1.6 Concept Selection

The final concept was selected by utilizing a Pugh chart and House of Quality (HoQ). Our selection was validated by use of the Analytical Hierarchy Process (AHP). The design that was chosen based off concept selection tools was concept # 7: a spring that locks at maximum compression.

1.6.1 House of Quality

To select a final concept, we first had to determine which selection criteria were the most important. The HoQ used is presented in figure E-1. First, we weighted the customer needs based on discussions with our sponsor and the overall goal of the project. We then compared each customer need with a functional characteristic. Each functional characteristic was given a score of 1, 2, or 3 corresponding to a low, medium, or high impact each function had on the customer need. If a function did not impact the customer need it was left blank. The score for each box was then multiplied by the weight factor of each row, and then each column was summed down to produce a raw score. This raw score allowed us to rank each functional characteristic in order of importance. The top 11 functional characteristics were chosen to be used in the Pugh chart.

1.6.2 Pugh Chart

The Pugh chart allowed us to choose our top three concepts, and then ultimately our final concept. Before the Pugh chart could be used, we first had to pick our top eight ideas. We did this by having each group member pick their two favorite concepts from the list while taking mass, power consumption, and physical feasibility into consideration. This gave us our top 10 concepts. Two concepts were eliminated from that list of 10 through group deliberations.

With the top concepts and functional characteristics selected we constructed the first Pugh chart, presented in Figure E-2. The datum used in the first Pugh chart was the crushable shock absorbers used on the Apollo lander. Each concept was compared to the Apollo shock absorbers for each functional characteristic. If the concept performed better it was given a '+', if it performed worse it was given a '-' and if it was judged to be about as effective it was given a 's'. The total numbers of '+' and '-' were summed down and the scores for each concept were compared. The top three concepts were #2, #7, and #4. Concept #6 was decided to be used as the datum in the next Pugh chart because it was a medium performer.

The second Pugh chart was constructed and is presented in figure E-3. The same procedure was followed for the first Pugh chart, except now only the top three concepts were being compared to concept #6, dubbed 'Spider Legs'. The outcome of the second Pugh chart indicated that the best concept was #7, dubbed 'Locking Spring'.

1.6.3 Analytical Hierarchy Process (AHP)

The first step in the AHP is to create a matrix of customer needs vs. customer needs. The diagonal of the matrix is given a value of 1, then rows are compared against columns and given a score. If the row is more important than the column it is given an integer score greater than one, with higher importance items given a higher integer score. The scores are then reflected and inverted across the diagonal, to give a fractional value to boxes with columns that are valued as more important than rows.

Columns were then summed down to get a cumulative score, and then a normalized matrix was form. The normalized matrix divided each element of a column by the sum of that column. Rows were then summed to the right and divided by the number of elements in each row to form the criteria weight vector. The criteria comparison matrix was then multiplied by the criteria weight vector to form the weighted sum vector. The weighted sum vector was then divided by the criteria weight vector to form the consistency vector. The average consistency, λ, was calculated from the consistency vector, the random index value was pulled from a table provided in the EDM lecture slides, and finally we were able to calculate our consistency ratio.

Our final consistency ratio was found to be 0.12, which is above the expected 0.1. However, in talking with our sponsor about our selected design concept we feel confident in our choice and stand by our decision.

1.6.4 Final Selection

Concept #7, the locking springs, was chosen based off findings from the concept selection tools. First in the HoQ, we found that absorbing impact energy, absorbing structural shock and supporting mass were our most important engineering functions.

Next, in the Pugh chart we found that compared to the Apollo shock absorbers, the top designs would be concepts #7, #4, and #2. We compared all of these to a moderately rated design, #___. Concept #7 did the best, with a total of 10'+'s and only one '-'. #2 and #4 tied at five '+'s and two '-'s.

We followed the AHP to determine which customer needs were most valuable and from here we found that the results from our analytical hierarchy chart are consistent with the concept #7. The most important need was found to be "handle impact speed of 10 ft/s" with a weight of 0.3140. This need would be met by concept #7 because it is a spring damper system designed to specifically handle that. The runner-up need was "can support 32800 kg" at a weight of 0.21. The part that makes the springs unique is that they will lock and that will provide great stability rather than the spring continuing to bounce. It was not surprising to see that consistent tooling was not a top need, but it would not be difficult to implement with our design. The surprising part was the runner-up least important was lightweight, but after speaking to our sponsor we realize that lightweight is much more important to the design which we would have to work on.

We still have some choices to make regarding the execution of the selected concept. The locking mechanism could either be mechanical, magnetic, electrical, or any combination of the three types. The spring would ideally be released upon take off to assist in launch from the lunar surface, however the springs could also be released in flight if conditions require. The type of spring can also be modified moving forward, a torsional spring was presented in the original concept, but a helical compression spring may also be used. A sketch of the concept is presented in figure 2.

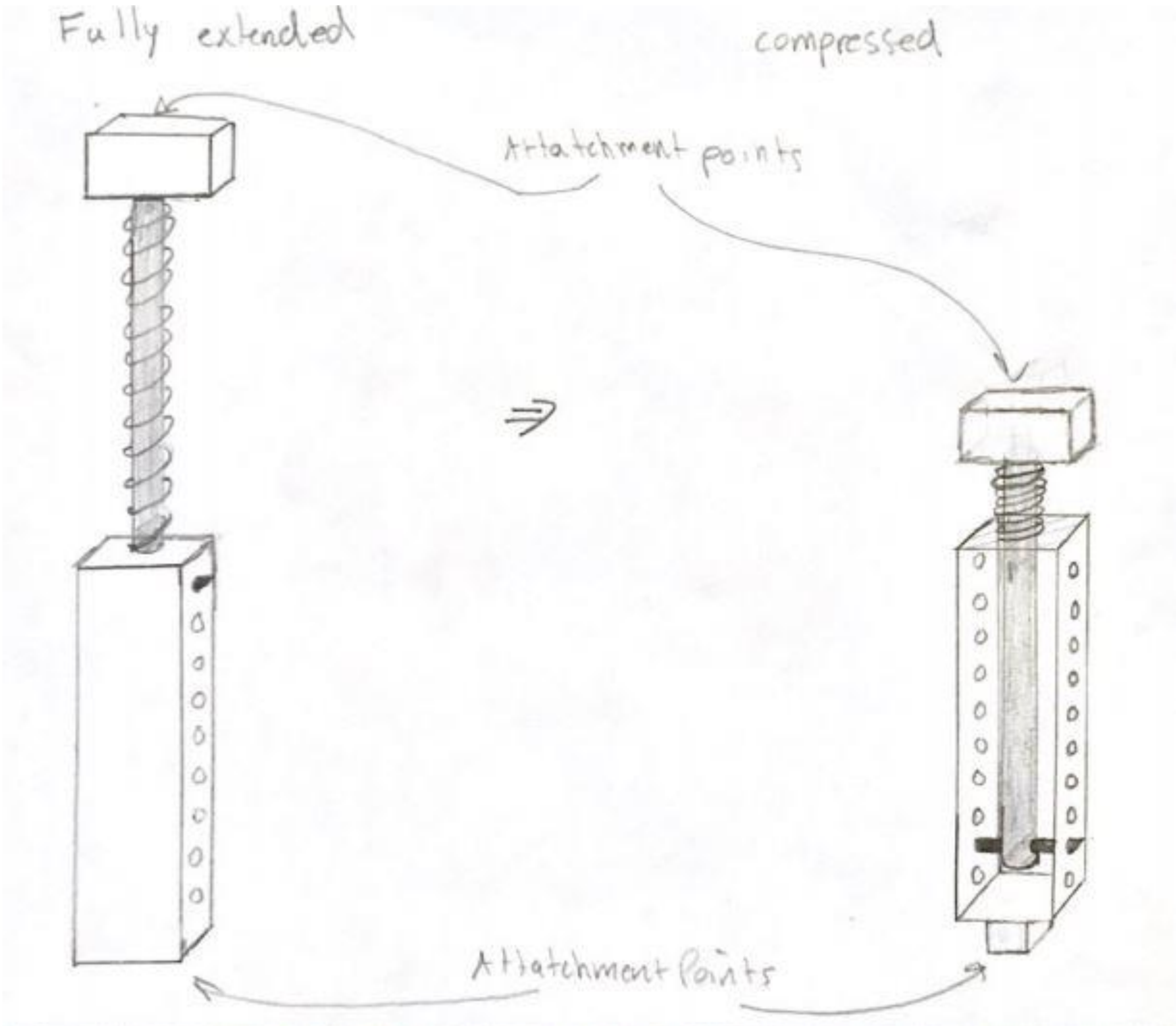

Figure 2. Locking spring sketch.

Appendix E: Concept Selection Supplement

	Importance rating	Absorb Impact Energy	Absorb Structural Shock	Support Mass	Return to Original State	Indicate Reusability	Prevent Excessive Rebound	Transform Energy	Dampen Vibrations	Dissipate Energy	Store Energy	Withstand Lunar Conditions
The product can be used indefinitely.	3	3	2	2	3	2		1	1	1	1	3
The product is lightweight.	3											
The product can be sent to the moon and used repeatedly.	3	3		1	3	2						3
No routine maintenance is necessary during remainder of each lunar trip.	1				2	1						
Shock absorber dynamic qualities does not change or diminish after an impact.	2	2	2	1	1		1	1		1	1	
The product can handle an impact speed of 10 feet per second.	3	3	3									
The product can support 25,000 kg.	2		3	3			2					
The product can land at up to a 10-degree offset from the z-axis.	1						1					
Raw Score (total)	146	31	21	17	21	13	7	5	3	5	5	18
Relative weight (%)	100	21.23	14.38	11.64	14.38	8.90	4.79	3.42	2.05	3.42	3.42	12.33
Rank Order		1	2	5	3	6	7	8	11	9	10	4

Figure E-1. HoQ used to determine most important qualities for the Pugh charts.

		Concept							
Selection Criteria	Datum	1	2	3	4	5	6	7	8
Absorb Impact Energy	Apollo Shock Absorbers	-	s	+	+	+	s	+	s
Absorb Structural Shock		-	+	-	+	+	-	s	s
Support Mass		s	s	-	S	s	s	s	s
Return to Original State		+	+	+	+	+	+	+	+
Indicate Reusability		+	+	+	-	-	+	s	-
Prevent Excessive Rebound		-	-	+	+	+	+	+	+
Transform Energy		S	+	s	s	s	+	+	s
Dampen Vibrations		+	+	+	+	+	-	+	+
Dissipate Energy		s	+	s	s	s	+	s	s
Store Energy		s	s	s	+	s	+	+	s
Withstand Lunar Conditions		-	+	-	-	-	-	s	+
#of pluses		3	6	5	6	5	6	6	3
# of minuses		4	1	3	1	1	3	0	1

Figure E-2. First Pugh chart used to select final 3 concepts.

	Concepts			
Selection Criteria	Datum	2	7	4
Absorb Impact Energy	Spider Legs	+	+	S
Absorb Structural Shock		+	+	+
Support Mass		s	+	-
Return to Original State		+	+	S
Indicate Reusability		s	-	+
Prevent Excessive Rebound		-	+	+
Transform Energy		+	+	+
Dampen Vibrations		-	+	+
Dissipate Energy		s	+	S
Store Energy		+	+	S
Withstand Lunar Conditions		s	+	-
#of pluses		5	10	5
# of minuses		2	1	2

Figure E-3. Second Pugh chart used to determine final concept.

Customer Needs	Lightweight	Reusable	Dynamic qualities do not change after impact "hopping"	Reduce to <3Gs acceleration	Consistent tooling	handle impact 10ft/s	can support 25000kg	<10 degree offset from z axis
Lightweight	1.00	0.33	0.33	0.20	3.00	0.14	0.20	0.33
Reusable	3.00	1.00	3.00	0.33	5.00	0.20	0.33	3.00
Dynamic qualities do not change after impact	3.00	0.33	1.00	0.20	3.00	0.20	0.20	0.33
Reduce to <3Gs acceleration	5.00	3.00	5.00	1.00	5.00	0.33	0.33	3.00
Consistent tooling	0.33	0.20	0.33	0.20	1.00	0.33	0.33	0.33
handle impact speed 10ft/s	7.00	5.00	5.00	3.00	3.00	1.00	3.00	5.00
can support 32800kg	5.00	3.00	5.00	3.00	3.00	0.33	1.00	5.00
<10 degree offset from z axis	3.00	0.33	3.00	0.33	3.00	0.20	0.20	1.00
Sum	27.33	13.20	22.67	8.27	26.00	2.74	5.60	18.00

Normalized Matrix									Sum {W}
Lightweight	0.04	0.03	0.01	0.02	0.12	0.05	0.04	0.02	0.0403
Reusable	0.1098	0.0758	0.1324	0.0403	0.1923	0.0729	0.0595	0.1667	0.1062
Dynamic qualities do not change after impact	0.1098	0.0253	0.0441	0.0242	0.1154	0.0729	0.0357	0.0185	0.0557
Reduce to <3Gs acceleration	0.1829	0.2273	0.2206	0.1210	0.1923	0.1215	0.0595	0.1667	0.1615
Consistent tooling	0.0122	0.0152	0.0147	0.0242	0.0385	0.1215	0.0595	0.0185	0.0380
handle impact speed 10ft/s	0.2561	0.3788	0.2206	0.3629	0.1154	0.3646	0.5357	0.2778	0.3140
can support 32800kg	0.1829	0.2273	0.2206	0.3629	0.1154	0.1215	0.1786	0.2778	0.2109
<10 degree offset from z axis	0.1098	0.0253	0.1324	0.0403	0.1154	0.0729	0.0357	0.0556	0.0734
Sum	1	1	1	1	1	1	1	1	1.0000

Weighted Sum Vector {Ws}	{W}	{Cons}
0.352	0.0403	8.737873
0.992	0.1062	9.337189
0.488	0.0557	8.754142
1.546	0.1615	9.571901
0.323	0.0380	8.492243
3.004	0.3140	9.567303
2.080	0.2109	9.863322
0.670	0.0734	9.124682
	Average:	9.181082

n	8
lambda	9.1810819
RI	1.4
CI	0.168726
CR	0.1205186

Figure E-4. AHP matrices.