UNDERWATER AUTOMATION

THE FUTURE OF FOOD

A Thesis Prospectus
In STS 4500
Presented to
The Faculty of the
School of Engineering and Applied Science
University of Virginia
In Partial Fulfillment of the Requirements for the Degree
Bachelor of Science in Mechanical Engineering

By
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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.

ADVISORS

Catherine D. Baritaud, Department of Engineering and Society
Tomonari Furukawa, Department of Mechanical & Aerospace Engineering

Over the years, trends in food have been drastically shifting from the past. More specifically, the type of meat people choose to eat have seen surprising changes. According to the Earth Policy Institute, for the first time in modern history, world farmed fish production topped beef production in 2011 (Janet Larsen, 2013, p. 1). Of the main four meats; poultry, fish, pork, and beef, only fish and poultry have seen upward trends since 1970. (Bentley, 2017, p. 2) This rise in poultry and fish represent something significant, people are willing and able to change their eating habits when given the option. People view white meat and fish as healthier than red meat and studies have shown that red meats like beef and pork have higher levels of cholesterol and saturated fat than white meat. (Why are chicken, fish and beans better to eat than red meat?, 2017, p. 1) There are other factors at play as well, including heavy marketing and advertising to stop the consumption of certain meats. Products such as animal cruelty free and range free foods have also been marketed as a better alternative to traditional foods. To fuel these new appetites, new ways of farming food have emerged. The most innovative of these are aquaculture fish pens. These pens are placed in deep ocean water and anchored to the bottom. Fish pens can span hundreds of feet wide and a thousand feet deep and can house thousands of fish in a stable, growing ecosystem. Fish are grown in the open system until ready for harvesting (Oliver Edwards, 2021, p. 3).

The technical project and STS research project are tightly coupled in this prospectus aimed to address fundamental issues. The objective of the technical project is to create both a surface vehicle and an underwater vehicle that will work together in an outdoor oceanic environment to clean and maintain fish pens. These pens pose a problem of constant maintenance and if to be scaled successfully, these problems must be addressed. Therefore, it is important to understand the current and future trends of food that will make these technologies relevant and abundant. The tightly coupled STS research project will explore this by investigating how people view and consume food over time shaped by public perception. Another problem the STS research will tackle will be the rising trend of segregation of health based on income. More specifically, the lack of healthy foods that seem to plague underprivileged communities. Food choice obviously plays a major role in this topic, but the availability of healthier alternatives is something that is not talked about enough. Many healthy food stores avoid low-income communities for fear their profits will decrease and will build in wealthier areas instead (Harris, 2019, p. 3). This, coupled with the increased cost of healthy foods, pose a major health problem to underprivileged communities. These disparages will be investigated through the Social Construction of Technology (SCOT) framework. In this system, all related and impacting parties will be investigated to show how the engineer can make the best possible solution.

Depicted in figure 1, this work will be accomplished over a 28-week period, during the Fall 2022 and Spring 2023 semesters. This project will be directed by Professor Tomonari Furukawa, Department of Mechanical & Aerospace Engineering along with myself and my technical team members: Kristen Babel, Alvaro Crisanto, Brian Richard, Charlie Tilney-Volk. My STS advisor will be Catherine D. Baritaud, Department of Engineering and Society.

TASK	ESTIMATED WEEKS
Understanding Previous Work & Filling Knowledge Gaps	7
Researching Products	5
Concept Generation for Vehicles	5
Concept Generation for Docking System	4
Purchasing of Products	3
Build/Execution of Vehicle Design	5
Build/Execution of Supplementary Spec Design	5
Testing and Reiteration	7

Figure 1: Chart of UVa robotics capstone. This figure visualizes expected time worked on each task in that order. (Stauffer, 2022)

UNDERWATER AUTOMATION

The technical project seeks to make underwater aquaculture fish farming more efficient, more effective, and completely autonomous. The problem this project hopes to address is the amount of resources needed to run an aquaculture fish pen. When approaching this project, there has not been significant work done in the past. This is a fairly new way of farming food and with that comes new problems. One of these is the manpower needed to successfully run a large scale operation. The pens need to be checked often for damage, the barrier needs to be cleaned regularly to remove debris, and the fish need to be monitored (Gunther, 2018, p. 1). Not to mention, this is miles out from the coastline requiring long distance travel every time a task is needed.

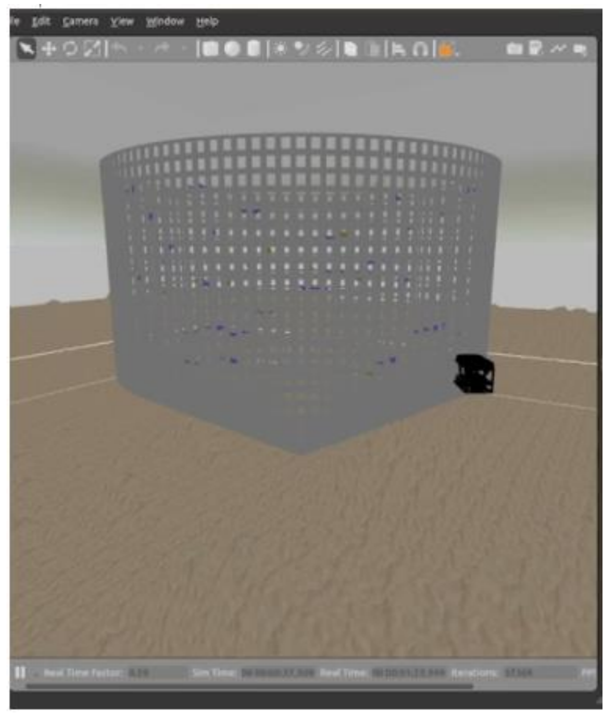

Figure 2: Simulations of fish pen and underwater vehicle through ROS. (Stauffer, 2022)

The technical project will be developed during two-semester capstone classes directed by Tomonari Furukawa, Department of Mechanical & Aerospace Engineering. The objective of this project is to build two vehicles that will work together to make the maintenance of fish pens autonomous, cost efficient, and self-sustaining. Our group will rely mainly on research-based papers. In addition, there will be a lot of research simulation through the Robotic Operating System (ROS), figuring how to program the vehicles and their responses to obstacles. Figure 2 depicts work already done through ROS. This simulation was done in order to see the scale of the fish pen and the underwater vehicle as well as simulate some pathways the vehicle might take. The project integrates both machinery and programming to create two autonomous vehicles that will traverse fish pens to clean, update, and modify. Of the two vehicles, one will be on the surface with the purpose to guide the underwater vehicle as well as recharge it. It will have a wave energy harvester built into it and will be able to collect energy 24 hours a day. The underwater vehicle will be tethered to the surface vehicle and will be able to receive inputs on what tasks need to be done. Figure 3 despite a proposed variation of an autonomous surface vehicle/wave energy converter. The most important parts of this vehicle are the buoy that will keep it afloat and stable while collecting energy from the waves, the generator that will work in conjunction with the push and pull tube, allowing the tube to move up and down with the waves, powering the generator. The battery will store energy and the propellers will allow the vehicle to move to its desired location.

The other vehicle will be the underwater vehicle called the autonomous underwater vehicle (AUV). The purpose of this machine will be to navigate the fish pens and clean debris from it. Our vehicle has a multitude of sensors on it to help navigate the dark waters. As depicted in Figure 4, The Low-Light Camera System will allow the vehicle to see and navigate. The thrusters will move the vehicle, and the frame will hold it together. On the inside, the microcontroller mounting will process data and directives, the data transmission terminals will export data, and the battery enclosure

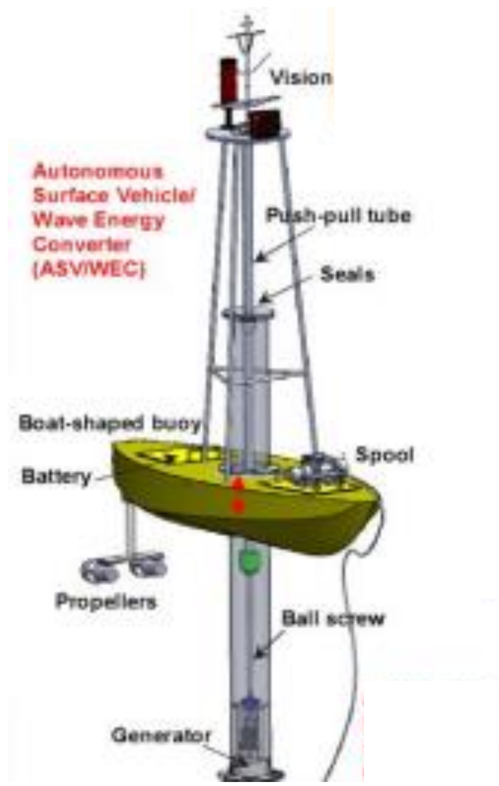

Figure 3: A proposed surface vehicle. Consists of generator, buoy, battery, ball screw, spool with tether, push-pull tube. (Stauffer, 2022)

tube will hold the battery. We plan on adding more sensors on the underwater vehicle that will allow it to self-navigate. One of these is Subsonus Acoustic Sonar. These sensors will help the vehicle navigate and have a positional accuracy of 0.1 meters and a range of 1000 meters, which will be perfect for the task at hand (Kevin, 2022, p. 5). In addition to the tasks, the underwater

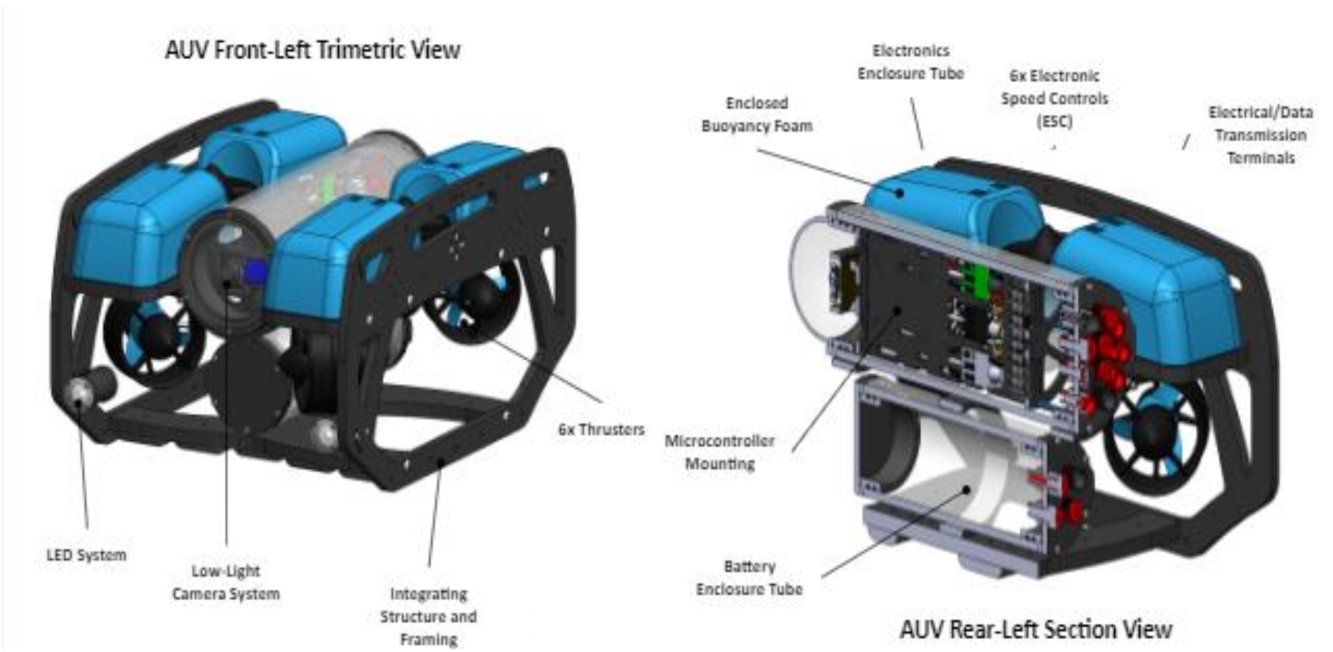

Figure 4: A visual of the AUV. Left visual is the outside view of the vehicle. Right visual is the vehicle split down the middle to provide an overview of its internal workings (Stauffer, 2022)

vehicle needs to be able to dock to the surface vehicle. Possible solutions for this are to use the underwater vehicle and install a subsea docking station to recharge batteries, upload videos, and receive update commands (J. Sverdrup-Thygeson, 2016, p. 3).

As shown in Figure 5, the design process used to achieve the project objective will include the following steps: (1) Planning, (2) Concept development, (3) System-Level Design, (4) Detailed Design, (5) Testing and Refinement, and (6) Production Ramp-Up. The most time-consuming task will be the concept development portion, which has a multitude of steps including identifying consumer needs, identifying target specifications, concept generation, selection, and testing, project planning, and economic analysis. The Observatory Mountain

Engineering Research Facility Laboratory has all the resources needed to complete this project and will be in the form of a scholarly article. Although this is the first group to ever work on a

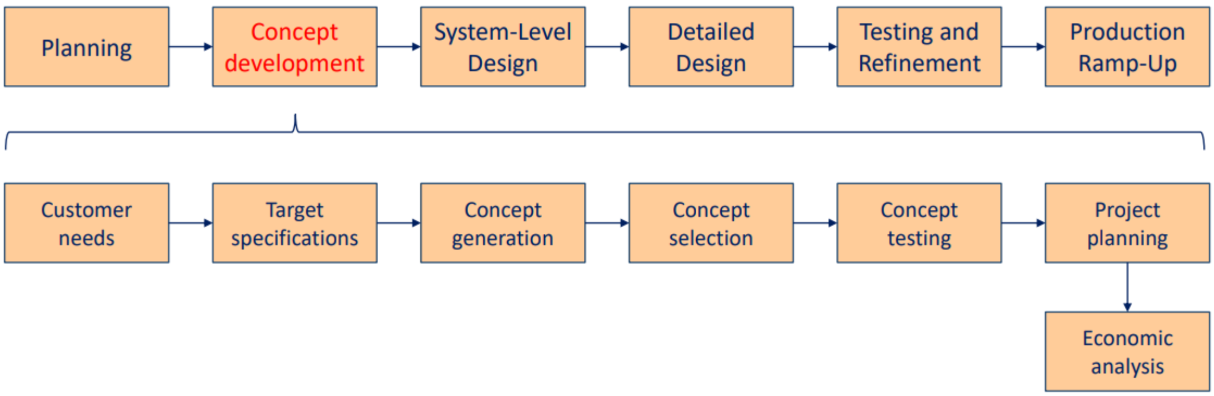

Figure 5: Visualization of the design process. (Stauffer, 2022)

project of this topic and scale, the hope is to have both vehicles completing functionality by the end of the spring semester.

THE FUTURE OF FOOD

The STS topic will compare the trends of meats and how they are promoted to better understand how Americans are influenced in their choice of food. While the main four meats of the U.S. have been staples for hundreds of years, this is the first time in history where we are seeing a dramatic shift in public consumption and opinion. The reasoning for this is because over the past decades, there has been an outcry for better food farming techniques that are more organic, create less environmental harm, and have better conditions for animals (Raghava R. Gundala, 2021, p. 1). Fish pen farming succeeded in these requirements and will lead the US to find better alternative ways to mass production of food. Aquaculture has been the fastest growing source of animal protein since 1990. These offshore aquaculture pens may yield 10-100 times the fish production, compared with inshore aquaculture (Bentley, 2017, p. 4). Needless to say, there is huge potential for offshore aquaculture.

Another problem this research aims to tackle is the element of segregation of food based on income. A study was conducted how poor households were forced to travel further for groceries and may find healthy foods unavailable at the grocery stores closest to their homes (Schauder, 2022, p. 1). This is concerning because the quality of food often directly relates to their quality of life (Raghava R. Gundala, 2021). It poses an interesting question as to what the reasoning is behind this. This topic is tightly coupled to my technical project. While the technical project is focused on how to make aquaculture fish pen farming more sustainable and autonomous, the STS topic can take parts of that and reference how it will impact the food market.

Through a study of food groups and economic factors, the trends and disparages will be investigated through the Social Construction of Technology (SCOT) framework pioneered by Trevor Pinch and Wiebe Bijker (Bijker, Hughes, & Pinch, 1987; Bijker & Pinch, 1984; Kline & Pinch, 1999). In Figure 6, the system shows each group provides a unique perspective that

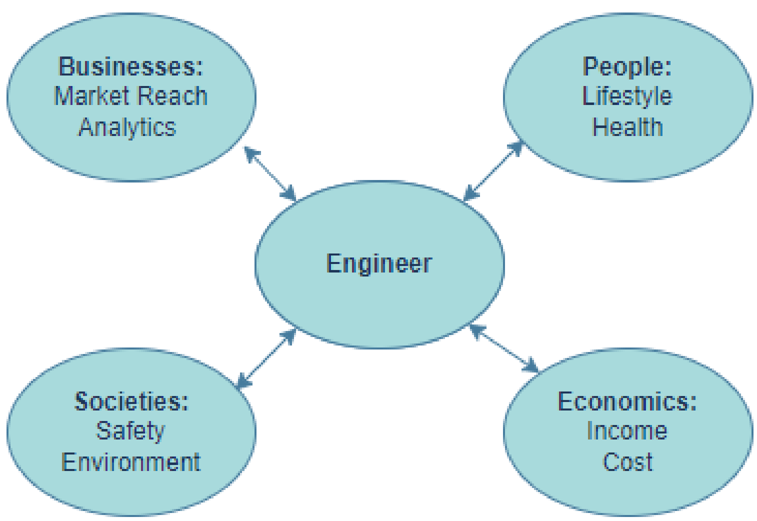

Figure 6: SCOT Model. The engineer provides a bridge between each group to form a better solution (Stauffer, 2022)

informs the engineers efforts and characteristics of the resulting product. This in term, will lead to a better understanding of the problem and an even better solution, in this case the necessary actions to take in order to bridge the disparage between economic groups and their access to healthy and nutritious food. Businesses play a key part in these interactions as they are the suppliers of the food and can choose where and where not to put their business. These businesses do extensive research in their market reach and analytics before ever thinking about building a physical store in a location. A key factor that influences their decision-making is the median household income in the potential county. An analysis by AggData found that Trader Joe's stores, notorious for their healthy and nutritious branding, are located in counties where the household median income is in excess of $100,000 (Harris, 2019, p. 2). Although they are totally within their rights to dictate where their locations will be, there could be incentives to encourage them to step outside their current demographic. Another key component are the actual people themselves. It has often been shown that families with poor eating habits often pass them to the next generation (Lubna Mahmood, 2021, p. 3). Poor dietary habits established during childhood persist into adulthood, increasing the risk of obesity and obesity related complications. A person's lifestyle transcends just their life and could lead to their children following in their footsteps. The economic factors of eating healthy also play a major part. Healthy food can be more expensive their unhealthy alternatives (Schauder, 2022, p. 4). Whether the buyer wants to take that factor into account before purchasing their food will directly impact their health and body. Therefore, socioeconomic factors are often brought up when the disparagement of food is raised. It's hard to imagine an impoverished person even being able to afford to think about purchasing the more expensive option when they worry about the dollars they spend daily. The impact of society on food should not be disregarded. Factors like the environment and safety have an impact on what foods are even abled to be processed. The anticipated outcome of this research should yield a better understanding of the problems and how to fix the disparagement of food.

AN EXCHANGE OF IDEAS

Engineers often are at the center of dialogue to facilitate the exchange of information between parties. The people provide the engineer with the information and their trust, hoping the engineer will in turn create something that will better not only their lives, but all of society. An engineer must take into social responsibility in order to make sure their appliances will not be used for the impediment of society. The product of an engineer must reflect the interests and concerns of all groups involved and only after the thorough understanding of these, can an engineer begin. New ways of farming food are necessary as the population and demand for food increases. Instead of looking to the land, water provides new and exciting opportunities. Oceans provides sustainable ways to safely and effectively resolve both food crisis and environmental problems (Janet Larsen, 2013, p. 4). This project will be coupled with research in the form of a scholarly article exploring the ways food culture is changing and how influencing factors effect it. Factors like economic and social status should not be limiting factors in ones ability to have a healthy lifestyle. These limiters are barriers that need to be broken down and restructured in a way that promote healthy food regardless of who the person is. To make it harder for people who aren't well off to have a healthy life only compounds and exacerbates problems when the goal should be reducing the problem. These projects will show ways new problems require new and innovative solutions while keeping the betterment of society in mind.

REFERENCES

Bentley, J. (2017, February 21). U.S. per capita availability of total red meat, poultry, and fish down from 2007. Retrieved from USDA: https://www.ers.usda.gov/data-products/chart-gallery/gallery/chart-detail/?chartId=82559

Bijker, W. E., Hughes, T. P., & Pinch, T. J. (1984) The social construction of technological systems. Zeitschrift für Wissenschaftsforschung, 2, 39-52

Gunther, M. (2018, January 25). Yale Environment 360. Retrieved from Can Deepwater Aquaculture Avoid the Pitfalls of Coastal Fish Farms?: https://e360.yale.edu/features/can-deepwater-aquaculture-avoid-the-pitfalls-of-coastal-fish-farms

Harris, J. (2019, August 28). Here's what Trader Joe's is looking for in a new location, and why it's not (yet) in the Lehigh Valley. Retrieved from The Morning Call: https://www.mcall.com/business/mc-biz-why-trader-joes-hasnt-opened-lehigh-valley-store-20190828-7icd2wpj25ezblyaci6ocoxsy4-story.html

J. Sverdrup-Thygeson, E. K. (2016). The Underwater Swimming Manipulator – A bio-inspired AUV. Retrieved from Centre for Autonomous Marine Operations and Systems, Department of Engineering Cybernetics, NTNU: https://ntnuopen.ntnu.no/ntnu-xmlui/bitstream/handle/11250/2434929/AUV2016.pdf?sequence=1&isAllowed=y

Janet Larsen, J. M. (2013, June 12). Farned Fish Production Overtakes Beef. Retrieved from Earth Policy Institute: https://www.earth-policy.org/plan_b_updates/2013/update114

Kevin, E. K. (2022). Blue Robotics. Retrieved from BlueROV2 Buyer's Guide by Options: https://bluerobotics.com/learn/bluerov2-buyers-guide-by-options/#sonar-accessories

Lubna Mahmood, P. F.-B.-G. (2021, March 30). The Influence of Parental Dietary Behaviors and Practices on Children's Eating Habits. Retrieved from National Library of Medicine: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8067332/

Oliver Edwards, B. B. (2021). An Introduction to Open-Pen Sea Cage Aquaculture. Retrieved from goodfishbadfish: https://goodfishbadfish.com.au/an-introduction-to-open-pen-sea-cage-aquaculture/

Raghava R. Gundala, A. S. (2021, September 10). What motivates consumers to buy organic foods? Results of an empirical study in the United States. Retrieved from Plos One: https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0257288#:~:text=Consumers%20perceive%20organic%20foods%20as,contributed%20significantly%20to%20its%20development.

Schauder, S. A. (2022, May 14). Income Segregation and Access to Healthy Food. Retrieved from National Library of Medicine: https://pubmed.ncbi.nlm.nih.gov/32418802/

Stauffer, P. (2022). Prospectus(Unpublished undergraduate thesis). Charlottseville, VA, University of Virginia.

Why are chicken, fish and beans better to eat than red meat? (2017, March 27). Retrieved from American Heart Association: https://studenthealth.ucsf.edu/sites/studenthealth.ucsf.edu/files/PDF/nutrition_handouts/Meat%20_%20Heart%20Health.pdf