Thesis Project Portfolio

Smart Sprinter

(Technical Report)

Barriers to Quantum-Resistant Digital Infrastructure: A Sociotechnical Analysis

(STS Research Paper)

An Undergraduate Thesis

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Table of Contents

Sociotechnical Synthesis

Inventing novel technology is one feat as an engineer, but achieving widespread implementation throughout society requires a more holistic set of skills. My capstone project, Smart Sprinter, addresses how sensor integration and data analytics can enhance athletic performance, while my STS research analyzes the sociotechnical barriers to implementing post-quantum cryptography (PQC) across global digital infrastructure. Although the fields of sports technology and cybersecurity seem unrelated at first glance, both projects deal with the challenge of integrating disruptive technologies into existing systems, examining how technical solutions must consider social dynamics, institutional inertia, and user adoption.

My team's capstone project, Smart Sprinter, targets a specific athletic training need: improving short-distance sprint starts through real-time data-driven feedback. Despite the prevalence of motion-capture and wearable analytic devices in sports, little attention has been paid to a low-cost, ground-mounted system for the starting block. The Smart Sprinter is a system consisting of force sensors embedded into the starting block, a laser height detector to flag excessive vertical rise, an STM32 microcontroller, and a Python-based graphical user interface (GUI) to collect and display three key performance metrics: force, block exit time, and height metrics. Unique linear transfer functions per force sensor were calibrated from empirical load tests and a robust PCB was designed to connect seamlessly as a peripheral shield to an STM32. The resulting system reliably delivers block exit time, force-time curves sampled at 1kHz, and height-clearance indicators allowing sprinters to refine their form based on data rather than subjective observation. Yet technical accuracy alone does not guarantee adoption by an athlete, coach, or team, thus we had to design the interface to be simple and intuitive. For the Smart Sprinter to be impactful we had to consider user accessibility, ease of interpretation, and knowledge of sprinting in addition to good engineering. This transitions naturally to my STS research, where I explore how technological superiority alone is insufficient for societal adoption.

In my STS research, I investigated why organizations have been slow to implement post-quantum cryptography (PQC), despite the existential threat posed by quantum computing to existing cryptographic systems. Soon, estimated to be around 2035, quantum computers will realize Shor's algorithm, rendering RSA and ECC encryption insecure, which much of the internet still runs on. Using the technological momentum framework of Thomas Hughes, I showed how cryptographic infrastructure becomes increasingly resistant to change over time, and how technical, social, and governmental barriers intertwine to delay the adoption of critical innovations. I analyzed three barrier categories: (1) technical constraints such as performance overhead and hardware-acceleration gaps, (2) social and workforce limitations including scarce cryptographic expertise and developer unfamiliarity, and (3) institutional inertia from regulatory ambiguity and compliance risks. Even though the PQC algorithms have been invented from a technical standpoint, slow developer adoption, governmental ineptitude, and bureaucratic inertia prevent rapid deployment. My analysis contextualized the PQC transition not simply as a technical upgrade, but as a multi-faceted sociotechnical evolution requiring coordinated action from private tech companies and the government.

My capstone and STS projects reveal a shared insight: technological innovation is inseparable from the society surrounding it. Whether designing tools for athletes or securing the future of digital communication, engineers cannot solve technical problems in isolation; they must also engage with society that will adopt, adapt, or reject new technologies. Therefore, engineering is not simply the technical application of math and science knowledge, but a sociotechnical career that requires understanding and shaping human systems as much as designing machines.