Design and Construction of a Ferrofluid Kinetic Art Clock

(Technical Paper)

Impacts of the Development of Environmental Suits on the Future of Human Spaceflight

(STS Paper)

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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

Introduction

Moore's Law is the idea that as the capability of our computers increases, both the size and the cost of these devices will decrease (Roser, n.d., Moore, 1998). As computing power increases, the size that it takes in physical space decreases proportionally, and this phenomenon is not restricted to computing power alone. Similar advancements have been made in mechanical motors, switches and relays that have become more powerful and versatile even as they use less space in the design. In mechanical devices, advanced manufacturing means more accurate servo and brush motors that can handle higher torques and respond more accurately to a given input. For example, the computing power required to get to the moon is present in every single phone in use today (Madrigal, 2019), and every capability of processing power and compact design will have to be used for the next generation of human spaceflight.

Manned missions to space face numerous challenges, including entering the atmosphere, extending the stay in space, offsetting the effects of space-based radiation, and mitigating the social impacts of isolation ("Pathways to Exploration," 2014). The STS topic is focused on the development of a new generation spacesuit, and the impact that this would have on the improvement and development of manned space programs. Safety is a significant factor, and preventing a catastrophic failure such as a tear must be a priority. While ensuring that workers are protected in space, the suit must also be user friendly and cost effective. Both government agencies and civilian companies are actively seeking space-based industries, so public and private sector funding could be pursued. Public opinion will play a role, and garnering public support could be seen as patriotic. Stakeholders in civilian space companies may see space exploration as an economic advantage, more effective mining and research efforts resulting in higher stock prices. Conversely, those affected by the cost could see the development of a new suit as extraneous and a waste of valuable resources. A further facet is technological, the incorporation of many new technologies into the suits themselves. Cooperation between many countries and scientists is a factor with the sharing of information and working through political and cultural boundaries. Technology has made enormous leaps since the Apollo and Skylab designs, such as astronauts 3-D printing needed analysis tools on demand (Vialva, 2018). Our own design process demonstrates the versatility of the technological advancement.

The technical portion of this paper concerns the development of a clock device, which utilizes miniature motor systems, precision laser cutting and additive manufacturing techniques. The bearings will actuate motors controlling a magnet that holds ball bearings in place behind a face, making the bearings appear to defy gravity as the balls display information. The connection between the technical portion and the STS project is readily apparent, in a direct application of the same technologies that must be implemented in the next generation of human environmental suits. This project provides experience directly handling materials and using manufacturing techniques applicable to the STS research, and the end result will be a kinetic art structure that can be used to beautify the Mechanical and Aerospace Engineering (MAE) building.

Technologies and advancements that are being used in our capstone project are also addressed in the technical paper, with the introduction of extremely strong nano-materials, miniaturized fully integrated motor systems, and the ability to create these next generation space suits from an additive manufacturing device. Next generation environmental suits will then enable further manned missions, expansion of space exploration, and the possibility for a space-based commercial industry.

Technical Topic

Kinetic art is any form of art that moves, with the movement integrated into the display and contributing to the function of the device. The core idea of this capstone project is to create a piece of kinetic art that also functions as a digital clock through the deployment of magnets to cause ball bearings to display the time. The clock is designed have the same functions as any other digital clock, such as the ability to have the time automatically reset in case of Daylight Savings Time or a power loss. The constraint of keeping the clock reasonably quiet is applied so that the clock can be displayed on the second floor of the MAE building. The clock will be able to be powered by a standard 120V AC wall outlet. To be aesthetically pleasing, the magnets would attract the ball bearings through a thin facing material, thus obscuring the mechanism from view. This will create the illusion that the bearings are being held by some invisible force, as well as obscuring the multiple forms that the device can take from the user.

In order to control whether or not a section of a digit will be displayed, two options are presented: electromagnets or actuated permanent magnets. Electromagnets could be kept in a fixed position and either be turned off or on depending on the numeral to be displayed. Alternatively, permanent magnets could be actuated closer or further ("on" and "off" positions, respectively) to the front face of the clock. Ultimately, the option of using actuated permanent magnets is optimal due to concerns with the amount of power electromagnets would consume in holding the bearings.

The clock will be controlled using a Parallax propeller microcontroller chip (Martin, 2011), utilizing its features of parallel processing and an internal oscillating quartz timer. The propeller chip will be used in conjunction with I2C protocol to allow the 47 motors controlling the magnets to be run using only one propeller chip (I2C, n.d.).

The strategy that will be pursued in this design is to make iteratively more complex prototypes, in order to address issues that may arise during each phase of construction. Iteration will be accomplished by creating a single prototype digit, modeling various magnet designs and ball bearing holding platforms, culminating in a four-figure design. This group will utilize Computer Aided Design (CAD), advanced manufacturing techniques such as 3D-printing and laser cutting for the purpose of rapid prototyping, and the use of iterative design techniques to overcome challenges as they appear (3-D CAD, 2019).

This project will add value to both the MAE department, as well as the educational development of team members. The department will have a functional, beautiful, and useful art installation that will serve students and faculty for years to come. A fully completed model of a single digit will be completed before the 23rd of November, with a full prototype complete by December first, and final installation and testing by the 15th of December. Group members will gain skills and knowledge in the additive manufacturing and other advanced manufacturing techniques, the design process, and working as part of an engineering team, with the organizational skills and tools involved.

STS Topic

Manned space missions were the ultimate goal of the Space Race during the Cold War, with millions of dollars and uncountable man-hours put into developing rockets, space suits, and technology that could safely propel equipment through space and protect the occupants on the journey (“Apollo Space Suit,” 2013). However, the most recent suit body was developed in 1975. (Chappell, 2017). Therefore, suits in use today face an increasing risk of failure, as well as not incorporating the most significant improvements in mechanical systems and materials (Chappell, 2017, ESA, 2013). The lack of suit development and incorporation of new materials leaves the spacesuit itself as a major obstacle to manned missions and the implementation of a space-based commercial industry. The Apollo era spacesuit was a multi-million-dollar construction that housed advanced material combinations and environmental controls, some of which were adopted into the civilian sector ("Space Suit Evolution," n.d., 2014, JPL). The age of this design, however, lends urgency to the necessity of a new design that is cost effective, safe, technologically advanced, and useful to a wide spectrum of government and civilian workers in space.

Upgrades have been the practiced method of improvement for the past five decades, but a dramatic shift is needed to prepare for the next generation of spaceflight, supported by technological improvements such as artificial intelligence and reusable booster rockets (Chang, 2017). Beneficiaries of a new suit base include both governments and private companies, as access to an extra-terrestrial environment expands and the opportunities for space-based industry grow. Protection of this new workforce must be paramount, for accidents and death could result in complete withdrawal of support by stakeholders and strangling legislation from lawmakers. Apollo spacesuits are a very notable artifact in this discussion, and including a comprehensive discussion of both advancements and drawbacks of the suit is paramount. Public opinion plays an important role in this discussion as well, for constituents must place pressure for funding to go towards spaceflight, and shareholders must speak out for the development of new environmental suit technology. Any country that successfully builds an extra-planetary platform or base would experience both a nationalistic and an economic boost.

Effectiveness of branding is seen in the Cold War era, where labeling the space race as a competition with an enemy generated support and funding, and is a perfect example of technological construction (Johnson, n.d.). The social construction of technology (SCOT), is the development of technology as an interactive process between all interested social groups, and is evident in the space race. Cooperation with multiple countries and across many varied groups of people was achieved by the central goal of a manned moon mission. One critique of the social construction of technology is the impact that technology itself may have in the form of technological determinism, which will be counteracted by looking at the many groups that participated. The Space Race, even with the same goals and obstacles, spawned very different technologies arising from the many interested social parties. At the same time, the space program itself represents a paradigm shift, moving from a completely nonexistent entity to a fully funded government apparatus in 18 years (Garber, n.d.). The next 50 years, however, consisted of moderate upgrades to rockets and suit technology ("National Aeronautics," 2017). Thomas Kuhn, the creator of the idea of a paradigm shift, believed that a there was a scientific norm of behavior, that would rapidly be upset and bring about a complete change of policy (Kuhn, 1970). A substantial investment in money, human capital, and natural resources is required to force a shift towards acceptance of pressure suits for protecting human life and incorporating mechanical counterpressure, electromechanical system, and more efficient life support modules (Torstein, 2019, Bethke, 2004). Kuhn (1970) also believes that paradigm shifts always seek a new truth, which critics see as not allowing any objective truth to be present. The idea of a paradigm shift is further supported by the idea that as supporting technologies advance, they allow for a dramatic shift in the development of spacesuit technology. Great developmental leaps signify that there is no best objective truth, in this case a space suit design, as the best design must be varied for need, and will change and advance with the technology that supports it. Constant improvement is the goal of spacesuit design, which implies there is no ultimate true best design. Therefore, a switch from Apollo era suits to the newest spacesuit would be a large coordinated effort between multiple countries and design organizations, but would significantly decrease any barriers to spaceflight and commerce.

Research Question and Methods

Research Question:

How is the absence of a next generation spacesuit design a barrier to an increase in spaceflight and space commercialization?

Research will focus primarily around historical case studies, both in the successful uses of the past generation suits, as well as the common issues that astronauts faced when operating a suit in space (Dick, 2015). Historical studies on the influence of various cultural groups on the drive for spaceflight can be used, the impact that spaceflight had on society, and how ideas about spaceflight were formed and shaped throughout the process.

Ethnography will also take up a significant fraction of the paper, for this is the most applicable method for looking at the cutting edge of research and design. This method is applicable for the use in looking at past and current astronaut training regimens and the behaviors and procedures that take place daily in environments such as the ISS. Further, labs that are making new materials such as carbon weave fibers or exosuit bodies and over-body prosthetics (Bethke, 2004), the processes that they are using, and how these technologies can be implemented into the suit bodies will be analyzed. Individual questionnaires of those that are involved with space related fields could be useful, such as the effects of space on the human body from kinesiology professors and the effect of hard radiation on materials in a vacuum. Those involved with the fields of materials science and artificial intelligence are also interview goals, which would provide insight into some of the technologies that would be integrated into the newest devices. Finally, policy and network analysis can be used to look at the regulatory side of spaceflight, what guidelines are already in place, and what would be required for a large-scale influx of workers into space using new suit technology (Alpert, 2015). Funding for these improvements should be analyzed in these sections, looking at government budgets and how monetary resources could be acquired from appropriations committees in multiple organizations.

Interview setup and large-scale data collection will take place over the months December 2019-January 2020. An impact analysis of this technology will be conducted during the spring semester, with a final research report completed by April 2020. The ultimate goal of this research is to address the four main topic areas concerning spacesuit design: the cost of development, the necessary safety features of any new suit design, useful technology for manned missions, and how to gather social support for development.

Conclusion

The technical device presented in this paper is a flowing spheres chronograph, in which magnets are actuated with servomotors in order to apply a magnetic force to bearings that are placed against the face of the device. A magnetic clock actuated with motors allows for the exploration of magnetic forces as a locking force for joints, and at the same time examine the capabilities of small motor systems actuated by a single controller to maneuver magnets. The ultimate goal of the technical project is a clock device, used in the MAE building to display time through the interaction of ball bearings and magnet forces driven by motor systems. In combination with the research done on stronger materials and computing devices, this technology can help provide insight and design to the next generation of environmental pressure suits for space applications. There are many possible features for a next generation suit, and the goal of this paper is to provide a closer look at the many other technologies that should be implemented in order to provide the safest experience in space. A major part of the design process is accurate identification of the problems experienced by past astronauts, and the necessity and support for a new spacesuit design. A report concerning cost, safety, and technological advancements will be complied and presented to NASA officials, as well as civilian industries involved in space exploration. A main target of this report is the NASA Director of Exploration Research and Technology Programs, Director Josephine Burnett. Further, requests for funding would be presented to the Congressional Committee on Science, Space, and Technology, which has funding control over NASA and therefore any spacesuit development costs, which would be supported by the report.

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