Prospectus

Kinetic Art Clock

(Technical Topic)

Galileo Satellite Failures

(STS Topic)

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.

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Socio-technical Problem Frame:

In 2014, a YouGov poll revealed that millennials tend to be late for work at a higher rate on a more regular basis than the average American population. 19% of millennials admitted they show up late to work at least a few times a week, if not every day, compared to 12% for adults age 55+ (McCarthy, 2014). Though some of this difference could be attributed to negligence, part of the issue can be attributed to the lack of an easy timekeeping method. Increasingly, younger Americans rely only on their phone to tell the time, but the process of pulling out one's phone each time can be tedious. As such, it can be useful to have more wall-mounted clocks in buildings to help younger Americans check the time and stick to their schedule without needing to pull out their phone.

To address this issue, I am developing a wall-mounted clock to go in the Mechanical Engineering building at UVA that not only displays the time accurately but highlights the type of work being done in the Mechanical Engineering department. By adding this clock to the building, students will have an easier method of keeping on time for class or work. Instead of constantly needing to pull out their phones, and potentially leading to further distraction, our clock will provide students the opportunity to simply look up at a clock on the wall to check the time. Additionally, since our clock incorporates a large amount of mechanical engineering design that is not only displayed in the clock, but is highlighted by the design, this clock will attract the attention of anyone walking by so they are more likely to both know the time and gain insight into the methods and skills being taught in the Mechanical Engineering department.

This technical solution relies on an understanding of the user, and the role the user plays within the larger UVA social and political system. Since the clock is a device meant to interact with individuals in the building, it is important as designers that we understand how humans interact with their surroundings. Additionally, it is important that UVA administration sees the clock as a benefit to the space, or else they may decide not to put up the clock at all, which would certainly nullify any benefits of our design. If the social aspects of the design were neglected, a design could be produced that accomplishes the technical goal of displaying the time but fails to interface properly with the user in a way that benefits the user.

By considering both the technical and social aspects of this project, we can produce a design that effectively and intentionally works with both the user and the UVA system. Below I outline a technical process for designing the clock in a way that accomplishes both the technical and social goals of the project. I also use actor-network theory with the case of the Galileo Satellite failures to underscore the importance of the social aspects of a technical project. Through an understanding of the technical side of this project, as well as an instance when the social aspects of a project were neglected and led to technical failures, we can piece together the full scope and system at play in the development of this clock.

Technical Problem Frame:

On the second floor of the Mechanical Engineering building at UVA, there is only one clock in the main hallway. Although many students simply check phones or watches to tell the time, there is great utility in having wall-mounted clocks that students can use to tell the time without needing to pull out their phone. While there are plenty of designs for wall-mounted clocks, ranging from traditional analog clock faces to intricate digital displays, current approaches, particularly in academic and professional spaces, tend to gravitate toward more subtle designs that do not draw any attention away from the work being done in the building.

These designs, however, tend to go wholly unnoticed by people walking by as they simply blend into the background of the room. Thus, these clocks fail to properly serve their function of helping people tell the time. Additionally, most current clock designs fail to complement and highlight the work being done in the building. Though many people do not see a wall clock as a potential design piece, it is a powerful and creative statement to take the process of something so integral as telling time and turn it into an exhibition of the work and talent going on in the building in which it resides. By failing to design a clock with intention with respect to the building, one would waste an opportunity to elevate the use of the clock by representing an important aspect of the building itself. Additionally, clock designs that fail to be noticed at all, fail to accomplish the functional purpose of the clock since nobody pays enough attention to the clock to retrieve any valuable information from it. By designing and building a clock that elicits excitement about the building itself while, most importantly, maintaining the critical timekeeping functionality of a clock, users are more likely to appreciate the design as an art piece while maintaining their personal daily schedule.

The goal of this project is to design and build a clock that accurately keeps time while being a featured design piece that highlights the type of work taking place in the Mechanical Engineering building at UVA. This design will use a system of ball bearings and magnets to represent the digits, and will feature a rotating drum on a rack-and-pinion system to deposit the ball bearings on the magnets and collect the ball bearings afterwards. In order to demonstrate the engineering behind the design, much of the mechanisms of the clock will be uncovered. This allows people to learn how the clock works and understand the mechanical systems behind it as they check the time.

The primary timekeeping device for the clock will be a 6.25 MHz quartz oscillator run through a Parallax Propeller microcontroller ("6.25 MHz crystal (through-hole)", n.d.). Though these oscillators are very accurate, since our device does not confirm the time through a Wi-Fi connection, a primary challenge for our design will be maintaining the correct time.

The physical digits for our clock will be represented with ball bearings attached to neodymium magnets. The magnets will be actuated using a system of 23 servomotors that are centrally controlled via the microcontroller chip through a servomotor driver that sends and receives data via the inter-integrated circuit (I2C) data communication system (Earl 2019).

By the end of the project we plan to showcase our clock on the second floor of the Mechanical Engineering Building, and plan to have it functional to the point that it can autonomously maintain and display the correct time.

STS Problem Frame:

Since the Soviet Union launched Sputnik in 1957, an important aspect of all global space agencies has been launching satellites to be used for a variety of purposes. Initially, a number of satellites were used for direct surveillance and monitoring of the Earth, but in 1978, the United States launched Navstar 1, which was the first satellite in the US Global Positioning System (GPS) (Williams, 2019). In the four decades since, other countries have created their own satellite systems to compete with GPS, such as the Russian Global Navigation Satellite System (GLONASS), and more recently, the European Space Agency's Galileo system ("Russia launches three more GLONASS-M space vehicles", 2008). While the first Galileo satellites went into orbit in 2011, the system continued to fail and malfunction in varying capacities through July 2019 (Coppinger, 2017). Among these malfunctions was a series of clock failures in early 2017 wherein the clocks of 10 of the 18 satellites failed due to unknown causes (Amos, 2017).

Based on current understandings of the situation, the clock failures could be attributed to faulty manufacturing that led to a short-circuit in the rubidium clocks that were being used, and to the hydrogen maser clocks not having been monitored closely enough to ensure that they were running properly ("Europe's Galileo satnav identifies problems behind failing clocks.", 2017). This approach, however, fails to recognize the political actors at play that may have led to oversight with regard to checking the parts for quality and monitoring them once they were installed (Aftenpost.no, 2011). Focusing only on the technical issues, and failing to see the importance of the other factors at play risks losing an understanding of how the development of the European Space Agency's Galileo system plays an important role in the global power struggle of the 21st century.

I argue that the power dynamics, and the European desire for independence from the global navigation systems of other space agencies, was the primary driver for the Galileo system falling behind its initial schedule, which in turn led to oversight of the manufacturing processes and monitoring of clocks in the Galileo satellites. My analysis of the Galileo satellite failures draws on the science, technology, and society (STS) concept of actor-network theory, which analyzes the power dynamics among human and non-human actors associated together in a network by a network builder to accomplish a particular goal (Cressman, 2009). Specifically, I will be using the idea that networks are inherently vulnerable to explain how the Galileo satellite network never fully reached stabilization and thus was unable to properly accomplish the outcomes of the network builder.

Conclusion:

The technical report will deliver a new design for a wall-mounted clock to be displayed on the 2nd floor of the Mechanical Engineering building at UVA. This clock not only will help students and professors accurately keep time and arrive on time to classes and meetings, but it will also serve to highlight the work being done in the Mechanical Engineering department and showcase the skills and methods being taught. The STS research paper will provide further insight into the concept of stakeholder design by analyzing the case of the Galileo Satellite failures. By understanding how various actors played a role in the technical failures of the satellites, we can learn how to properly consider all actors and stakeholders in our clock design.

The designs and prototypes from the technical report will provide a solution to the broad socio-technical issue of helping people keep time accurately and dependably by exploring the design outcomes of considering the project to be an art piece in addition to being a technical product. The STS paper will additionally expose a system for network design to consider in future designs as the numerous stakeholders in the Galileo Satellite system demonstrate the necessity to consider all actors in a technical system.

Word Count: 1771

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