Project 1: Egg Descent System

Team 11

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Executive Summary

The problem that the team was tasked with solving was to create an Egg Descent System (EDS) that controls the descent of an egg when dropped from a height. The egg needed to be able to be dropped from a height of 11.4 meters while not exceeding an acceleration of 40 m/s^2 at any point during the descent.

The team went through a couple of design iterations before they arrived on their final design, including many unique features. The design was not only able to fully withstand the approximately 11.4 meter drop in testing several times, but it was also able to withstand a drop test from 20 meters without any of the device breaking or in need of being replaced. The EDS is also made of only three basic materials, meaning it is very easy to replicate at scale and with a low cost. It also is very basic in construction, meaning it can be built within a small time frame. Unlike other descent systems, the EDS does not depend on drag force to slow the egg's descent, ensuring a slow landing, the EDS relies on a plastic frame and inflated latex balloons to absorb the landing shock, distinguishing the design from other models.

In the demonstration the egg fell as intended by the team. It fell with a controlled descent and a minimal impact. While there was some bounce back after the EDS hit the ground, it did not bounce back up more than a couple of feet. The data collected from the pocketlab appears to be inconsistent, which could be due to the flipping of the EDS during descent. This poses a unique problem to the design. Due to this, it is difficult to know for sure if the EDS experienced an acceleration of higher than 40m/s/s during the descent; however, the team is confident that an acceleration of that magnitude was not reached at any point.

The final design of the EDS met the design specifications that the team put forth, with a final estimated cost of $1.28, a fall time of 2.4 seconds during the demonstration, and only 3 unique materials used in the final prototype. The final score from the demonstration for the design was a 17.05, with the egg staying intact and the EDS safely within the fall time constraints of between 2 and 4 seconds. Overall, the team is satisfied with the performance of the designed EDS as it showed at the demonstration that it's unconventional design could compete with the well-established, conventional designs.

Design Considerations

Customer Need	**Technical Need**	**Technical Requirement**	**Target Value**
Has a low cost	Dollar amount	Under 12 dollars	Under 7 dollars
Short fall time	Amount of time to reach ground	3 seconds ± 1 seconds	3 seconds ± 0.5 seconds
Low material usage	Number of unique items used	Under 10 items	Under 6 items

Table 1. Specification Chart

Goals:

The primary goal in designing the EDS was cost. The target value of 7 dollars was decided upon after research into the prices of various materials. Eventually, straws and balloons were decided to be the cheapest, and most usable materials. Thanks to the relatively small size of the egg, the number of straws and balloons needed were small, which also helped keep the total cost to a minimum.

Prototypes and Iterations:

During the brainstorming process, the team discussed prior egg drop experiences, where ideas such as crumple zones, parachutes, and complex geometry were mentioned; however, after consideration of price, complexity, and customer needs, the team decided on a simple pyramid shape for a simple, cost-effective design.

Design type:	Pyramid Design	Parachute Design
Cost (lower is better)	2	4
Descent Speed (lower is better)	4	2
Perceived Effectiveness (lower is better)	5	3.5
Simplicity (lower is better)	3	5
Total (all equally important)	14	14.5

Table 2. Decision matrix between pyramid and parachute design

Originally, the only materials containing the egg were straws connected by duct tape, but after considering the height of the drop, it was decided to use inflated balloons to cushion the impact. It was found that a cylinder is the most structurally sound 3D shape, but since it would be difficult to create a cylinder out of straws, a pyramid shape was used to contain the egg instead. Once the egg was encased in the straws, an inflated balloon was taped to each face of the pyramid shape.

Figure 1. First built prototype of pyramid design

After a significant amount of testing, it was noticed that the EDS tended to fall on one face more often than the others. To adapt for this, the balloon on that face was inflated more to create more of a cushion for the egg.

Once more testing was done, the balloons began to shift around on their faces, which sometimes exposed parts of the egg. To rectify this, layers of duct tape were wrapped around the entire EDS to keep all the balloons from wobbling and possibly falling off the system. Soon after this, one of the balloons popped during testing, so to avoid this happening again, more balloons were added to reduce the amount of force each balloon would take on impact. Once this addition was in place, the testing went much smoother with no new revisions needed.

Theoretical Model:

Throughout the testing of the EDS, the designs continued to increase in the level of their performance as more and more revisions were added. Once the final revision of wrapping duct tape around the system was finished, the EDS was dropped from a six story stairwell, and none of the balloons popped, nor did the egg fall out. This was considered a successful model, and no more revisions were made. Given that the system had survived a drop of almost twice the height of the final testing conditions, it was assumed that the model would perform just as well in the final demonstration.

As for on-paper calculations, the team conducted a work energy analysis to estimate what the velocity of the EDS would be when it landed, and found the minimum collision time with the ground in order to not achieve an acceleration of 40m/s/s. This estimation was used in conjunction with the team's testing of the EDS to determine if the model would meet the customer's requirements, which it did in the theoretical model.

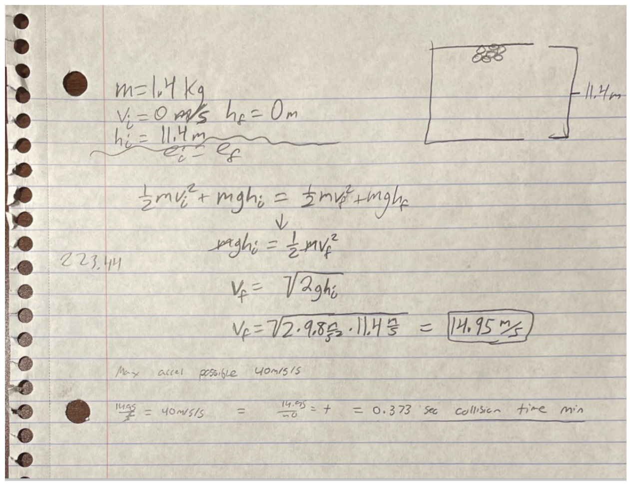

Figure 2. Written out work for the theoretical model

<u>Conclusions:</u>

Overall, the design process for the EDS was fairly simple. The primary method for deciding on aspects of the system were cost, and testing. The goal was to design a protective system that was cheap, but also provided sufficient protection to the egg. The final result achieved both these criteria, and should perform well in the final demo based on performance in several tests.

Results and Discussions

The Egg Descent System (EDS) proved to excel in areas required by the client. In the theoretical model, the team used a simple energy model using gravitational potential energy and kinetic energy of the EDS. The team's predictions found that the maximum velocity of the EDS would be about 14.95 meters per second. In the actual demonstration, the readings shown were about 1,040 meters per second. This excessively large velocity value received from the data suggests that the gyroscope/accelerometer were potentially improperly calibrated. Based on the calculation of maximum velocity, the team estimated that the balloon needed to be in contact with the ground for at least 0.373 seconds in order to not exceed the 40 meters per second squared acceleration. Based on video footage, the collision time was about 0.43 seconds, thus ensuring the design acceleration was below the design criteria. When dropping the EDS, it gradually accelerated down to the floor and landed smoothly after having a small bounce due to the balloon's compression. In designing the EDS holder system, the team decided to use a straw frame held together by duct tape. The model egg was used to find dimensions necessary in order to have a balance of easily being able to take the egg in and out without compromising security of the package in descent. Duct Tape was also wrapped around the model to ensure the balloons were held tightly together to the straw holder system core. A partial remake of the design was necessary as the balloons had lost air over time due to the containment environment. In testing the EDS, the team was not able to accurately determine the behavior of the system on impact as recordings were top down views of the drop. During these trial tests, the system never appeared to bounce. However, in the demonstration, the EDS bounced off the ground and showed sporadic data readings from that time. In calculating the final score, the team had to use the cost of the device, a function with output relative to time of descent, and the maximum descent acceleration reached. The cost of the device was $1.28 using solely straws, balloons, and duct tape. This low cost proved to tremendously help the overall score as even spending an additional dollar at the current rate would have nearly halved the score. The time of descent was roughly 2.38 seconds with a recorded drop time of 14.2 seconds and a landing time of 16.58 seconds. Based on the calculations, this allowed the team to gain the maximum score in the time section with a value of 10. Finally, the maximum acceleration was hard to determine based on the complexity of the outputted data file. Our data gave multiple spikes that were indicative of forces applied after the descent due to the balloon's bounce. However, the team was able to reasonably estimate with multiple high value data points that the relative maximum acceleration was around 37.4 meters per second squared. This was quite close to the maximum of 40 meters per second, however, the drop was successful as the EDS fell within the constraint of the client's acceleration needs. Overall, the team was able to successfully produce an Egg Descent System that was low cost, fell within the time constraint, and had an acceleration below the desired threshold.

Figure 3. Final EDS before the demonstration

$$\text{Score} = \frac{12}{1.28 + 0.001} \times (10)^{(40-37.4)/10} = 17.05$$

Figure 4. EDS Demo Score calculation

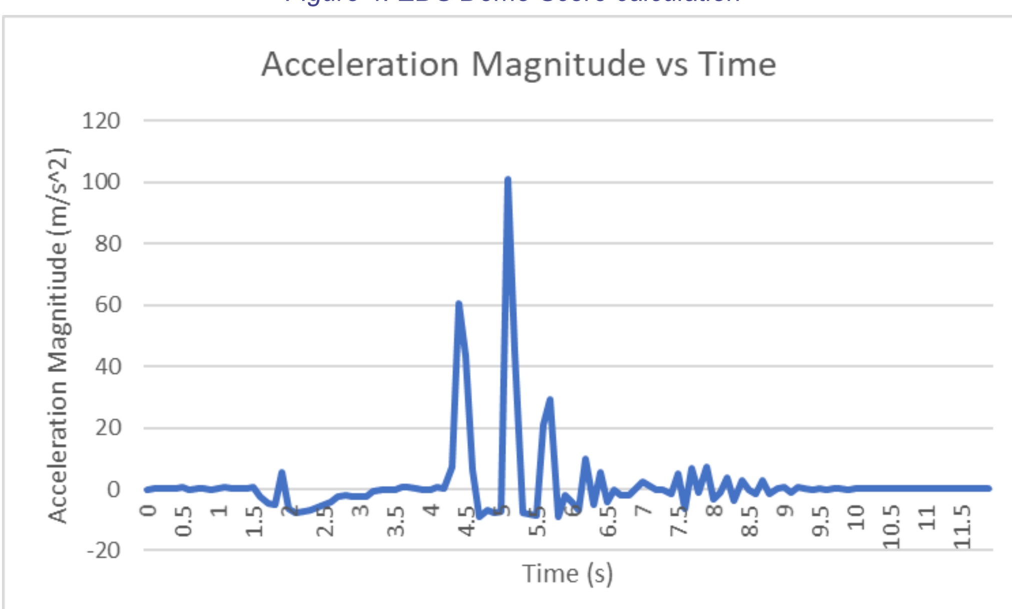

Figure 5. Acceleration magnitude vs time graph

Conclusions and Recommendations

The EDS performed as well as the team expected with it falling within the given timeframe, as well as being simple to build and inexpensive. One issue the team had was the balloons popping before the EDS was going to be used. This would necessitate the blowing up of more balloons to add to the EDS system and thus, increasing the cost of the device. The main cause determined for this was that the balloons were left out for several days, allowing them to weaken and deflate. If this were to be attempted again, the team would recommend blowing up and attaching the balloons to the device as close as possible to the time of use to ensure maximum strength of the balloons.

One other recommendation the team would make if this design were to be created again in the future, is to add a ballast weight to one end of the EDS designated as the “bottom”. This would reduce the amount of spinning and turning of the device in midair as well as ensure there would be a known side that the EDS would land on. This would make data collection significantly easier because the axes would stay in mostly the same direction, ensuring the axis of impact would be known. This would also make the readings from the PocketLab more consistent, giving the team a better idea of how their design fared in the demonstration. This improved data could then be utilized to create a more accurate representation of how the system was performing, allowing the opportunity to ensure the egg is being completely protected.

A third and final recommendation the team would make would be to add some sort of parachute type device if the acceleration and speed desired by the client were slower than how the EDS was performing. This would allow the EDS to travel at a significantly slower speed, decreasing the amount of force on the egg upon impact with the ground. This could also be done at a very small cost while greatly reducing the speed of the EDS upon descent.

These design alterations in conjunction with each other would improve upon the current design to make an enhanced design to be implemented in future egg drops.

Appendix

Balloon Cost - Website 100 Pack for $7.29, 5 in use = $0.37 (estimate)

Straw Cost - Website 250 Pack for $6.99, 10 in use = $0.28 (estimate)

Duct Tape - Website 1 Pack for $4.98, 1/8 of roll in use = $0.63 (estimate)

Total Cost - $1.28

Team gathered materials at no cost, this cost analysis is an estimate of the cost of the materials used.

Sources:

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