Introduction
The Johnson Space Center’s Space Environment Simulation Lab (SESL) houses two specialized chambers. Chamber A, seen in Figure 1, is the world’s largest purpose-built thermal vacuum chamber capable of creating deep space conditions. Chamber B, seen in Figure 2, is the largest thermal vacuum chamber designed for human-rated operations. Chambers A and B were built in 1964 to support testing of the Apollo vehicle and command module to train astronauts in a simulated space environment. For the James Webb Space Telescope (JWST) thermal vacuum test in 2017, Chamber A was upgraded to simulate a deep space environment with temperatures as low as 11 Kelvin.

Building the Thermal Model of Chamber B
To begin this process, a feasibility study, requiring the analysis of a model of the chamber in Thermal Desktop, was conducted. Within Chamber B, there are four different LN₂ shroud zones (labeled as N1, M1, L1, and P1) and an LN₂ shroud covering the outer walls of the chamber (labeled as N2) as seen in Figure 3 below. In addition, there are fifteen cryopumping panels (labeled as P1) located behind each inner LN₂ panel. It should be noted—neither the cryopumping panels nor the outer shrouds of the LN₂ panels can be controlled individually. Since there is no individual control of the LN₂ panels, the model assumed all of the helium cryopumping panels were insulated with mylar for the feasibility study. The surface emissivity of the shrouds and panels was needed for the model and was measured using an emissometer/reflectometer. The front of the LN₂ panels, which are coated in black paint, have a measured emissivity of 0.89, and the back of the LN₂ panels, with no paint, have a measured emissivity of 0.16. The helium cryopumping panels, which are uncoated, have an emissivity of 0.13.

In March of 2023, a full thermal vacuum functional was run on Chamber B in preparation for future testing. This presented the opportunity to collect data regarding the temperature of the LN₂ zones and the helium cryopumping panels to feed into the analysis. The time that the cryopumping panels took to go from their initial [room temperature] steady state condition to their final cold steady state condition was used to make the Thermal Desktop model as accurate as possible. Figure 4 above shows the helium cryopumping panel temperature, and Figure 5 shows the LN₂ shroud temperature in Zone N1 of Chamber B throughout the functional.

Helium Cryopumping Panel Background
A unique design feature of these chambers is the presence of gaseous helium cryopumping panels within the chamber’s liquid nitrogen shroud. This shroud is used to bring the chamber to cryogenic temperatures while the cryopumping panels utilize their extensive surface area to trap gases, creating a high vacuum environment with pressures as low as 5*10⁻¹⁰ Torr. In preparation for the JWST flight test, a series of functional tests were performed on the cryopumping panels. Both the liquid nitrogen shroud and the cryopumping panels were required to be cryogenic in order to prevent the chamber from becoming warm. This strategy proved effective in improving efficiency and mitigating contamination, and became part of operations during JWST testing.

Proposed Insulation on Cryopumping Panels
Currently, Chamber B has requests from both commercial and NASA space suit tests to accurately generate thermal models at both high and low temperatures. High temperature tests would greatly benefit from simultaneous shroud warming and the high vacuum environment provided by the cryopumping panels. To enhance the efficiency of operations during these tests, it has been proposed that thermal insulation be added to Chamber B’s cryopumping panels.

Conclusion
Three insulation configurations of the cryopumping panel were analyzed. These cases modeled insulation on the front of the cryopumping panel, pointing towards the center of the chamber, on the back of the panel, and a final case with both sides insulated. These cases were run parametrically, with layers modeled from five to fifty, in increments of five. Additionally, a control case with no insulation was run. The heat flux of the cryopumping panels in each instance was recorded, and these values were compared to the heat flux of the control group, as a percentage.

We would like to thank John Tatum, Cody Schaefer, Gerardo Barrios, Steven Del Papa, Shaiya Moreno-Felix, Josh Graham, Rumaldo Gonzales, Darren Nelson, Tayera Ellis, Sam Vengerik, Miranda Finckenor, Meghan Carrico, and Jesse Macias. In addition, we would like to thank everyone in the Systems Test Branch of the Crew and Thermal Systems Division at NASA JSC.

References