Developing a Cheap and Effective Electric Outboard Motor-Powered Freshwater Propulsion System

(Technical Paper)

Likely Consumer Acceptance of a Recreational Freshwater Propulsion System that is Electric-Powered

(STS Paper)

A Thesis Prospectus Submitted to the

Faculty of the School of Engineering and Applied Science

University of Virginia • Charlottesville, Virginia

In Partial Fulfillment of the Requirements of the Degree

Bachelor of Science, School of Engineering

Justin Allen

Spring, 2020

Technical Project Team Members

Colin Allison

Julianna Chaput

Miles Coe

David Gordon

Brian Lithen

Troy Meurer

Jon Ramirez

Bryce Shelton

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

Signature ____ Date ___________

Justin Allen

Approved ____ Date ___________

Gavin T. Garner, Department of Mechanical and Aerospace Engineering

Approved ____ Date ___________

Kathryn A. Neeley, Associate Professor of STS, Department of Engineering and Society

I. **Introduction:** Developing an Effective Electric Outboard Motor-Powered Freshwater Propulsion System for Recreational Use

Humans have a long history of interaction with freshwater environments. Rivers and lakes have served as sources of water, food, power and travel. Yet, the last century has seen a dramatic increase in its use as a source of recreation. Recreational boating has become increasingly common and has exacerbated the issue of freshwater habitat destruction. There is a vast array of recreational watercraft propulsion systems and each has benefits and consequences. Watercraft most notably can be propelled by gas motors, electric motors or by humans. Inboard motors that run on petrol, oil, or diesel harm the environment the most by a significant margin. In fact, gas-powered motors add chemicals and metals to water which can influence the type and amounts of aquatic wildlife. Traditional inboard gas-powered propellers further disturb environments by uplifting sediment. Human-powered watercraft have limited application due to its minimal speed, power and size. Electric outboard motors represent a quiet, emission-free alternative to gas-powered motors while sacrificing price and convenience. However, boat manufactures do not have the necessary technological capabilities or government support to produce electric boats with comparable price, range or power. With current public sentiment the majority of consumers opt to purchase gas boats over electric boats. As a result, manufacturers lack the necessary support and incentive to mass produce electric boats. Lacking demand, production and technology forces recreational freshwater boaters to continue to disrupt aquatic ecosystems with gas-powered watercraft. In his book, *Polluting for Pleasure* (1993), Andre Mele estimated that approximately 150 million to 420 million gallons of unburned fuel are emitted into aquatic environments each year by recreational boats (p. 29). If consumer acceptance can be achieved, electric outboard motors may be the solution to current aquatic problems. Before consumer acceptance is achieved, a method for reducing habitat destruction from recreational boating is needed.

The technical project outlined in this prospectus seeks to deliver an innovative electric freshwater propulsions system for lightweight watercraft. Through the application of water jet technology, the prospective new technology will enable environmentally friendly propulsion of lightweight watercraft in shallow waters and where gas-motors are prohibited. This technology will utilize a powerful rechargeable battery to power multiple outboard water jets for freshwater propulsion.

The final deliverable for the technical project may reduce gas motor usage in some scenarios but current electric boats do not have the power or range for extensive application. It will be imperative for shipping and aquatic organizations to work together with engineers, scientists, and the public to develop effective outboard electric motors for widespread application. Current acknowledgment and willingness of politicians and shipping organizations to address the problem provides optimism. An examination of "Hurricane Katrina: One Year Later," a statement released by the American Society of Civil Engineers Hurricane Katrina External Panel (2006), reveals the need for technology, culture and organizations to work synergistically for an effective solution to be developed. The STS research will focus on the interactions of relevant actors involved in the potential consumer acceptance of electric boats.

II. **Technical Topic:** Developing a Cheap and Effective Electric Outboard Motor-Powered Freshwater Propulsion System

The U.S. Environmental Protection Agency explains that the market for aquatic engines is currently dominated by two-stroke engines, however, a shift to four-stroke engines is currently in progress. A report by the Vermont Water Resources Board (1999) explains that the most efficient four-stroke engines can reduce pollution by up to 95% but still pollute at significant levels. In fact, Recayi, Pecen and Hay (2005) explain that electric boats pose an intriguing alternative to gas boats that emit roughly 8.6 kilograms of carbon dioxide for every gallon of fuel consumed. Increased use of electric boats will have great implications on freshwater pollution and sediment disruption.

Electric outboard motors solve many environmental problems caused by gas-powered motors but are not widely produced due to limitations from price, range and power of electric batteries. Current technology does not support the power, range and price needs for use of electric outboard motors for recreational aquatic use. Aleksandra Lapko (2016) explains in a study on electric boats that higher power electric boats "require the use of several batteries, which increases the weight of the system and makes the costs much higher than is the case in the traditional solution" (p. 327). Electric boats only become cost competitive in very low power boats but still lack the range of traditional boats. As a result, recreational boating companies have only developed electric outboard motors for limited applications. Thus, recreational boaters do not have access to comparable and affordable environmentally friendly alternatives to gas-powered watercraft.

My capstone group will build upon current electric outboard motor to produce an attachable electric outboard freshwater propulsion system for lightweight watercraft. This new technology will be particularly desirable for use in shallow water and where wakes and gas engines are not allowed. This technology will be adjustable for attachment to a variety of lightweight watercraft and will act as an intermittent discretionary replacement for existing propulsion systems. To achieve these goals, the propulsion system will be composed of an electric motor that powers a water jet. Water jets operate differently from conventional propulsion systems due to their use of an impeller. As shown in Figure 1 below, impellers and propellers appear to produce thrust for propulsion in very similar ways. However, impellers produce thrust by creating a pressure differential in an internal flow. Water jets operate at and slightly below water which enables

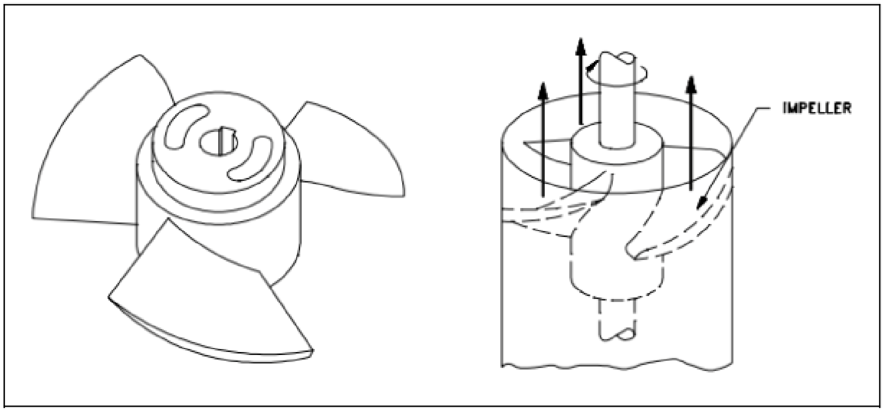

Figure 1: Propeller (left) creates thrust using radial motion in an external flow. Impeller (right) creates thrust by producing a pressure differential in an internal flow (n.d., Ezekiel Enterprises).

propulsion in very shallow water while also minimizing sediment disruption. A variety of jet ski designs will be explored – due to their relevant application of water jets - and research will be explored to determine suitable designs for the water jet. This technology will face challenges in achieving sufficient durability, price, power and range. As a result, the team will need to prioritize those characteristics; price will constrain improvements to durability, power and range. The team expects to produce a final prototype that can be attached to a kayak that will enable effective propulsion in the shallow waters of the Rivanna Reservoir where gas motors are prohibited.

III. **STS Topic:** Likely Acceptance of a Recreational Freshwater Propulsion System that Is Electric-Powered

The negative effects of recreational boating on freshwater habitats is clear. As freshwater habitat destruction has accelerated, governments have begun limiting the use of gas-powered watercraft. To further protect freshwater ecosystems, greater limitations on gas-powered watercraft must be enforced or widespread acceptance of electric-powered watercraft must be achieved. A study by the National Marine Manufacturers Association explains that “in America’s nearly 1,800 federal lakes, which host more than 900 million visits each year and generate over $44 billion in economic impact, almost 40 percent are said to suffer from some source of pollution or habitat degradation” (Fontaine & Dunn, 2007, p. 57). Figure 2 below depicts the precarious state of America’s largest bodies of freshwater. To mitigate freshwater habitat destruction while preserving economic stability and alignment with cultural values,

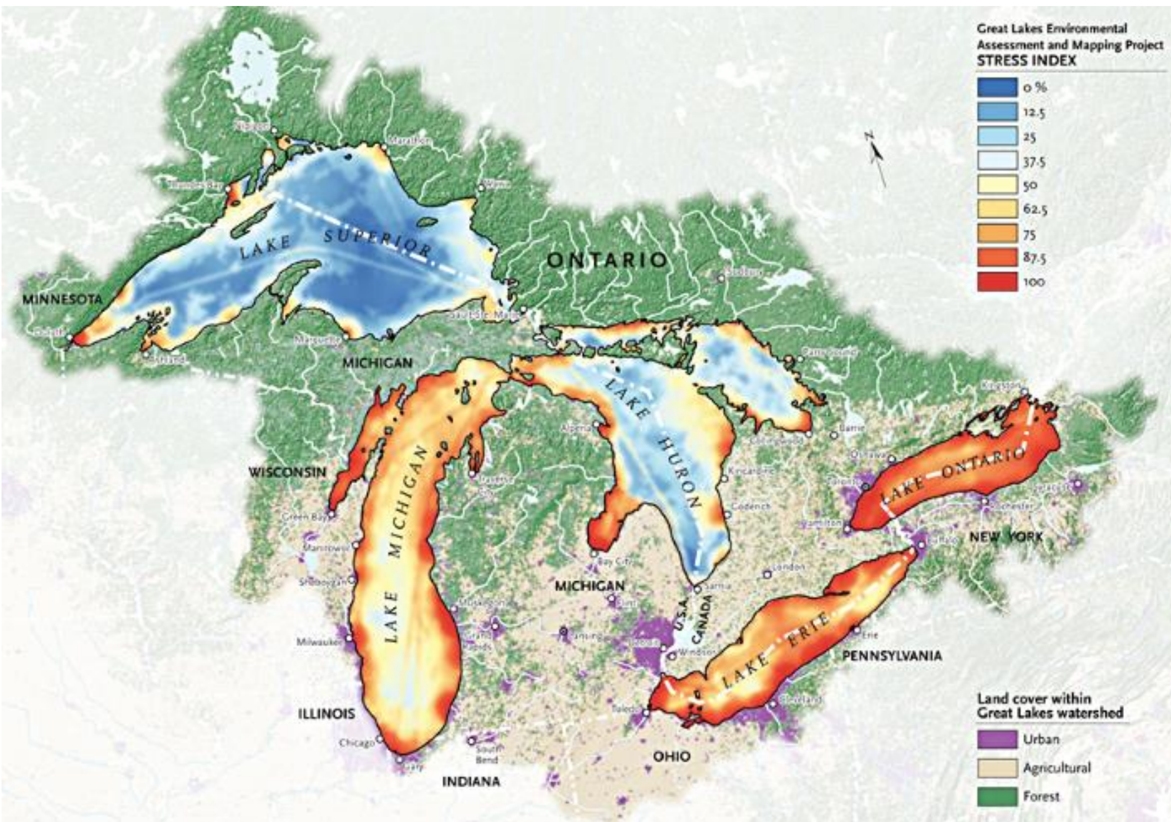

Figure 2: Tremendous ecological strain is placed on the Great Lakes - home to more than a fifth of Earth's freshwater (Walker, 2013).

consumer acceptance of electric-powered watercraft is the favored solution.

As explored earlier, electric boats currently lack the power, range and price to compete in an open market with gas-powered watercraft. Monica Anderson reveals that approximately three-quarters of U.S. adults are concerned about helping the environment but only about one-fifth of U.S. adults try to protect the environment consistently (2017). With a low proportion of citizens actively attempting to protect the environment, a transition from gas boats to electric boats is unlikely. Most American adults do not value the environmental protection provided by electric boats enough to sacrifice power, range and price. Watercraft manufacturers that perceive a lack of demand for electric boats recognize that production of electric boats will likely be an unprofitable endeavor. Although the government has the ability to support the electric boat industry, politicians are driven by the values of their constituents. Public sentiment does not currently warrant significant government action. As a result, current consumer acceptance of electric boats relies on purchases by affluent environmentally friendly consumers.

Unless electric boats achieve sufficient comparability to gas-powered watercraft, shifts in cultural values, government policies, and institutional efforts are needed. In his book titled *Technological Change: Its Impact on Man and Society* (1970), Mesthene presents a model for thinking about the contingent and predictable avenues through which technological innovation can lead to conflict and social or political innovation. This model will be employed in the STS project to explore potential rejections of electric boats and the possibility for eventual widespread acceptance of the technology. The final STS deliverable will explore research to determine possible avenues for consumer acceptance of electric boats contingent on various levels of advancement in electric boating technology. Avenues through which electric boats find widespread acceptance will likely involve a combination of the following shifts: increasing consumer sentiment towards environmentally friendly technology, government subsidization of electric boats, bans on gas boats, effective marketing for electric boats, and increased manufacturing focus on electric boats. The framework introduced by Mesthene will also be complemented by the economic approach to technological determinism set forth by Heilbroner. Heilbroner (1994) describes this approach as "applying an analytic understanding to such large-scale social changes as the composition of the labor force and the hierarchical organization of work, not to mention the dynamic characteristics of economic activity as a whole" (p. 73). Economic feasibility drives much of supply, demand and public policy so this framework will better inform the likelihood of different avenues of electric boat acceptance. Thus, academic, government and market research will be explored to determine the dynamics of these possible shifts. Conclusions drawn from this STS research will inform relevant actors on how to design, market, and support the production of electric boats.

IV. **Conclusion**

Continued advancements to battery technology and electric motor technology pose significant opportunities for reduced environmental impact from recreational boating. The attachable electric outboard motor propulsion system produced for my Capstone Project will be attached to a kayak on the Rivanna Reservoir to enable propulsion in shallow waters where gas motors are prohibited. Successful completion of this project will evidence the potential to reduce the use of gas-powered propulsion systems in freshwater environments. With the completion of my STS thesis, different public, government and manufacturer interactions working within economic constraints that may lead to consumer acceptance of electric boats will be developed. This knowledge will inform interested parties of the relevant factors to acknowledge and design for when working towards widespread electric boat acceptance.

References

Andersen, C. F., Battjes, J. E., Daniel, D. B., Edje, B. L., Espey, W. S., Gilbert, R. A., … Traver, R. undefined. (2006). Hurricane Katrina: One Year Later. Retrieved October 31, 2019, from https://collab.its.virginia.edu/access/content/group/72310c18-588c-4702-a564-839ffb2c5c0c/Readings/Andersen, Katrina Nexty.pdf.

Anderson, M. (2017, April 20). For Earth Day, here's how Americans view environmental issues. Retrieved October 10, 2019, from https://www.pewresearch.org/fact-tank/2017/04/20/for-earth-day-heres-how-americans-view-environmental-issues/.

Davies, E. A. J., Vance, J. E., Stilwell, J. J., & Woodward, J. B. (2018, June 22). Ship. Retrieved October 14, 2019, from https://www.britannica.com/technology/ship.

Fontaine, M. W., & Dunn, M. P. (2007). Overview of the Recreational Boating Industry's Aquatic Stewardship through Technology, Innovation, and Education. In *American Fisheries Society Symposium* (Vol. 55, pp. 55-72).

Heilbroner, R. (1994). Technological determinism revisited. In M. Smith, & L. Marx, *Does technology drive history?* (pp. 67-78). Cambridge, MA: MIT Press.

Jones, N. (2019, April 10). Ocean uproar: saving marine life from a barrage of noise. Retrieved October 1, 2019, from https://www.nature.com/articles/d41586-019-01098-6.

Łapko, A. (2016). The use of auxiliary electric motors in boats and sustainable development of nautical tourism–cost analysis, the advantages and disadvantages of applied solutions. *Transportation Research Procedia*, *16*, 323-328.

Mele, A. (1993). Polluting for pleasure. United Kingdom: W.W. Norton.

Mesthene, E. G. (1970). *Technological change: its impact on man and society*. Cambridge, MA: Harvard University Press.

Pecen, R., & Hay, M. E. (2005). Design and Implementation of Solar Electric Boats for Cleaner US Waters. In *Proceedings of the 2005 American Society for Engineering Education Annual Conference & Exposition, American Society for Engineering Education* (Vol. 10, pp. 1-10).

The potential effects of engine emissions. (2001, October). Retrieved October 1, 2019, from http://www.ukmarinesac.org.uk/activities/recreation/r03_01.htm.

Vermont Water Quality Division. Report on possible water pollution from the use of two-stroke carbureted marine engines, Report on possible water pollution from the use of two-stroke carbureted marine engines (1999). Waterbury, VT, VT. Retrieved from

https://anrweb.vt.gov/PubDocs/DEC/WSMD/lakes/docs/lp_2-strokereport.pdf
[Government Document]