The Automatic Dog Ball Launcher and the Purpose of Unsuccessful Engineering Work

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On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

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Introduction

According to the University of Michigan (2021), “about 10% of US adults adopted a new pet last year”, referencing the year 2020 (American Animal Hospital Association (AAHA), 2021, para. 2). These pets have spent an unprecedented amount of time with their owners due to the pandemic as individuals worked from home, and this could cause a large rise in separation anxiety in dogs across the United States as the owners are now beginning to return to work and the dogs have never experienced time alone (AAHA, 2021, para. 2). Separation anxiety is a mental health issue that is usually caused by sudden schedule changes by the guardian, extended periods of time alone or lack of attention and exercise (America Society for the Prevention of Cruelty to Animals (ASPCA), 2021, para. 1). Due to the pandemic and the increasing number of adopted pets, this problem is only going to become more prevalent as the pets have never experienced extended periods of time alone with remote work being the new normal.

The main symptoms of separation anxiety are destructive behavior: urination, barking, escaping, and chewing. There are also underlying mental health conditions that may develop in the dog like depression, anxiety, and general nervousness (ASPCA, 2021, para. 4-7). Understanding the effects of separation anxiety on pets is critical as it will allow any individual to develop a solution that can properly target the direct causes of the problem. If separation anxiety continues to rise unchecked, relationships between owners and pets may worsen as they fail to understand why their pet is suffering and how to help them.

The technical portion of my project sought to describe an automatic dog ball launcher mechanism that was conceived with the purpose of providing dogs with a form of entertainment when the owner returns to work after the pandemic to alleviate separation anxiety. The owner would schedule the machine to turn on for a certain amount of time later on in the day before

they leave using Bluetooth commands, such as 2:00 – 3:00 pm, allowing the dog to play with the machine to deal with some of the loneliness they may be experiencing. However, upon initial research and analysis, which will be delineated further on, it is unlikely that the machine will be much use as treatment for separation anxiety. Through this new understanding, the following questions arise: why was the machine created in the first place, why are engineers accepting of failure? In order to tackle these issues, Pacey's framework will be utilized to provide a new lens to look at engineering practice with, and a failure spectrum will be analyzed to gather information about engineering failure and its purpose. Both of these will be discussed briefly, and then overall connections and conclusions will be made to the ball launcher and engineering practice as a whole.

The Development of Separation Anxiety and Assessing the Created Machine

In order to understand the development of separation anxiety in dogs, it is critical to understand the origins of the relationship between dogs and humans. According to National Public Radio, the evolution of the relationship between dogs and humans is frequently discussed. Many scientists believe that humans first domesticated wolves, while others think that humans had been taking care of wolves since they were puppies (National Public Radio (NPR), 2011, para. 2). Additionally, Derr believes that humans and dogs developed a strong relationship with respect to their hunting abilities (NPR, 2011, para. 3). The dogs used their keen senses to assist humans in tracking and killing prey, and in return, the humans provided food for the dogs. In modern times, it is easy to see that the two have a strong emotional connection. However, even in the past, humans and dogs had more than a mere symbiotic relationship. One example to elucidate this is a skeleton of a disabled dog that was found in Germany, buried with a man and woman about 14,300 years ago (Boehringer, 2021, Back to the Beginning). The extent to which

humans were emotionally connected to their dogs started thousands of years ago and continues today.

Continuing on the concept that the relationship that dogs have with humans is clearly emotional, Herzog (2014) argues that the relationships themselves are affectionate and long-lasting stating, "relationships between pets and keepers are typically characterized by affection and are relatively long-lasting as opposed to transient" (Herzog, 2014, Evolutionary Theories of Pet Keeping). Sargisson describes the emotional attachment that dogs have with their owners to resemble that of a human adult and a child (Sargisson, 2014, para. 2). Additionally, a 1965 study done by Scott and Fuller found that 10-week-old puppies were more likely to focus on the social relationship with a human being than to search out food (Parthasarathy, V., & Crowell-Davis, 2006, Attachment). Even at a young age, dogs clearly have a strong connection to humans emotionally, illustrating the dependence that may be created in dogs towards humans which may lead to separation anxiety. Moreover, humans benefit from the relationship with the dogs as well.

Smolkovic, Fajfar and Mlinaric argue in their paper that there is evidence to suggest numerous psychological and social benefits to owning pets, most specifically cats and dogs (Smolkovic, Fajfar, Mlinaric, 2012, Introduction). Additionally, they (2012) touch on the human-pet relationship stating, "The human-pet relationship can be simple and safe, with minimal risk" (Smolkovic, Fajfar, Mlinaric, 2012, Attachment to People and Animals). Continually, the main points of why humans become emotionally attached to pets lie in the following: pets can serve as a substitute for an owner for other social relationships that they may be lacking, offer shared pleasure through recreation, comfort, etc., and add to the overall quality of life for the owner (Smolkovic, Fajfar, Mlinaric, 2012, Social Support). Dogs clearly provide humans with love and support in ways that they may not always be able to fill with other humans, which creates a

strong bond between the two in the relationship. However, the bond itself can sometimes lead to an unhealthy dependence between pets on humans which can develop into separation anxiety.

Emotional Connections and the Main Cause of Separation Anxiety

Continuing on the study that was done by Parthasarathy, V., & Crowell-Davis, they found that the main cause for separation anxiety is a dysfunctional relationship/attachment between the dog and the owner (Parthasarathy, V., & Crowell-Davis, 2006, Discussion). Essentially, when a dog and an owner have a strong emotional connection and attachment to each other, yet a very dysfunctional relationship, separation anxiety and other problems are likely to develop with the study (2006) arguing, "The results of this study suggest that in the general population, dogs with separation anxiety do not have an excessive attachment, but potentially an attachment pattern that is inappropriate" (Parthasarathy, V., & Crowell-Davis, 2006, Discussion).

This argument is crucial to understand the origins of separation anxiety, as it has long been thought to be an excessive attachment to the owner by the dog. With this in mind, it is evident that the origins of separation anxiety in most dogs is likely not an excessive emotional connection that dogs and humans have but is more likely the way the relationship itself functions. How does the owner interact with the dog? Does the dog live with other dogs, and does the owner treat each dog equally? By analyzing the relationship behavior and patterns that the owner has with the dog, it will be much more effective to both diagnose and treat separation anxiety with both new and traditional solutions like counterconditioning. This means that with a full understanding of the problem, better solutions can be created that will more effectively target the main causes of the situation.

Counterconditioning

Counterconditioning is the primary way of treating separation anxiety as of now. Essentially, counterconditioning entails associating an event, person, or item that the dog strongly dislikes with something that the dog loves, like treats or toys (ASPCA, 2021, para. 23). It is an attempt to train the dog to associate the owner leaving with pleasant things rather than stress, depression, anxiety, and fear that they may normally be experiencing. Usually, counterconditioning functions through the use of desensitization (Gibeault, 2020, Desensitization). The dog is presented with the negative situation in small amounts, slowly building up to the final scenario. All the while, the owner is using counterconditioning to associate the negative scenarios with treats, toys, games, and other items (Gibeault, 2020, Desensitization). This process essentially desensitizes the dog to the negative scenario, and with each level, it progressively becomes more like the situation where the problem always occurs. At the end of the process, the dog is exposed to the full scenario and counterconditioning is continued to be used to associate the overall problem with positive items. By understanding the goal of counterconditioning, how it functions, and the relationship that the dog has with the owner, the effectiveness of the device can properly be predicted by looking at the main cause of separation anxiety and the implementation of counterconditioning. An assessment of whether or not the launcher will actually target the main problem will occur, and whether or not it would properly implement counterconditioning.

Effectiveness of the Launcher

There are two main factors to discuss regarding the effectiveness of the device: the main cause of separation anxiety and the implementation of counterconditioning. Primarily, the main cause of separation anxiety, as discussed in this paper, is determined to be a dysfunctional

relationship between the dog and the owner where there is a critical behavioral issue in the relationship, such as the owner having multiple dogs and treating all of them equally except one (Parthasarathy, V., & Crowell-Davis, 2006, Discussion). The fetch machine, illustrated in Figure 1, is intended to be a tool for the owner to use to provide entertainment for the dog at some point in the day, predetermined by the owner.

Figure 1: Automatic Dog Ball Launcher (Created by Author)
Overview of the device that was created by the group. The motors would spin at various speeds with the entire launching mechanism rotating at different angles as well. In order to launch, a ball would be placed in the white tube and would roll to connect with the wheels spinning via the motors.

Setting the launcher to run at a point later on in the day would have little to no effect on mending or fixing any relationship issues that may exists between the dog and the owner. In this regard, the fetch machine would fail to target the main cause behind separation anxiety as it would not alter the relationship itself at all. With respect to the second subject, counterconditioning is typically implemented through desensitization, and is a slow and tedious process where the overall problem scenario is broken down and manipulated in small pieces, building up to the final situation (Gibeault, 2020, Desensitization).

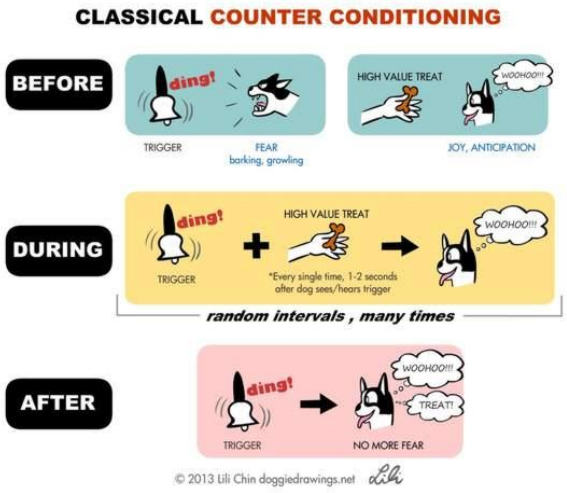

Figure 2: Classical Counterconditioning (Dogo App, 2021)
Illustration to predict the general process of counterconditioning when traditionally implemented

However, the fetch machine operates through the use of an application where the owner predetermines the time for the machine to turn on, such as 2:00-3:00PM in the afternoon, hours after the owner has already left. While this would accomplish the goal of providing some entertainment for the dog, the situation where the separation anxiety initially occurs has long passed, meaning that the machine has failed to properly implement the principles of counterconditioning. Therefore, the machine is not useful at all for alleviating separation anxiety and serves minimal purpose at best.

This analysis and conclusion lead into the discussion where Pacey's framework can be aptly applied. The machine clearly would not achieve its primary goal and would not help alleviate the overarching problem, which leads to the question of why the machine was developed in the first place? Why are any machines that serve little purpose developed and created? Why are engineers accepting of creating work that fails? Pacey's framework will now be applied to analyze engineering values and discuss these questions in the next section of this paper.

Discussing Pacey's Framework and Failure in Engineering

Pacey's framework establishes how all engineering practice relies on three underlying motives: working towards accomplishment, working towards financial gain, or working towards the benefit of others. In Pacey's table, he uses the terms, "Virtuosity Values", "Economic Values", and "User or Need Values" to further highlight these three categories (Pacey, 2005, pg. 102). Essentially, Pacey discusses how all engineering work falls into these three sections and attempts to discover why engineering practice is done. An example that would fall into each category according to Pacey's table, which is shown below in Figure Two, would be heart transplant surgery for virtuosity values, drug manufacture for economic gain, and nursing for user or need values (Pacey, 2005, pg. 102).

TABLE 5 Three sets of values involved in the practice of technology

	Virtuosity values	Economic values	User or need values
Exemplars	adventurers (Odysseus), smiths, warriors	merchants, working men	women (Athene, Penelope)
Applications	tractor driving high technology (aerospace, weapons) ——— heart transplant surgery	cash cropping production engineering food technology drug manufacture	gardening craft work, appropriate technology cooking, handmilling childcare, primary health work, nursing
Priorities	pursuit of the technically sweet mastering natural forces extending frontiers	pursuit of profit managing a workforce economic growth	maintenance, subsistence care for people, care for nature stability
View of technology	construction for prestige value	construction, production for exchange value	management of process: use value
Typical evidence of 'progress'	improving performance (figures 3 and 5)	increasing GNP	falling infant mortality (figure 7)
Attitude to risk	risk as challenge; offset by fixes	risk balanced by potential gain	risk avoidance and prevention
Views of creativity	innovative, adventuring, unrestrained	equated with enterprise	tempered by responsibility
Cross references: Table 3 Figure 6	 technical fix expert sphere	 economics expert sphere	 bio-economics user sphere

Figure 3: Pacey's Table of Values (Pacey, 2005, pg. 102)
This table outlines the three major types that all engineering work falls in according to Pacey

Figure 3 clearly highlights the different main categories of the values table, and also has some other examples that Pacey discusses. One important note to make about this framework is that many projects will fall into multiple categories. There is very little work that would only apply to financial gain, or only serve to meet a need without considering finance or being technologically interesting. This means that while many creations will primarily fall into one category, the other two must still be considered when the engineering process is being completed.

Creating the Failure Spectrum

When looking at the question of why engineers are accepting of failure, there are multiple viewpoints that can be addressed. Primarily, engineers are able to learn from failure and make improvements on designs and machinery through failure. The article done by Florida State University highlights the importance of this concept as the first example that it brings up is the Tacoma Narrows Bridge. The article discusses how and why the engineers failed, being that the calculations used were for a much smaller bridge and the engineers did not realize that they were unable to scale calculations up linearly with three dimensional structures, and how this failure can now be used by any bridge developer in the future (Florida State University, 2022, Tacoma Narrows Bridge). While this is an important understanding, there are and will always be times when failure is not an option for engineers as lives are on the line. Failure will always be used as a learning experience, but no one desires to fail when they know the extent as to what the cost of their failure could be. When thinking about this topic, "acceptable" failure can be looked at as a spectrum, illustrated in Figure 4.

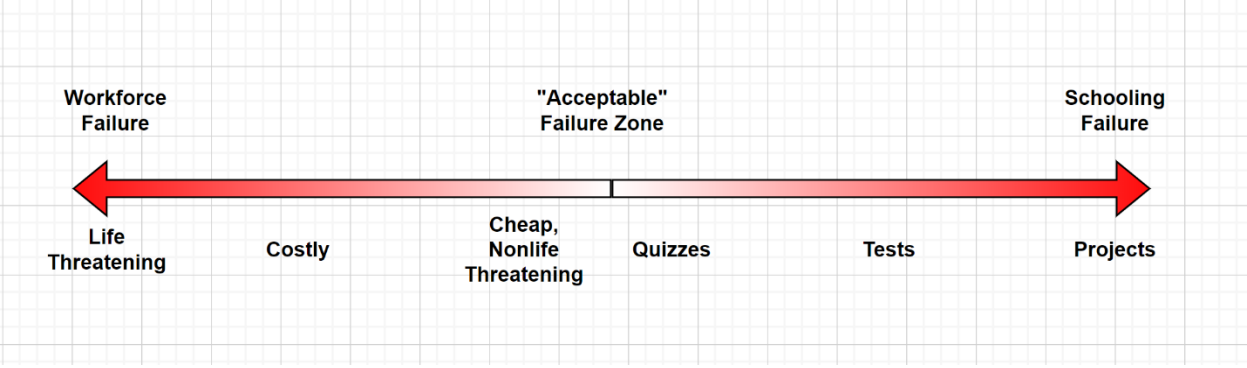

Figure 4: An Outline of the Failure Spectrum (Created by Author)
This figure outlines the failure spectrum that is discussed, which highlights the two types of unavoidable failure.

This spectrum highlights how there are two distinct types of failure that typically occur in an engineer's lifetime, especially from the perspective of a current student: failure in school and failure in the workforce. Failure in the workforce with respect to this discussion means a project

or task that resulted in failure in the end for the engineers that completed the work. In both cases, failure ranges on a scale where there are smaller projects where failure can occur, and an individual will be able to learn from the experience and little harm will come from it, such as a quiz in school or a small side project in the workforce. However, as the cost of failure increases, there are times when it is not acceptable. A semester long project would not be acceptable to fail, and in the case of many real work projects, failure will lead to the loss of life. A prime example of this would be the crash of two Boeing 737 aircraft, which led to the deaths of 346 individuals. This arose from not only a failure of the sensor systems that were implemented in the system that was not addressed, but a failure of management and the system in place throughout the company as well (Cusumano, 2021, para. 17). A critical error in the sensors was detected, but the company chose to ignore this rather than reporting it to try and save money, which eventually led to two planes crashing. Making this important distinction between when failure is acceptable and when it is unacceptable is critical to understanding the situation. It leads to the conclusion that engineers are accepting of failure because it is inevitable, but in certain scenarios, it must be avoided at all costs. With these two structures in place, conclusions and results can be drawn to further answer the two questions of why engineers are accepting of failure and why engineers make machines with little purpose.

Applying Pacey's Framework and the Structure of Failure

When discussing the launcher itself, it has already been established that it does not achieve the primary purpose it was intended for. However, it is important to look at all of Pacey's values to understand why creations like this are still important. First, the virtuosity lens will be utilized. Pacey's table in Figure Two highlights the main priorities of the virtuosity lens being, "pursuit of the technically sweet," "mastering natural forces," and "extending frontiers"

(Pacey, 2005, pg. 102). There is little argument to be made that the dog ball launcher is mastering natural forces or extending frontiers, however; a discussion could arise about the first topic. Obviously, the machine is not extremely advanced technology, but for a capstone project with a small group, it was perceived as an interesting idea that would be very fun to complete. This does mean that the machine itself fits the value of virtuosity based on that lens. This provides at the very least, one reason why the machine's creation is important based on Pacey's framework despite not achieving its primary purpose.

Next, the economic lens will be touched on to understand the relation of the launcher to Pacey's economic values. The priorities of this lens revolve around the following, "pursuit of profit", "managing a workforce", and "economic growth" (Pacey, 2005, pg. 102). Clearly, the launcher does not fit into any of these values. While it could be possible for it to be marketable in the future, this was not at all the primary intention, and it will not be commercialized as a general product. Finally, the last lens is user or need values, and the priorities are, "maintenance, subsistence", "care for people", "care for nature", and "stability" (Pacey, 2005, pg. 102). With relation to this section, it is clear that the initial purpose of the machine was to care for dogs and to try and improve a situation for these animals. However, it failed in this regard and was unable to achieve any of these goals.

Overall, the launcher answers the question of why something should be created even when it fails its primary purpose. Despite the fact that the launcher intended to provide a need for animals and failed, it still applied to the pursuit of the technically sweet. As long as an individual or group are passionate about their work, this will always apply, and individuals will always be able to create projects that have an underlying purpose.

The Launcher with Respect to Failure

The launcher fit the critical failure section of the spectrum that was created in Figure 3. It was not an option for our group to build a dysfunctional capstone project. However, it was conceivable that the launcher, as previously assessed, could fail at its intended purpose. As an understanding of the main cause of separation anxiety and primary form of treatment has been established, it leads to the conclusion that the launcher was doomed to fail at this purpose from the beginning. This provides future engineers with documentation into a nonlife threatening failure where they will be able to learn from our work. These two points provide both a benefit and a limitation of failure to engineers. Obviously, if our project failed, we would not have passed the class. This could not happen and illustrates that in some situations engineers are not accepting of failure. However, the machine functioning but failing its primary purpose still benefits engineers in the future as they will be able to learn from the mistakes that were made and create a solution that will focus in on the problem.

The Engineering Process with Respect to Pacey

Pacey's framework elucidated how any engineering creation will always have some form of a purpose based on his three lenses. With this in mind, designing and implementing a project using Pacey's values and focusing on the specific purpose the project is trying to solve may provide some insight into how the engineering process should flow throughout each step and what should be emphasized. For example, three projects that clearly focused on different lenses of Pacey's framework would be the space race, Wall Street coding applications to analyze the stock market, and healthcare technology like an EKG system, which all satisfy virtuosity, economic and user or need values respectively. The space race was worked on through the ideology of fighting for what is right for an individual's country and a sense of pride with Davis (2021) stating, "American citizens regained confidence that they belonged to the 'superior'

nation" (Davis, 2021, para. 17). Wall Street software applications are typically created for individual financial gain as seen in a quote by Rayome (2018), "By better understanding coding, our business teams can speak the same language as our technology teams, which ultimately drives better tools and solutions for our clients" (Rayome, 2018, para. 6). Finally, medical applications are developed solely to help others and to meet a need with Skinner (2021) arguing, "The use of technology increases provider capabilities and patient access while improving the quality of life for some patients and saving the lives of others" (Skinner, 2021, Quality Care Through Health Information and Technology). Each one of these fits a completely different category of Pacey's framework.

By understanding what lens the project fits in, an individual will be able to shape the engineering process to best suit the needs of their work. For example, the EKG system was designed to help doctors and patients. When designing the system, engineers would want to utilize the framework to understand that their technology is designed *for doctors and patients*, which might make them emphasize the research phase much more and include extensive interviews with stakeholders to ensure that the technology is properly meeting the need and problem. Moreover, once the device is finished, they might want to try and cut down prices as much as possible as they know that the project is helping people save lives and continue extremely important work. On the other hand, something that is developed for pure financial gain, like the Wall Street code, may not consider the thoughts of others as much. While it is important to consider the ethical ramifications of any technology that is created, a business would design something for financial gain with the sole purpose of benefitting the business. There may be much more extensive work in the backend of the engineering process, focusing on how to market and cater the design to what the customers want and how to be as cost-effective as

possible with the design itself. Rather than emphasizing quality, the engineers may seek to use cheaper materials to try and shave down the cost as much as possible. Finally, an ambitious project, like the projects amidst the space race, done for the sake of technological advancement may put much more emphasis on the design phase of the engineering process, attempting to unlock new ideas and intuition leading to much less practical and cost-efficient items. Understanding all of these factors would lead to a much deeper knowledge of the engineering process itself.

If an individual were to understand what section of Pacey's framework their project lay in, they would be able to know where they may have shortcomings in the engineering process, such as not gathering enough information from the stakeholders or spending too much money on reducing costs. It would be much easier to recognize that they are cutting corners to save money when they have the understanding that their project is solely to try and make as much financial gain as possible for their corporation, or that they are creating something that may be too extravagant and difficult when they are simply trying to achieve the unachievable. Applying this concept to the launcher yields a similar result. The launcher's location in Pacey's framework was to satisfy a need, being that of the dog's, to try and alleviate a medical condition. If this were understood better, our group most certainly would have emphasized understanding the problem and the stakeholders to try and create the best solution possible. This would have led to us finding the research presented here and acknowledged that our current implementation would not alleviate separation anxiety and make changes to the design itself.

The Engineering Process and Failure

When discussing failure and the engineering process, the spectrum must be kept in mind to attempt to understand the actions of engineers. The engineering process is inherently cyclical,

and Pacey's framework gives meaning to any failure that occurs as it will later provide a user with a need as they learn from the shortcoming of the initial design. A prime example of this is the sinking of the Titanic and shipbuilding in general. With this specific example, Petroski (2012) argues, "Imagine that the Titanic had not struck that iceberg,… That would have just reinforced the misconception that it was unsinkable. And every time it went across the Atlantic, it would further confirm that hypothesis" (Northwestern, 2012, para. 5). If the Titanic never sank, millions of ships would have been built to model its design, which would have possibly led to more crashes and issues as the flaws the Titanic had would not have been found until it had been mass produced. Since the Titanic did sink and a massive failure occurred, engineers recognized critical flaws that were made in the design and improved ships in the future to meet those problems. With the spectrum in mind, the Titanic would fit in the scenario where failure is not an option for the engineers, as hundreds of lives were lost. Yet, like Petroski brings up, if the Titanic had not failed, hundreds of thousands of lives could have been lost as all ships would follow in the Titanic's footsteps. Failure in engineering is a tricky tightrope that must be navigated wisely, and any engineer should do their best to avoid it, especially when lives are on the line. But there is no denying the cyclical nature of the process, how failure will eventually provide purpose to anything as it will be used later on as a learning experience, and failure inherently breeds success.

Limitations

There are multiple limitations to applying these methods in this way. The primary one regarding Pacey's table of values to better understand the engineering process lies in the fact that most engineering projects have numerous purposes and will fit in all of the categories. In these cases, the model would not provide much information towards benefitting the engineering

process except emphasizing all aspects of it as each section is highlighted. Rather than being able to focus in on any one section, gathering the conclusion to emphasize all sections of the engineering process no matter what does not shape the process to your project, it just emphasizes everything about it. Regarding the failure spectrum, when using this spectrum to think about failure, it may foster the mindset that failures that are not "critical" on either side, are okay to occur. While this is true, engineers should still strive to not fail as much as possible. Developing a mindset that accepts failure and is nonchalant about it occurring is not healthy and could have drastic results if this mindset develops in nonlife threatening projects and translates over to life threatening projects. Failure should always be avoided at all costs but having the mindset of knowing it is inevitable and is a great learning tool is healthy.

Conclusion

A greater understanding of the main cause of separation anxiety and the typical treatment revealed that the automatic dog ball launcher itself would not be a good solution to the problem that it sought to solve. However, Pacey's framework provided some insight as to why projects, like the launcher, which do not achieve their primary purpose are still important. This information led to a discussion about the importance of all engineering practice and work, and why engineers are accepting of failure in the work that they complete. When Pacey's framework was applied to engineering practice at large, it elucidated how the engineering process may change on the category that the project best fits in and provided the knowledge to tackle these issues. A virtuous and ambitious project would have different focuses than an economic one solely for profit. Finally, failure is inevitable, but it will eventually lead to success as engineers are constantly learning from past mistakes to improve on their work and create the best products possible.

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