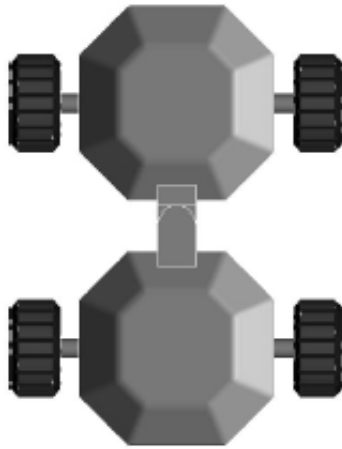


Steering and Suspension Systems

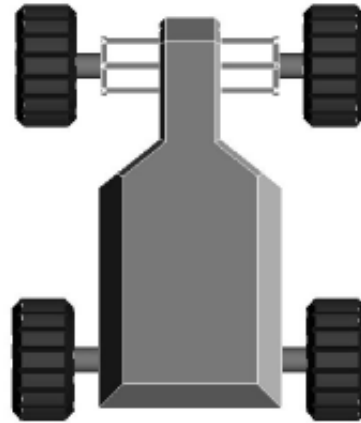
- Steering Systems
 - Skid-Steer
 - Differential drive
 - Trailer steering
 - Ackerman steering
 - Actively controlled steering (Independent / explicit)
 - Holonomic vs. Nonholonomic Systems
- Suspension Systems
 - Rigid Suspension
 - Independent Suspension
 - Articulated / Split-Body Suspension
 - Rocker-Bogie Configurations
 - Segmented-Body Rovers
 - Active Suspension



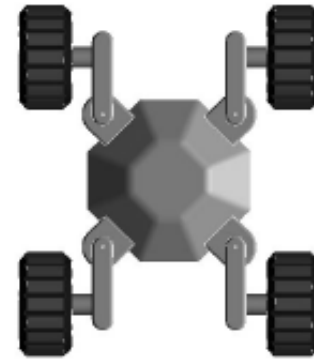
Steering Schemes



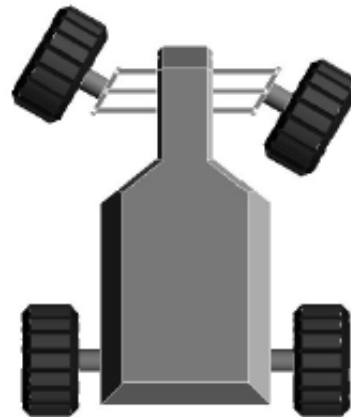
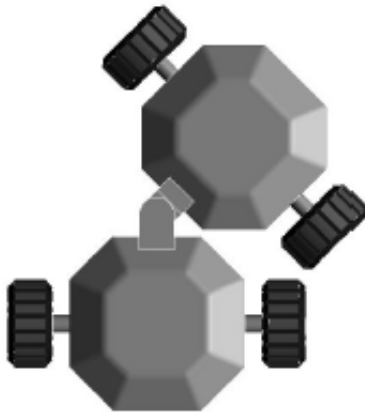
ARTICULATED



COORDINATED
(Ackermann Type)



INDEPENDENT
EXPLICIT



Fixed Suspension - Electric Tractor (JSC)



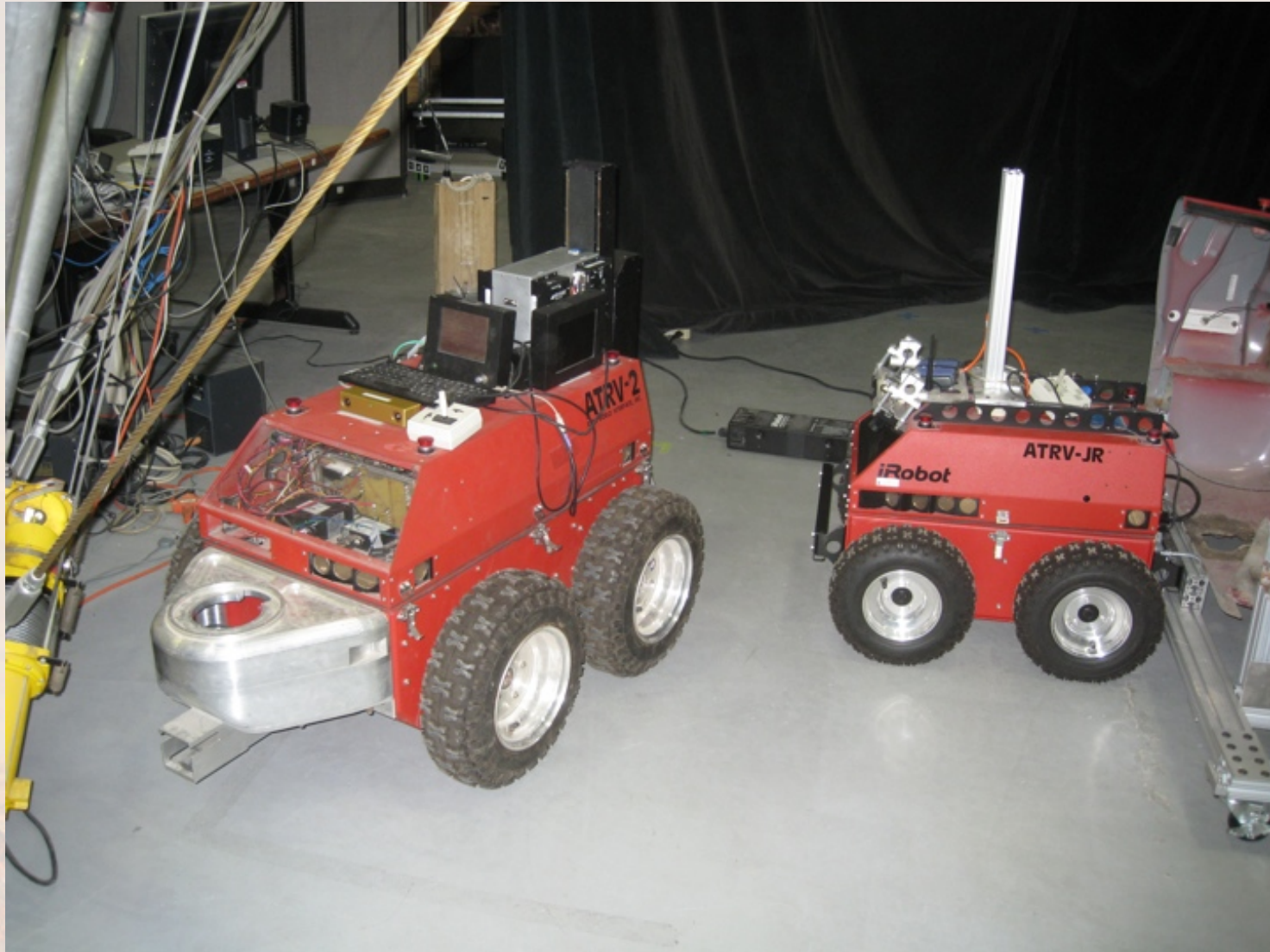
ET "Suspension"



Fixed Suspension in Hilly Terrain



ATRV Skid-Steer Robots



Laboratory Robot (CMU)



Laboratory Robot (CMU)



RAVEN (UMd/ASU)



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RAVEN in Mobility Testing



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Steering and Suspension Systems
ENAE 788X - Planetary Surface Robotics

Tooth (JPL) - Ackerman Steering



Hyperion (CMU)

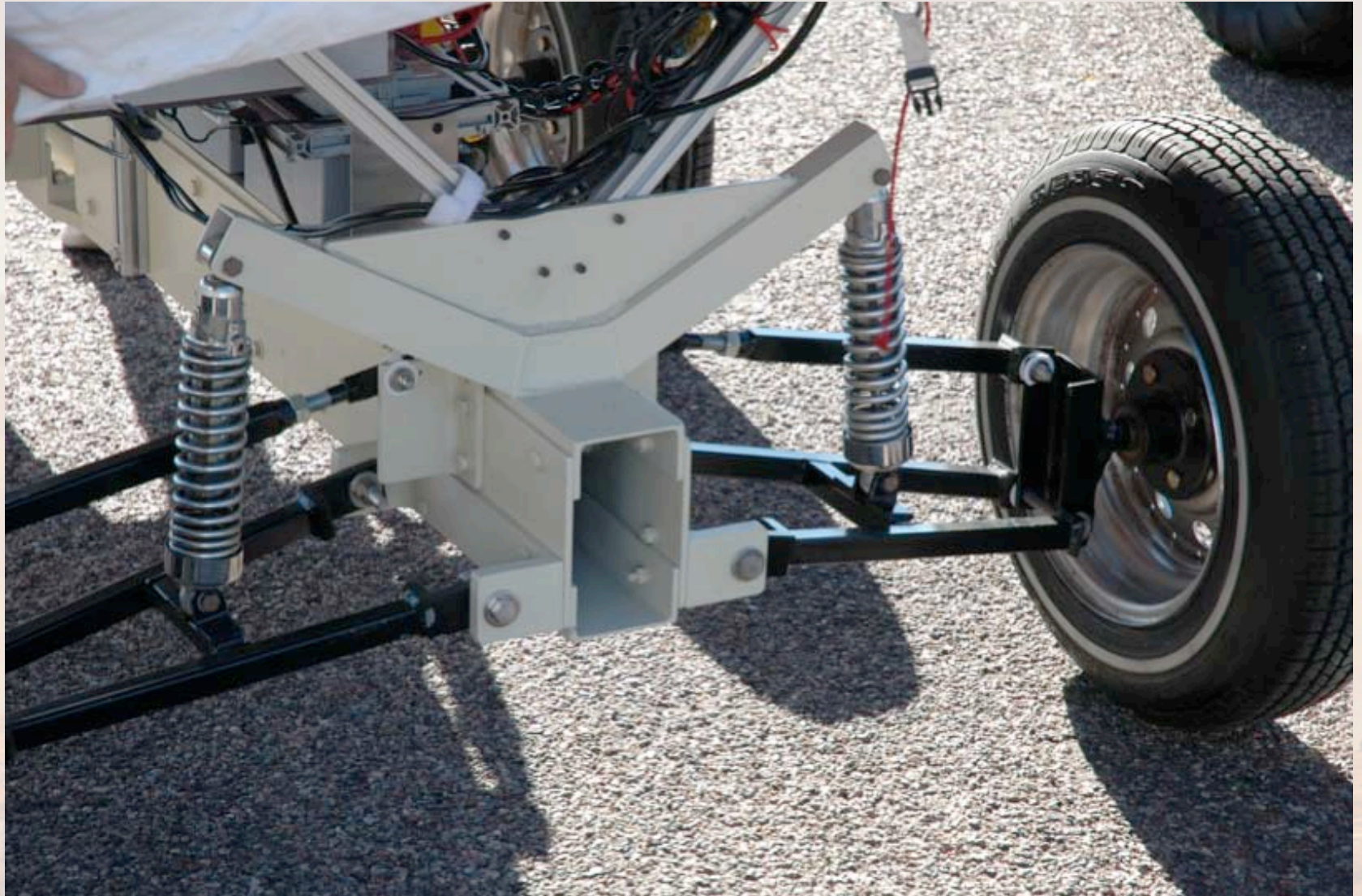


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Hyperion (CMU) - Trailer Steering



Independent Suspension (Towed Vehicle)



SCOUT Astronaut Support Rover (JSC)



SCOUT Suspension and Steering



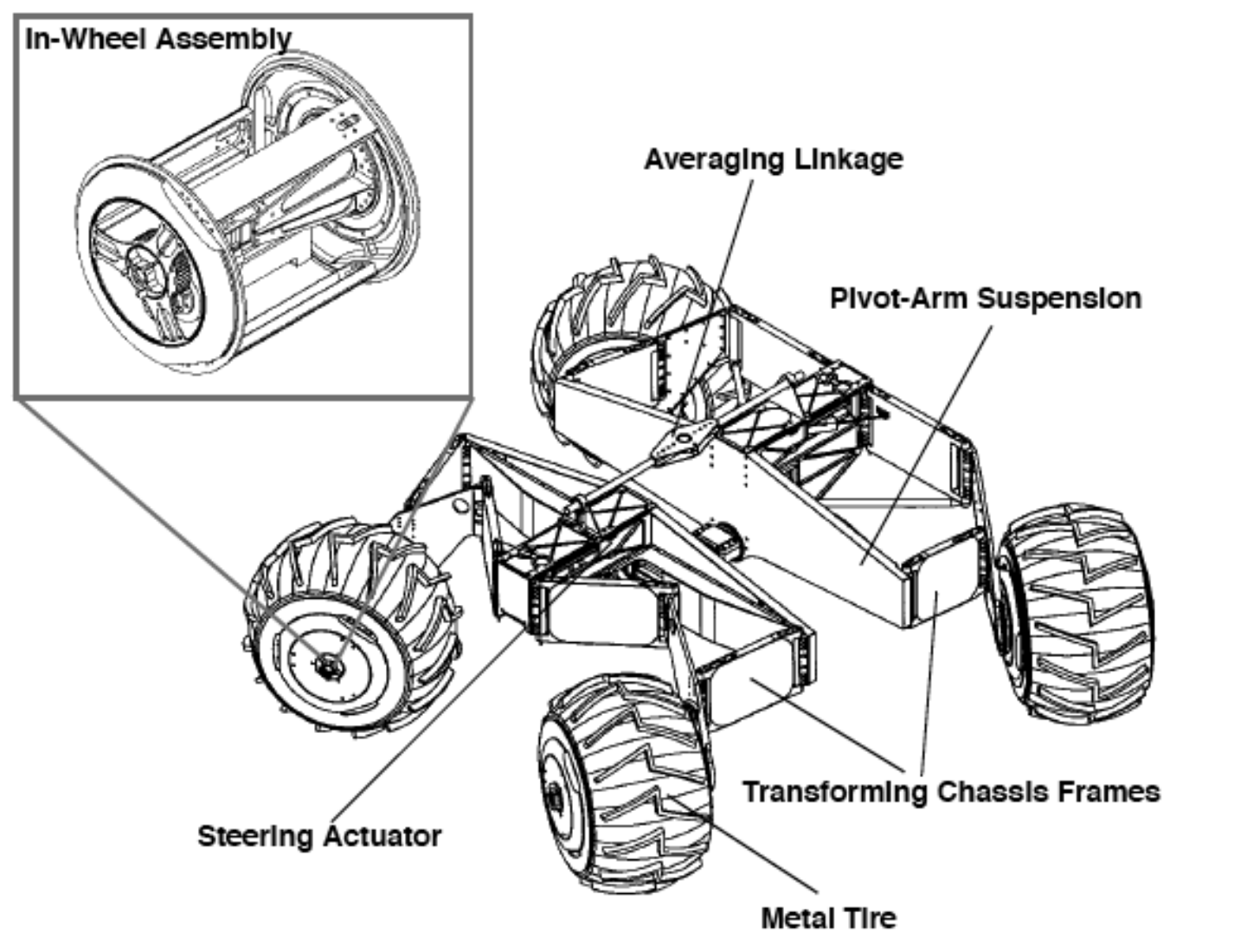
Articulating Suspension - Nomad (CMU)



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Steering and Suspension Systems
ENAE 788X - Planetary Surface Robotics

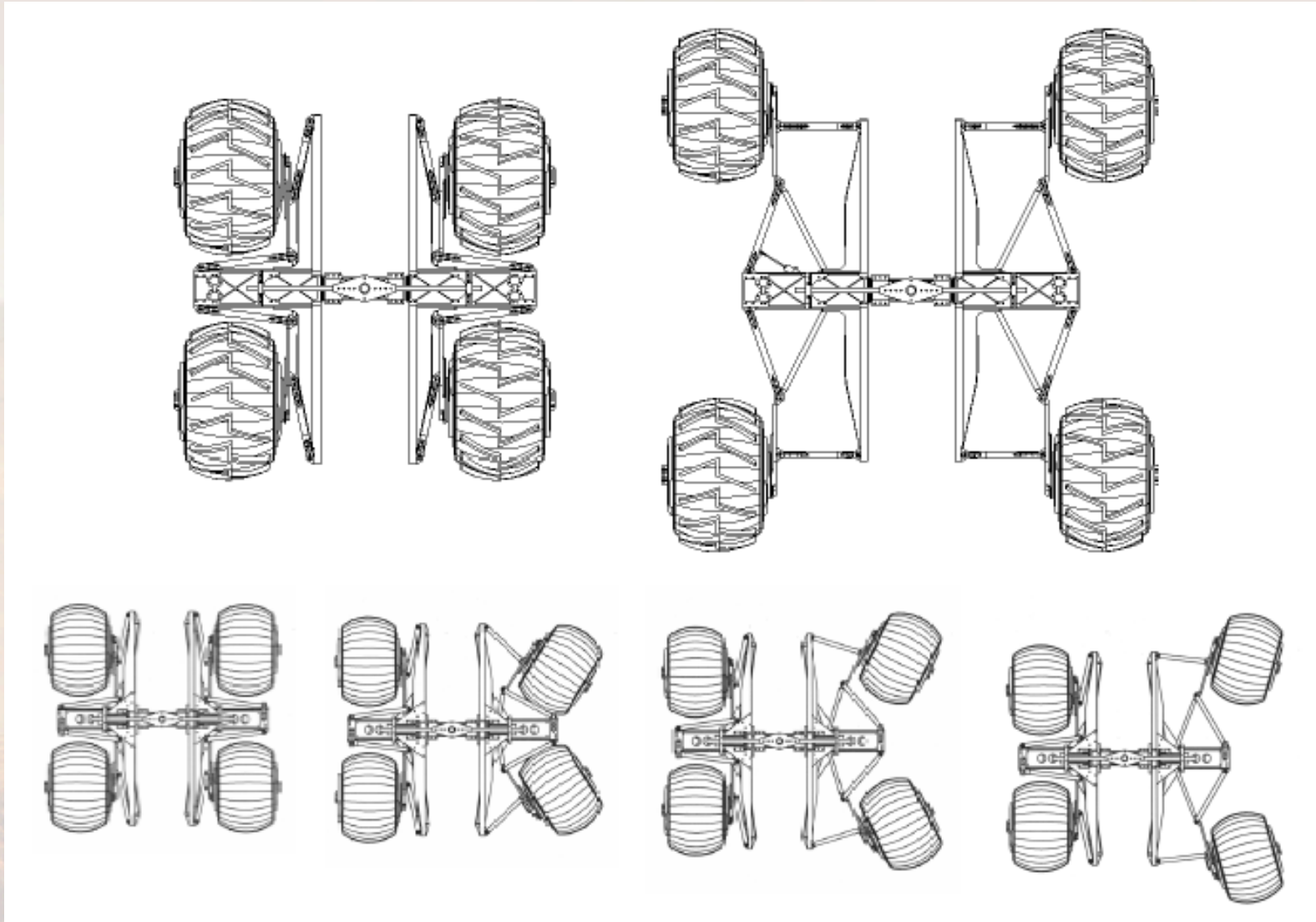
Nomad Transforming Chassis



Nomad in Rough Terrain



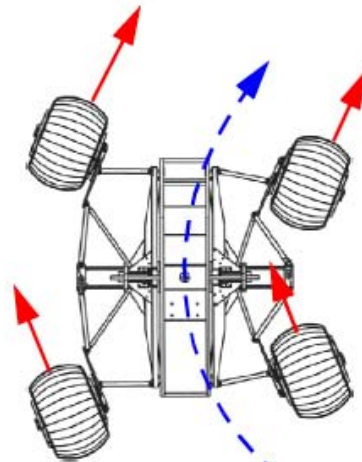
Nomad Chassis/Steering System



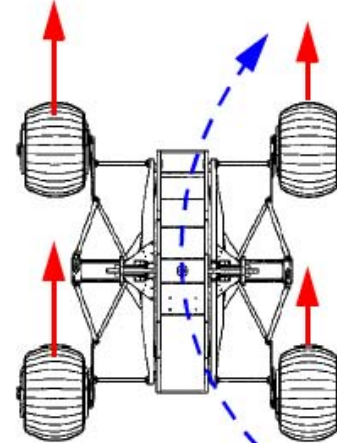
Nomad with Wheels Stowed



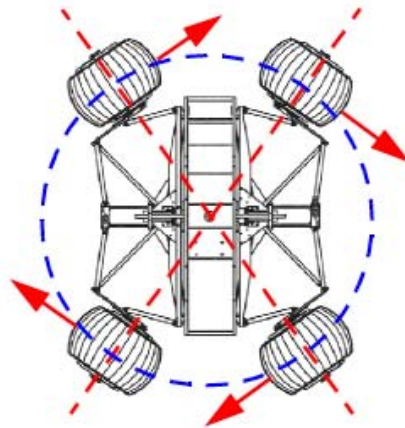
Nomad Steering Schemes



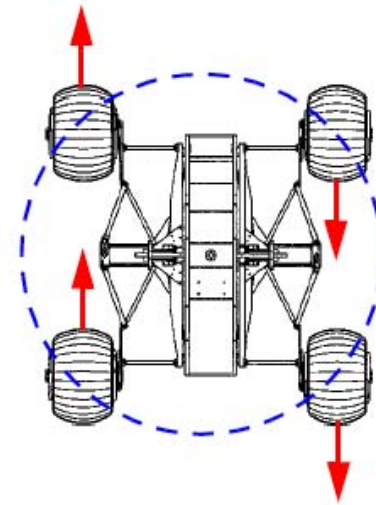
Dual Ackermann



Differential Skid Steering



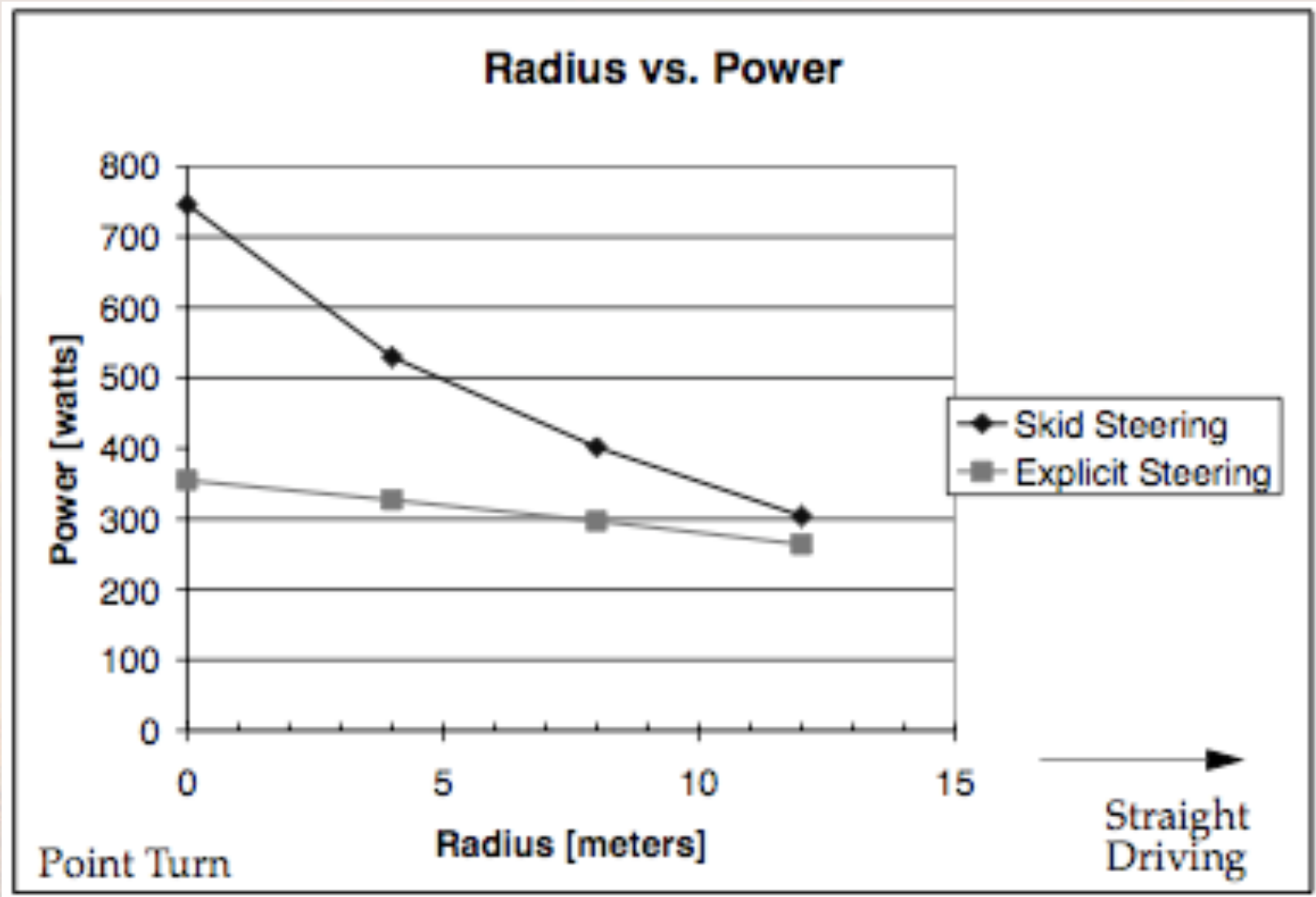
Rolling Point Turn



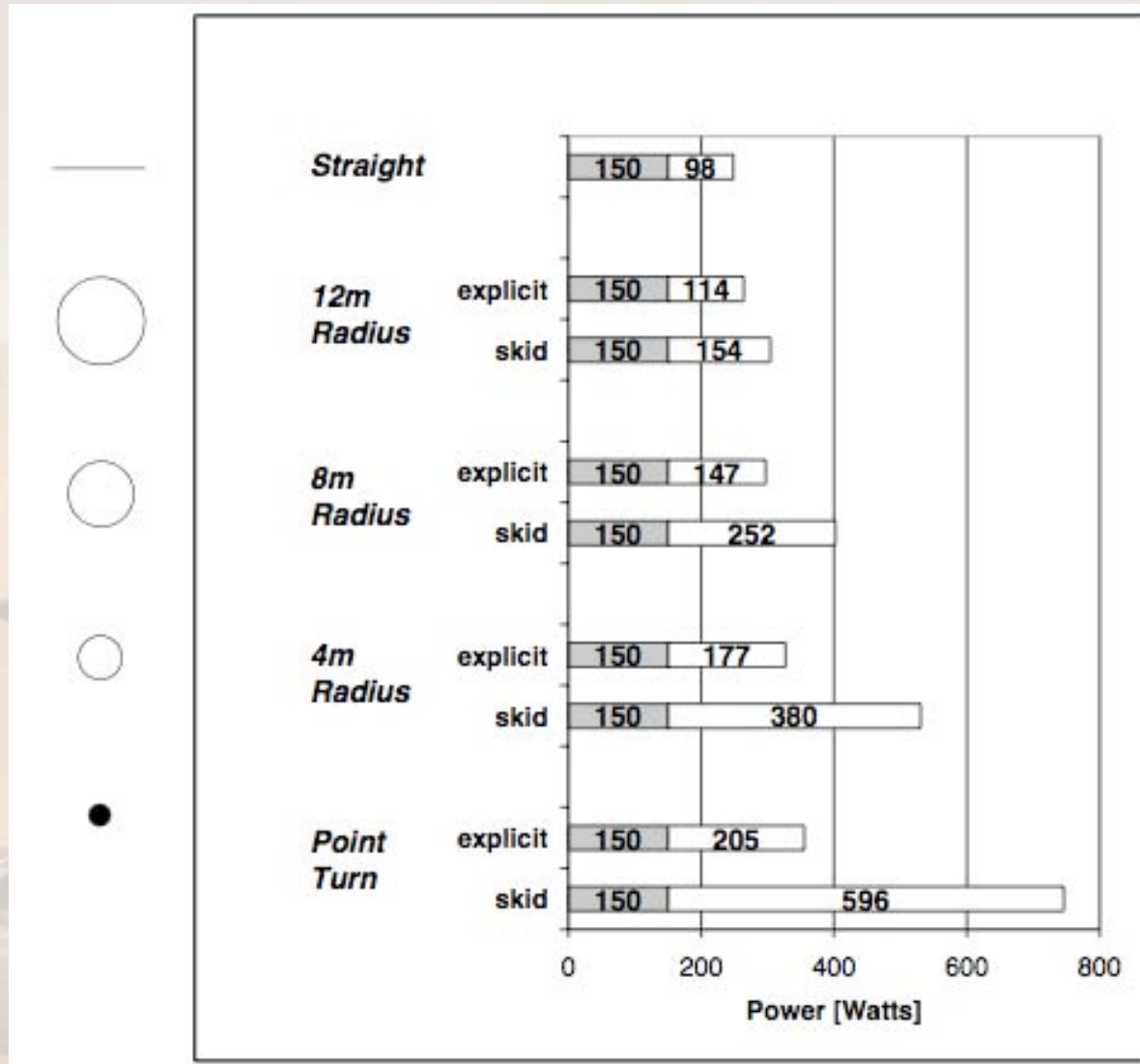
Skid Steering Point Turn



Nomad Power in Skid and Explicit Turns

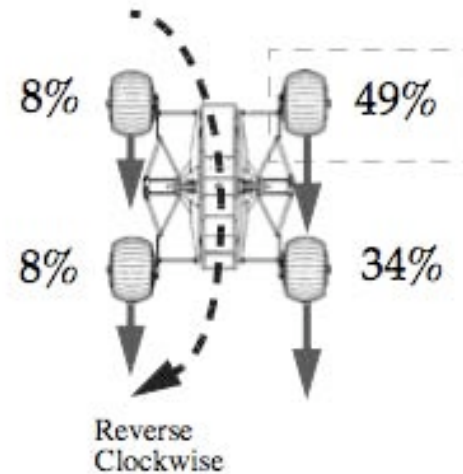
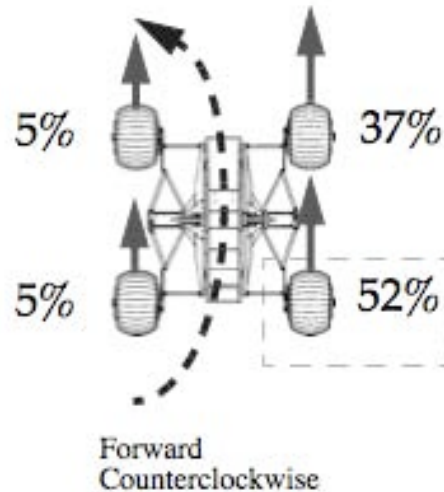
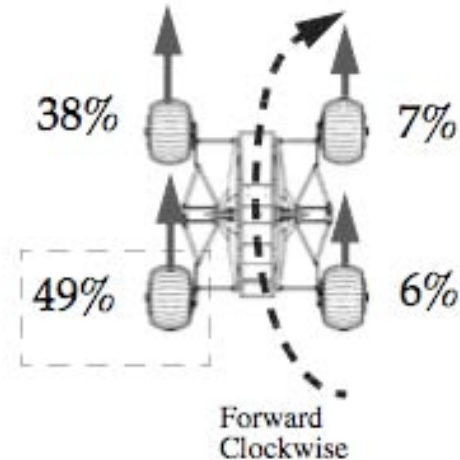


Steering Power Comparison with Fixed Loads

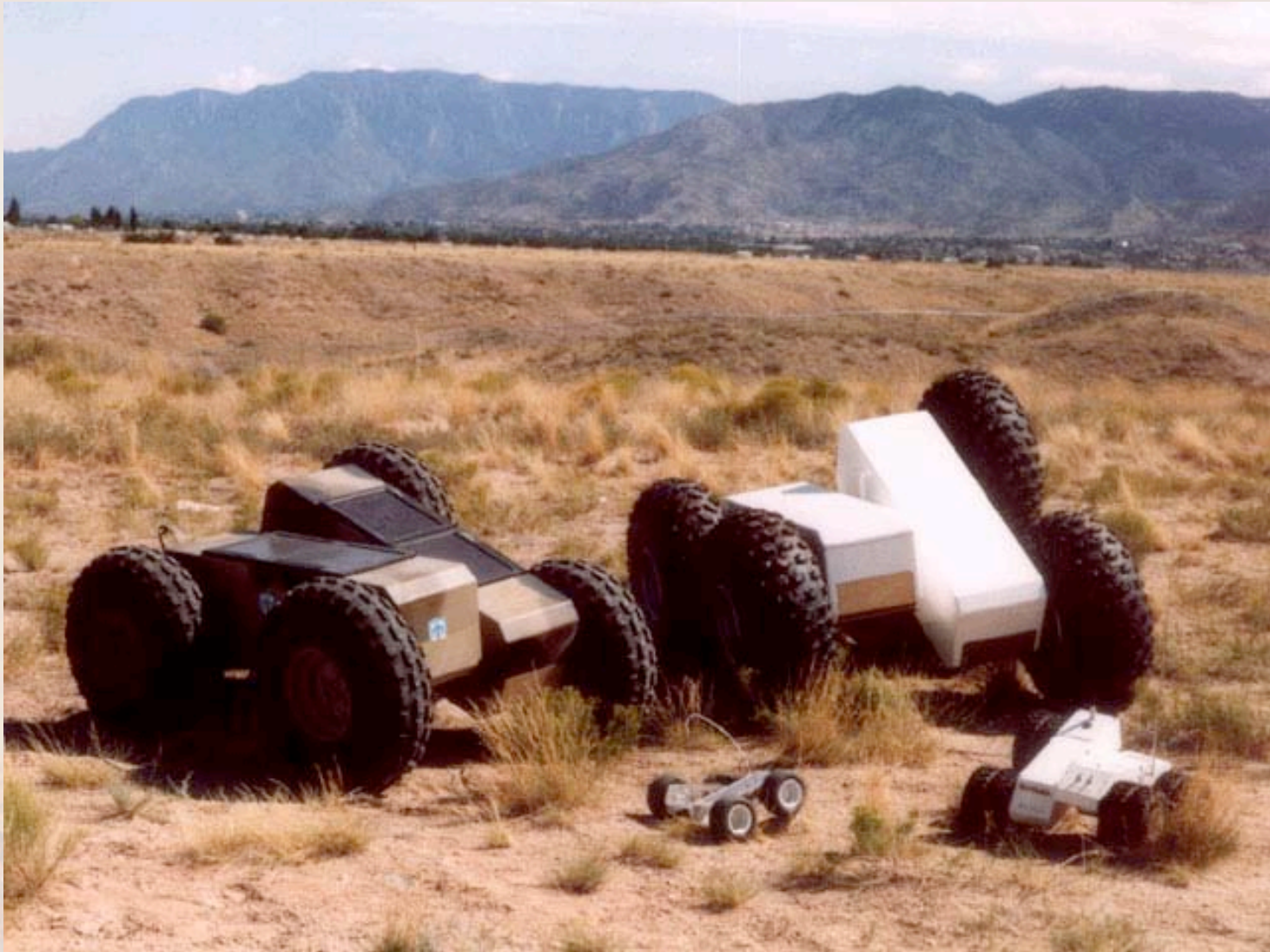


Nomad Wheel Torques in Skid Turn

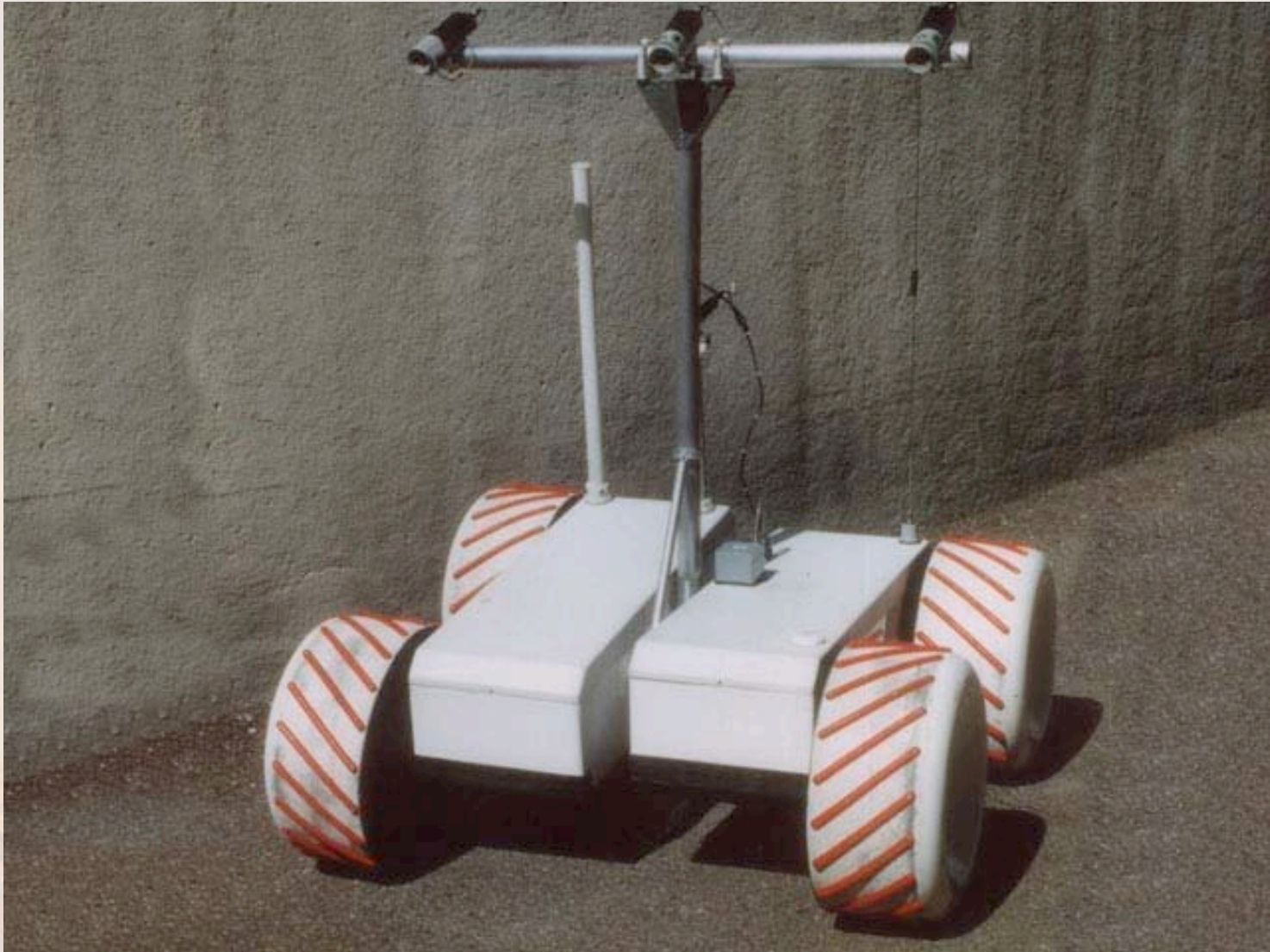
% of total torque contribution by each wheel for 4m radius skid steering turns



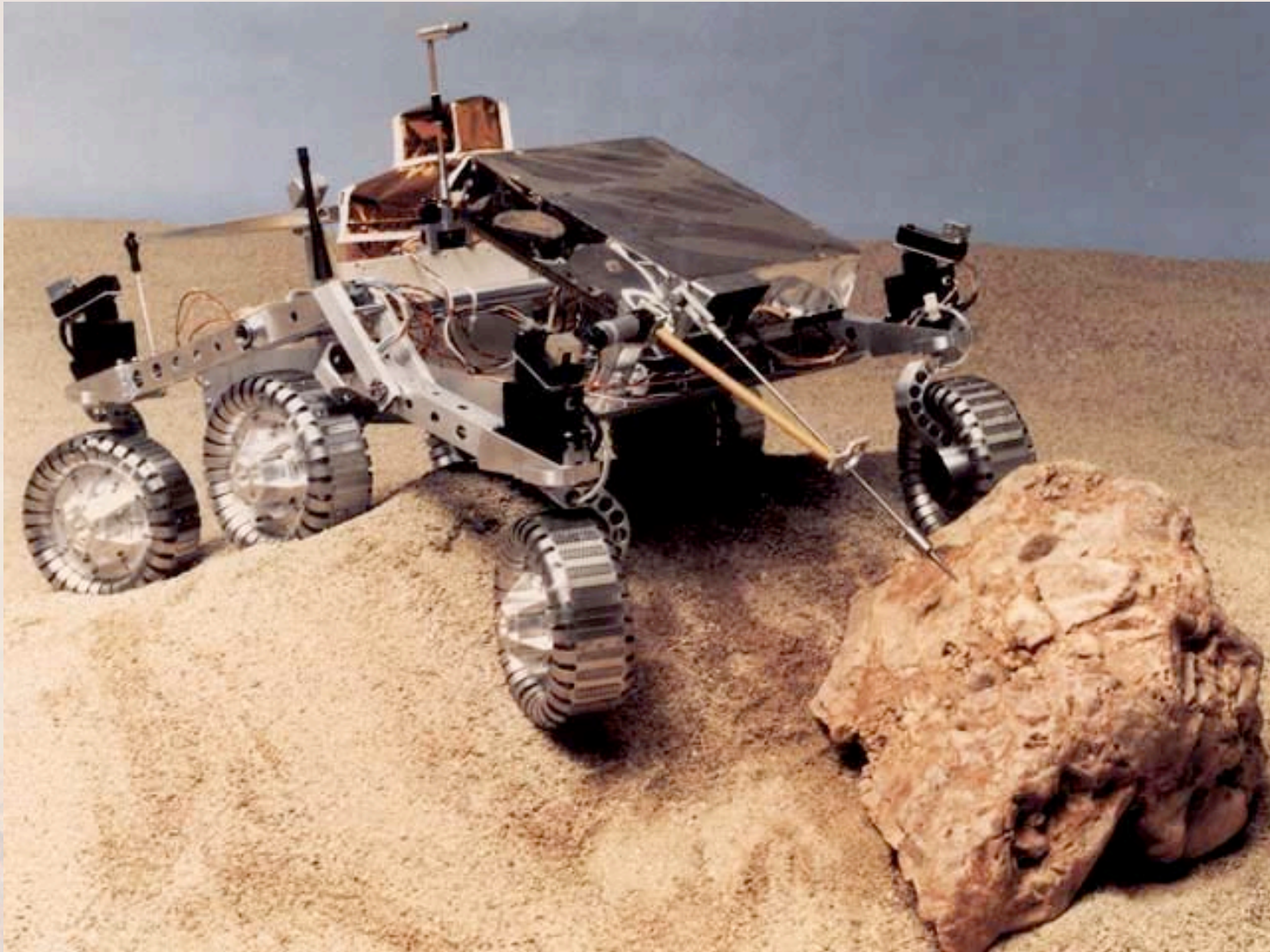
Split-Body Rovers (Sandia Labs)



Ratler (Sandia Labs)



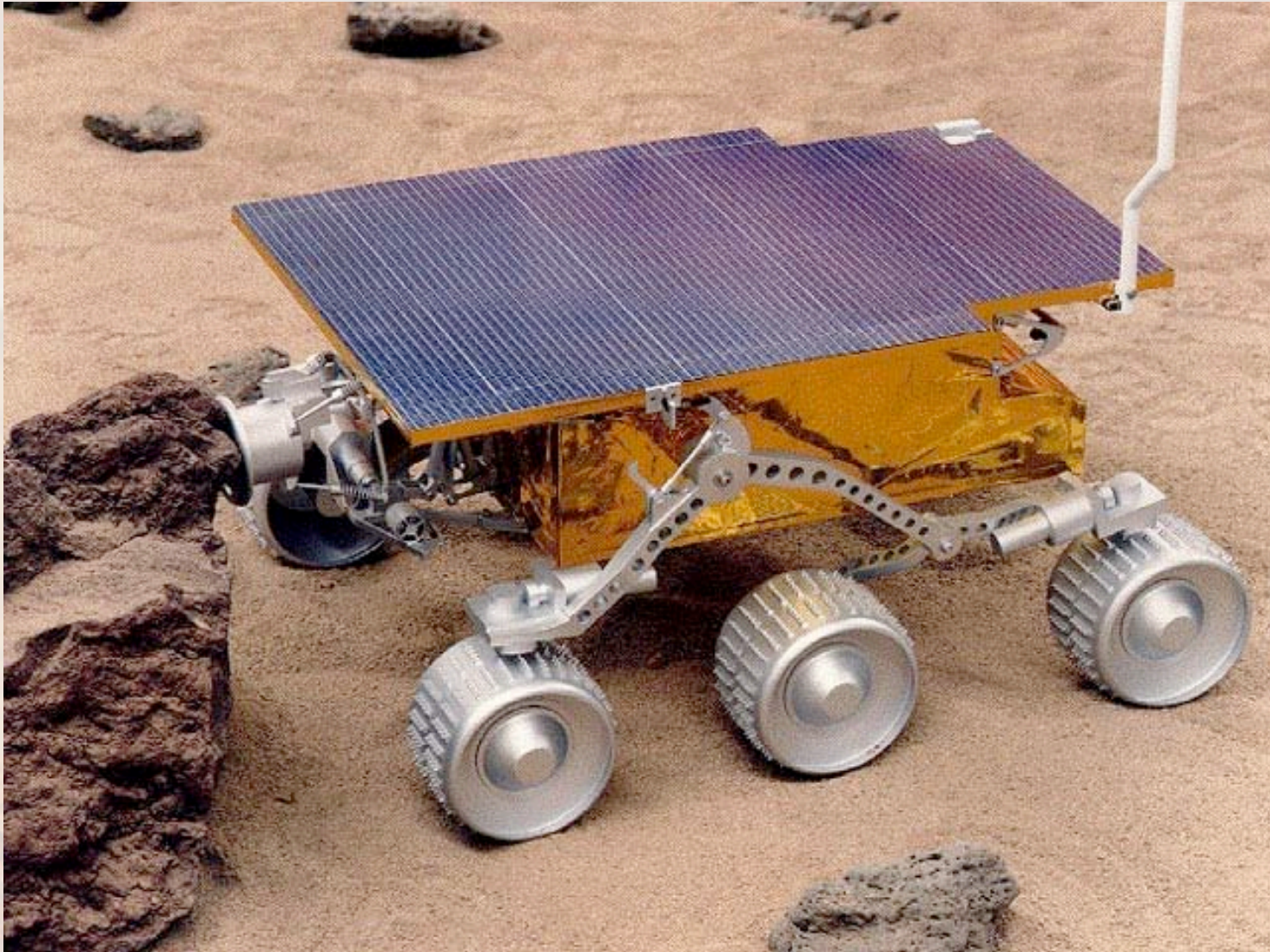
Rocker-Bogie - Rocky 4



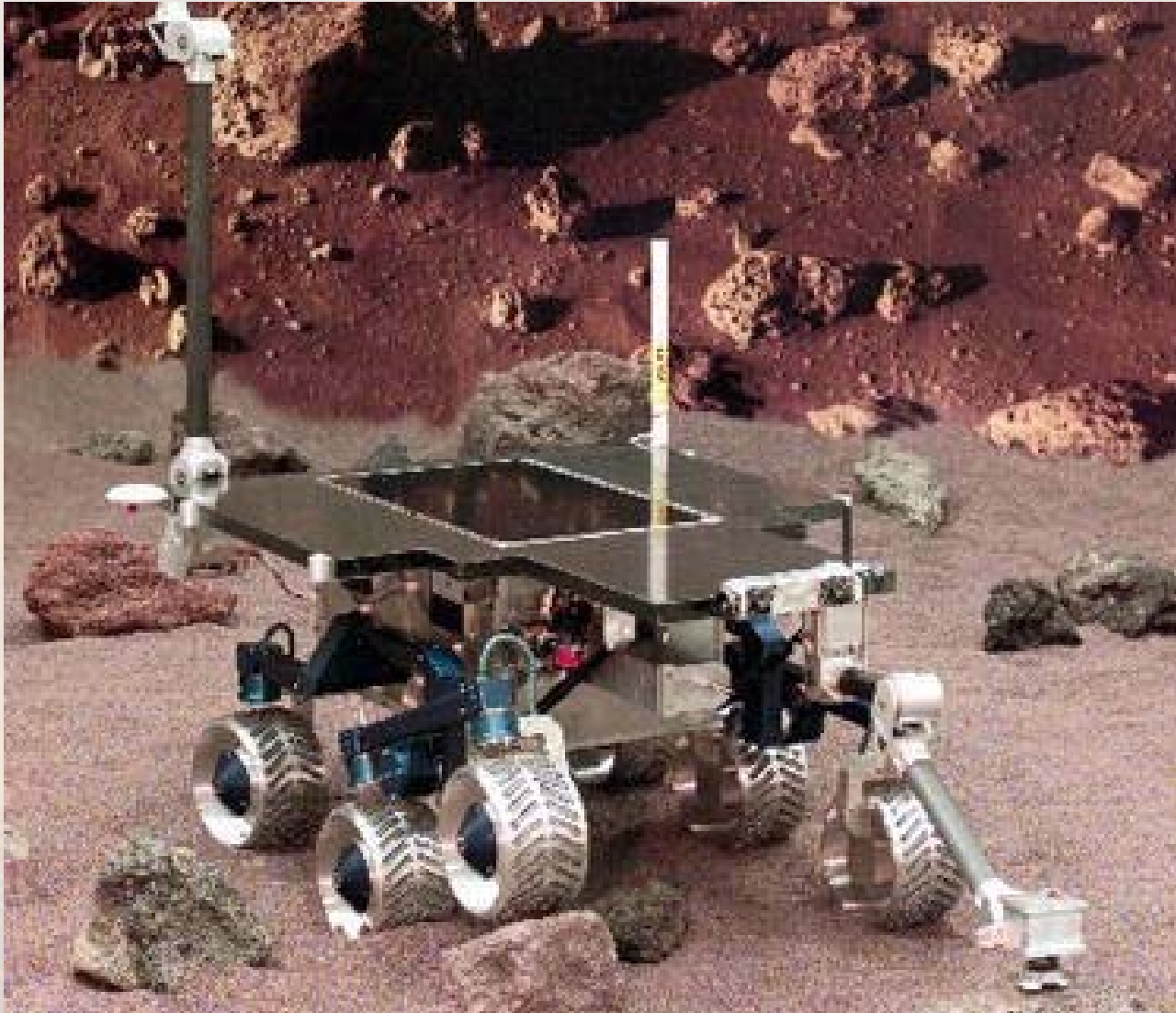
Rocky 7



Sojourner

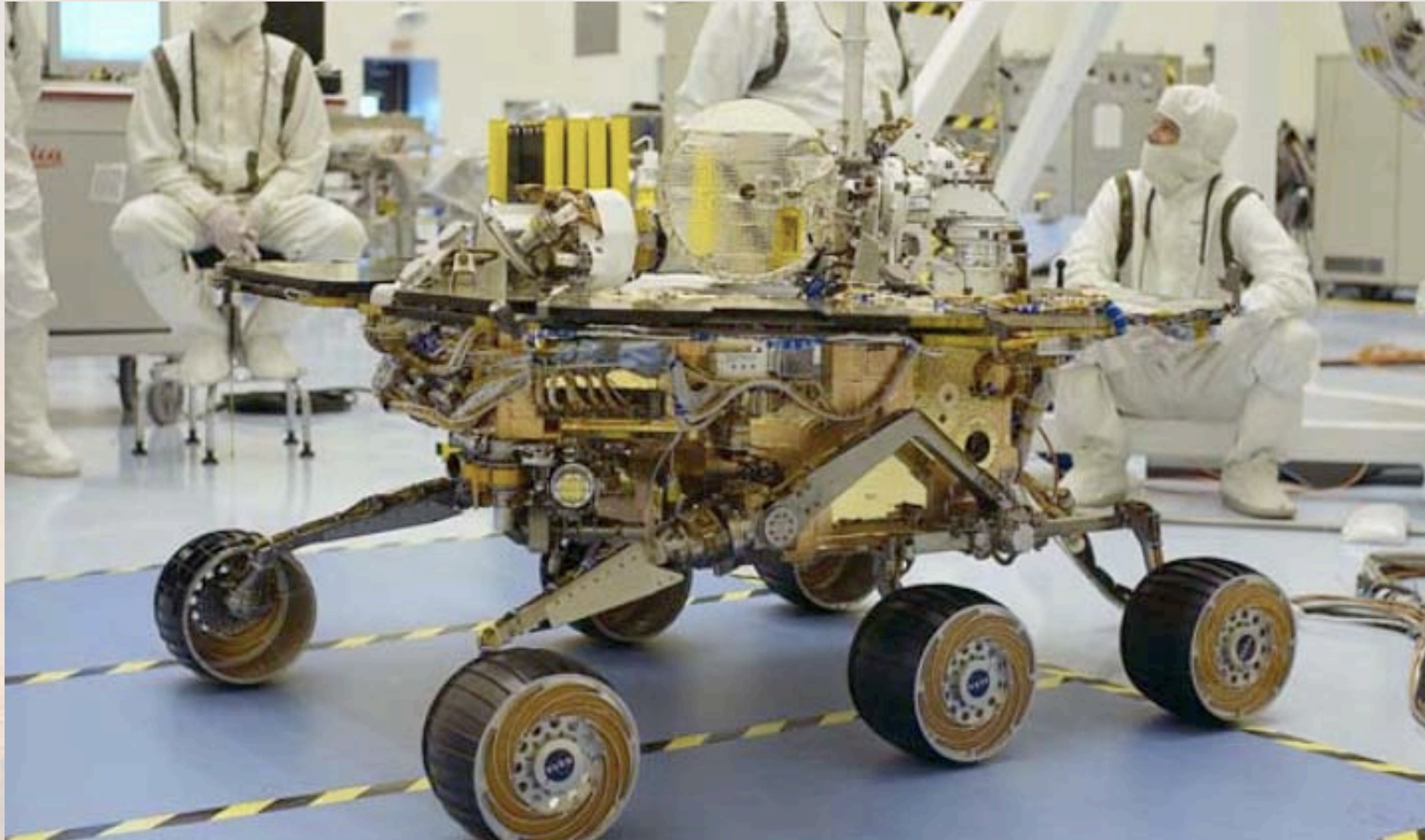


FIDO (JPL)

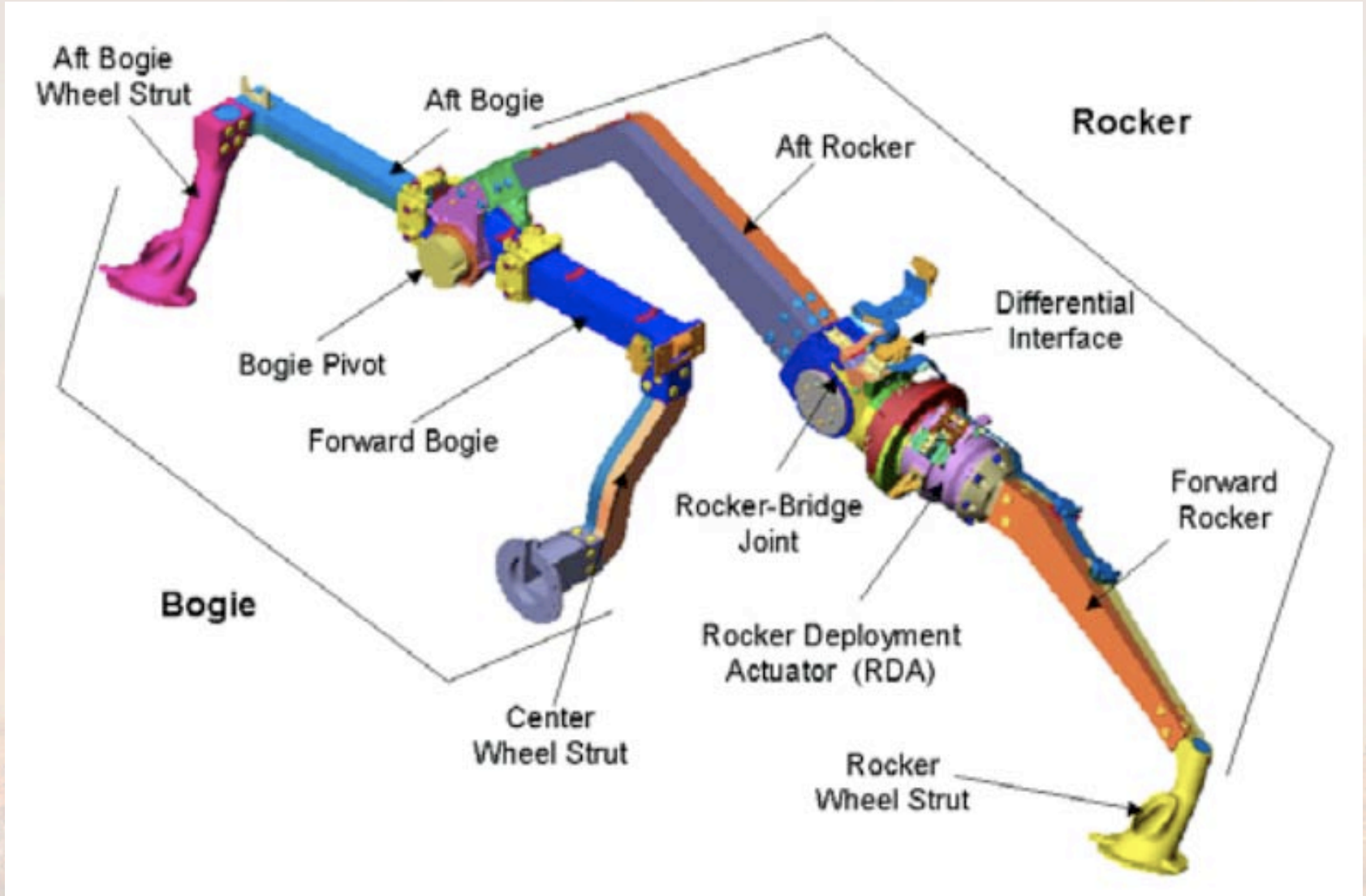


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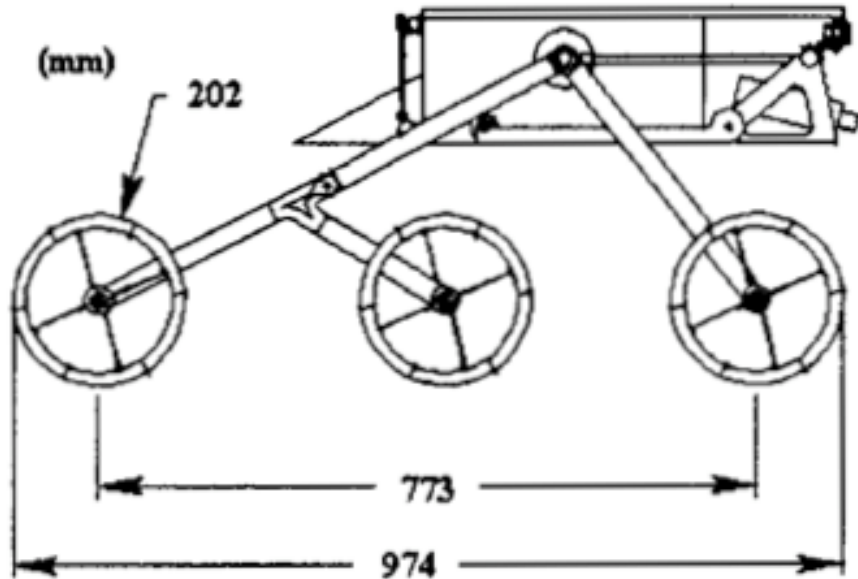
Mars Exploration Rover "Spirit"



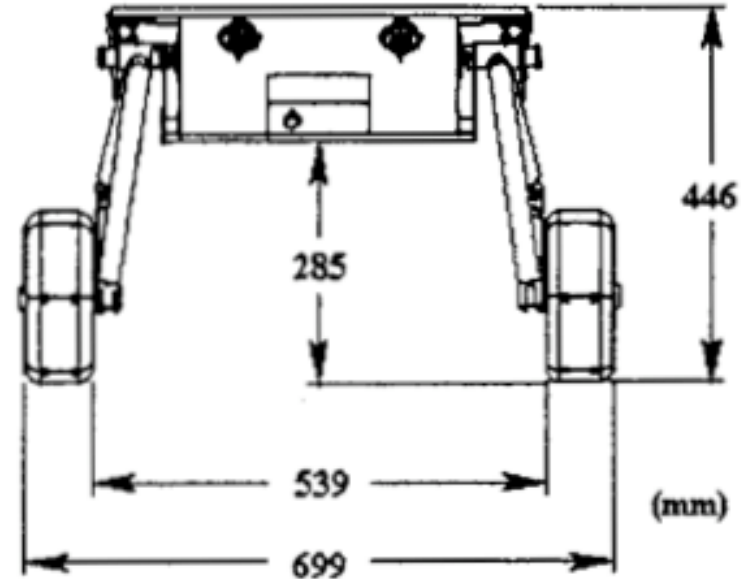
MER Rocker-Bogie Configuration



Lightweight Survivable Rover Dimensions



SIDE



FRONT



Mars Science Laboratory Development Unit



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Steering and Suspension Systems
ENAE 788X - Planetary Surface Robotics

MSL Engineering Development Unit

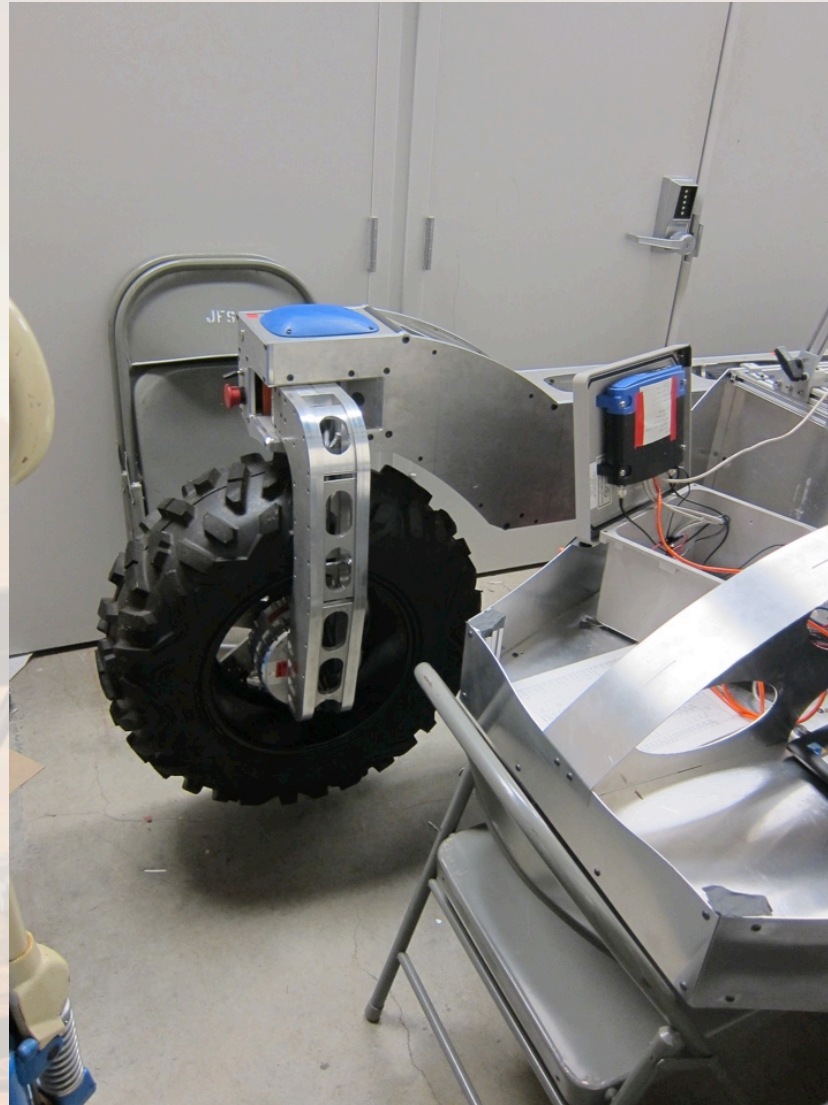


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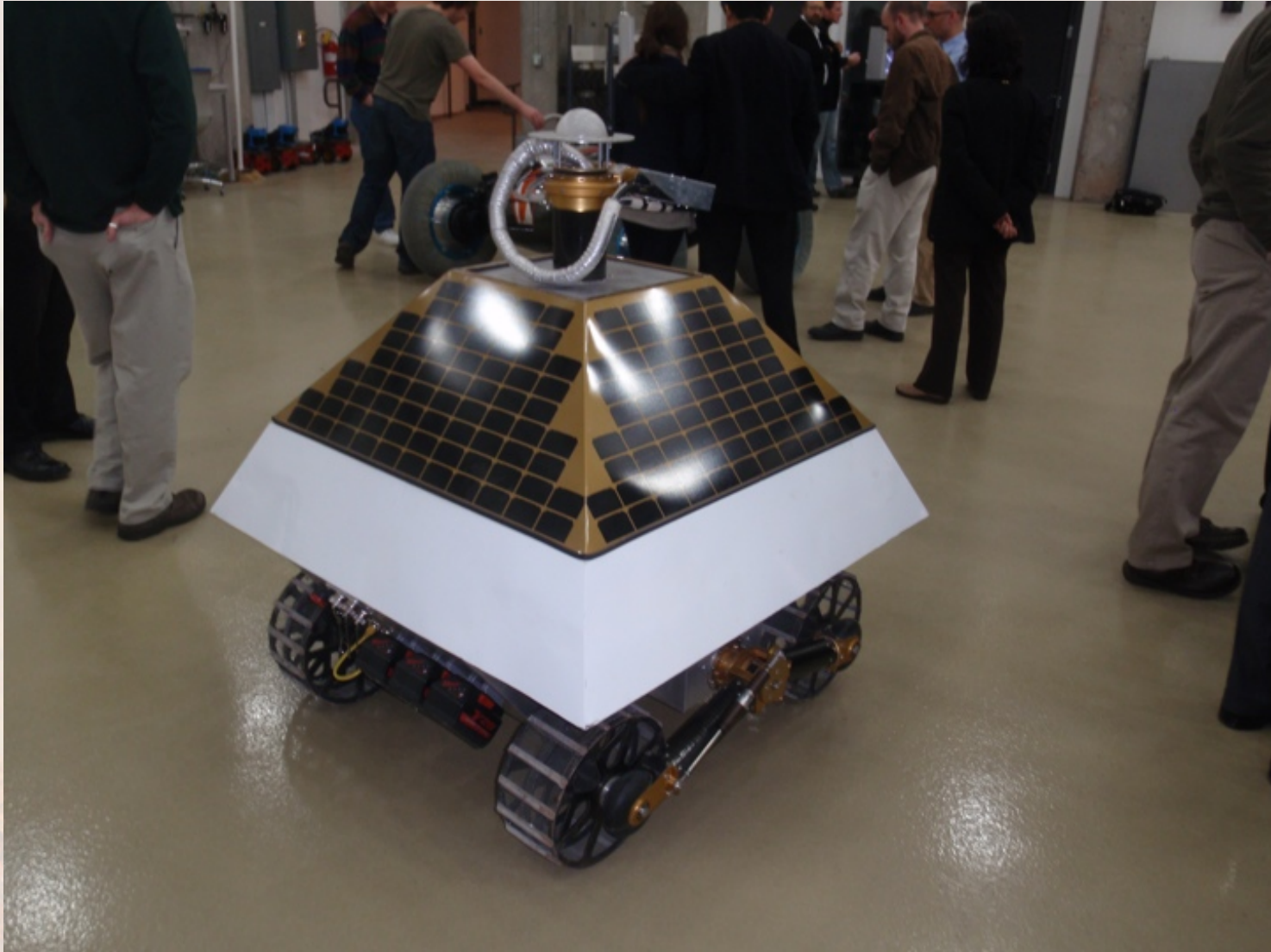
K-Rex Rover (CMU for NASA Ames)



K-Rex Wheel Drive/Steering System



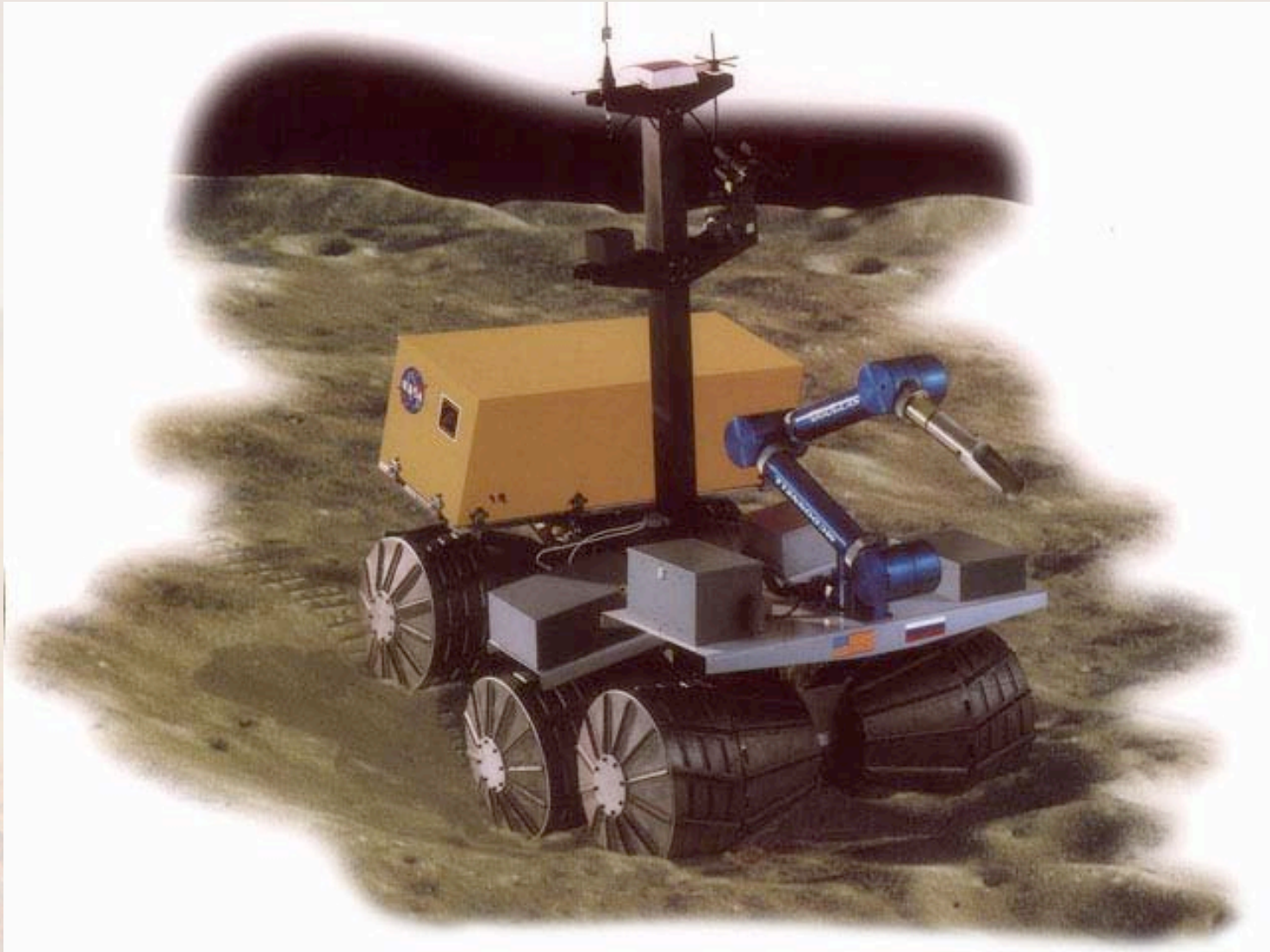
Lunar X-Prize (CMU)



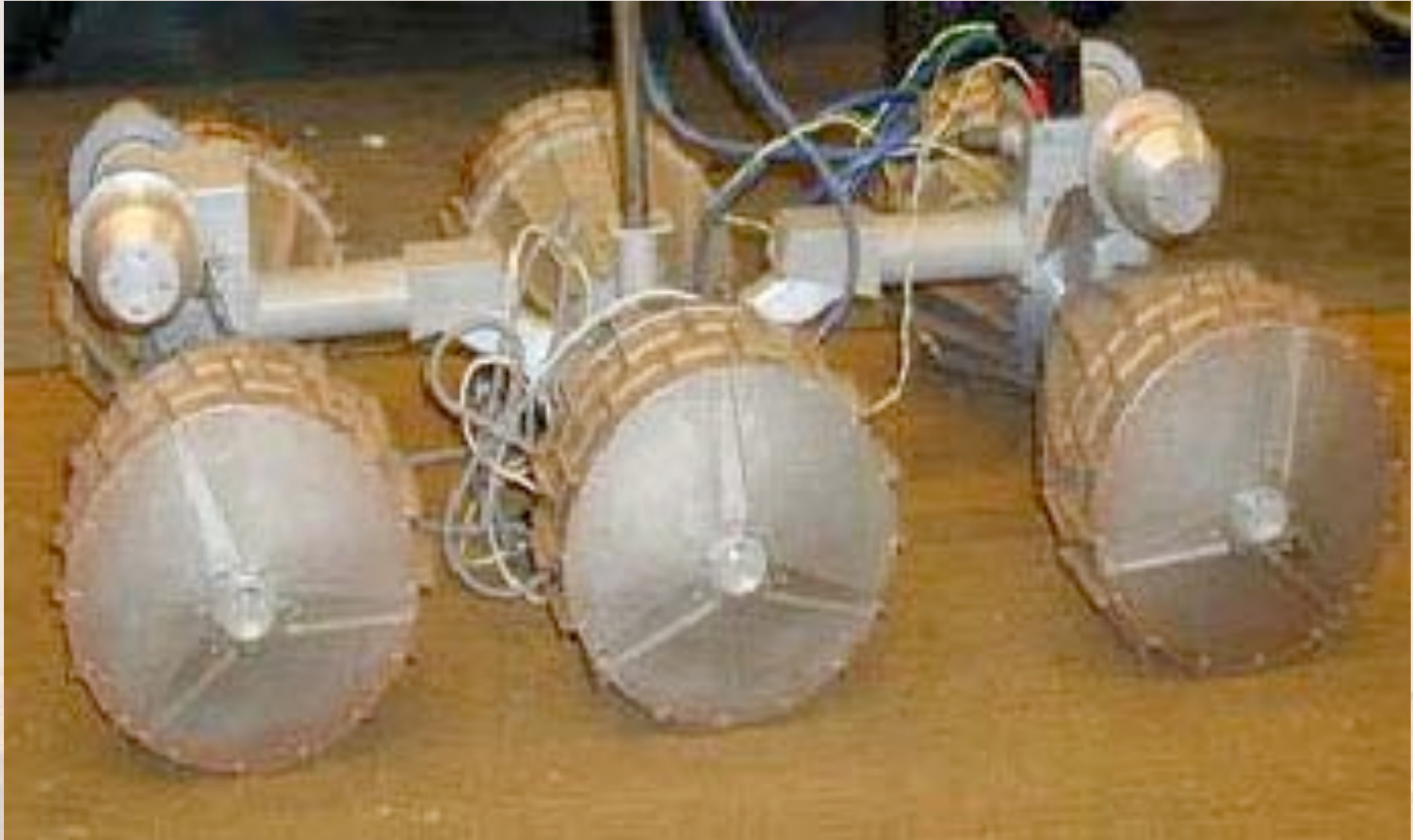
Articulated Bogey Configuration



Segmented Body - Marsokhod



Marsokhod Chassis



Robby (JPL)



Go-For (JPL)



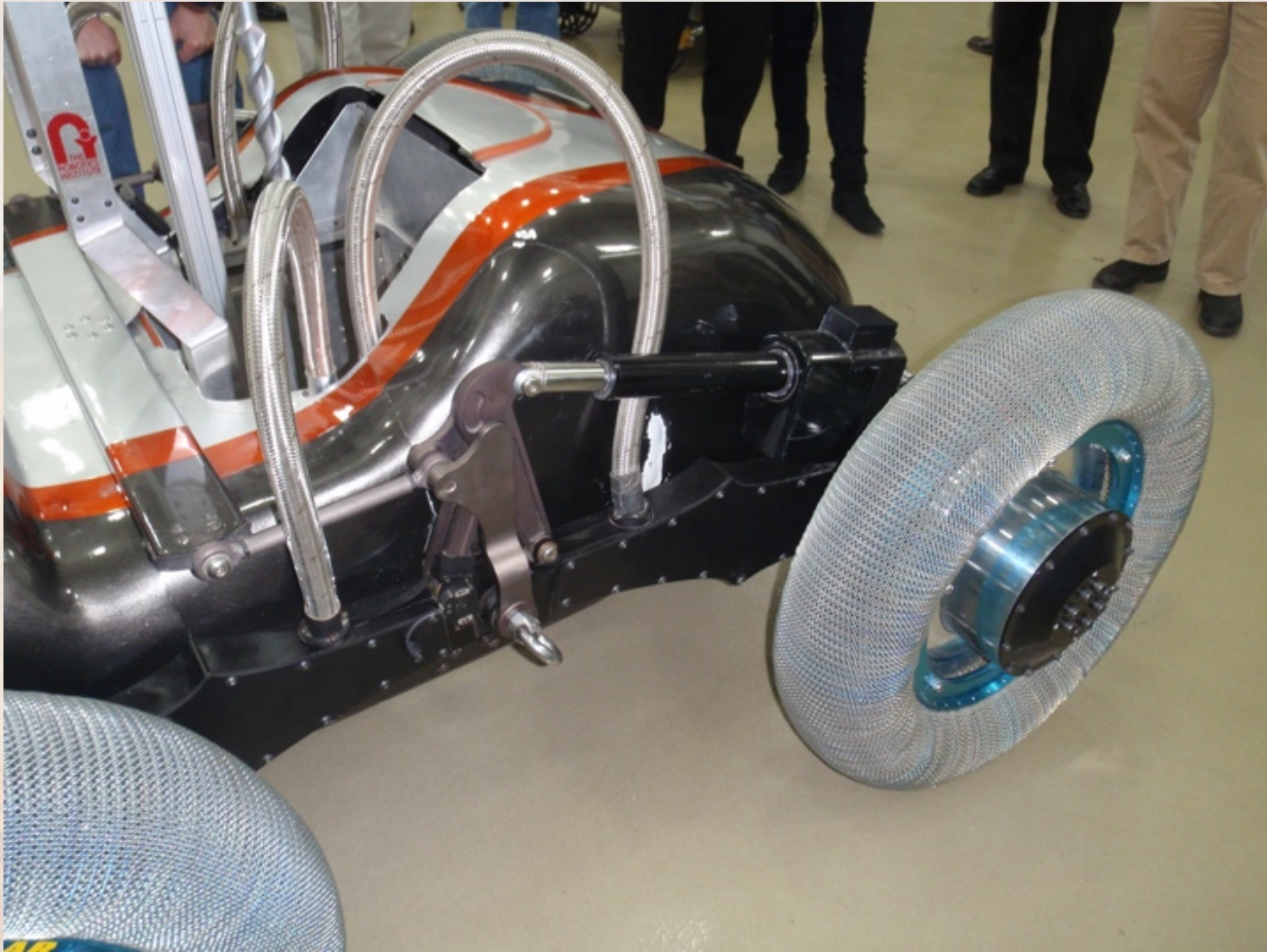
SCARAB (CMU)



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Steering and Suspension Systems
ENAE 788X - Planetary Surface Robotics

Scarab Wheel Articulation (CMU)



SCARAB at Full Extension (CMU)

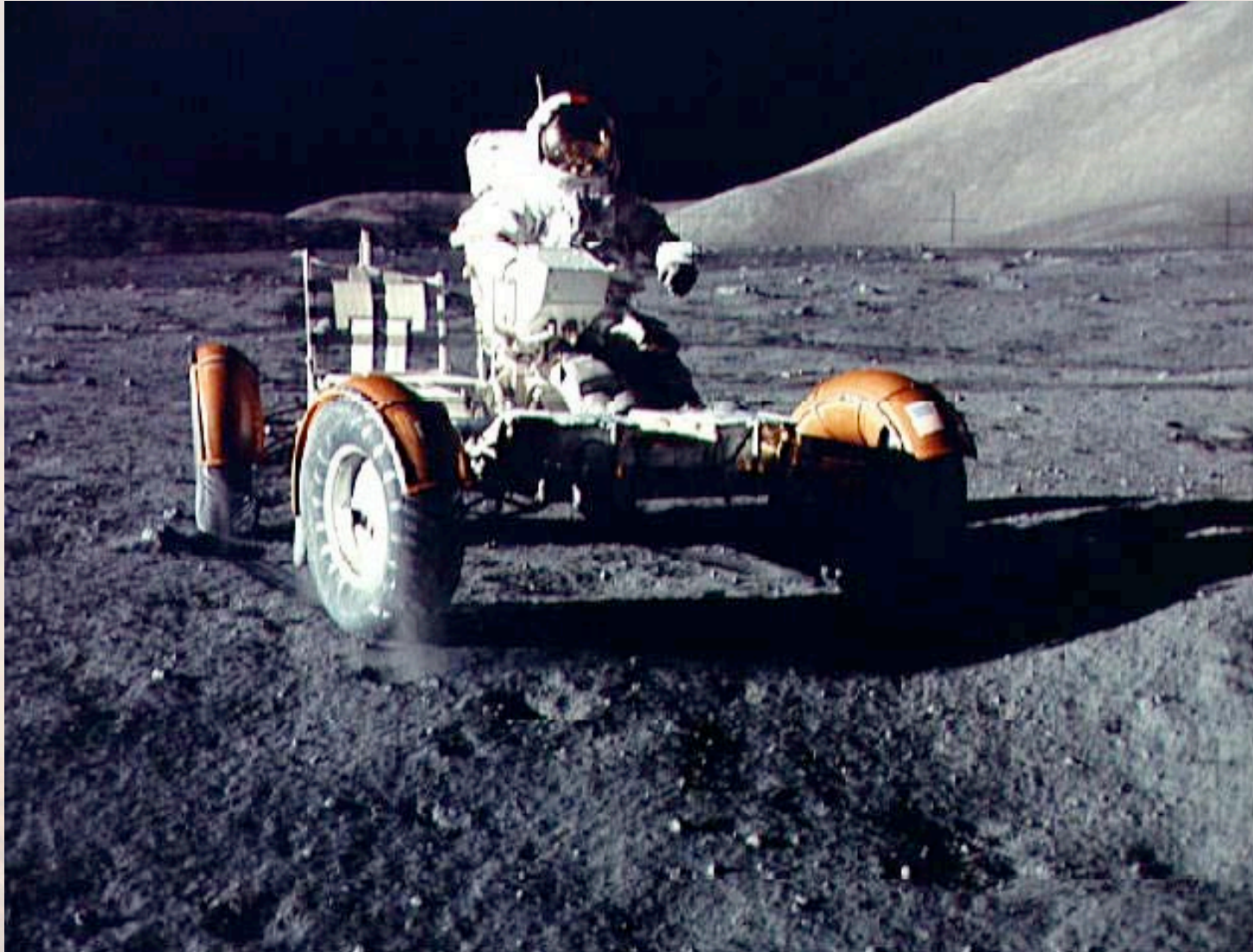


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Mars Rover (VNIITransmash -



Apollo Lunar Roving Vehicle



SCOUT Rover (JSC)



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Steering and Suspension Systems
ENAE 788X - Planetary Surface Robotics

Electric Tractor and Chariot (JSC)



Active Suspension - Chariot



Chariot B Climbs a Boulder Field



RAVEN in Field Trials



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Steering and Suspension Systems
ENAE 788X - Planetary Surface Robotics

SEV Driving Onto $\sim 20^\circ$ Slope



SEV on $\sim 20^\circ$ Slope



SEV Dual Bogie Soil Contact



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ATHLETE (JPL)



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Centaur with Robonaut (JSC)



Centaur Body Pose and Turning



Palm Pilot Robot (CMU)(Holonomic)



Tessellator (CMU) (Holonomic)

