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Mathematical thinking in the Nuclear Navy

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The careers of every nuclear operator in the United States Navy begins the same way. Every hopeful candidate gathers at the Naval Reactors headquarters at the Navy Yard in Washington, D.C. to conduct technical interviews with the designers, regulators, and operators of America's nuclear fleet who test our knowledge of physics, mathematics, and problem-solving abilities. Those of us who demonstrated suitable knowledge were then ushered to a large conference room where we awaited a time-honored and storied final chapter to the interview process: the admiral interview. Since the inception of the Naval Nuclear Propulsion Program, the program director, a four-star admiral, has personally interviewed every operator to personally verify their character and knowledge.

The pomp and circumstance around the admiral interview is a hallmark of the Nuclear Navy's mythos. When a young Jimmy Carter sought to join the program in 1952, then-Captain Hyman G. Rickover, the founder of the program, inquired the future President on his class ranking at the Naval Academy. Carter proudly responded that he was in the top 10% of his class. When pressed if he always gave his best effort Carter hesitated to answer, prompting Rickover to ask a question at the core of the Nuclear Navy's ethos: "Why not the best?"

I am sure it is obvious to any student considering a career in nuclear science and engineering that a robust education in mathematics is core to one's success. But in my time thus far as an ensign in the United States Navy, I have encountered plenty of peers with exceptional skills in mathematics, physics, and engineering principles who struggle to succeed in the rigorous training pipeline that this program demands of us. This article seeks to convey that a core tenet to success in the Nuclear Navy —– and, I suspect, in many other advanced STEM fields —– is the appreciation of nuance, interconnectedness, and creativity.

I am Ensign Matthew Hornak, a prospective submarine warfare officer and graduate of the University of Pittsburgh, class of 2024. I commissioned as an officer in the

Navy through the Carnegie Mellon University Naval Reserve Officer Training Corps the same year, and earned a Bachelor of Philosophy in International and Area Studies with a double major in Mathematics-Economics. I spent my college years pursuing just about as interdisciplinary and rigorous education as one could conjure up at Pitt. While my love for learning motivated my educational path, I quickly grew to appreciate in my time in college that everything I studied influenced one another, and an education in one aspect would be incomplete without the others. A competent naval officer has a strong grasp of current events and cultural competency; a core understanding of international happenings requires an understanding of the economics that underpins these currents; economics studies human interaction, in part, through robust mathematical models and perspectives. As I progressed through these programs, I realized that a core understanding of mathematics would be an invaluable tool at my disposal in synthesizing a vast breadth of knowledge.

In my senior year I learned that the Navy had selected me to become a submarine warfare officer, where after roughly a year of training I would report to one of the United States' 67 nuclear-powered submarines. The submarine fleet currently consists of three types of submarine: Fast Attack (SSN), Ballistic Missile (SSBN), and Guided Missile (SSGN). SSNs carry out a variety of mission sets, including intelligence gathering operations, cruise missile operations, and silently patrolling the seas. SSBNs silently carry one leg of America's Nuclear Triad: Submarine Launched Ballistic Missiles (SLBMs). SSGNs are equipped to carry cruise missiles and provide support to Special Operations forces across the globe.

While the United State's has utilized nuclear-powered vessels for 71 years, it's worth taking a beat to appreciate how sophisticated and groundbreaking these ships are. I assume most readers have seen a traditional nuclear power plant, either in person or in media. These stations are behemoths, taking up vast space to power cities. And I am sure that most readers have at least heard of one of the following: Chernobyl, Three Mile Island, and Fukushima. These places are remembered as the three worst nuclear incidents in human history. In 1946, Hyman Rickover was tasked with taking the innovations and discoveries of the Manhattan project and atomic bomb program to create war-ready vessels powered by nuclear fission. In short, in the course of eight years, the the United States Navy harnessed the tremendous and unspeakably destructive power of elements like Uranium and Plutonium not just into the massive power stations you and I know, but into a 30-foot "tin can" meant to travel the world in the harshest conditions imaginable. And to crown this achievement, the nuclear navy has never suffered a reactor accident in its nearly 80 year history. In short, humanity's greatest achievements in science and engineering are on display with outstanding success in the nuclear navy.

To ensure this reputation, prospective nuclear operators undertake over a year of intensive training before ever stepping foot on a seafaring vessel in three steps: Nuclear Power School, a Prototype Training Unit, and for submarine officers, Submarine Officer Basic Course (SOBC). At Power School, students have six months to digest and excel at a wide variety of topics in a classroom setting; everything from chemistry and fundamental radiological safety to reactor theory and electrical engineering. At Prototype, officers are tasked with synthesizing their Power School knowledge to successfully manage an operational nuclear reactor and its associated power plant. At SOBC, one learns the fundamentals of driving, navigating, and utilizing a warship. While it may seem that a STEM student would have a leg up in this training by having seen much of this information in their four years of college, this is not always the case. The Navy expects students to learn the vast material presented to them in a specific sequence and manner, no more and no less. While a deep understanding of some engineering concepts can help, it can also hobble some who struggle to exchange the very academic knowledge they gained in college for the at times simpler and more pragmatic knowledge we learn.

Thus, while the standard calculus and physics classes all engineers take certainly set me up for success, the class that actually best prepared me for my career thus far was MATH 0420: Introduction to Theoretical One Variable Calculus with Dr. Sparling. 0420 pushed my knowledge of math past algorithmic memorization of procedures and toward a deeper appreciation of the ideas that a language like mathematics best conveys. I no longer just took a derivative or optimized a parameter, nor did I regurgitate standard proofs that one may find in introductory theory classes. Instead, I had to prove rather abstract ideas with fundamental facts and axioms in unique ways; no two problems were answered in exactly the same way. While I don't find myself using the epsilon-delta definition of a limit in my career, the substance of the math in 0420 wasn't the most important lesson. Rather, the creativity needed in approaching a problem and concocting my own reasoning for the truth of the answer taught me to tackle topics with which I am unfamiliar with curiosity and to seek out the fundamental truths I needed. My tendency to approach problems this way garnered me a reputation in my class for being the nerd that dug beyond the provided textbooks and scouring through the copious volumes of technical manuals that usually just gathered dust in the classroom.

For students who may be considering working not just in the nuclear fleet but in any engineering field, the best advice I can provide from my experience thus far is to seek out the fundamentals of what you are working on. The three nuclear accidents I mentioned earlier —— Chernobyl, Three Mile, and Fukushima —— all share a common hallmark: Their operators failed to understand the implications of their emergency procedures or indications. When an issue became apparent or an emergency began, they simply went through the motions their procedures told them. But they failed to ask: Could this indication mean something else? Why are we doing things this way? Could this cause any future problems? As you progress through your careers and earn greater responsibility for the safe operation of something, you ought to take time to understand the core principles that you must satisfy and how your actions affect them. As is true in theoretical math, even a small mistake or misunderstanding can mean all the difference in your success.

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