THESIS PROJECT PORTFOLIO

PORTATIVE PIPE ORGAN

(Technical Report)

EVALUATING THE POTENTIAL ECONOMIC ADVANTAGES OF SMALL MODULAR REACTORS AND HOW THEY MAY CONTRIBUTE TOWARDS FUTURE EMISSION REDUCTION GOALS

(STS Research Paper)

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Contents of Portfolio

Executive Summary

My technical report covers the work done by myself and my team in designing and fabricating a mechatronic portative pipe organ. While traditional portative organs require the player to pump bellows to push wind through the system, our organ was designed to do so automatically through a pair of reciprocating box bellows powered by a DC brush motor. The organ was meant to ultimately serve as a display piece that might inspire the imagination of children through its music and motion. My STS research sought to address the question of how big of a contribution small modular reactors (SMR) might realistically make towards increasing the share of electricity generated by nuclear power to reduce carbon emissions. This was primarily explored by discussing the potential economic advantages they promise, as well as how close we are to seeing commercial SMRs generating electricity in the U.S. relative to deadlines and goals set by the federal government on emission reductions.

Our goal for the organ was for it to be able to play preloaded MIDI files on a microcontroller automatically in the style of a player piano, as well as accepting input through a MIDI keyboard. Ideally, it could be used as an educational display piece that would demonstrate mathematical patterns in music while simultaneously promoting interest in mechatronics. Through 3D printing and laser cutting, we were able to rapidly iterate through multiple prototypes, which was particularly useful while designing the pipes. We even ran a computational fluid dynamics simulation on our models to better understand how air flowed through them, allowing us to optimize performance and material cost per

pipe. The total Solidworks assembly of the organ ended up being well over 200 separate parts. As we were limited heavily by time, materials, and budget, there were several instances where we were forced to make sudden changes or compromises on the design to complete a functioning prototype. Ultimately, only three pipes were produced, and, due to being unable to obtain a motor with the necessary speed and torque, the airflow from the bellows had to be augmented with a small compressor for the pipes to speak properly. Additionally, we did not make any progress towards MIDI implementation. However, our prototype was able to produce sounds at the correct pitches when demonstrated, and through this project, we learned many valuable lessons about designing, iterating, and fabricating mechatronic systems that will serve us well in the future.

My STS research paper was concerned with how realistically SMRs would be able to make an impact towards reducing carbon emissions in the future. A major challenge that nuclear power faces, particularly in the US, is being able to compete with cheaper, less-risky sources like natural gas. While the levelized cost of electricity (LCOE) of nuclear can be made competitive, a major barrier to investors are the steep upfront capital and financing requirements that large nuclear reactors require compared to their competitors. Proponents of SMRs present several factors that would help to significantly reduce the upfront costs of nuclear power, such as smaller size and serial production. Some critics argue that the loss of economy of scale would actually increase the specific cost per watt in SMRs. Ultimately, as these designs are largely unproven and still being researched, it remains to be seen which side is proven correct. This leads to the discussion of SMRs' potential to reduce carbon emissions. Considering the Biden administrations aggressive goals on reducing emissions, as well as the fact that the Nuclear Regulatory commission has only approved one SMR design for commercial use, it is safe to assume that, barring a dramatic change in the current situation, SMRs will have a minimal effect on emissions by 2030. However, SMR development is still worth pursuing, as they promise zero-emissions electricity 24/7 that can complement power sources that are intermittent, such as solar and wind. Applications of SMRs in other countries and industries are also being explored, meaning that even if they ultimately are proven to be unviable in the U.S. electricity market, they can still potentially make an impact in a different context.

Through my technical project, I learned many important lessons about design, iteration, and working against harsh constraints to produce something that I could be proud of. Through my STS research paper, I learned a lot about how technology and society interact with each other, particularly regarding technological development is dependent on much more than simply finding the "best" solution. While the two projects were not connected by a common question, a common theme between the two was learning that theory and ideal models often do not line up with reality. To make a positive impact on society, it is important to recognize this and work within these limitations to produce good work and improve the conditions of our fellow man.