2023 Undergraduate Research Summer Internship (URSI) Appointment Reflection

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Mentor: Dr. Wesley Williams

This internship came the summer after completing my undergraduate degree at the University of Tennessee in Nuclear Engineering. My focus at Oak Ridge Nation Laboratory has been on the Nuclear Thermal Propulsion (NTP) project. At first, my work was almost entirely under my mentor, Wes, who is the group leader of the Advanced Reactor Systems Group. His group had developed a model of the NTP rocket (see Figure 1). ORNL's NTP model is constructed within the Dymola integrated development environment (IDE) of the Modelica programming language; it utilizes the ORNL-developed TRANSFORM library package of nuclear and thermal hydraulic components. The NTP model is well developed and designed to accommodate the dynamically changing specifications provided by the US National Aeronautics and Space Administration (NASA). I helped extenuate and further this work by developing fault mode models. Collaborators on our project who have a similar model have also considered fault modes. However, their model does not have a focus on instrumentation and control like the ORNL NTP model.

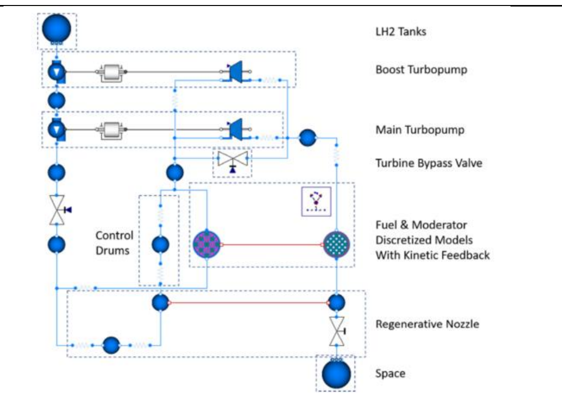

Figure 1. Simplified graphic of the Modelica NTP model

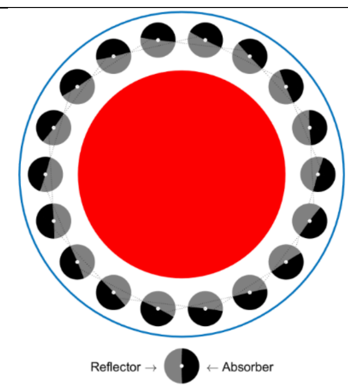

Figure 2. Example control drum arrangement

The degradation modes I focused on dealt with the control element of the nuclear reactor in the NTP system. A nuclear reactor, which heats up and expands hydrogen to provide thrust, is surrounded by control drums (see Figure 2). This work represents a great opportunity to compare our model response to that of our collaborator's more detailed models of the nucleonics response of the core. Such models pave the way for deploying digital twins that can be used for predicting system performance or forecasting maintenance and component failure. This work has been documented and submitted for presentation at the 2023 American Nuclear Society Winter Conference.

The two types of fault modes in the drum system are a stuck drum, and resolver error. The control drum could get stuck due to the cold conditions of space or a mechanical failure of the drum motors. For my chosen simulation, the drum gets stuck right after ramping up the thrust, before finding a steady state thrust. As more drums get stuck, the other drums need to compensate more, this can be seen in Figure 3. The other failure mode occurs in the resolver, which measures drum position. When this fails, it changes the angle quickly. The response for a positive resolver error can be seen in Figure 4. More details about results and methodology can be found in the previously mentioned ANS summary. I am glad to be presenting this work at a professional conference and improving my public speaking ability, as well as putting the spotlight on the great work being performed by ORNL.

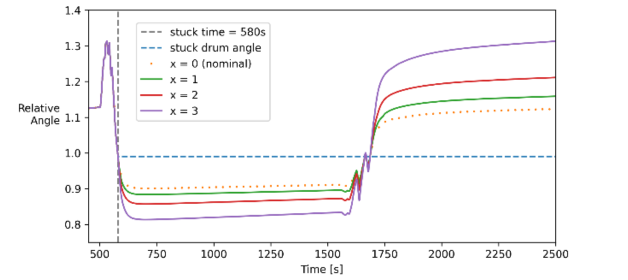

Figure 3. Controller response for x number of stuck drums. Failure occurs at the gray vertical line at 580~s; the healthy response is indicated by the dotted orange line; the stuck angle is represented by the dashed blue line.

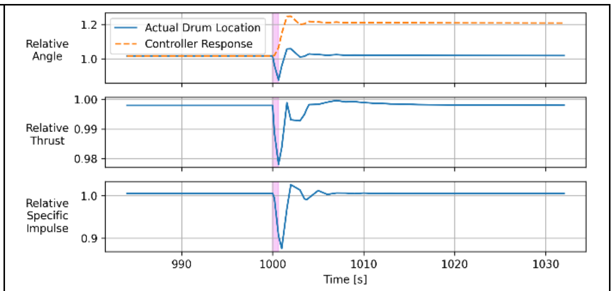

Figure 4. System response to a positive resolver error.

The second portion of my appointment has been spent working with Dr. Dianne Ezell and Dr. Brandon Wilson of the Nuclear and Extreme Environment Measurement group. They have a physical two-phase mock reactor that needs to be paired with the NTP model. I have been working on methods to interface these two media through a MQTT brokers and, running an exported version of the model via a python script. This has been a great learning experience, and I have gained a valuable set of tools that not many others have. I have also been tasked with documentation of this work, in the case that I am not able to continue working on it. This is good practice and I’m glad I had to do it for the researchers I am working under.

Overall, this has been a very positive research internship opportunity. The staff at both ORNL and ORISE have been fantastic. I have greatly enjoyed the researchers that I have been able to interact with and learn from.