Scope of Work

Presented by:

Ethan Clark, Alec Stonehouse, Mitch Anderson, Omeed Ostry

Sponsor: Tony Emanuel   Advisor: Dr. Elghandour

October 18, 2022

Abstract

The purpose of this document is to highlight current research, main outcomes, and goals that the team has in order to create a stabilized light for recreational use. The objective of this project is to take a light and stabilize it when attached to something that is moving. This could include someone running, biking, or hiking with a headlight, or a light attached to a bike. The team's goal is to create a stabilization system while using an optimal light that can be purchased. If time and funding permits, it would also be beneficial to create a mounting system as well. The primary goal of this project is to create a stand-alone bike light with a damping system and light built in. This document highlights the current research that has been done along with a plan on how to successfully deliver a product that meets the needs of the sponsor and customers. This will include current solutions that can inspire design choices for the final product along with analysis of challenges that may be faced throughout the design, manufacturing, and testing processes.

Table of Contents

1.0 - Introduction

The project sponsor, Tony Emanuel, has provided a mission to create an innovative solution to an issue he believes many hikers, runners, bikers, and campers are facing. The average headlamp/bike light is typically worn or mounted in such a way that rigidly connects the light source to the user. This may not seem like a problem to most people but for frequent headlamp/bike light users, the problem arises with the stability of the light source. When being worn, the light will mimic every movement, impact, and vibration that the user or bike experiences so the light from the headlamp or bike light will be very shaky and vibratory, making it less effective in lighting a path.

The task is to develop a mechanism that can stabilize this light source throughout several types of movement and impacts. The team responsible for this challenge, Stable Light, is comprised of four intelligent mechanical engineer students that are motivated to find a new solution and are excited about design; Ethan Clark, Alec Stonehouse, Omeed Ostry, and Mitch Anderson. The following report is presented with the intention of defining the complete scope of the project, including who will be the target consumers, the requirements provided by the sponsor, details about the existing patents and light products that cover parts of the solution, the goals that are hoped to be achieve, and the plan for the rest of the design process.

The background section contains the bulk of the research that has been done on the stakeholder's wants and needs, the existing products and solutions, and the technical challenges involved with the problem that has been presented.

The project scope portion visualizes the bounds of the project and which components of the light the team is going to be designing. This section will explain the functions that will be incorporated in the design, and the physical deliverables that are to be returned to the customer at the end of the process.

The objective section defines the official problem statement and the main goals for the project. It also attempts to explain the research and scope definition process by discussing the different activities we participated in that helped organize the priorities for this project.

The project management section is all about the envisioned design process and the plan to be followed as this process moves along. Here, the methods for product development and the possible design approaches will be outlined. This will also include the key milestones along with the expected completion dates.

All references and supporting documents will be located directly following the end of the report in order to provide extra information about the intended process and research.

2.0 - Background

2.1 - Stakeholders' Wants & Needs

The initial action for gathering research commenced with the first meeting with Tony Emanuel, the project sponsor. This was quite necessary to begin the research for the project for several reasons, and the primary reason was that we needed a better understanding of Mr. Emanuel's vision. He began by explaining his first-hand experience with the problem while on a camping trip, and the issue was the rapid motion of the headlamp being a bother to his vision. From this experience, Mr. Emanuel has broadened the scope to see what other markets could be targeted with the product he is envisioning. This initial meeting with Mr. Emanuel set the tone for the project, and it got the wheels spinning in the team's minds.

After the initial meeting, a short list of potential users and markets that could possibly be interested in the product was created. These included outdoorsmen, cyclists (mountain and road), miners, athletes, mechanics and technicians, and commercial fishermen. One thing that all of these groups have in common with the project was the presence of continuous movement in their work while using some type of light. After conducting several interviews, lots of useful information surfaced, including users' opinions on the usefulness of the ideal future product. The most important questions that were asked were: How frequently is a light used while active? Does the rapid movement of light bother while in use? Are the lights ever effective enough to provide safety and sufficient visibility? What is the highest price you are willing to spend on an obviously superior product? The importance of these questions was to really get a better idea of where the design direction will go and to ensure that the design is prioritized to the market in most need of a solution.

This issue of deciding which market will be the primary target has really presented a challenge, and because of it, the team has benefitted from many of these interviews. This showed that the design direction should be primarily to create a design that could be applicable to virtually all these markets. This can be done with lots of testing, which is where the vibrations lab will come into play. The goal is to take into consideration all of the people that were interviewed and design shake table tests to mimic the movement of their work. For example, for mountain bikers, a common mountain biking terrain with a higher amplitude, lower frequency, and random variation could potentially be modeled. The product would need to dampen vibration primarily in the pitch and yaw of the light. Then, for someone like a fisherman, there is constant motion and high amplitude as well, thus the tests would need to mimic this situation and see what other effects the motion of the moat might have on the light direction.

The next steps in the background research are quite extensive. The significance of determining what exactly the direction of design will be is most critical in the matter of whether the team will pursue a totally mechanical solution, or also try out devices like IMUs (Inertial Measurement Units). Once this is determined, soon after the Scope of Work document is released, the team will be able to dive deep into the design ideas and prototyping. Prototyping is going to be a crucial aspect to this project, and it should be cost efficient as well.

2.2 - Existing Products/Solutions

The bulk of the research regarding the existing products and solutions has come from internet searches of headlamps and bike lights as well as going to outdoor stores like REI and testing out products they have in stock. The team was able to conduct a few interviews with friends that ride bikes and use headlamps often. This was the better mode of collecting information since the team could really break down the problem and determine which components need the most attention. A mountain biker that was interviewed and does a lot of night riding said, “The bike light I currently use is pretty bright but when I’m trail-riding it does make it harder to focus on the trail”. Doing online research of the existing products was helpful when it came to comparing the features of each product and relating the features to the different price points. This research provided the basic features that the end product should contain in order to compete with the existing products.

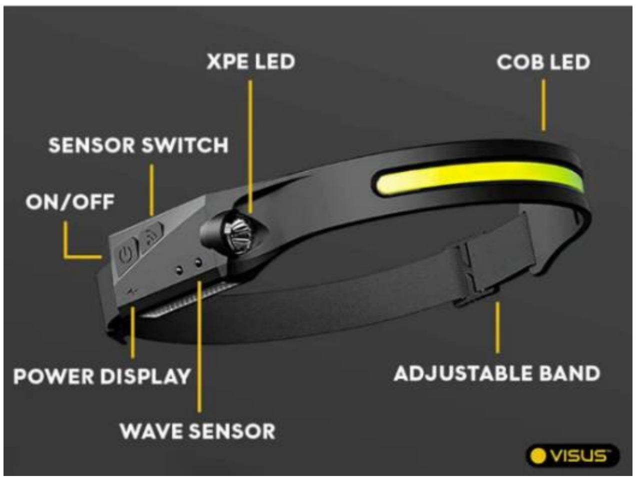
Currently there are no products that solve the problem being tackled since no products can stabilize or dampen the impact and motion inputted by the user. Most headlamps on the market are very similar as they all have a different band that mounts to the user’s head, multiple LEDs in various patterns, and differing power supplies and lumen ratings. There seems to be a range of products stringing from cheap Amazon options like the DanForce Headlamp [1] for $40 all the way to the Ledlenser H19R [2] from REI for $400 that has the same exact features but different levels of quality.

DanForce Headlamp ($40) [1]

LEDLenser H19R ($400) [2]

The product that attempts to solve part of the problem is the Visus LED Headlamp [3] which illuminates 230 degrees of light around the user effectively reducing the shakiness of the light since the edges are further out of view. The lack of effort towards stabilizing the actual light does not help the team in the design aspect but will help the sponsor in the marketing aspect since the product, if successful, will be the first of its kind. The bike lights that currently exist are also very similar to one another, the variety lies within the mounting and the span of light that it portrays. The bike light would be an easier option to stabilize since the mounting has more room for stabilizing mechanisms whereas the headlamp will require a much smaller stabilization mechanism or an awkward mounting option. Also, a decent amount of research on passive damping using magnetic fields has been done and there seems to be a lot of information about magnets reducing the vibration of structures. Specifically, the research has been regarding eddy currents and how they play a part in damping oscillatory motion. This could be a great application for magnets since very small magnets can be obtained and the damping can be fine tuned using different strength magnets or possibly hydraulic dampers.

The team still needs to interview more people because it was difficult to find people with enough time to do full interviews, so the plan is to interview professors for their opinions on the subject matter and hopefully gain more design ideas and damping options.



Visus LED Headlamp ($35) [3]

Petzl IKO Headlamp ($100) [4]

BioLite HeadLamp 330 ($60)   [5]

Light & Motion Seca 2500 ($400) [6]

Specialized Flux 1250 Headlight ($140) [7] **VIS 1000 Trooper Bike Light ($60) [8]**

Figure 1: Existing Products/Solutions

2.3 - Technical Challenges

When initially researching the project, it started with searches that would involve stability in cameras. The thought process was that there is already technology that can be applied to a camera or to a camera mount that allowed for photographers or videographer to have a clear shot. The team found that many of these cameras were using a three-axis gimbal system. While a gimbal was a wise solution for the troubles, we found that not all of them are strictly mechanical systems. Most of them are using miniaturized motors to counteract sudden movements. Lots of research went into understanding how a gimbal works.

The team then broadened the research and investigated other systems that are used to stabilize systems such as gyros. Gyros were used on a slightly larger scale to counter act large forces against objects such as boats. This prompted an idea to investigate ways that damping could be used to absorb the shock from sharp movements. The challenge with the damping will be to find a suitable material that can fit into or on a light frame or mount and still allow for enough shock resistance.

In references [9] through [11], research was active-passive magnetic dampers, which are often referred to as Eddy current dampers. What seems to be convenient for how these are implemented is that its damping effects can be extremely effective, and the damper can be very scalable. However, the first step is to learn how to make this type of damper and mount it properly to the design. For example, when riding something like a mountain bike, you experience large impulses, which eddy current dampers could potentially reduce to nothing.

References [1] through [8] are all “existing solutions”. There is a large variety of head lamps and bike light, but the problem with all of them is that none of the achieve what the team is trying to do. They all just cast a light that has a limited amount of stability and will be shaky for any of the stakeholders who use them.

The references [14] through [18] are about gimbals and how they work. They talk about different applications for them and go into the science behind them. As mentioned before, most of them have three different axes called the pitch, roll, and yaw. These all work together to combat any unwanted motion in the system.

The first five relative patents, [25] to [29] are all about gimbals that can be applied to a system like the problem at hand. They are all based on the application of a camera. By replacing the camera with a light, it would cause it to stabilize. These are all ideas that could be purchased on their own then constructed to a preexisting light, or they can be used to help create something that incorporates different applications from each other.

Source [19] and [20] are about gyroscopes and how they are commonly used in aircraft and boats. The ones used in compact cameras use sensors to detect movement and trigger a command for the camera to counteract that movement to keep the frame steady. This uses lots of power and is not the ideal mechanical system. If you refer to [12], the exoskeleton designed to reduce firearm impulses could help us begin to understand the use of gyroscopes in current designs. These impulses of the firearms are a similar input to what a mountain biker or long-distance runner would experience. Thus, by continuing to learn about the implementation of the exoskeleton design, the team can hopefully take some ideas from the article for ideation processes.

As of now the next step is to dive deeper into further research of dampening and find the best possible solution that can be applied to a light that already exists. StableLight will use different materials and test them on a vibration table to see the different effects they will have on a light source. Reference [13] mentions a passive-damping material made of elastic and magnetic particles that could potentially be of use to current prototypes. Testing materials like these will be critical to design iterations, and if the material tested in [13] is not compatible, then research will continue.

3.0 - Project Scope

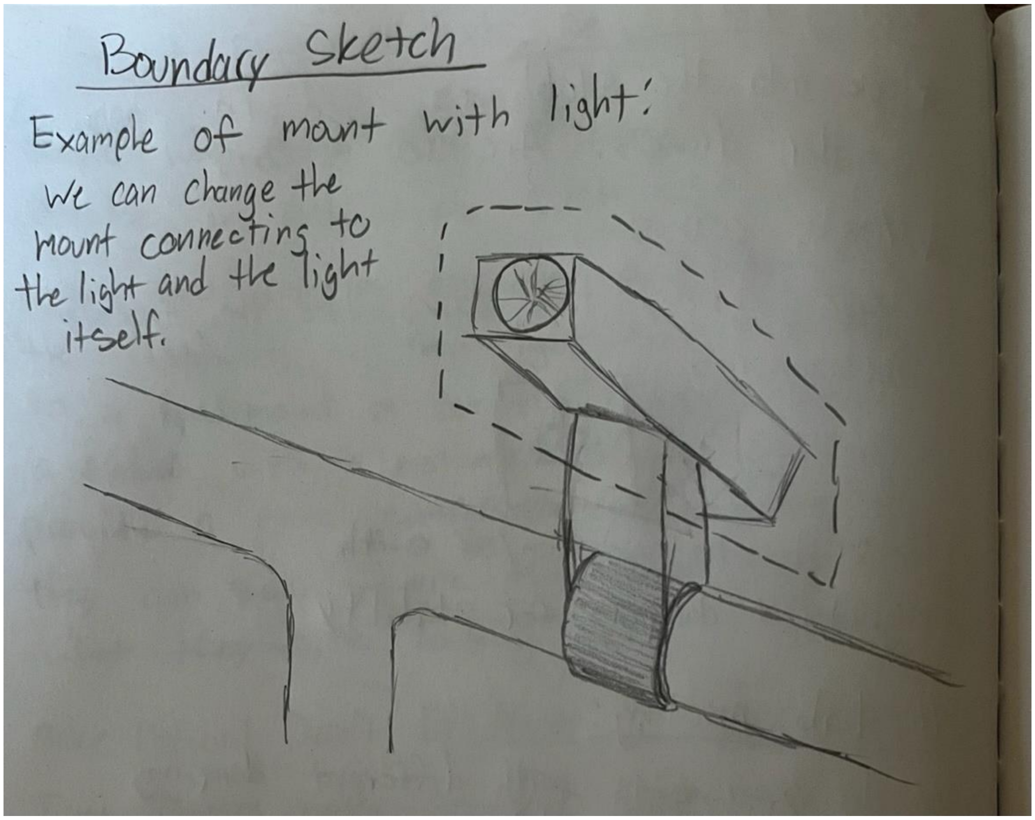


Figure 2: Boundary Sketch of the Intended Scope

For the boundary sketch the team chose to model the mounted bike light. This was just to make it a bit clearer about what exactly would be modified. To have a stable light the team will modify the mount that connects to the light and the light itself.

3.1 - Stakeholders' wants & needs

The main priority of the stakeholders is to have a stable light that will not shake when it is on their head or on their bike. Ideally the product would be fully mechanical, even though there are electrical/ automated systems available. A fully mechanical system would be recommended because it would not draw power from the battery to stabilize the light and it would bring the overall price down, which would create a cheaper product. Because the market is for mostly people who spend their time outdoors it will need to be weather resistant and have universal mounting- the ability to mount to a bike, helmet, etc. Along with a self-centering light, it would need to be strong enough to not break if it would fall from someone's head or off the front of someone's bike. For the actual light itself it needs to have a strong, directed light that campers or bikers could feel comfortable always using. A strong light will require a strong battery. This battery will need to last a minimum of three hours.

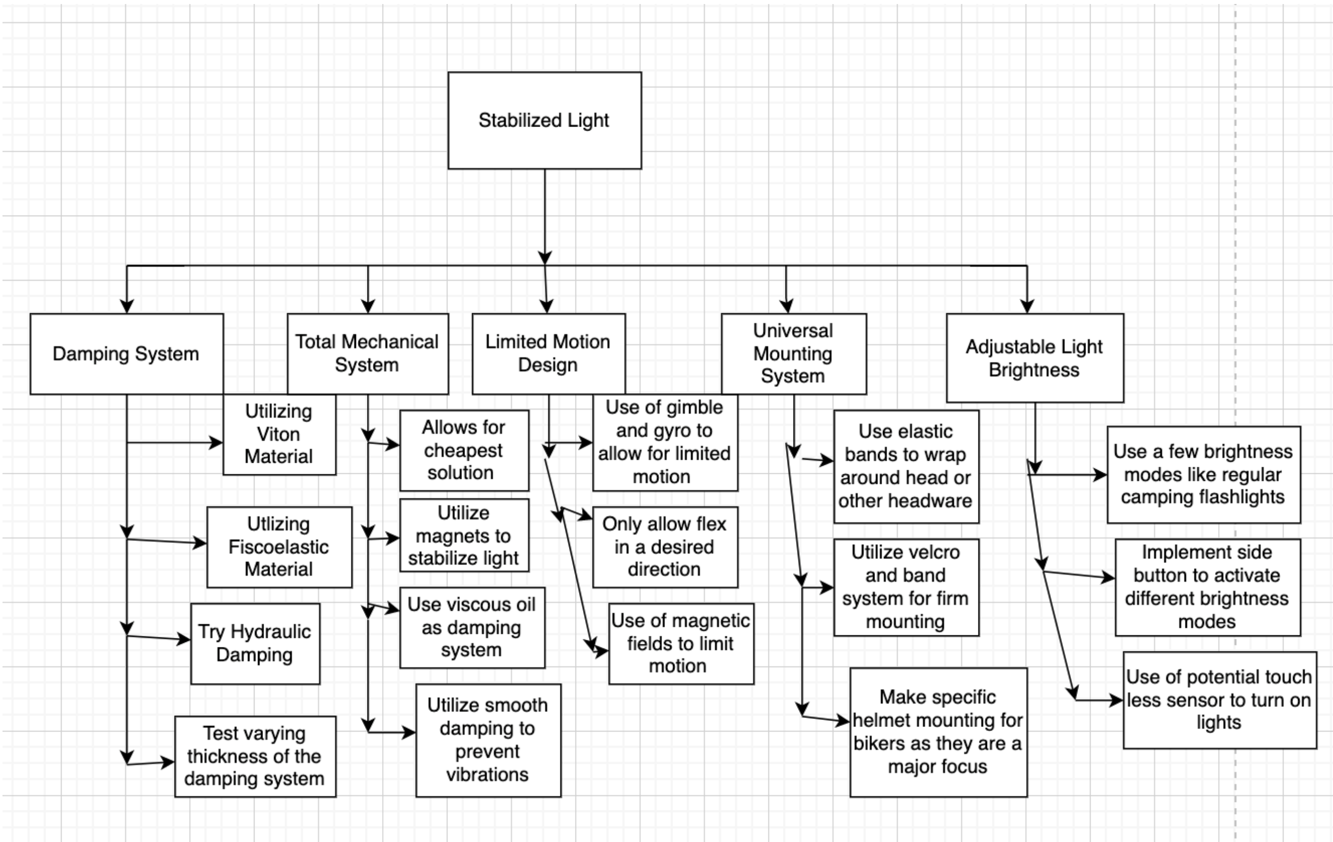


Figure 3: Functional Decomposition Diagram

The design needs to have a damping system that is totally mechanical, utilizes a gimble and gyro that is testable with optimal light. The design should be able to withstand the shaking force of a runner when their foot hits the ground, when a mountain biker hits rocks on the path, or when a fisherman hits a wave. This means that when the light encounters a force it will not shake. Additionally, the use of a completely mechanical system will decrease cost for manufacturing and allow for more profit. The design should have a gimble and gyro to allow for motion in desired direction while restricting motion in other directions. Additionally, it should be able to withstand a shake test and have enough brightness to illuminate 200 feet ahead of the person.

3.2 - Expected Outcome

By the end of this process, the team hopes to deliver a fully functional prototype that stabilizes a light and responds appropriately to input motion. This prototype, however, may not be as small as it was planned to be since incorporating a stabilizing mechanism that is on the headlamp scale would be quite expensive and difficult to manufacture in comparison to a slightly larger model that encompasses the same mechanism. The team also plans to deliver shake table test data that shows the damping of the system and determine the maximum and minimum loads required to initiate the stabilizing effect so that the prototype can be properly scaled if it ever needs to be manufactured at the correct size.

4.0 - Objectives

4.1 - Problem Statement

People who often like to be outdoors and partake in activities such as hiking, biking, and camping encounter a problem with the instability in their light fixture attached to a head/ bike mount. Ideally, a product or fixture that provides motionless/ stable light would give people a more comfortable environment so they can properly see where they are going and what they are looking at. This can be achieved by testing existing products and seeing how they differ when different variables are added. These variables can/ will include different materials for passive or hydraulic damping, gimbals, gyros, and possibly a system using magnets with a fluid base damper.

4.2 - QFD Process

To ensure the team is on track to deliver a successful product it is important to clearly define specifications in the product. These specifications are directly related to the customers' wants and needs. One of the biggest concerns is considering the voice of the customer and making sure that their priorities are met. Therefore, the team has taken the time to meet and understand the needs of the sponsor while also interviewing other stakeholders. By referencing the House of Quality (HOQ), current priorities are: self-centering, non-shaking light, lightweight, having the light be strong and directed, water resistant, cheap to manufacture, has universal mounting, is shock resistant, and has a long battery life. The importance of each priority was determined through stakeholder research, which is incorporated in the HOQ. Additionally, what drove the quality for design (QFD) was making sure that the specifications aligned well with customer requirements. A big part of this process was making sure that the product is durable and functional. Therefore, product characteristics have big importance on passing several tests such as shake tests and drop tests. A focus of the project is to make sure that a unique product is delivered that is better than another competitor on the market. Hence, extensive research into current designs has been made. Lastly, the team weighed the importance and technical difficulty of ensuring each specification has been met.

Table 1: Engineering Specifications Table

Spec Number	Specification description	Target Requirement	Tolerance	Risk	Compliance
1	Distance Illuminated	200 feet	Minimum	L	T
2	Weight	1 lb.	0.5	M	I
3	Cost to Manufacture	$50	maximum	H	A
4	Ease of Use	Easy	NA	L	T
5	Drop Height	6 Feet	max +1 foot	M	T
6	Max Biking Speed Stabilized	20 mph	5 mph	M	T
7	Max Running Speed Stabilized	10 mph	5 mph	M	T
8	Deflection/ Time to Stabilize	45 degrees/ 0.25s	0.1 s	H	A
9	Water Resistant Depth	5 Feet	1 foot	M	T
10	Battery Life	4 hours	0.5 hour	L	T

Legend:

Risk – (H) High, (M) Medium, (L) Low

Compliance – (A) Analysis, (I) Inspection, (T) Test

5.0 - Project Management

The benefits to the project and prospective designs are that prototyping should be low cost and all testing can be done on campus. Thus, the team will be able to learn most efficiently through prototyping due to vastly different designs. For now, two primary ideas are to either utilize an IMU with a gimbal [22], which has been extensively researched, or create a entirely mechanical solution using dampers, magnets, and bearings. Using references [21-24] on IMU stabilization, this technology could be used, but it would be much more expensive and be a bit out of the skill range of mechanical engineers. Based on the skillset of the team members and the desired price range of the sponsor, most of the time spent will be attempting to create a mechanical product. However, there is no way to know that this will work, thus, simultaneous research and development into some form of IMU plus gimbal solution will be done as well.

Table 2: Milestones to hit on the way to a final product.

Deliverable	Description	Due Date
Scope of Work (SOW)	Defining the problem and direction of the project in a descriptive outline.	10/19/2022
First Design Ideation/Iteration	Create at least one detailed design for a prototype.	11/8/2022
Preliminary Design Review (PDR)	Submission for first review evaluating the state of the project.	11/15/2022
First Basic Prototype Testing Plan	Create testing plan for first prototype/design iteration.	11/29/2022
Critical Design Review (CDR)	Finish presentation and submission for most significant design review.	2/14/2023

In Appendix B there is the project Gannt chart, and this is currently guiding us on the first milestone of completing this Scope of Work. The significance of this chart is to keep each other accountable and on track to ultimately create a good product. The first design will incorporate the use of bearings to restrict rotation about certain axes, magnets to ensure smooth transitions of motion, and dampers to keep the light aiming in the correct direction. Although a totally mechanical solution is desired, part of the design process will be to continue researching as many solutions as possible. There is no way to know which solution is best without enough research and testing, which will remain as the primary design method that will be taken. After this design has been further developed, the team will be able to have it evaluated by advisors and the sponsor through PDR.

6.0 - Conclusion

This is a unique challenge that has been given since there are no current solutions on the market for us to get ideas from which is going to make this slightly more difficult but much more rewarding as this group will have the first headlamp/bike light that is mechanically stabilized. The goal is to design a mechanism that dampens the impact that the user experiences to prevent excessive motion in the light shining from the headlamp/bike light, allowing the user to keep a full field of view ahead. This Scope of Work report is being delivered to present the most up to date research into the problem at hand and the existing solutions, explain the rest of the planned work to come, as well as state what the team believes is the issue to be solved. The existing products are for the most part very similar in that they are all mounted rigidly mounted to the user or bike and contain a few LEDs to increase the appeared brightness and 4-5 light modes, none of which can keep the vibrations in the light lower. The customers that will be attracted to this product are going to want a mechanical, more robust, and cheaper option so electric motors will be avoided to stabilize it. Within the next month the team plans to deliver multiple design ideas and potentially a cheap prototype to portray the general idea of the design.

StableLight would like to finish this report by asking you, Tony, for your approval of the proposed project scope and to continue in the direction detailed above.

References

Existing Products/Solutions

[1] "Amazon.com: DanForce headlamp. USB rechargeable led head lamp. ultra ..." [Online]. Available: https://www.amazon.com. [Accessed: 14-Oct-2022].

[2] "Ledlenser H19R signature headlamp," *REI Co-op*. [Online]. Available: https://www.rei.com. [Accessed: 13-Oct-2022].

[3] "Visus™ led Headlamp." [Online]. Available: https://visuslights.com/products/visus-led-headlamp. [Accessed: 14-Oct-2022].

[4] "Petzl Iko Core Headlamp," *REI Co-op*. [Online]. Available: https://www.rei.com. [Accessed: 13-Oct-2022].

[5] "Headlamp 330," *Biolite*. [Online]. Available: https://www.bioliteenergy.com/products/headlamp. [Accessed: 13-Oct-2022].

[6] "Light & Motion Seca 2500 Enduro Front Bike Light," *REI Co-op*. [Online]. Available: https://www.rei.com. [Accessed: 13-Oct-2022].

[7] "Flux™ 1250 headlight," *Specialized Bicycle Components USA*. [Online]. Available: https://www.specialized.com. [Accessed: 13-Oct-2022].

[8] "Vis 1000 trooper," *Light & Motion | StellaPro*. [Online]. Available: https://lightandmotion.com/products/vis-1000-trooper. [Accessed: 13-Oct-2022].

Journal Articles

[9] Sodano, H. A., Inman, D. J., and Belvin, W. K. (November 3, 2005). "Development of a New Passive-Active Magnetic Damper for Vibration Suppression." ASME. J. Vib. Acoust. June 2006; 128(3): 318–327. https://doi-org.ezproxy.lib.calpoly.edu/10.1115/1.217225

[10] Arif Aksekili, A., and Topaloglu, N. (March 30, 2016). "Design and Experimental Verification of Position-Dependent Passive Electromagnetic Damping." ASME. J. Dyn. Sys., Meas., Control. June 2016; 138(6): 061003. https://doi-org.ezproxy.lib.calpoly.edu/10.1115/1.4032828

[11] Sodano, H. A., Bae, J., Inman, D. J., and Belvin, W. K. (November 3, 2005). "Improved Concept and Model of Eddy Current Damper." ASME. J. Vib. Acoust. June 2006; 128(3): 294–302. https://doi-org.ezproxy.lib.calpoly.edu/10.1115/1.2172256

[12] Baechle, D. M., Wetzel, E. D., and Agrawal, S. K. (September 8, 2016). "MAXFAS: Mechatronic Arm Exoskeleton for Firearm Aim Stabilization." ASME. J. Mechanisms

Robotics. December 2016; 8(6): 061013. https://doi-org.ezproxy.lib.calpoly.edu/10.1115/1.4034015

[13] Liu, J. (March 5, 2009). "Analysis of a Porous Elastic Sheet Damper With a Magnetic Fluid." ASME. J. Tribol. April 2009; 131(2): 021801. https://doi-org.ezproxy.lib.calpoly.edu/10.1115/1.3075870

Gimbal/Gyro Research

[14] Maio, Alyssa, et al. “The Essential Guide to Gimbals.” *StudioBinder*, 24 Mar. 2021, https://www.studiobinder.com/blog/what-is-a-gimbal-stabilizer/.

[15] Admin. “What Are Drone Camera Gimbals and How Do They Work?” *EDrones.review | Read Latest Drones Reviews.*, 21 Mar. 2021, https://www.edrones.review/what-are-drone-camera-gimbals-and-how-do-they-work/.

[16] Ltd, VEEM. “Gyro Stabilizers: How Does a Boat Stabilizer Work?” *VEEM Marine*, 29 Aug. 2022, https://veemmarine.com/gyro-stabilizer/gyro-stabilizers-technology/.

[17] “How Does a 3-Axis Gimbal Work.” *GOGIMBALS*, 14 Jan. 2022, https://gogimbals.com/3-axis-gimbal/.

[18] Han Jin Han Jin is co-founder, et al. “How Does a Gimbal Work: Top Full Guide 2022.” *LucidCam*, 18 June 2022, https://lucidcam.com/how-does-a-gimbal-work/.

[19] YoungWonks. “An Introduction to Gyroscopes, Where Are They Used and How Do They Work? Read This Blog to Know More...” *YoungWonks*, https://www.youngwonks.com/blog/What-is-a-Gyroscope-and-How-Does-It-Work.

[20] “Gyro Sensors - How They Work and What's Ahead: About Gyro Sensor: Technical Information: Information.” *About Gyro Sensor | Technical Information | Information | Epson Crystal Device*, https://www5.epsondevice.com/en/information/technical_info/gyro/.

Stabilization Research

[21] “Adi: Inertial Measurement Unit (IMU)-Based Stabilization.” *ADI: Inertial Measurement Unit (IMU)-Based Stabilization | Analog Devices*, https://www.analog.com/en/education/education-library/videos/6107196218001.html

[22] Auysakul, Jutamanee, et al. “A Hybrid Motion Estimation for Video Stabilization Based on an IMU Sensor.” *Sensors (Basel, Switzerland)*, MDPI, 17 Aug. 2018, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6111248/.

[23] Corrigan, Fintan. “Drone Gyro Stabilization, IMU and Flight Controllers Explained.” *DroneZon*, 6 Nov. 2020, https://www.dronezon.com/learn-about-drones-quadcopters/three-and-six-axis-gyro-stabilized-drones/.

[24] “Deep Online Video Stabilization Using IMU Sensors.” *IEEE Xplore*, https://ieeexplore.ieee.org/document/9681170.

Related Patents

[25] “US9998669B2 - Camera Gimbal.” *Google Patents*, Google, https://patents.google.com/patent/US9998669B2/en?q=camera%2Bgimbal&oq=camera%2Bgimbal.

[26] “KR101617808B1 - Installation for Helicam Gimbal Having a Function of Controlling Center of Camera.” *Google Patents*, Google, https://patents.google.com/patent/KR101617808B1/en?q=camera%2Bgimbal&oq=camera%2Bgimbal.

[27] “US10228609B2 - Camera Gimbal Mount System.” *Google Patents*, Google, https://patents.google.com/patent/US10228609B2/en?q=camera%2Bgimbal&oq=camera%2Bgimbal.

[28] *Google Patents*, Google, https://patents.google.com/?q=camera%2Bgimbal&oq=camera%2Bgimbal.

[29] “WO2021020617A1 - Gimbal Camera Device.” *Google Patents*, Google, https://patents.google.com/patent/WO2021020617A1/en?q=camera%2Bgimbal&oq=camera%2Bgimbal.

Appendix A: QFD- House of Quality

Correlations	
Positive	+
Negative	−
No Correlation	

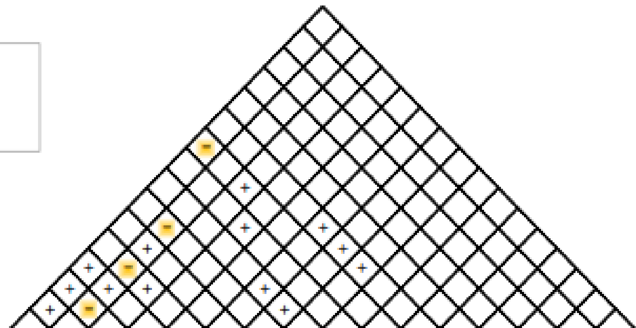
Relationships	
Strong	●
Moderate	○
Weak	▽

Direction of Improvement	
Maximize	▲
Target	◇
Minimize	▼

QFD House of Quality

Project: ___Stable Light_______________

Revision Date: __________________



								Column #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16					
WHO: Customers								Direction of Improvement	▲	▼	▼	▲	▲	▲	▲	◇	▲	▲							NOW: Curr. Products				
Row #	Weight Chart	Relative Weight	Bikers	Runners	Campers	Fisherman	Maximum Relationship	WHAT: Customer Requirements (Needs/Wants) / HOW: Engineering Specifications (Tests)	Distance Illuminated	Weight	Cost to manufacture	Ease of use survey	Drop Test Height	Biking speed stabilized	Running speed stabilized	Deflection/Time to stabilize	Submerge test	Hours Battery Lasts	Shake Table Test						Palawalk Strip Headlight	Energizer X400 Bike Light	Petzl IKO Core Headlamp	VIS 1000 Trooper	Row #
1		10%	8	6	5	5	9	Self Centering				○		●	●	●			●						2	1	0	1	1
2		11%	5	7	8	6	9	Non-shaky light	▽	▽				●	●	○			●						2	3	1	1	2
3		12%	7	9	7	6	9	Lightweight		●	○														9	8	9	6	3
4		13%	8	7	8	8	9	Strong Directed Light	●																9	7	7	7	4
5		9%	4	4	6	9	9	Water-Resistant			○						●								8	9	6	9	5
6		10%	7	6	5	6	9	Cheap $$		○	●														9	9	4	7	6
7		7%	7	2	2	8	9	Universal Mounting		▽	○	●													4	3	6	6	7
8		8%	7	4	3	6	9	Shock Resistant				▽	●												6	2	4	4	8
9		11%	7	5	7	9	9	Battery Life	○	○	○							●							5	4	6	4	9
10		10%	9	6	4	6	9	Secure Mounting		○	○	●							●						4	5	7	6	10
11		0%																											11
12		0%																											12
13		0%																											13
14		0%																											14
15		0%																											15
16		0%																											16

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
HOW MUCH: Target Values	200'	1 lb	$50	Easy	6'	20 mph	10 mph	45deg/.25s	5'	4hrs						
Max Relationship	9	9	9	9	9	9	9	9	9	9	9					
Technical Importance Rating	157.4	217.6	235.5	191.4	70.74	183.7	183.7	119.2	83.01	100.9	273.1	0	0	0	0	0
Relative Weight	9%	12%	13%	11%	4%	10%	10%	7%	5%	6%	15%	0%	0%	0%	0%	0%
Curr. Products: 0																
Palawalk Strip Headlight	9	9	9	8	5	4	4	2	4	9						
Energizer X400 Bike Light	8	7	7	4	5	7	4	3	4	2						
Petzl IKO Core Headlamp	7	8	4	7	6	6	7	3	2	9						
VIS 1000 Trooper	5	7	6	6	6	6	4	3	4	3						
Column #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16

Appendix B: Project Gannt Chart