Cooling Rb-87 Atoms with Adiabatic Expansion in Microgravity
(Technical Report)

A Virtue Ethics Analysis of the Mars Climate Orbiter Failure
(STS Research Paper)

An Undergraduate Thesis Portfolio

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Sociotechnical Synthesis: Adiabatic Expansion and the Mars Climate Orbiter Failure

This semester I worked on a new technique for cooling atoms in microgravity and studied the role of engineering virtue ethics in the Mars Climate Orbiter failure. Central to both projects is the engineering/research process. In my technical project, I worked as a researcher on a complex project, while in my STS project I studied the failure of an engineering project. While the actual topics of the two subjects were quite different, both involved the engineering process.

In my technical project, I collaborated on the development of a new technique for cooling Rubidium-87 atoms to extremely low temperatures. The technique, called adiabatic expansion, requires microgravity conditions. Because of this condition the experiment is taking place using NASA JPL's Cold Atom Laboratory (CAL), which is located on the International Space Station (ISS). The CAL apparatus creates Bose-Einstein Condensates (BECs), a type of ultracold quantum gas, in tightly confining magnetic traps. These magnetic traps are controlled by running currents through a set of coils and a wire chip configuration. Adiabatic expansion uses the manipulation of the electric current magnitudes to relax the magnetic trap and cool the condensate even further, from the millikelvin to the nanokelvin regime. We have demonstrated the ability to displace atoms from the original configuration into a trap with 3 Hz frequency, with minimal residual center-of-mass motional excitation. We also explored how different trap turn off procedures affected the population of different magnetic states, as well as how stray background fields in the apparatus may limit the length of condensate observations.

In my STS research paper, I used virtue ethics to evaluate the morality of the Mars Climate Orbiter's navigations engineering team and navigation operations team. The Mars Climate Orbiter was a NASA robotic space probe that failed due to a unit conversion error in a

software file. I concluded that since the teams lacked the virtues necessary for responsible engineers, then their actions were unethical. Specifically, the engineering team lacked the virtue of striving for quality, and the operations team lacked the virtue of professionalism. Both teams failed to display the virtue of communication. Using virtue ethics, the actions of these engineers were evaluated and it was determined that they were immoral due to failing to possess the virtues needed for ethical engineering. The goal of my research was to understand how cultivating the necessary engineering virtues makes it much less likely that an error will cause the total failure of a project.

Working on both projects at the same time gave me a better understanding of the engineering/research process. In my technical project, I worked on a novel atom cooling process in the field of ultra cold quantum gases. My STS project on virtue ethics in engineering helped me to understand the importance of cultivating good engineering virtues, especially when working on large and complex processes. This is the best way to keep small errors from causing the failure of a project.