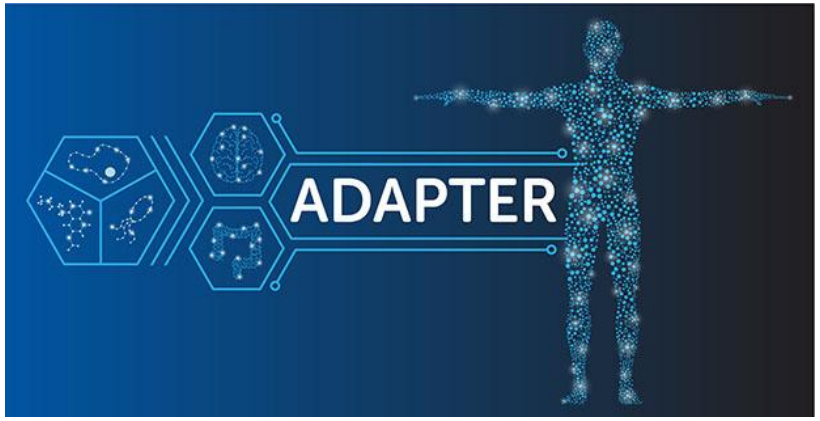
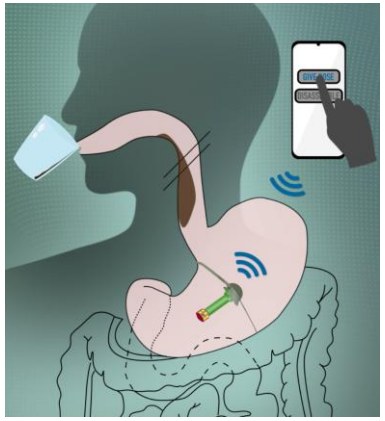
# Ian Ballinger's Research Portfolio

12/07/2023

Massachusetts Institute of Technology

Mass General Brigham



# ADvanced Acclimation and Protection Tool for Environmental Readiness (ADAPTER) - 2.5 Years of Effort

DARPA

Program Announcement

Active Program Website

Design and build an “ingestible pharmacy” to enable patients to control aspects of their physiology, functioning as a travel adapter for the human body

Some Figures taken from the Publication

The variability of gastric environments and Ingestible device size constraints result in antenna performance degradation due to resonant frequency shifting in proximity to gastric fluids, among other problems

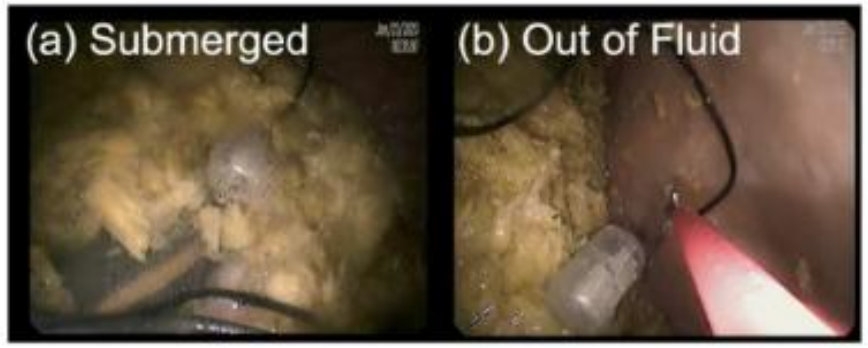



Figure 2. Endoscopic photos of a capsule inside the stomach when the capsule is (a) fully submerged in the gastric fluid and (b) out of fluid, showing dynamic GI environment.

We quickly identified this as a major barrier to device design. How do you compensate for the unknown composition of lossy materials in the near field region of an antenna?

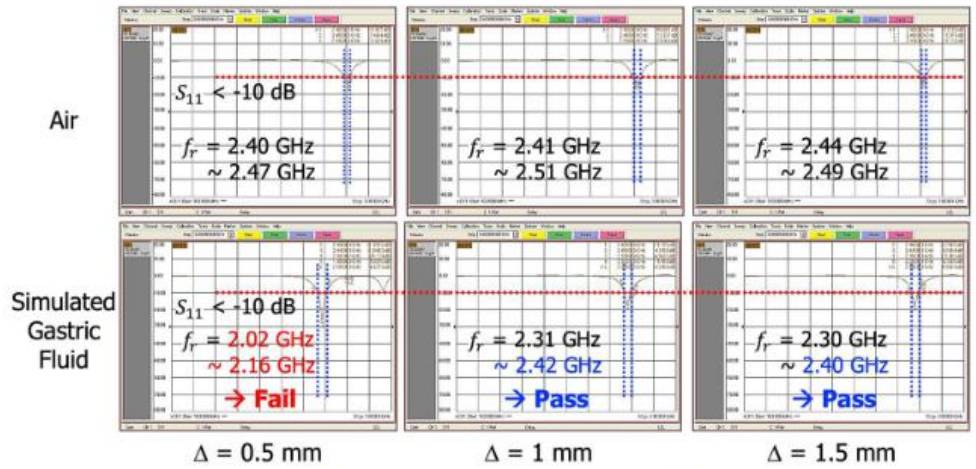
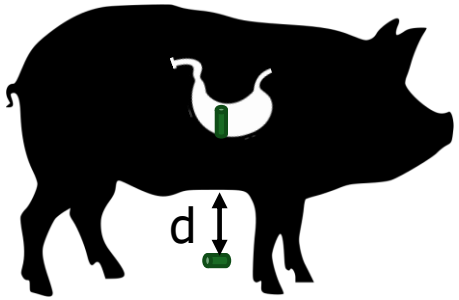



Figure 6. Antenna resonant frequency of a 2.4-GHz chip antenna surrounded by air gaps with various sizes when each capsule is over the air (top) and fully submerged inside the SGF (bottom).

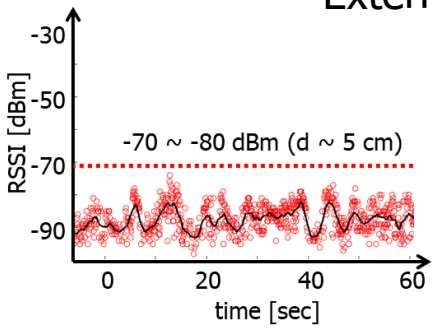
# Technical Problem Spotlight – Secure and Stable 2.4GHz Communication for an Ingestible Device

Some Figures taken from the Publication

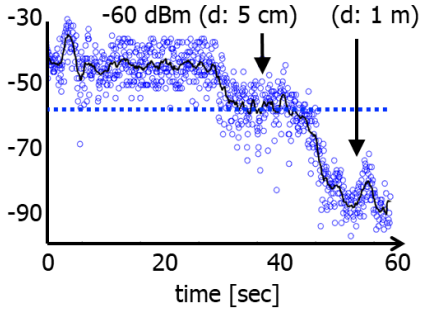
I discovered that we don't need to contain the whole near field region to reliably tune antenna resonance, and experimentally measured the appropriate air-gap distance for fabricating gastric devices.



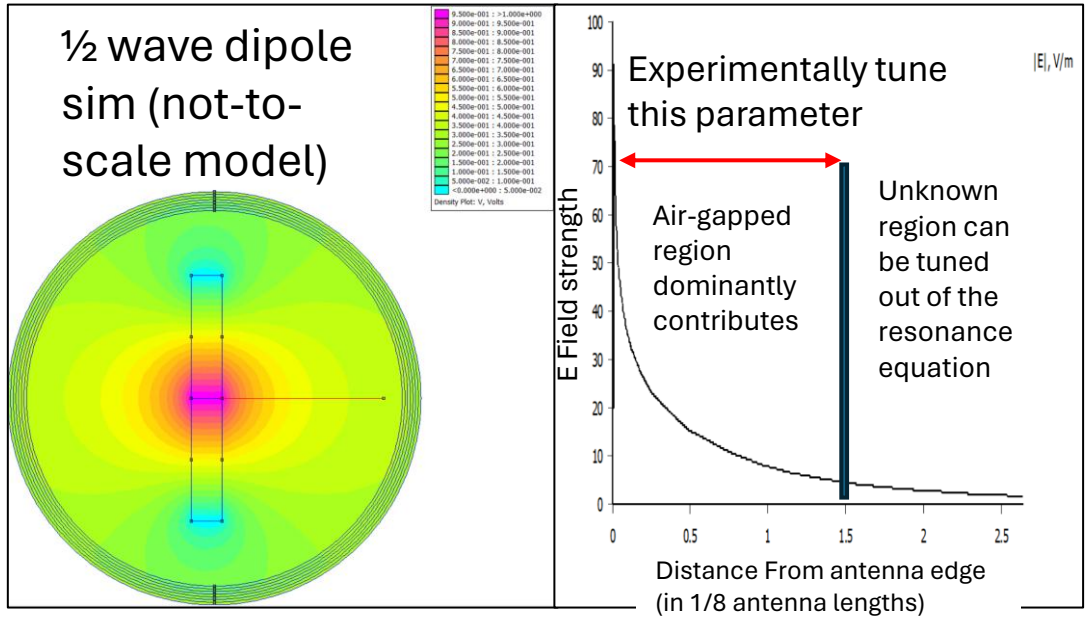

External receiver




w/ 0.5-mm air gap




w/ 1.5-mm air gap



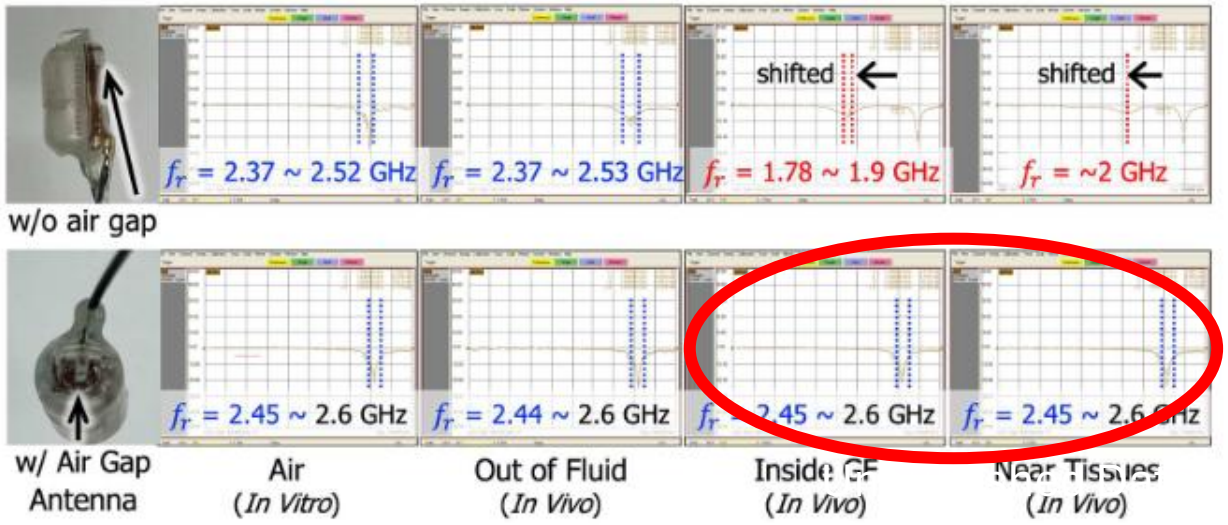
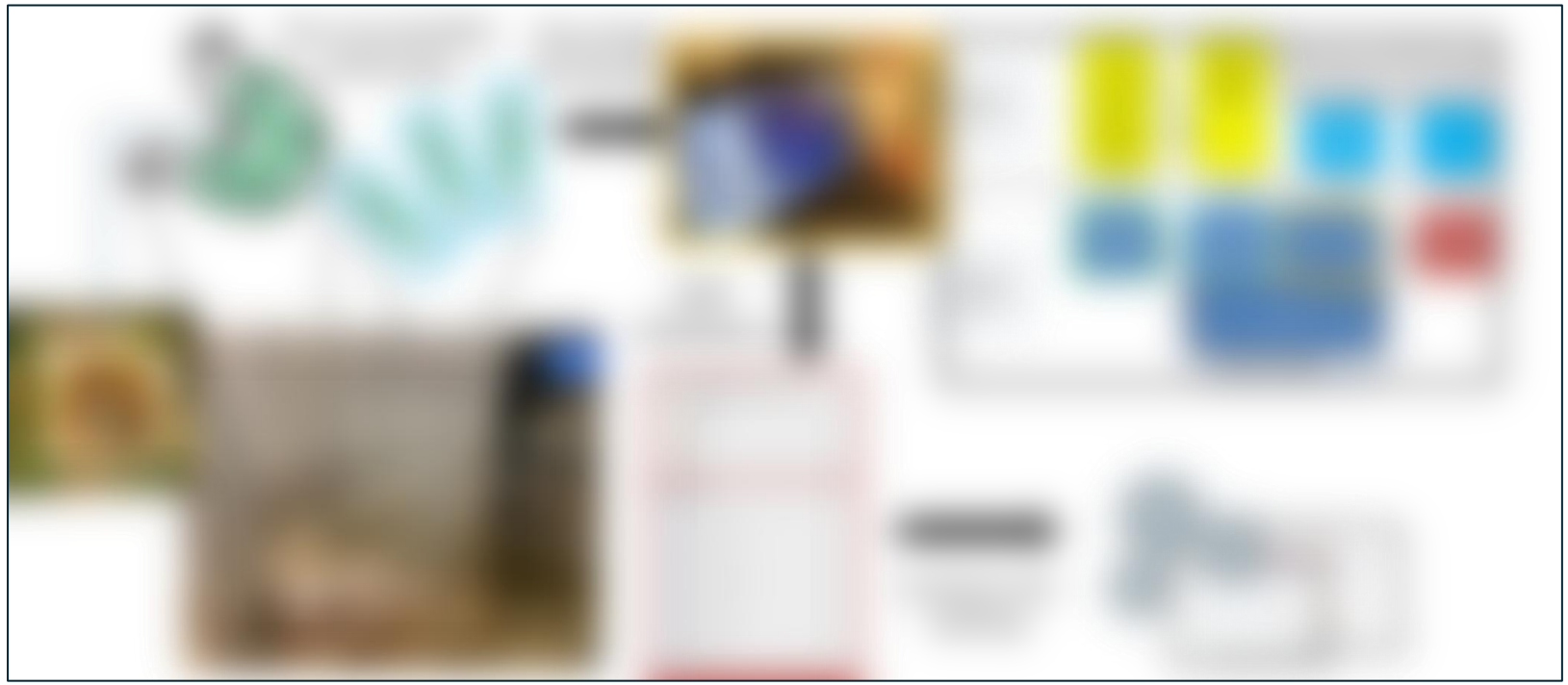




Figure 7. *In vitro* and *in vivo* tests on the antenna resonant frequency of the chip antenna without and with air gap under various environments (air, out of fluid, fully submerged inside the GF, and near tissue when the stomach deflated).

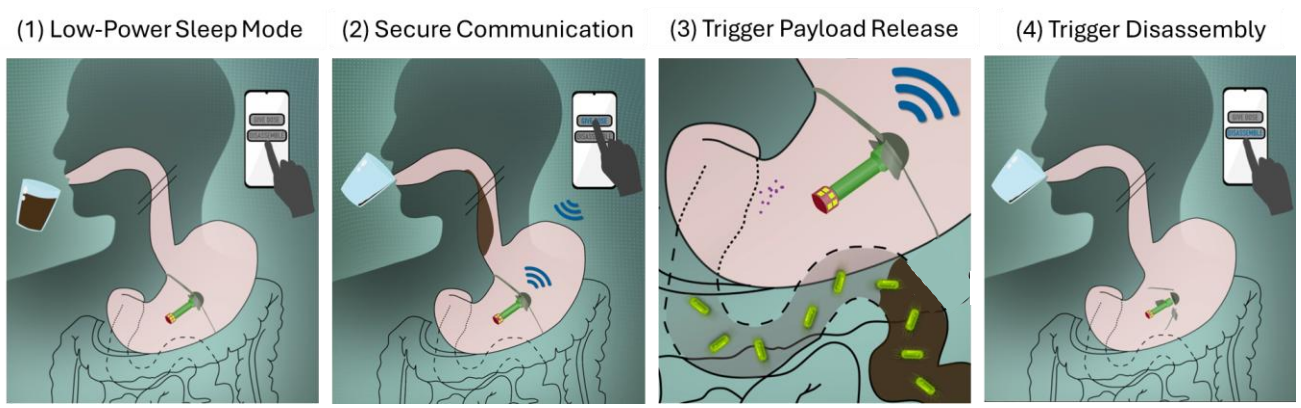
No shift when well tuned, compared to a poor tuning above

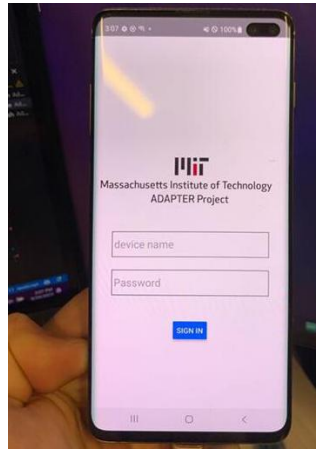
# ADAPTER – Developed remote and automated in-vivo data collection infrastructure

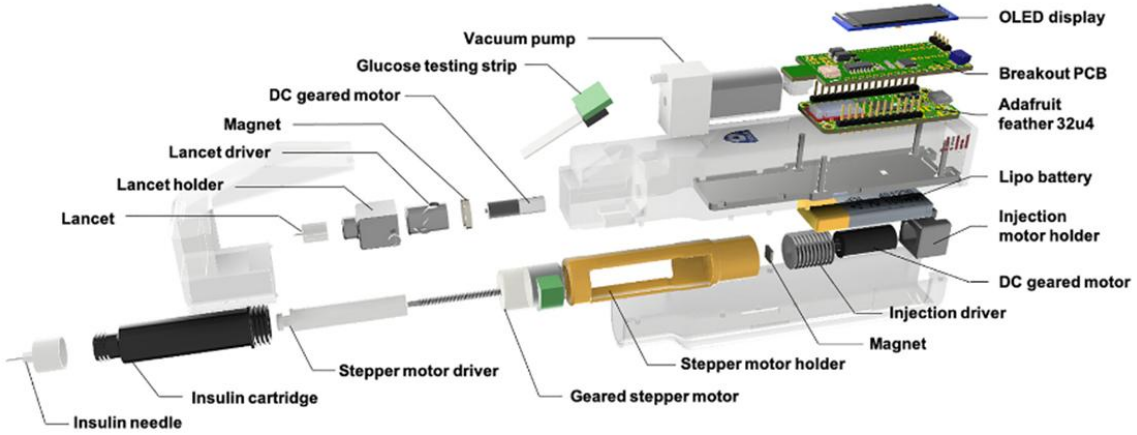
I built ingestible systems that minimize the performance impacts of gastric operation and built secure ingestible drug-delivery devices compatible with commercial smartphones using these robust radio systems. These gastric systems operationally resident in the body for longer than 80 days.



(Final results not yet published, so the data I can show here is limited. The program is advancing towards human trials. Keep an eye on Google Scholar)






# An automated all-in-one system for carbohydrate tracking, glucose monitoring, and insulin delivery – 3 Months of Effort

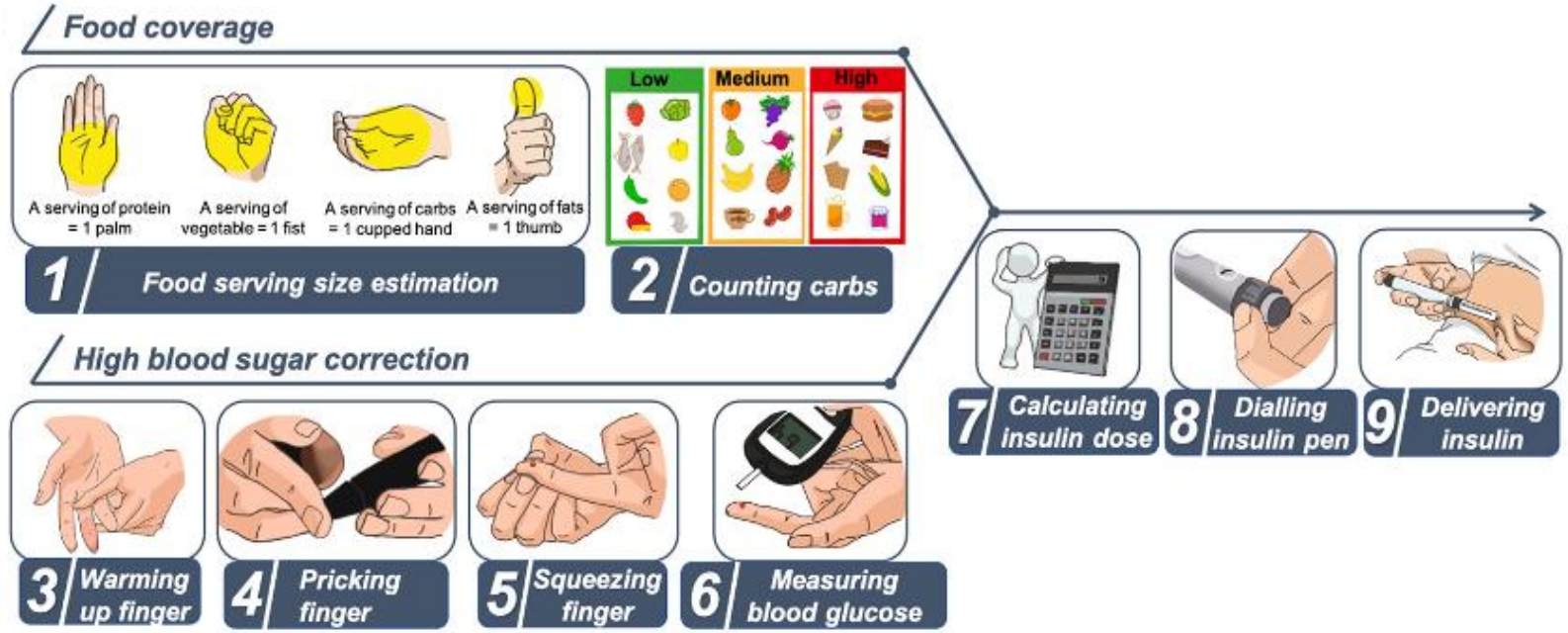
I improved accuracy of self-administered insulin therapies with closed loop control.

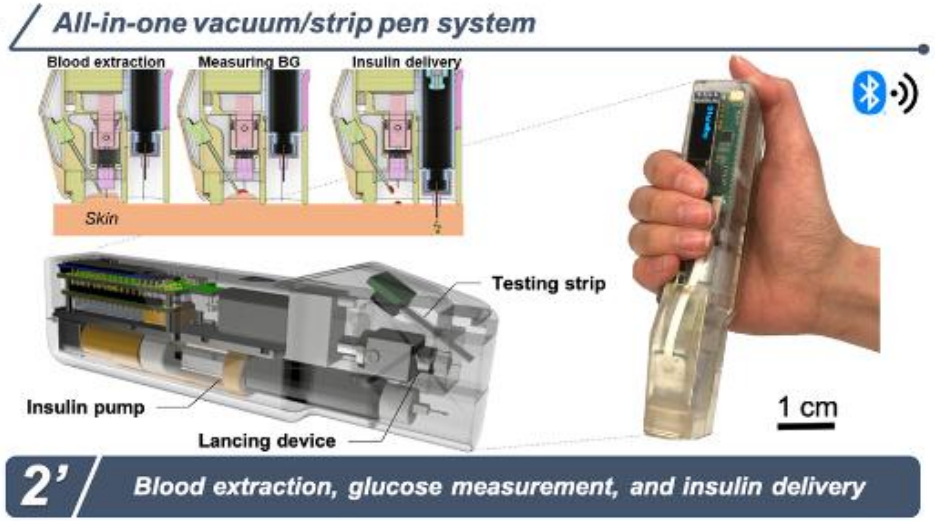
# All-in-One system for Glycemic Control

Figures taken from the Publication

I was responsible for:

- Device design, fabrication and testing
  - Electrochemical glucose sensor development
- Firmware programming for closed loop control of drug delivery systems
  - Vacuum pressure and Injection actuator
    control loops with blood glucose computation and insulin dose calculation
- UI, Bluetooth, and scientific programming



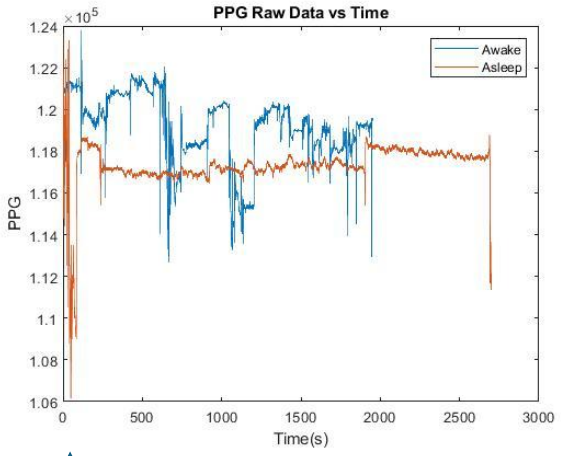



# Implantable System for Chronotherapy

# Implantable System for Chronotherapy

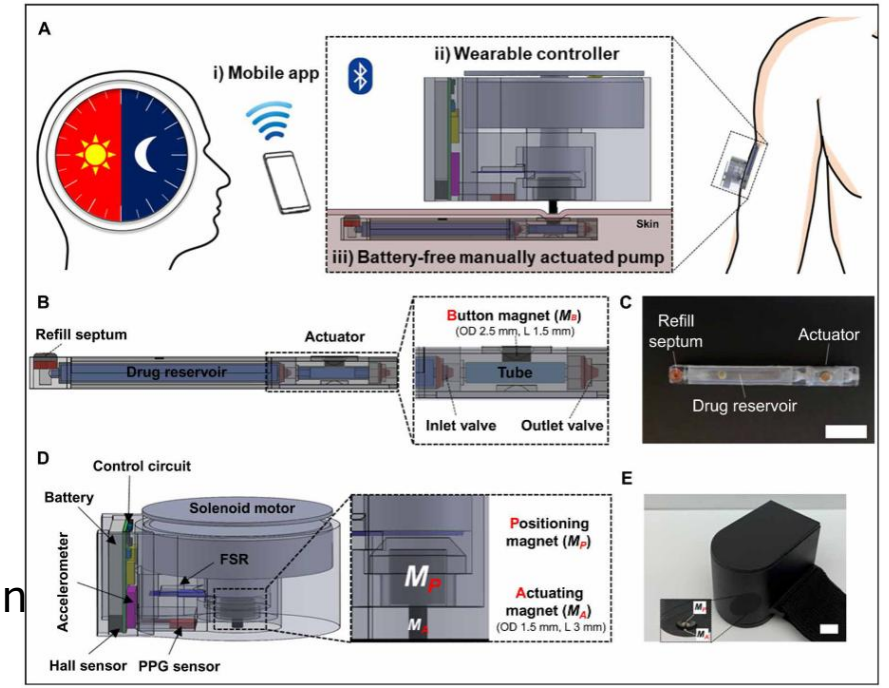
I was responsible for:

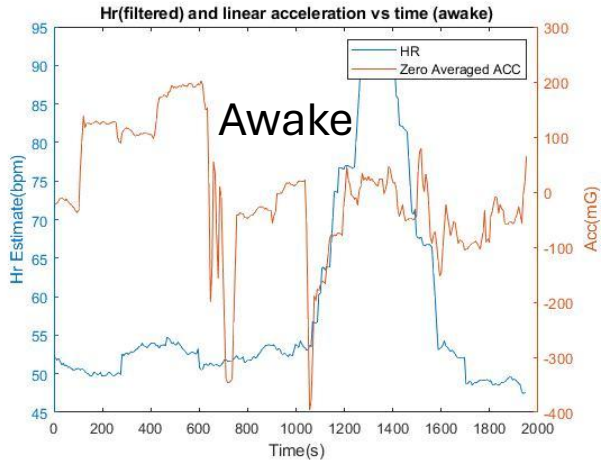
- Device design, fabrication and testing
- Bluetooth telemetry systems
- Postprocessing in Matlab for real-time algorithm design
- Real time signal processing for PPG processing, heart rate estimation, and sleep detection on-device in embedded C++
- Real-time PPG motion artefact compensation algorithm development
- Transdermal pump actuator control system

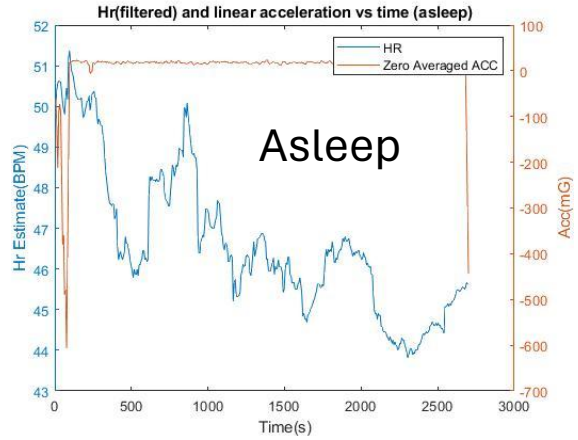



Raw PPG sensor data

On-device filtering to observe body acceleration and heart rate



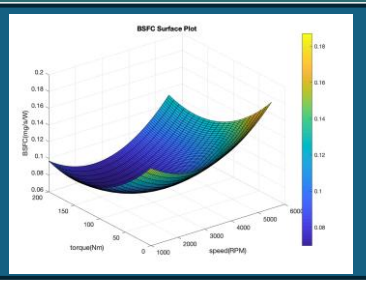



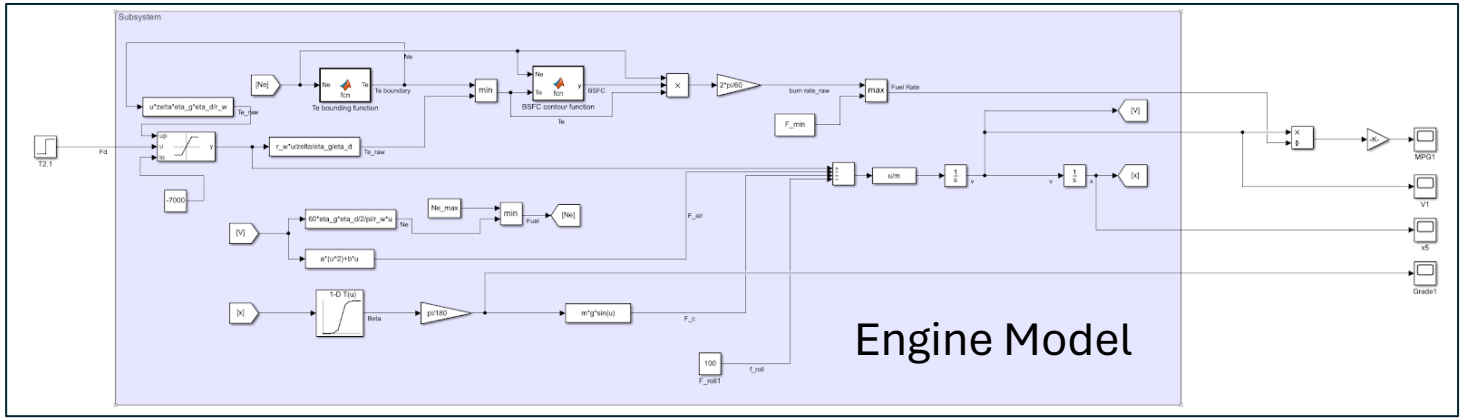
# Personal Projects

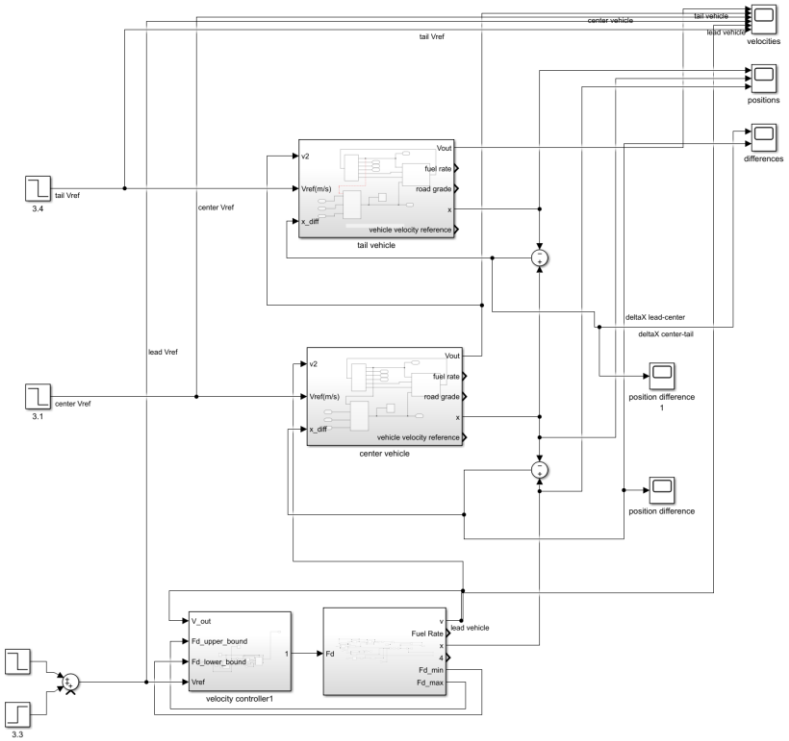
# Undergraduate course project: Real-Time (discrete) PI Cruise Controller for a simulated vehicle with anti-windup pre-compensation

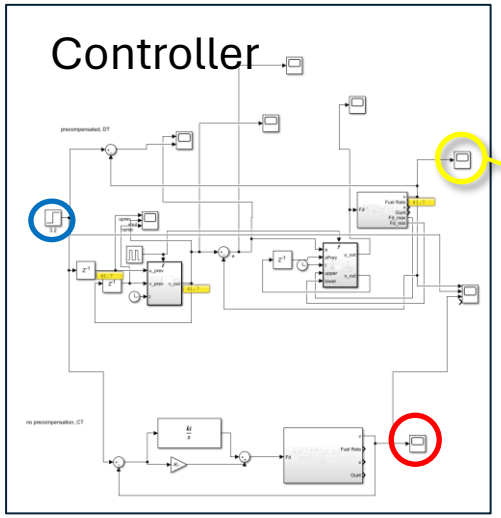
I designed adaptive cruise control systems for simulated vehicles, using PI controllers with anti-windup (results pictured), where the system respects actuator limits and admissible state boundaries to implement collision avoidance

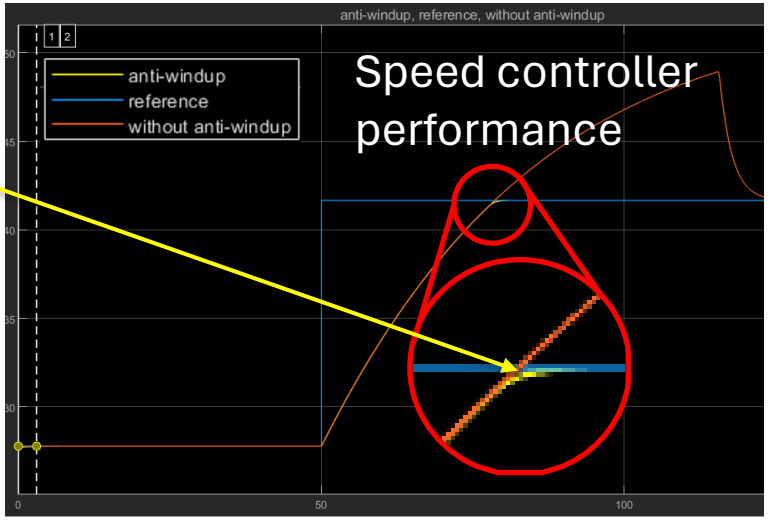
Engine Fuel Efficiency and control variable boundaries



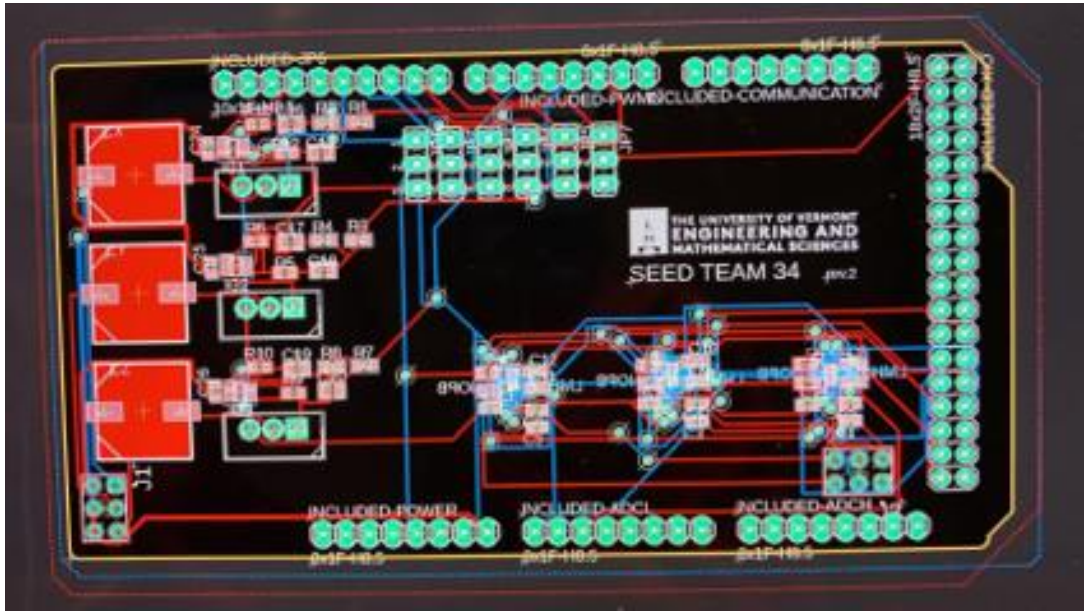



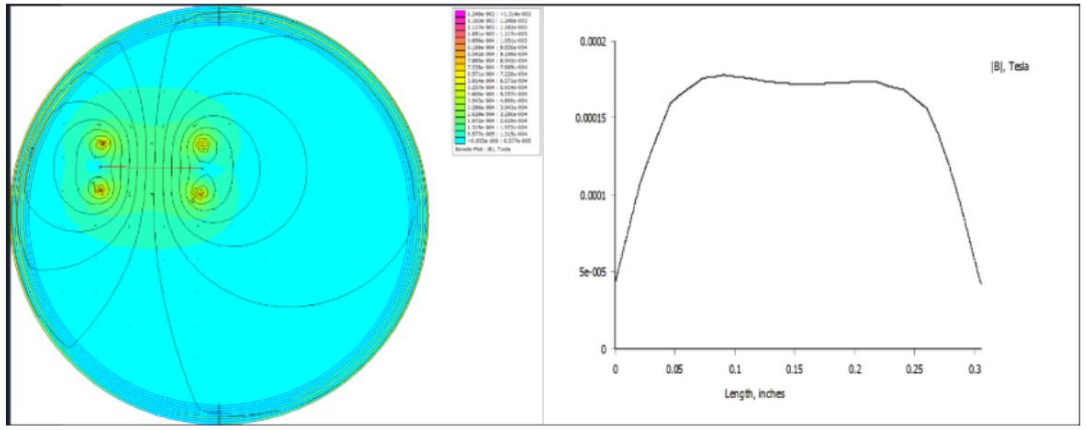



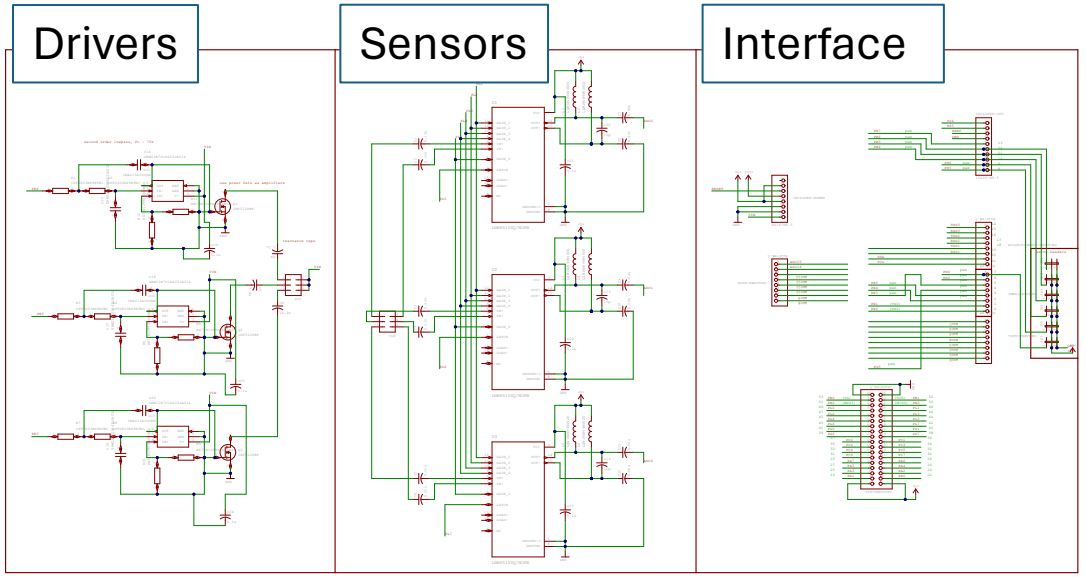
# Undergraduate capstone project: Helmholtz Steering for Arbitrary Pose Evaluation

I designed and realized a calibration verification system for tri-axial resonant magnetic sensors used in object tracking applications. This work utilized Euler rotation sequences in Matlab for electromagnetic signal post-processing.

The project was cut short due to Covid-19, so no final system verification occurred.



# Glow-in-the-dark 3D-printed Friend's Brain

Brain segmentation of raw MRI output files (.nii) using freesurfer

3d-model reconstruction and hemisphere alignment

3d-printed a life-size model as a birthday gift for a friend with glow-in-the-dark filament

Wear your helmet!