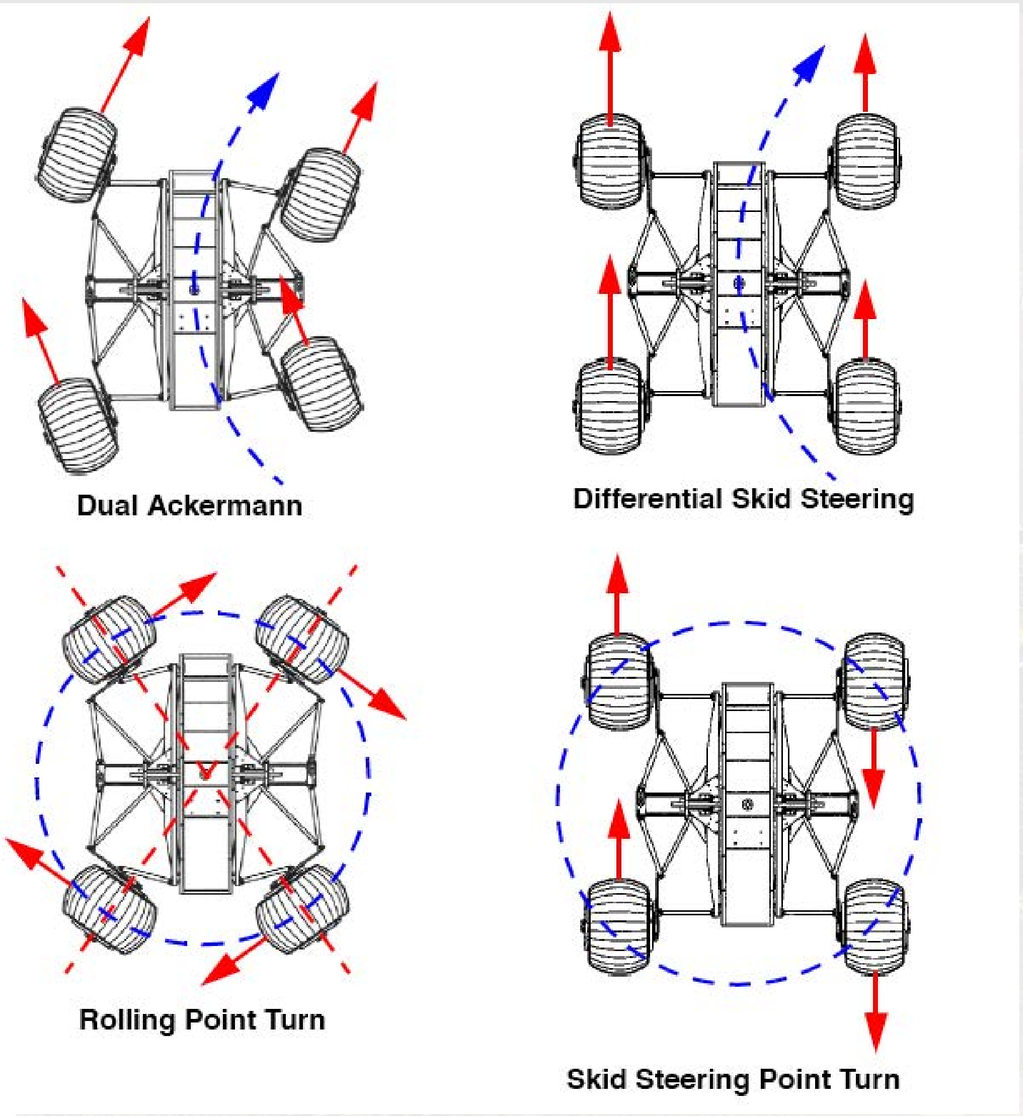
Nomad in Rough Terrain

Nomad Chassis/Steering System

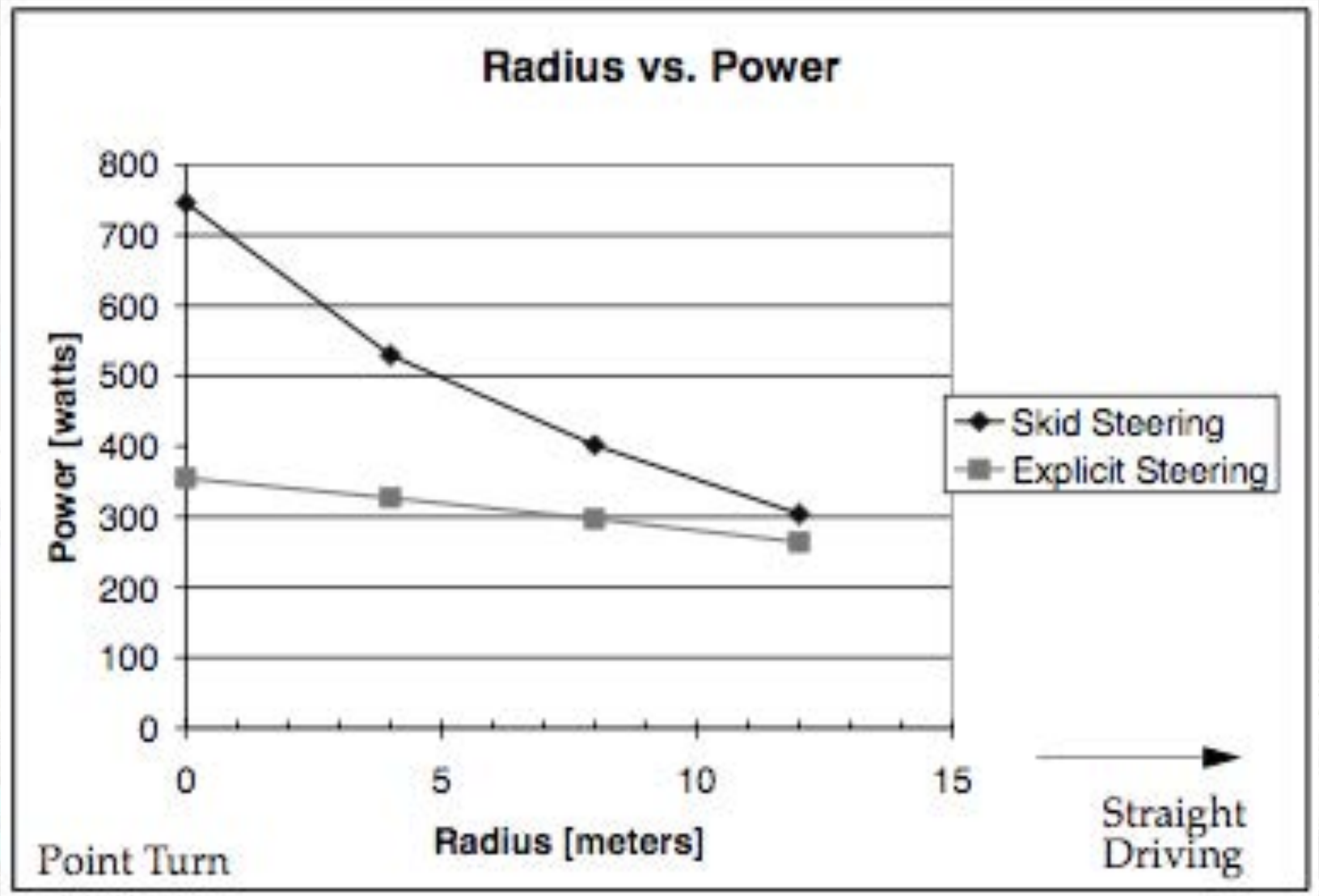


Nomad with Wheels Stowed

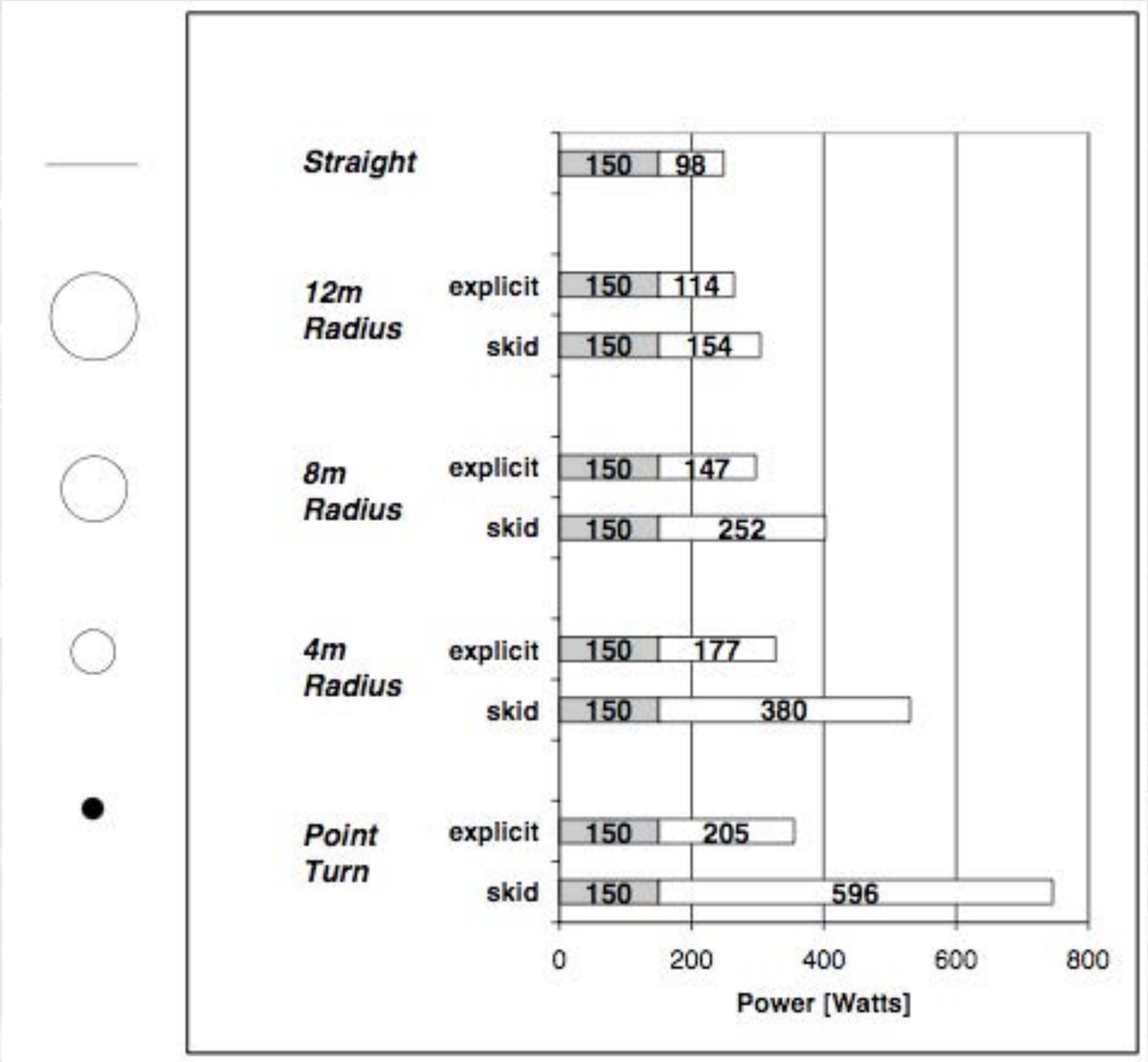
Nomad Steering Schemes



Nomad Power in Skid and Explicit Turns



Steering Power Comparison with Fixed Loads



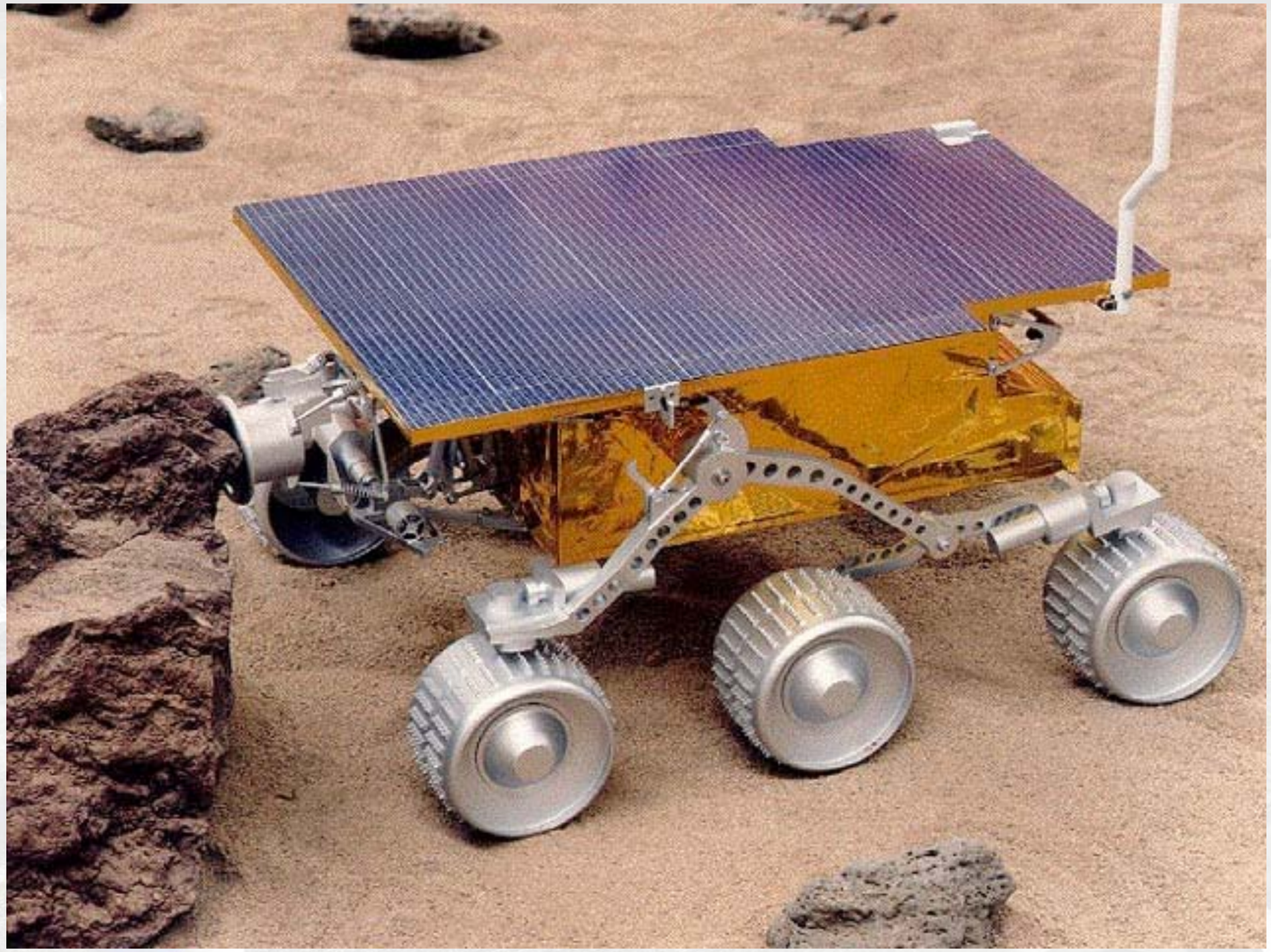
Split-Body Rovers (Sandia Labs)

Ratler (Sandia Labs)

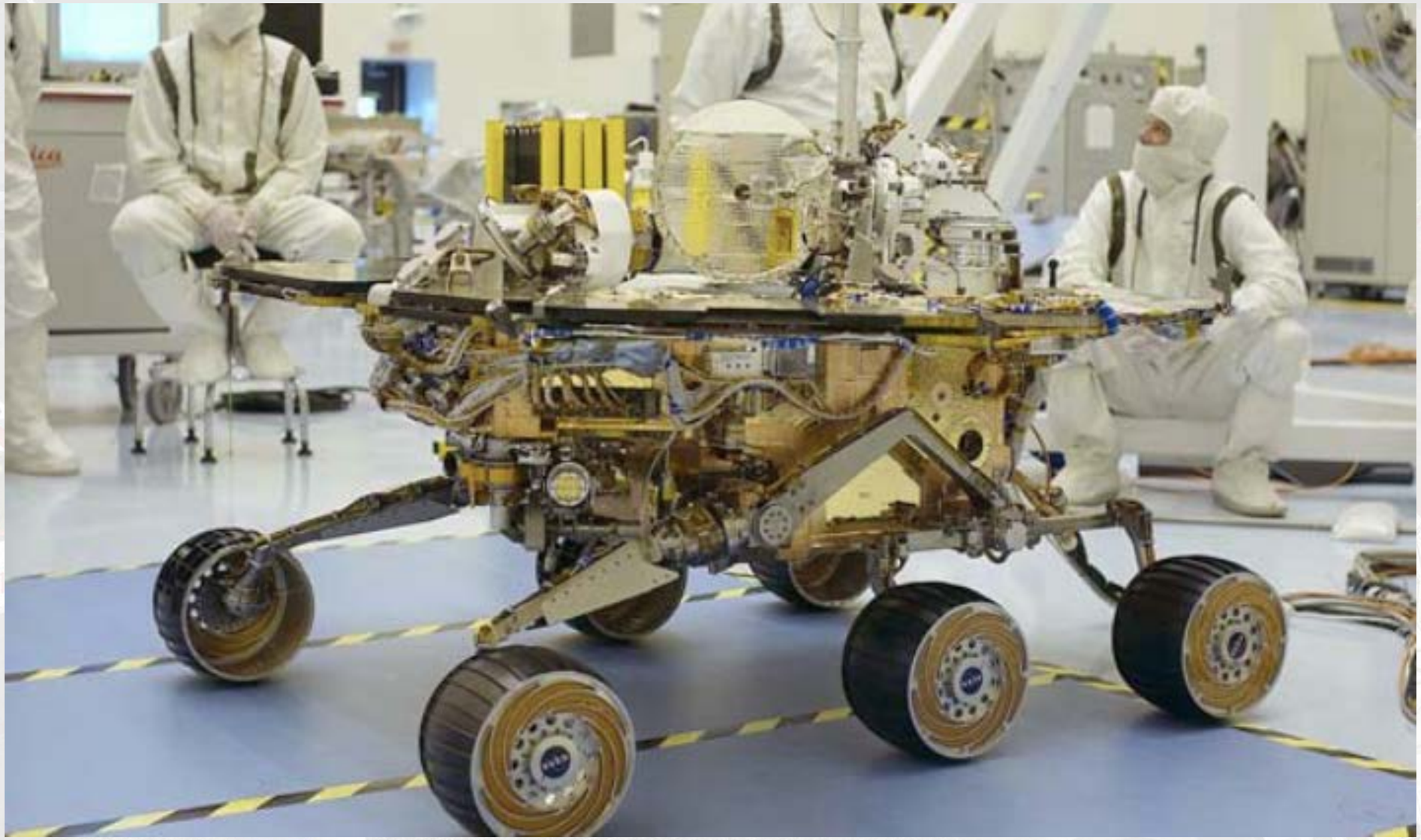
Rocker-Bogie – Rocky 4

Rocky 7

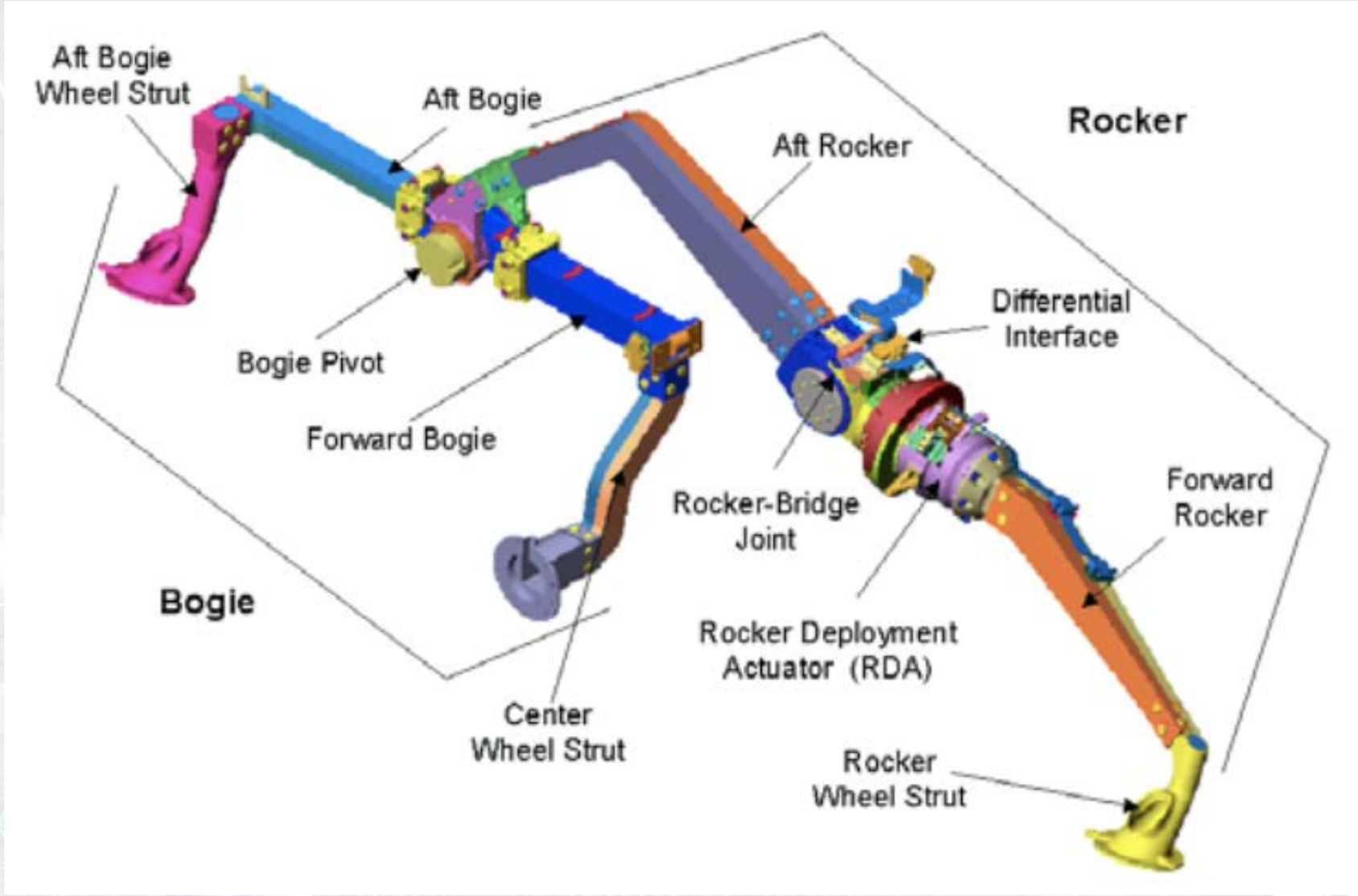
Sojourner



Mars Exploration Rover "Spirit"



MER Rocker-Bogie Configuration

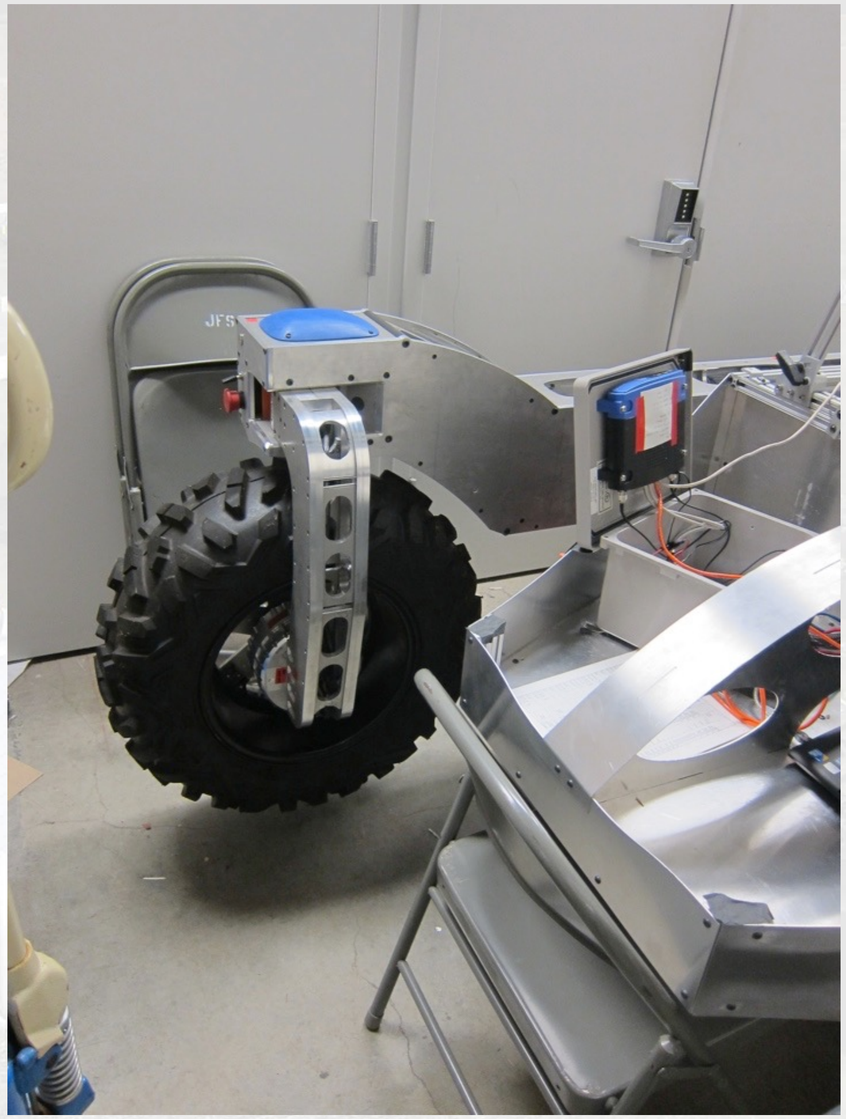


Mars Science Laboratory Development Unit

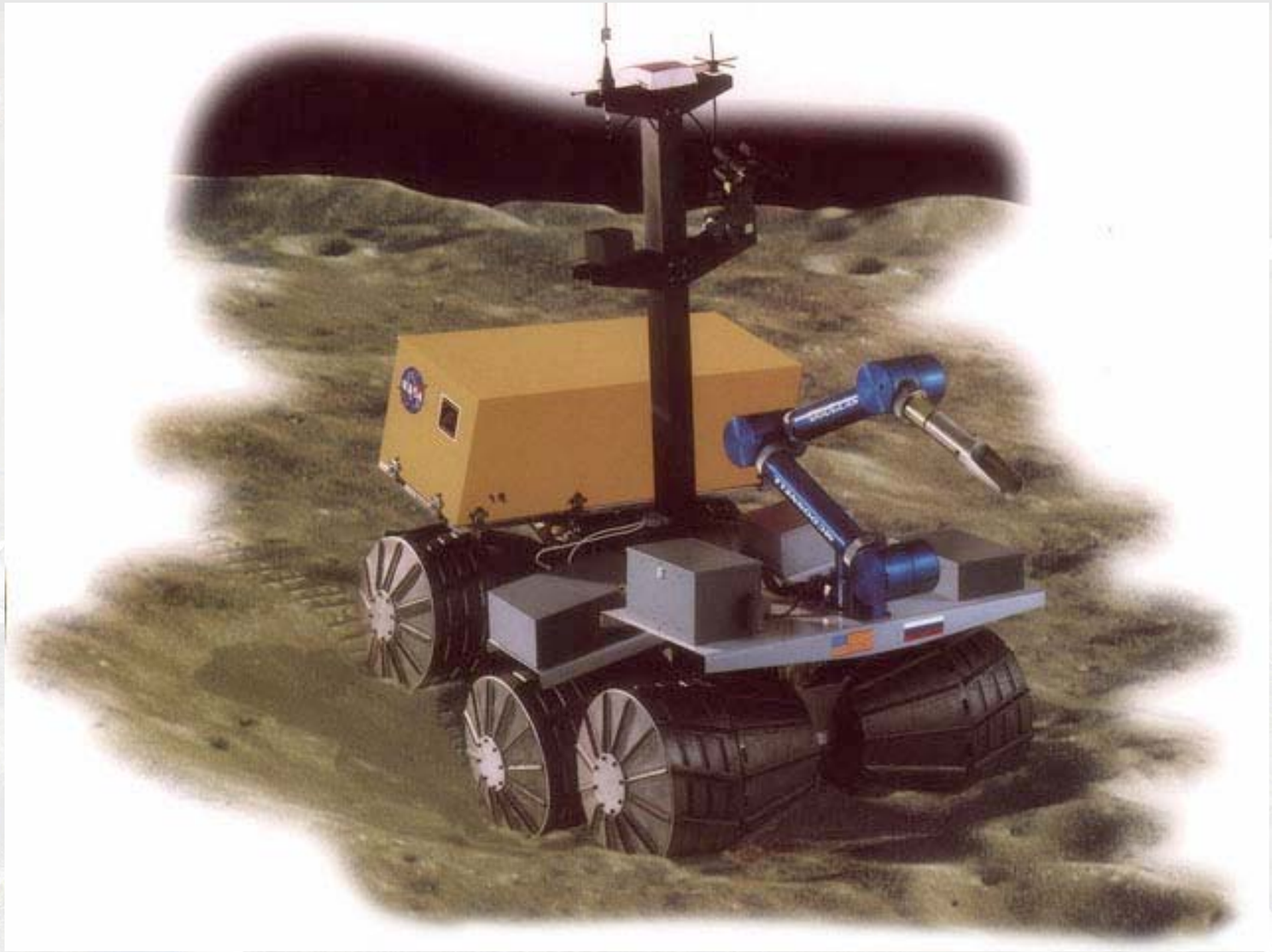
MSL Engineering Development Unit

K-Rex Rover (CMU for NASA Ames)

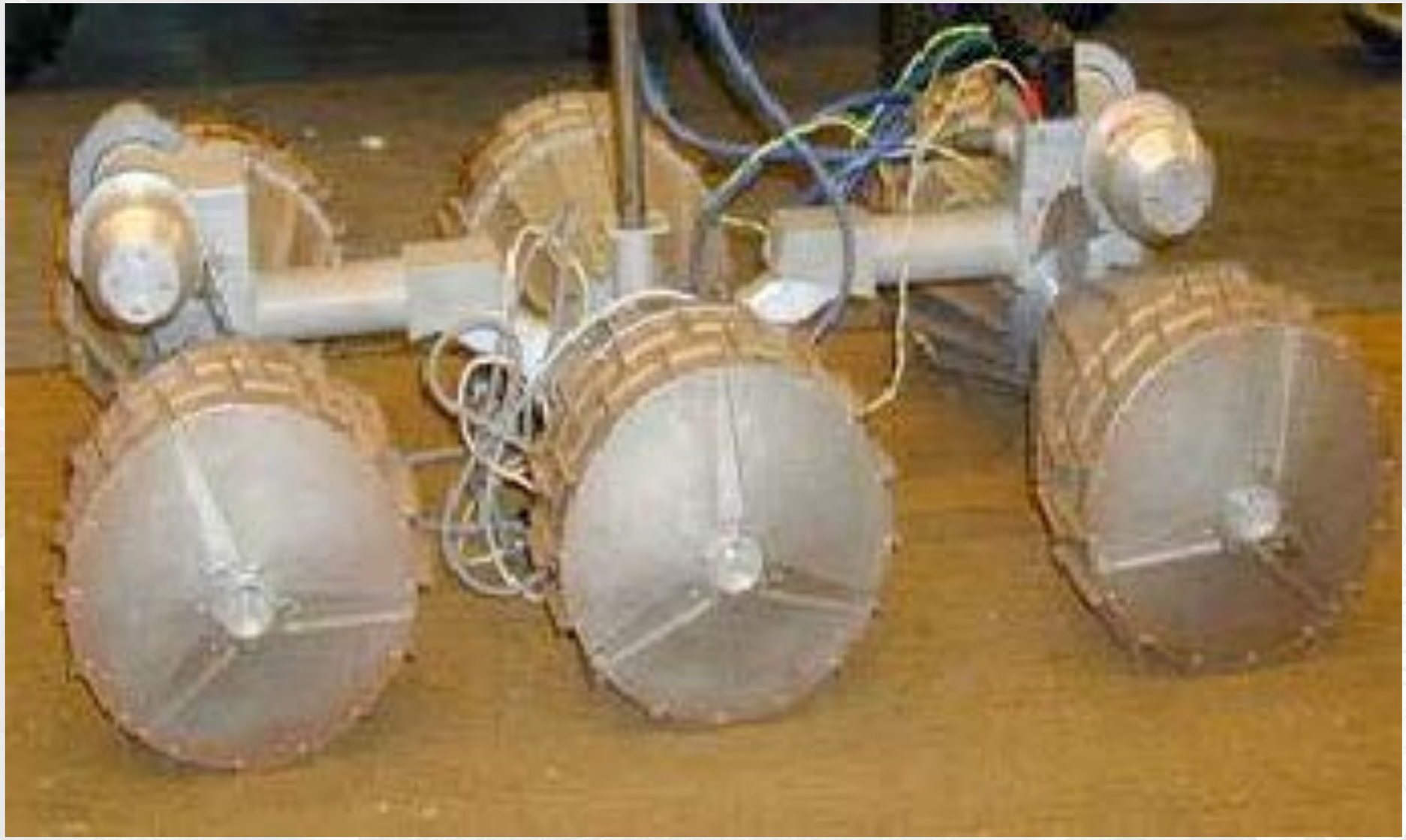
K-Rex Wheel Drive/Steering System



Segmented Body - Marsokhod



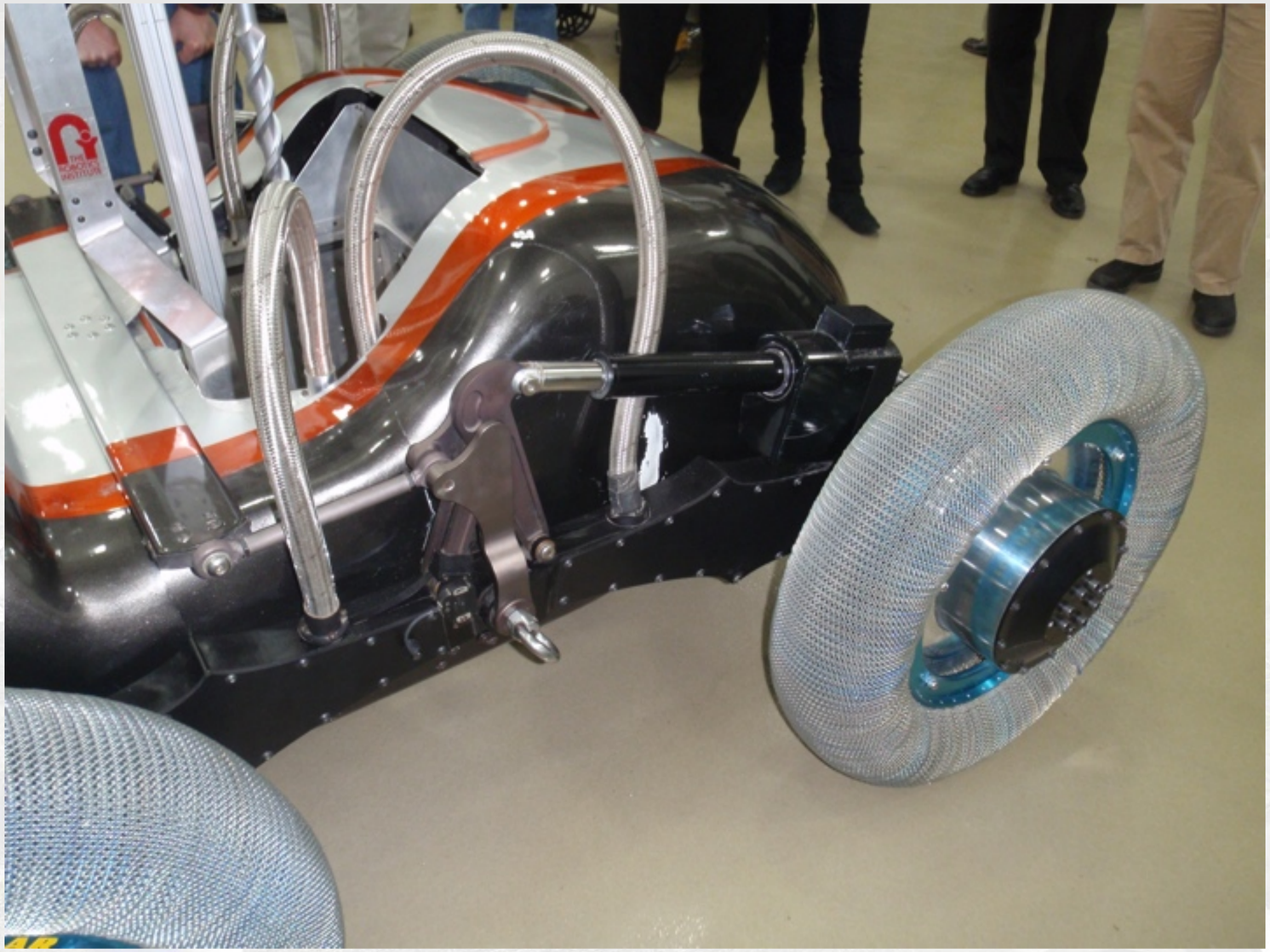
Marsokhod Chassis



Robby (JPL)

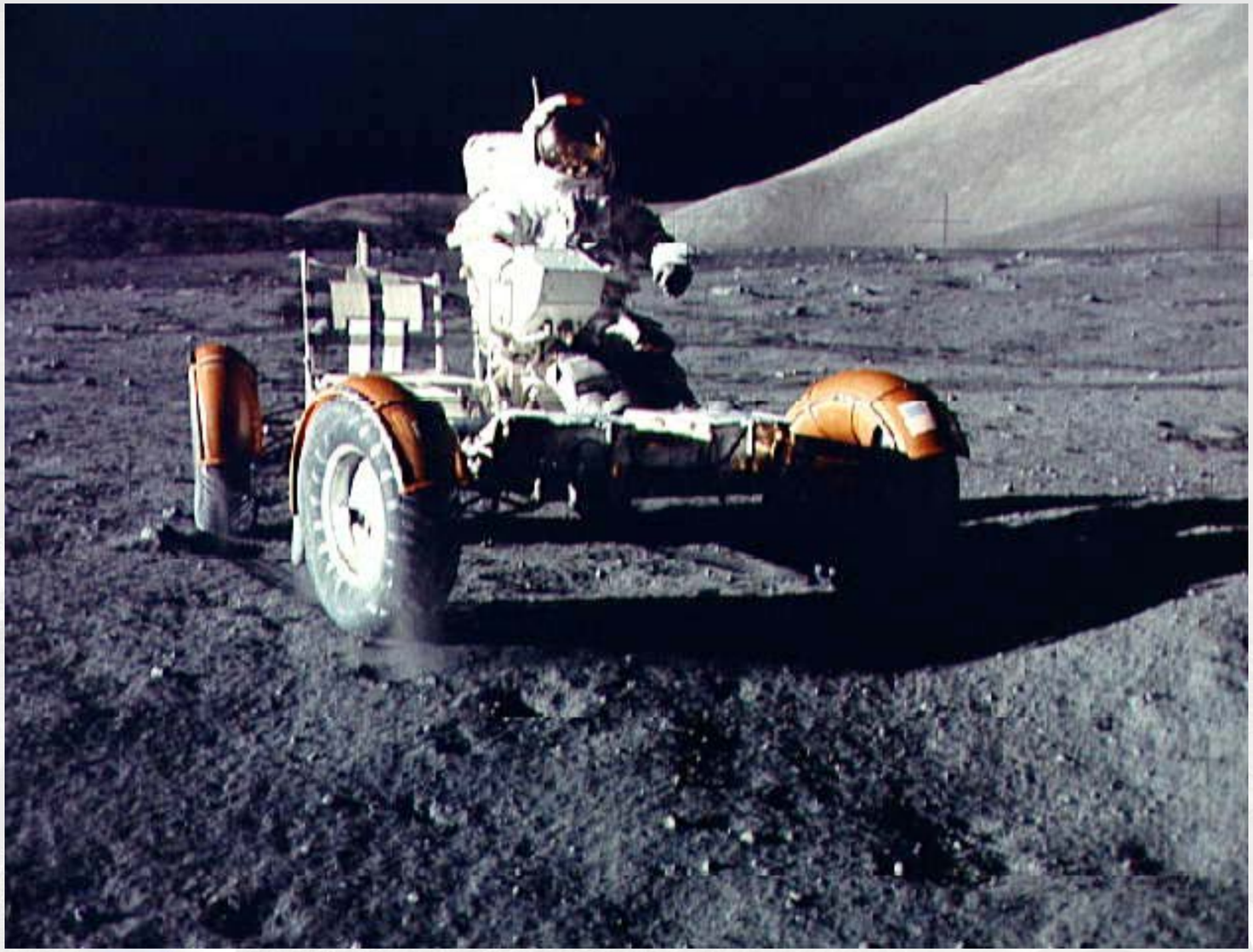
SCARAB (CMU)

Scarab Wheel Articulation (CMU)



SCARAB at Full Extension (CMU)

Apollo Lunar Roving Vehicle



SCOUT Rover (JSC)

Active Suspension - Chariot

Chariot B Climbs a Boulder Field

SEV Driving Onto ~20° Slope

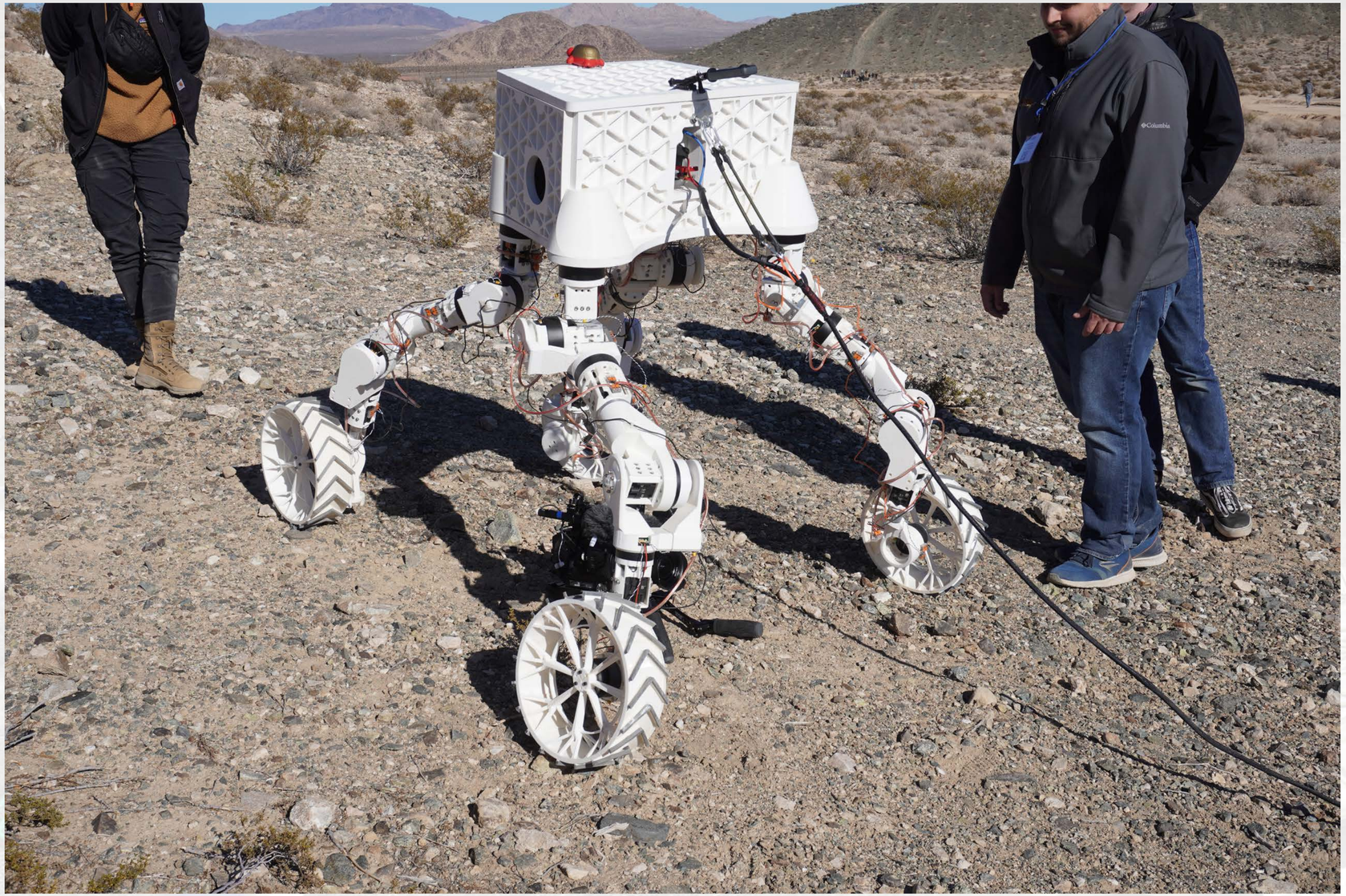
SEV on ~20° Slope

VERTEX Accommodation for 30° Side-Slope

SEV Dual Bogie Soil Contact

ATHLETE (JPL)

TRAVELS Wheel-on-Limb Robot



Centaur with Robonaut (JSC)

Centaur Body Pose and Turning

VERTEX in BioBot Test Configuration