1.5 Concept Generation

For this project 100 design concepts were generated. Each team member generated 10 concepts on their own, then concept generation tools were utilized to assist the team. Biomimicry was the first concept tool used, and was focused on animals that hop, jump, or land. Several animals that were identified were crabs, spiders, insects, and kangaroos.

The anti-problem method was used to help identify concepts that tackled specific problems associated with the shock absorber, such as deceleration displacement, returning to its original state, and energy dissipation. The battle of perspective method was used by dividing the team members into outdoor/indoor preference, like/dislike pumpkin spice, and cats/dog people. The crapshoot method and morphological chart were used to generate the balance of the 100 concepts. The morphological chart used is presented in figure D-1 in appendix D.

Concept 1

The first concept that was generated is 4 accordion/scissor jacks at each corner that extend down before landing. Each joint of the accordion contains a friction disc damper. Upon landing, an electric motor slows down the compression of the 4 jacks. This is a medium-fidelity concept

Concept 2

The next concept that was generated is the use of traditional heavy equipment leaf springs positioned at each corner with a landing pad axel that runs between the opposite springs. Energy is dissipated through frictional forces between the leaves of the springs. This is a high-fidelity concept.

Concept 3

The next concept that was generated is an electromagnetic coil with a magnetic responsive core attached to the footpad part of the leg. Initially starts with large magnetic flux before landing, then a feedback control system regulates power to the coil, which regulates the magnetic field, to bring the core to a slow stop. This is a medium-fidelity concept.

Concept 4

The next concept that was generated is the use of battery powered motors to move spring mounted weights up and down to damp the vibration out. This is a high-fidelity concept.

Concept 5

The next concept that was generated is the use of compliant joint mesh filled with foam in empty spaces. The joint mesh would deform elastically upon impact and the foam would dampen the return motion of the mesh. This is a medium-fidelity concept.

Concept 6

The next concept that was generated is the use of spider style legs that would absorb shock through the leg joints (trampoline type effect). Rotational friction dampers used at each joint, and springs attached between each leg link. This is a medium-fidelity concept.

Concept 7

The next concept that was generated is the use of torsion springs within joints that can be locked at different angles to prevent bounce. The joints can be released mechanically until the load is equal to the spring force. This is a high-fidelity concept.

Concept 8

The last concept generated was an inverted tripod with internal viscous fluid resisting motion. The legs of the inverted tripod would be filled with a viscous fluid with ferritic particles suspended in it. As the legs deflect, the fluid is ported between the legs, and the rate at which the fluid flows can be controlled by varying the electromagnetic field around the flow orifices. As the magnetic field is intensified more magnetic particles stick to and clog the orifice, restriction flow and dampening the return rate of the deflected legs. This is a medium fidelity concept.

Appendix D: List of Concepts

1. Electromagnetic particles in the working fluid.
2. Inverted tripod with internal viscous fluid resisting motion.
3. Inverted tripod with electromagnetic particles resisting motion.
4. Inverted tripod with large magnets pushing each other apart to dampen the impact.
5. 4 legs with a motor that pushes the legs up during impact.
6. A crushable shock that has elastic deformation as opposed to plastic deformation.
7. Inverted tripod with internal viscous fluid resisting motion as a result of springs at each end.
8. Skid type mechanism that is spring loaded.
9. Landing skids to land like a plane.
10. Hydraulic solenoids that compress upon impact.
11. Giant crab legs with a rotational motor at each joint that opposes collapsing. Legs can fold up into each other.
12. 4 accordion/scissor jacks at each corner that extend down before landing and an electric motor slows their compression as it lands.
13. Electromagnet attached to the moving part of the leg interacts with a magnetic piston that compresses fluid in a regular hydraulic cylinder.
14. As the spring is compressed a ratchet pawl is rotated and locks the spring at max compression.
15. Conical helical springs that expand radially as the springs are compressed to interact frictionally with the walls.
16. Springs with empty space filled with a memory foam type polymer that expands slower than it compresses.
17. 4 traditional heavy equipment leaf springs at each corner with a landing pad axel that runs between opposite springs.
18. Helical leaf springs, basically two springs sandwiched together that rub together as the springs are compressed.
19. A chain of short springs, double helical springs with frictional rotation pads in between springs that rub against each other as the spring compression creates a rotational output.
20. A combination compression spring and extension spring. As the compression spring is compresses, the extension spring ratches up and locks into position when the compression spring is at maximum compression. Then as the compression spring expands, the extension spring extends and resists the expansion of the compression spring.
21. An electromagnetic coil as the whole leg with a magnetic responsive core attached to the footpad part of the leg. Initially starts with large magnetic flux before landing, then a feedback control system regulates power to the coil, which regulates the magnetic field, to bring the core to a slow stop.
22. A landing pad that compresses a fluid and uses a turbine to regenerate energy.
23. Replaceable aluminum honeycomb cartridges.

24. Nitrogen gas springs that compress the gas and reclaim it.
25. Nitrogen loaded cylinders that bleed off compressed nitrogen above a certain pressure to the aether. Basically, a compressed gas cylinder attached to a plunger with a relief valve that vents to atmosphere. Just bring a lot of nitrogen.
26. Really long extendable stiff legs that allow for the rocket to be on for the complete decent and rocket control accounts for shock absorption.
27. Really long stiff legs that are attached after the HLS is in space, and then the rocket decent engine control accounts for the shock absorption. The legs are sent up with, but detached from, the HLS and are attached in space during a spacewalk, or with the Canadarm, at the ISS or in transit to the moon.
28. Put a superconducting landing pad down before the HLS is set to arrive, wait for the lunar night, then when the HLS nears the landing pad supercurrents are formed that repel the HLS and levitate it.
29. Very high tolerance pneumatic shocks with helium as the working fluid because the properties are probably pretty constant across the temperature range.
30. Hydraulic shocks with electrical heater temperature control to ensure relatively constant viscosity across the full external temperature range.
31. Long, low angle legs that deflect a lot as the HLS approaches the surface.
32. Gas filled (He) copper bellows that plastically deform upon impact but once back up in 0g heaters heat the bellows to annealing temperature and the bellows are stretched back to the original length.
33. Use a skycrane like with the Curiosity rover on Mars.
34. Rotary friction damped insect legs. 2+ link legs with rotational friction pad assembly at each joint and a mechanical compression spring between links to resist crumpling and reposition legs once off the surface.
35. use battery-powered motors to move spring mounted weights up and down to damp the vibration out.” source
36. Spring damper with shielding and temperature regulation attached to each leg that absorbs all the shock.
37. Spring dampener attached to each leg that stores energy and uses it to bounce a couple of times before finally landing.
38. Airbags that deploy when landing.
39. Crushable shocks that can be decompressed.
40. Spider-like legs that absorb shock through the leg joints (like a trampoline type effect).
41. Trampoline type thing that it lands into with assistance of thrusters.
42. Sealed strut type suspension (Orion).
43. Absorb shock and store it as heat to fuel the next trip.
44. “spring-loaded ring that would detune the stack by softening the interface between the first and upper stages while preserving lateral stability”. source
45. Pour a liquid that works like water on earth into a moon crater and then land in that.
46. Seismic inspired shock absorber, like the pendulum form. source
47. Shock absorber that uses oobleck as the fluid.

48. Spring in a retractable beam that locks into notches and is slowly released mechanically.
49. Electromagnetic shock absorber using ferrofluid to vary the viscosity and thus the damping.
50. Base unit filled with compressed air that is released upon impact at a rate that reduces the impact energy.
51. Base unit filled with oobleck or other non newtonian fluid.
52. Thrusters that are on the side of the module so they can be used all the way to the ground.
53. Wave spring with damper.
54. Torsion spring to act as knees.
55. Rubber bands inside of a temperate container to keep properties constant.
56. Compliant joints that lock at different angles.
57. Electromagnetic resistance with force proportional to velocity (Pure Electromagnet).
58. Stiff yet flexible compliant joint mesh.
59. Compliant joint mesh filled with foam in empty areas.
60. Airbag with folding skeleton to retract.
61. Thruster usage to reduce speed.
62. Telescopic piston.
63. Locking the Springs.
64. Separate Landing Pad.
65. Momentum transfer mechanism.
66. Rubber Bands.
67. Excite Regolith for softer landing area.
68. Give astronauts pogo sticks.
69. Steal pillows from Russian space agency and use them.
70. Dry friction damper. (perhaps with leaf springs)

Concepts 70-100 were created using the morphological chart in figure D-1.

Control vibrations (main type)	Return to original state	Energy absorption	Energy Dissipation/ storage	Indicate reusability	Withstand lunar conditions
Electromagnetic	Natural return	Pressure increase	Heat	Red, yellow, green light	Regolith shielding/ sealing
Electric motor	Forced return	Elastic deformation	Electricity	Position indicator	Avoid open parts
Mechanical springs	Manual return	Plastic Deformation	Kinetic Energy	Percentage indicator (like phone battery)	Temperature controlled casing
Fluid based					

Figure D-1. Morphological chart used to generate concepts.

71. Electromagnetic, natural return, pressure increase, heat, RGB lights, regolith shielding
72. Electromagnetic, natural return, pressure increase, heat, RGB lights, avoid open parts
73. Electromagnetic, natural return, pressure increase, heat, RGB lights, temp controlled casing
74. Electromagnetic, natural return, pressure increase, heat, Position indicator, regolith shielding
75. Electromagnetic, natural return, pressure increase, heat, Position indicator, avoid open parts
76. Electromagnetic, natural return, pressure increase, heat, Position indicator, temp controlled casing
77. Electromagnetic, natural return, pressure increase, heat, percentage, regolith shielding
78. Electromagnetic, natural return, pressure increase, heat, percentage, avoid open parts
79. Electromagnetic, natural return, pressure increase, heat, percentage, temp controlled casing
80. Electromagnetic, natural return, pressure increase, electricity, RGB lights, regolith shielding
81. Electromagnetic, natural return, pressure increase, electricity, Position indicator, avoid open parts
82. Electromagnetic, natural return, pressure increase, electricity, percentage, temp controlled casing
83. Electromagnetic, natural return, pressure increase, kinetic energy, RGB lights, regolith shielding
84. Electromagnetic, natural return, pressure increase, kinetic energy, Position indicator, avoid open parts
85. Electromagnetic, natural return, pressure increase, kinetic energy, percentage, temp controlled casing
86. Electromagnetic, natural return, elastic deformation, electricity, Position indicator, avoid open parts

87. Electromagnetic, natural return, elastic deformation, Electromagnetic, natural return, pressure increase, kinetic energy, Position indicator, avoid open parts
88. Electromagnetic, natural return, elastic deformation, heat, percentage, temp controlled casing
89. Electromagnetic, forced return, plastic deformation, electricity, Position indicator, avoid open parts
90. Electromagnetic, forced return, plastic deformation, kinetic energy, percentage, temp controlled casing
91. Electromagnetic, forced return, plastic deformation, heat, percentage, temp controlled casing
92. Electromagnetic, manual return, pressure increase, heat, percentage, temp controlled casing
93. Electromagnetic, manual return, pressure increase, heat, percentage, temp controlled casing
94. Electromagnetic, manual return, pressure increase, heat, percentage, temp controlled casing
95. Mechanical springs, natural return, pressure increase, heat, Position indicator, regolith shielding
96. Mechanical springs, natural return, pressure increase, heat, Position indicator, regolith shielding
97. Mechanical springs, natural return, pressure increase, heat, Position indicator, regolith shielding
98. Fluid-based, natural return, pressure increase, heat, RGB lights, regolith shielding
99. Fluid-based, natural return, pressure increase, heat, RGB lights, avoid open parts
100. Fluid-based, natural return, pressure increase, heat, RGB lights, temp controlled casing
101. Fluid-based, natural return, pressure increase, heat, percentage, temp controlled casing