Undergraduate Thesis Prospectus

A CubeSat's Hypersonic Flight: Effective Software and Avionics Systems

(technical research project in Mechanical Engineering)

Fast Track: The Competition for the Future of High-Speed Rail in the United States

(sociotechnical research project)

by

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On my honor as a University student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

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General Research Problem

How may high-speed vehicles be most cost effectively developed?

State-of-the-art transport modes are expensive and controversial; most also require political support. Development of such systems therefore requires efforts to enlist public confidence by demonstrating such systems' benefits.

A CubeSat's Hypersonic Flight: Effective Software and Avionics Systems

How can HEDGE use software and avionics systems to develop fast and efficient atmospheric data transmission systems?

The Hypersonic ReEntry Deployable Glider Experiment (HEDGE) is a CubeSat that will be launched into orbit and reenter the Earth's atmosphere at hypersonic speeds to collect data. A CubeSat is a standardized miniature satellite (Caldwell, 2023). The Software and Avionics subteam is tasked with developing the hardware and software system of HEDGE for data collection, storage, and transmission. Our role emphasizes interfacing the onboard computer (OBC) with other hardware components due to the interdependencies of various subteams with the OBC.

Objective of Research Work

The core aim this year is to build and evaluate a prototype encompassing key hardware and software for HEDGE. We'll expand on last year's efforts, focusing on vital electronics like the pressure transducer, the Endurosat onboard computer, and the thermocouple. Our priority is to assure smooth communication between these components and efficient data transmission via the Iridium transceiver module.

Our mandate further entails software development for real-time data handling during the CubeSat's operation, ensuring alignment with the avionics. Post prototype and software completion, our next objective is developing comprehensive testing methods, focusing on hypersonic re-entry conditions. Additionally, our remit includes task scheduling and operation balancing across all teams, emphasizing the significance of university-driven, industry-relevant research.

Approach and Methods

Our approach begins with integrating the selected electronics, transitioning from the previous ISS OBC to the new Endurosat OBC components. In collaboration with electrical engineering students, we will design circuit boards for the thermocouple, pressure transducer, and receiver, referencing the data flowchart shown in Figure 1.

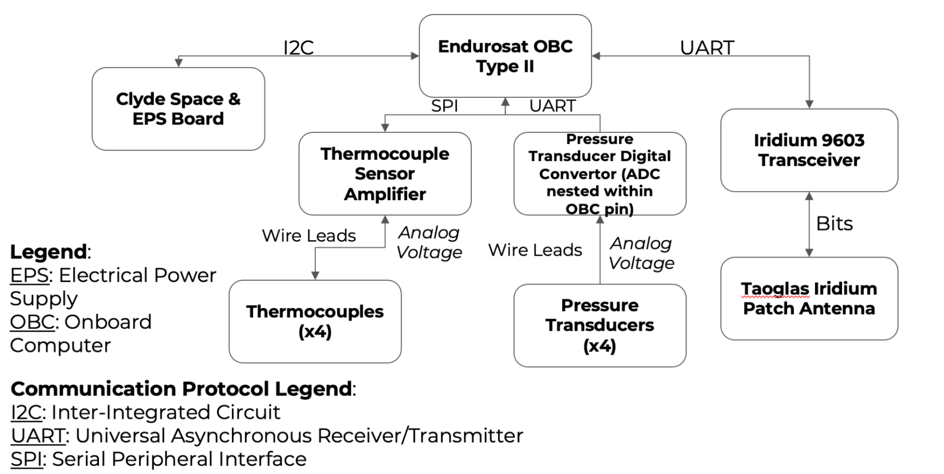

Figure 1: Hardware data flowchart (UVA MAE 4700 2023 Students, 2023)

The software, which consists of freeRTOS, COSMOS, and CFS, will be developed to work alongside the hardware. Then, multimeters and microcontrollers will test the hardware and software to ensure the OBC communicates well with all components. Final designs will be shared with other subsystem teams for a cohesive HEDGE prototype.

Resources

For command and control, the Endurosat onboard computer will be used. The endurosat onboard computer user manual is a great resource which has key information about hardware and software integration, application programming information documentation, initial configuration procedures, troubleshooting, and safety guidelines (Endurosat, 2018). To manage onboard processing, NASA's core flight system, a reusable software framework, will be used due to its reliability and portability (NASA). The COSMOS operating system will be used to set up the ground-based system and also run simulations software and hardware components (OpenC3, 2023). Both CFS and COMOS are open source, which allows for collaboration with others. Professor Mike Mcpherson of the University of Virginia and the electrical computer engineers will be invaluable resources, aiding in circuit board design and software setup.

Objectives for Spring Semester

By Fall 2023's end, the software and avionics team will present hardware components for the MSP300 pressure transducer and the Iridium 9603 transceiver module. The OBC testing will commence in Spring. We aim to integrate CFS programs with the pressure/temperature and communication hardware components on a Raspberry Pi 4b, transitioning later to a more compact microcontroller with FreeRTOS. Spring 2024's primary objective is to migrate the CFS software to the Endurosat OBC, focusing on precise input/output functionality between software and hardware. Testing frameworks from OpenC3 COSMOS will assist in simulating the satellite's operational environment (OpenC3, 2023). Lastly, we will collaborate with the integration team to map the satellite's interior, ensuring smooth avionic operations.

In the upcoming semesters, we will prepare for a Technical Interchange Meeting (TIM) and, subsequently, collaborate with all subteams for a System Integration Report (SIR) and a technical thesis.

Fast Track: The Competition for the Future of High-Speed Rail in the United States

In the United States since 2008, how have interest groups competed to promote or prevent high-speed rail proposals?

Since Japan pioneered high-speed rail in 1964, over 20 countries have followed suit. Though the U.S. has grappled with its adoption, California's approval of a San Francisco-Los Angeles bullet train bond in 2008 marked hope. However, with construction only beginning in 2022 and costs surging to an estimated $113 billion, the path forward remains undetermined (Frommer, 2023).

Existing Literature

The impacts of high-speed rails (HSRs) on environments, societies, and economies have been deeply investigated over the years. These examinations will illuminate the comprehensive effects and potential trade-offs involved in implementing such expansive projects.

Damián and Zamorano (2022) pinpointed that during high-speed railway tunnel construction, materials like concrete, diesel, and steel substantially contribute to the environmental toll, accounting for approximately 70% of the total impacts. Notably, as the Rock Mass Rating (RMR) decreases, indicating poorer rock quality, a surge in required resources and materials for excavation leads to an escalation in emissions across all assessed environmental impact categories. However, beyond environmental concerns, there's an essential dimension of social justice: high-speed rail users predominantly hail from specific socio-economic brackets, characterized by higher income, education, and occupational positions. It's distinctively noted that the profile of these passengers is markedly different, being "anything but neutral" when compared to the broader population (Dobruszkes, 2021).

The mobility dynamics introduced by HSRs are also pivotal. The Paris-Lyon HSR's impact was transformative, with rail traffic soaring from 40% to 72% within just three years, whereas air traffic dwindled from 31% to 7% (Albalate, 2012). This shift emphasizes the considerable potential of HSRs in altering transport patterns. Globally, insights from nations like Japan shed light on these effects. Shinkansen, connecting Tokyo to Osaka, introduced in 1964 due to post-WWII mobility demands, now serves over 300 million passengers yearly, highlighting HSR’s vast economic and regional influences (Albalate, 2012).

While providing enhanced accessibility to cities, HSRs also come with unintended economic repercussions. These infrastructures can significantly influence regional economic activities. Notably, while certain cities benefit from improved accessibility, there's the underlying phenomenon of the "tunnel effect:" HSR lines can lead to territorial polarization rather than fostering increased interterritorial cohesion (Albalate, 2012).

Participants

The US High Speed Rail Association ardently advocates for the transformation of America's transportation landscape, championing high-speed rail as a pivotal solution to both environmental and economic challenges. Their perspective is encapsulated in the assertion: "High speed rail is the single largest climate solution that can decarbonize the majority of our transportation network quickly" (US HSR, 2022). Drawn from their official documentation, the US HSR not only emphasizes the environmental merits of the rail system but also underscores its potential in reshaping real estate dynamics and making transportation more affordable for American families.

The Show-Me-Institute, rooted in its stance of fiscal responsibility and a preference for market-driven solutions, staunchly questions the financial and practical viability of high-speed rail in the U.S. Drawing from O'Toole's publication, the institute cautions that while high-speed rail projects might seem promising, their "high costs, tiny benefits, and interference with property rights" could mean that taxpayers end up bearing significant financial burdens without seeing proportionate benefits. Highlighting potential environmental downsides and arguing for more cost-effective incremental upgrades to current systems, they uphold their motto as the "Guardians of taxpayer interests" (O'Toole, 2009).

The California Labor Federation fervently endorses the immediate development of high-speed rail in California, citing an array of compelling reasons outlined in Hunter's report. He argues that such projects would not only alleviate transportation challenges and reduce fossil fuel dependency but also spur significant job creation in the construction and transportation sectors. Invoking historical parallels to the initial opposition faced by iconic projects like the Golden Gate Bridge, the Federation emphasizes the long-term advantages and sustainability that high-speed rail promises, "underscoring the need for immediate action" (Hunter, 2014).

The Environmental Defense Fund (EDF) conditionally supports high-speed rail in California. Per Festa's report, the EDF firmly believes in supporting initiatives that showcase tangible environmental gains. However, their backing is predicated on broad public consensus and the assurance of long-term benefits, rather than momentary gains (Festa, 2019). They argue that while reducing emissions is of paramount importance, true resilience, and sustainability in the face of climatic challenges hinge on collaborative endeavors. To foster resilience, the EDF emphasizes the need for community-wide involvement, where every stakeholder visualizes a prosperous future for themselves within the scope of these projects. This perspective seeks to integrate environmental considerations with public sentiment, making decisions "on the condition of broad public support and environmental benefit" (Festa, 2019).

The American Public Transportation Association (APTA) champions the advancement of public transportation systems, representing diverse modes of transportation across North America. Regarding high-speed rail, APTA confronts criticisms, emphasizing the importance and viability of such projects in uniting and benefitting the nation. They believe that while the challenges for passenger rail exist, the benefits outweigh the criticisms. APTA urges advocates to actively counter misleading arguments, championing a vision of America with a leading passenger transportation system inclusive of high-speed rail (APTA, 2012).

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