ECE 445

Senior Design Laboratory

Design Document

STORM: **S**print **T**raining **O**ptimization and **R**eal-time **M**onitoring

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Team #7

Trivikram Battalapalli (tb17)

Dev Patel (devdp2)

Abhee Jani (abheej2)

TA: Angquan Yu

September 30, 2024

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1 Introduction

1.1 Problem

In most sprint and distance running training, there is a significant lack of accessible tools for monitoring key biomechanical and biometric metrics. Metrics such as ground contact time, stride cadence, thigh angular velocity, heart rate, and VO2 max are critical to optimizing an athlete's performance, particularly in short-distance sprints like the 100m. However, current solutions, including force-sensing treadmills, motion analysis systems, and coaching, are expensive and inaccessible to most athletes. This is because these tools are usually only found in specialized gyms, hindering athletes' ability to make immediate adjustments to their form and training intensity when training alone.

Additionally, existing fitness wearables are typically designed for long-distance runners and only track general data like speed and heart rate averages, which are not applicable to short-distance sprints. They also do not provide the detailed biomechanical analysis necessary for improving running form during both sprints and distance running. For example, thigh angular velocity and ground contact time, which are the most impactful metrics on running speed, remain untracked by most commercially available devices. These wearables also lack visualization systems for such data, which are essential for athletes aiming to learn about ther performance and optimize their sprinting form and efficiency through training adjustments.

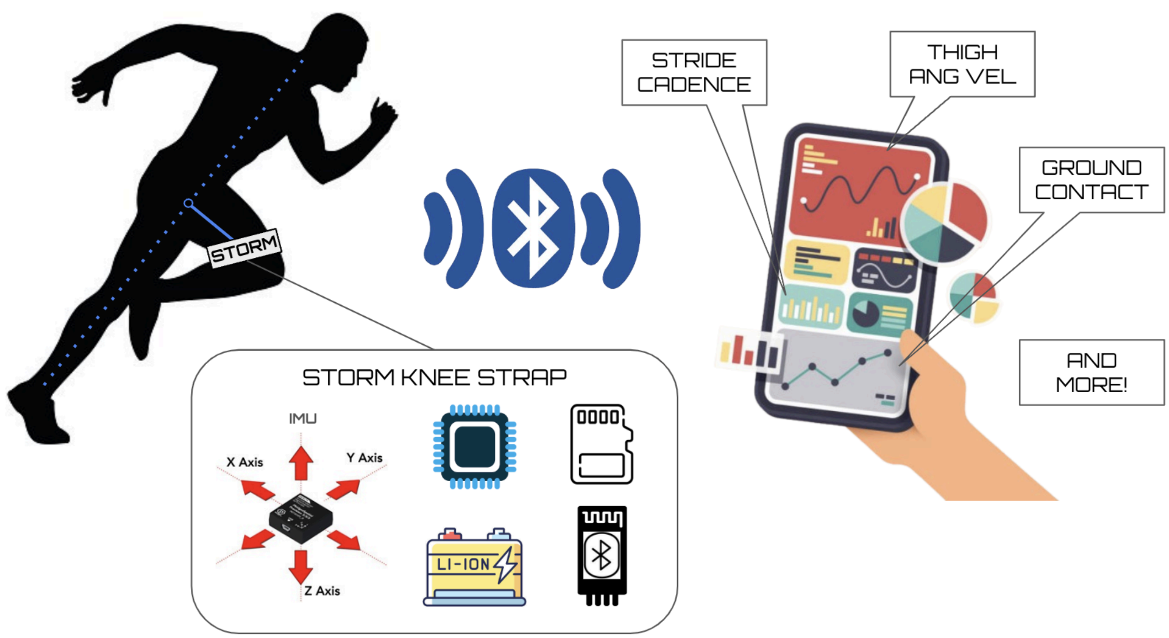
There is a clear need for a more affordable, comprehensive system that can track both biomechanical and biometric data in real-time, providing actionable insights that help athletes improve sprint technique and performance.

1.2 Solution

Our primary solution, or Minimum Viable Product (MVP), is a knee strap monitoring system paired with a mobile app designed to track and analyze both sprint and distance running form and technical performance. The knee strap includes a gyroscope, accelerometer, power circuitry, microcontroller, and memory system, allowing it to capture essential biomechanical data such as stride cadence, ground contact time, and thigh angular velocity during runs. This data is wirelessly transmitted to the mobile app, where athletes can visualize their performance metrics in real-time and gain actionable insights to improve their running technique. Whether for sprints or longer distances, this system directly addresses the gap in affordable, accessible tools for optimizing running performance from a technical perspective.

As for the stretch goal (above the scope of the main project), we propose introducing an additional chest strap system to further enhance the solution's capabilities. The chest strap will track additional metrics such as overall body position, overall speed, and heart rate, and will include a haptic feedback motor to notify athletes when their heart rate has dropped to a level indicating full recovery between efforts. While the knee strap and app alone provide a comprehensive solution to the core problem of improving running form and technical performance, the chest strap adds value by offering insights into cardiovascular performance and recovery, particularly for distance runners and those focused on conditioning.

1.3 Visual Aid



1.4 High-Level Requirements

1. Accuracy and Precision of Biomechanical Measurements:
    - Requirement: The subsystems shall have a measurement accuracy within a 10% margin of error for the biomechanical metrics of ground contact time, stride cadence, and thigh angular velocity in comparison to high-speed video analysis.
    - Justification: This ensures that the sensor provides reliable and accurate data, which is crucial to assess performance effectively.
2. System Reliability and Environmental Durability:
    - Requirement: The system will withstand typical environmental conditions that occur while training a sprint, such as impacts, moisture (sweat resistant), and temperature fluctuations between 30℉ and 120℉ without any loss of performance for at least 90 minutes.

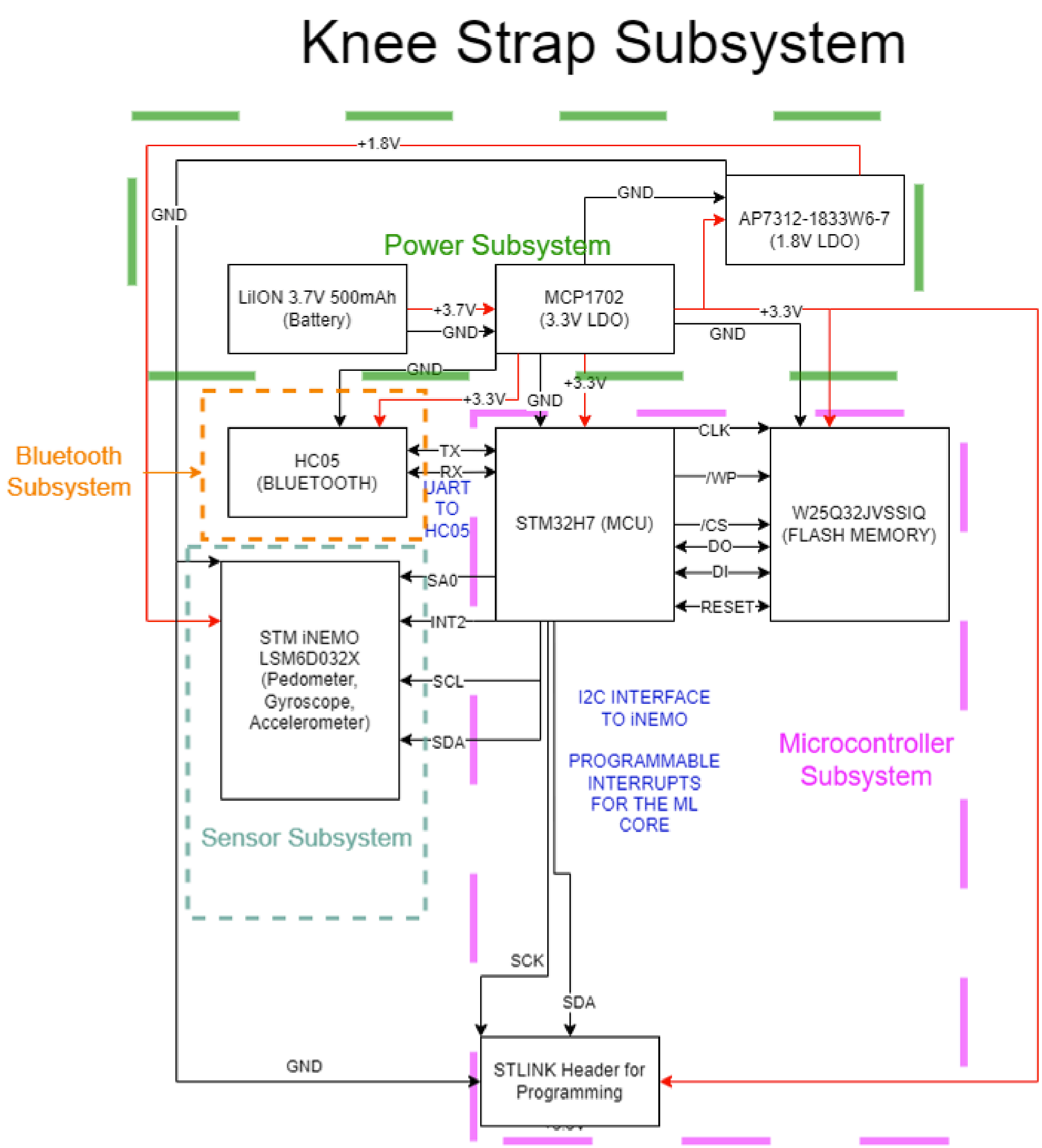
- Justification: Ensures that the device is robust and would be suitable for continuous athletic use in realistic climatic conditions.

3. Data Collection and Bluetooth Transmission:
    - Requirement: The subsystems will collect and write biomechanical data to its flash memory at a rate of 10 data points per second, ensuring that data is recorded within 0.1 seconds per measurement. Once all data is collected, athletes can press the "Load Data" button on the mobile app, which will initiate the Bluetooth transmission, and complete data transfer must take less than 5 seconds.
    - Justification: The data must be collected at least 10 times per second to create detailed, useful data about sprint form, and efficient transmission of data allows for the user to quickly see results at the end of their workout.
4. App Performance and Usability:
    - Requirement: The mobile app will present sprint data in a user-friendly UI that displays real-time metrics with no more than a 5-second delay. The app must provide a clear, intuitive display of performance metrics, including progress over multiple training sessions spanning at least 3 months. It will generate updated AI-driven training recommendations within 1 minute of receiving new workout data. Of course, app usability and user-friendliness are subjective measures, but we will try our best to deliver an objectively high-quality app.
    - Justification: The app must be intuitive and responsive, ensuring that athletes can quickly interpret their performance metrics without delay. The ability to track progress over time is critical for long-term improvement, and AI-generated recommendations will provide personalized training guidance.

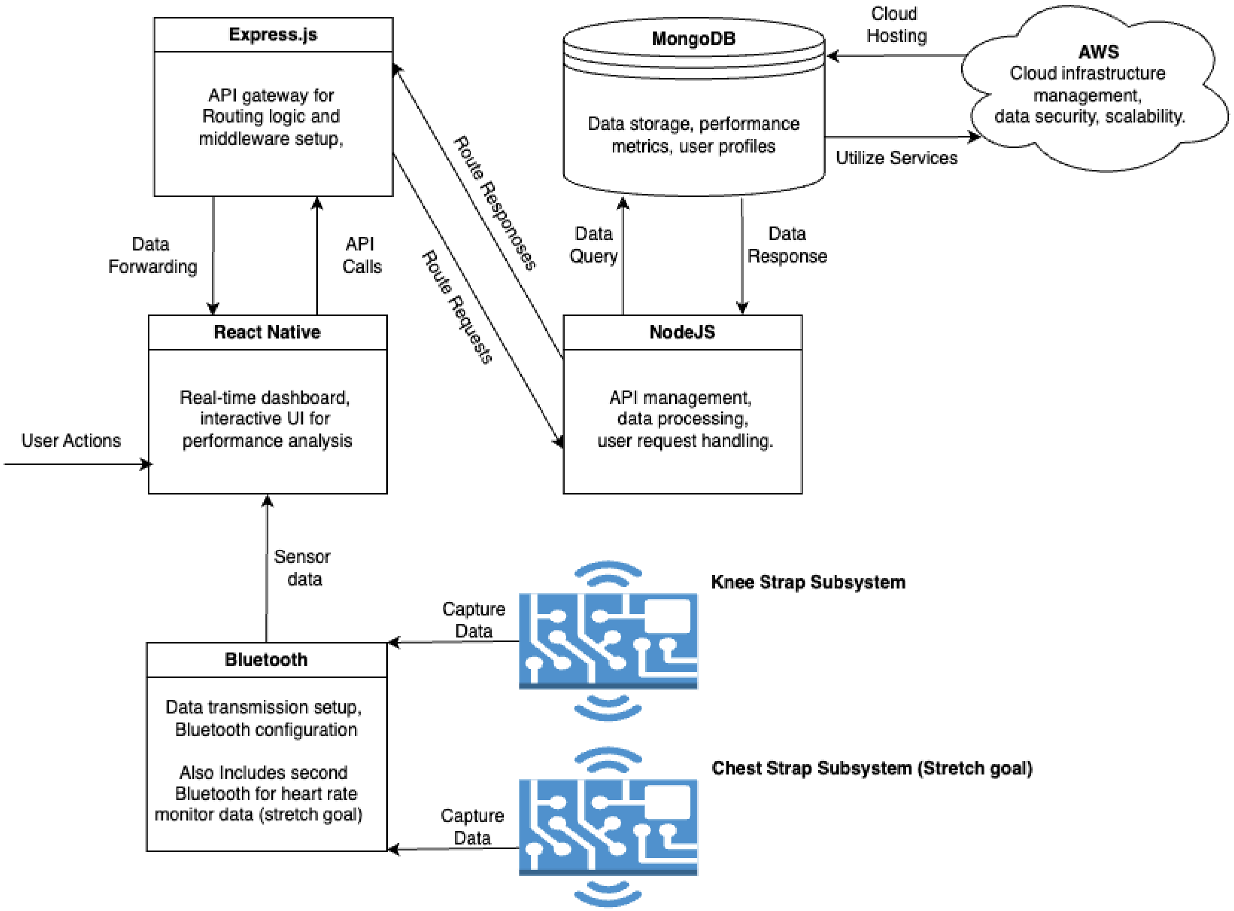
2 Design

2.1 Block Diagrams

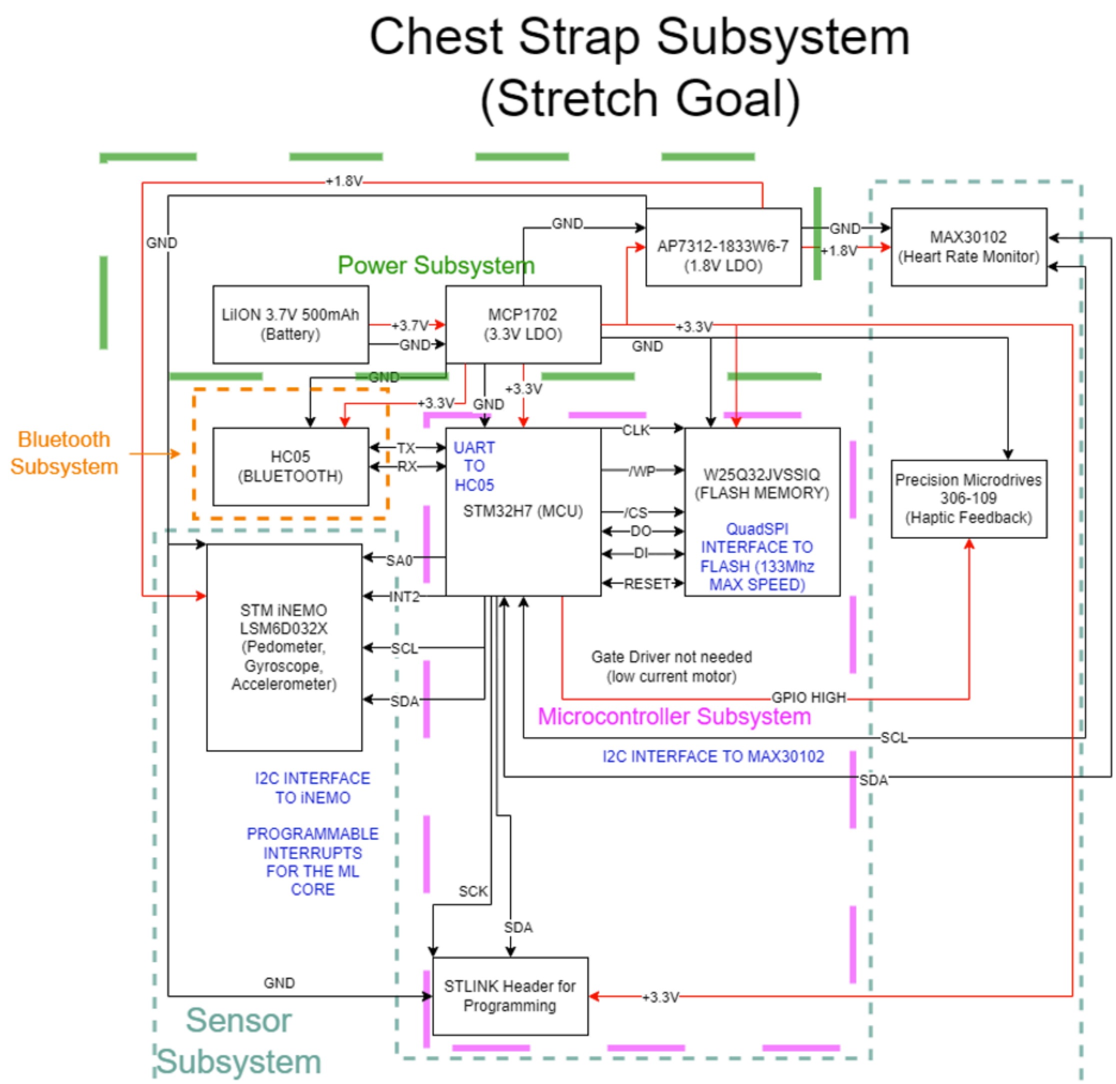
2.1.1 Knee-Strap Subsystem



2.1.2 Mobile App Subsystem



2.1.3 Chest-Strap Subsystem (Stretch Goal)



2.2 Subsystem Overview and Block Descriptions

2.2.1 Knee-Strap Subsystem

The knee strap subsystem is the physical component of the MVP of the project. It consists of the microcontroller system (which contains an STM32H7, W25Q32J Flash, and STLINK programming header), the power subsystem (Lithium Ion cell, 3.3V LDO, and 1.8V LDO), the Bluetooth subsystem (HC05 Bluetooth module), and the sensor subsystem (STM32 iNEMO Inertial measurement unit). The STLINK was chosen to avoid the bulk of a traditional JTAG debug connector, and the iNEMO inertial unit was chosen to combine the accelerometer and gyroscope into a single package, reducing latency and helping to bring the system close to real time analysis. The STM32H7 communicates with the Flash memory over QuadSPI, and uses I2C for the iNEMO accelerometer unit. We utilize I2C to communicate with the iNEMO to take advantage of the ML Core and preprocessing hardware available in the sensor module. Bluetooth communication happens over UART, as that is a hardware limitation of the HC-05 Module.

2.2.2 Mobile App Subsystem

The mobile app processes data from the sensor subsystems and displays it to the user in an intuitive, technical layout. Our app will be built using a MERN stack with AWS backend infrastructure and Bluetooth connectivity. First, the data is retrieved from the sensor subsystems through Bluetooth and preprocessed by the NodeJS backend. This data is then sent to the AWS Cloud for further processing using AWS cloud services, Python functions, and ML analysis. Then, this processed data is stored in a MongoDB database and relevant data is sent back to the mobile app, where the data is presented to the user in our intuitive, user-friendly React Native frontend. All of the communication between the frontend and backend is done through our Express API gateway for efficient communication. While using the app, the athlete can view detailed, technical graphs and time-series data related to their training and performance. The mobile application will also offer AI-driven recommendations on training adjustments and long-term graphs for tracked performance and improvements over multiple training sessions, in addition to more granular, intra-session analysis.

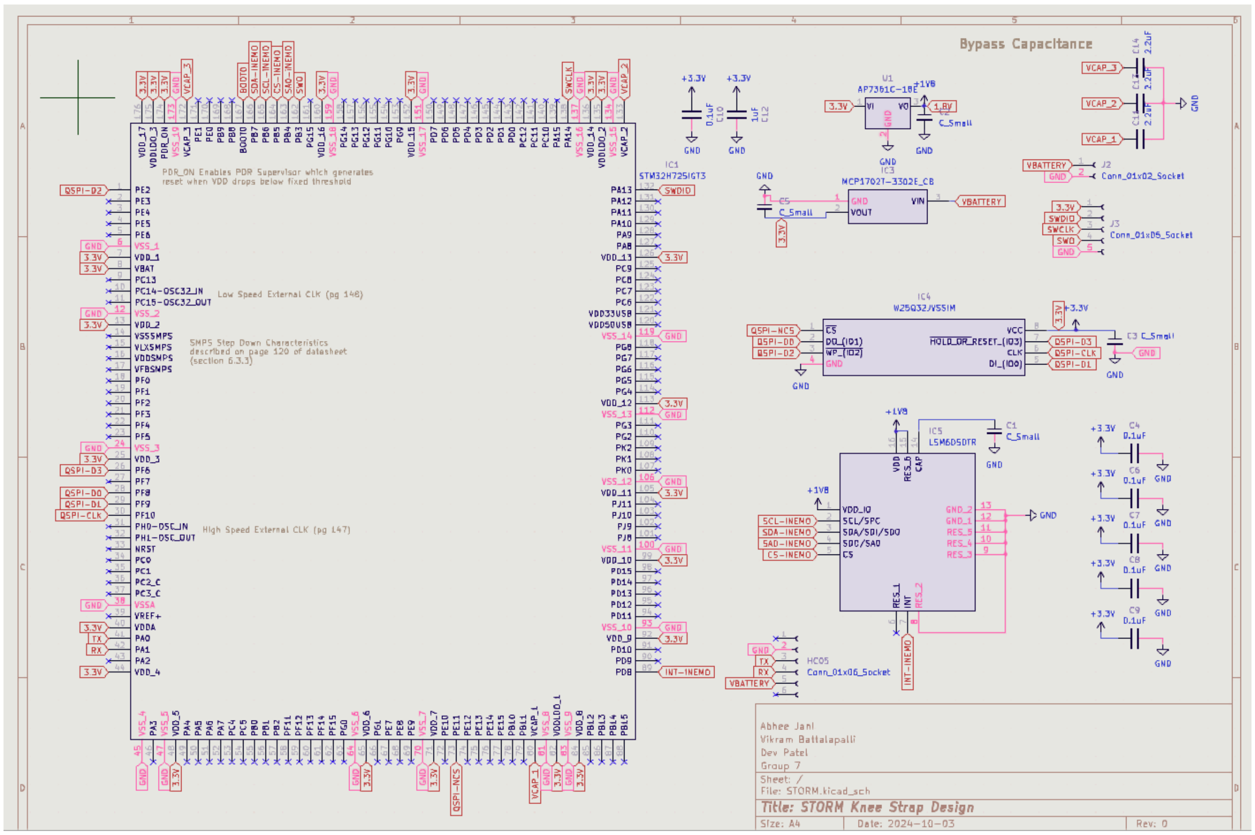
2.2.3 Chest-Strap Subsystem (Stretch Goal)

The chest strap subsystem is the stretch goal of the project. To be clear, this subsystem functions independently of the knee-strap subsystem. It consists of the microcontroller system (which contains an STM32H7, W25Q32J Flash, and STLINK programming header), the power subsystem (Lithium Ion cell, 3.3V LDO, and 1.8V LDO), the Bluetooth subsystem (HC05 Bluetooth module), and the sensor subsystem (STM32 iNEMO Inertial measurement unit, MAX30102 Heart rate sensor, and a haptic motor). The STLINK was chosen to avoid the bulk of a traditional JTAG debug connector, and the iNEMO inertial unit was chosen to combine the accelerometer and gyroscope into a single package, reducing latency and helping to bring the system close to real time analysis.The STM32H7 communicates with the Flash memory over QuadSPI, and uses I2C for the iNEMO accelerometer unit. We utilize I2C to communicate with the iNEMO to take advantage of the ML Core and preprocessing hardware available in the sensor module. Bluetooth communication happens over UART, as that is a hardware limitation of the HC-05 Module. The heart rate sensor is also connected to the STM32 over I2C, and the haptic motor driver is driven directly from the GPIO pin. We did not use a gate driver in our design because the motor is extremely low current and can be driven directly from the GPIO pinout of the STM32H7 (which was chosen to take advantage of multiple communication protocols and the higher current output). The additional heart rate sensor and haptic motor are used to monitor biometrics and provide feedback to the user on heart rate based recovery timing and confirmation of data transfer from the onboard system to the bluetooth mobile app.

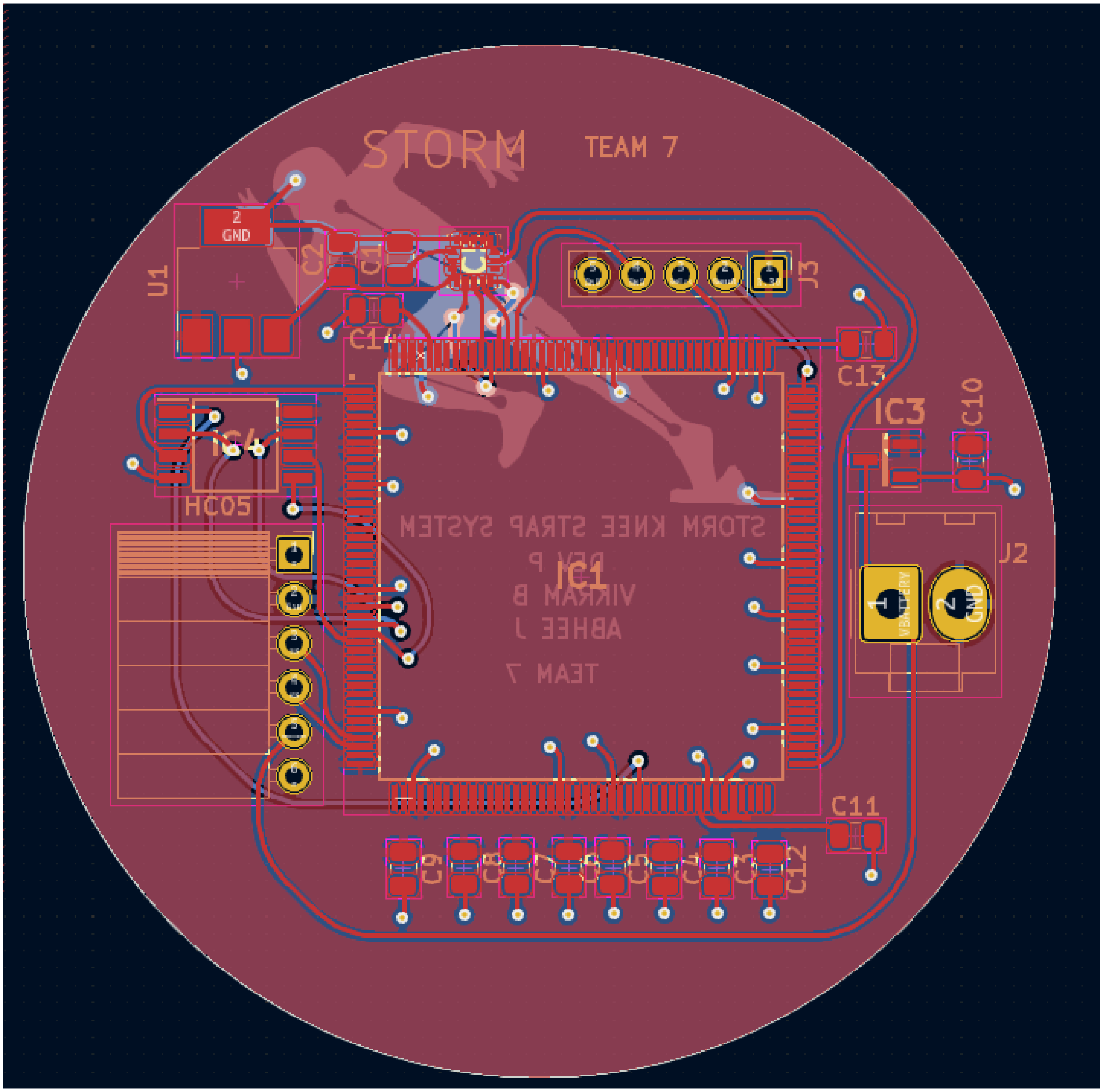
2.3 Physical Design

2.3.1 Knee-Strap Subsystem Physical Design

For the Knee-Strap subsystem physical design, we created a schematic and PCB layout to verify dimensions and sizing of the system. The schematic can be seen below:

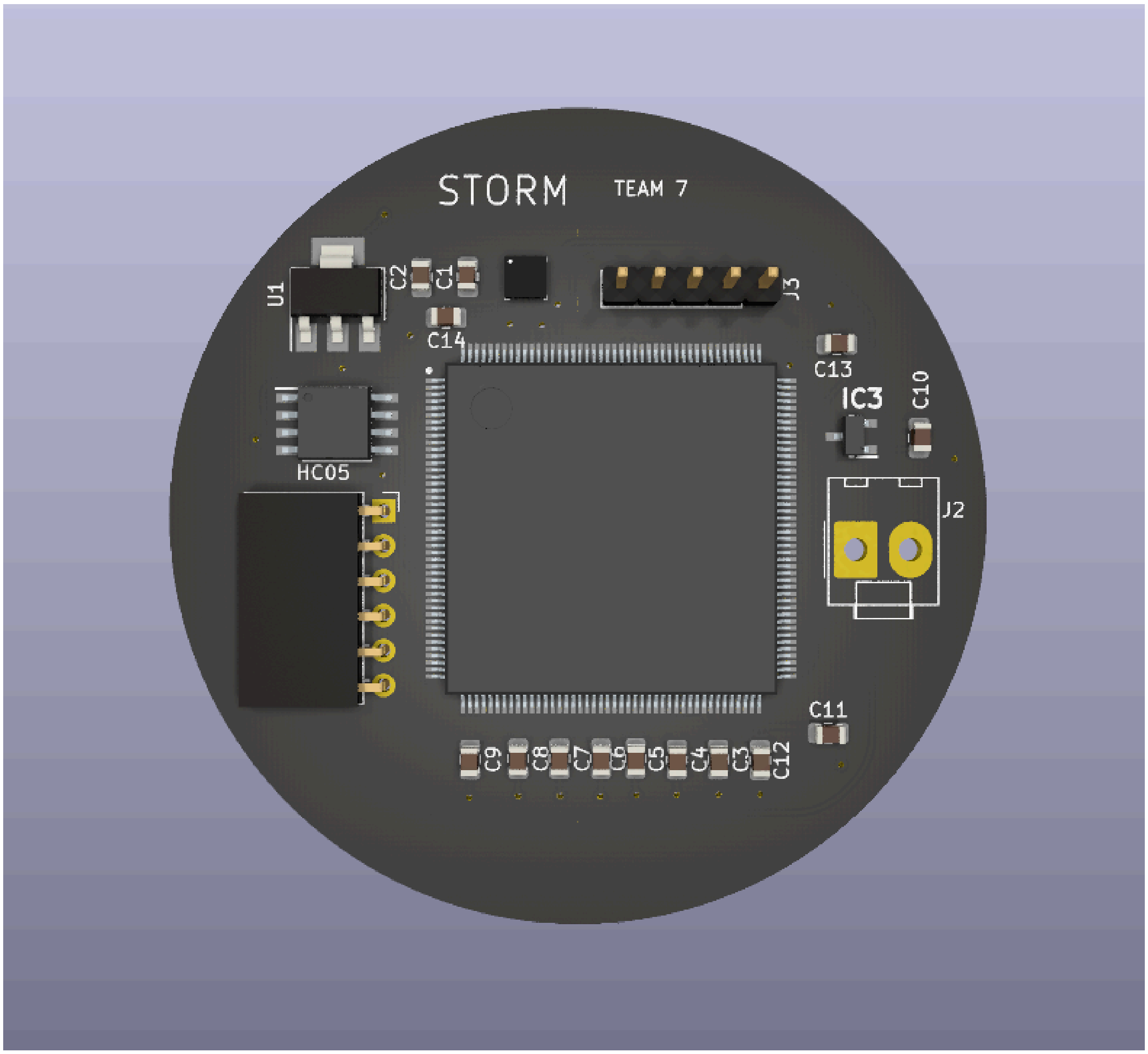


The PCB layout can be seen in the image below:

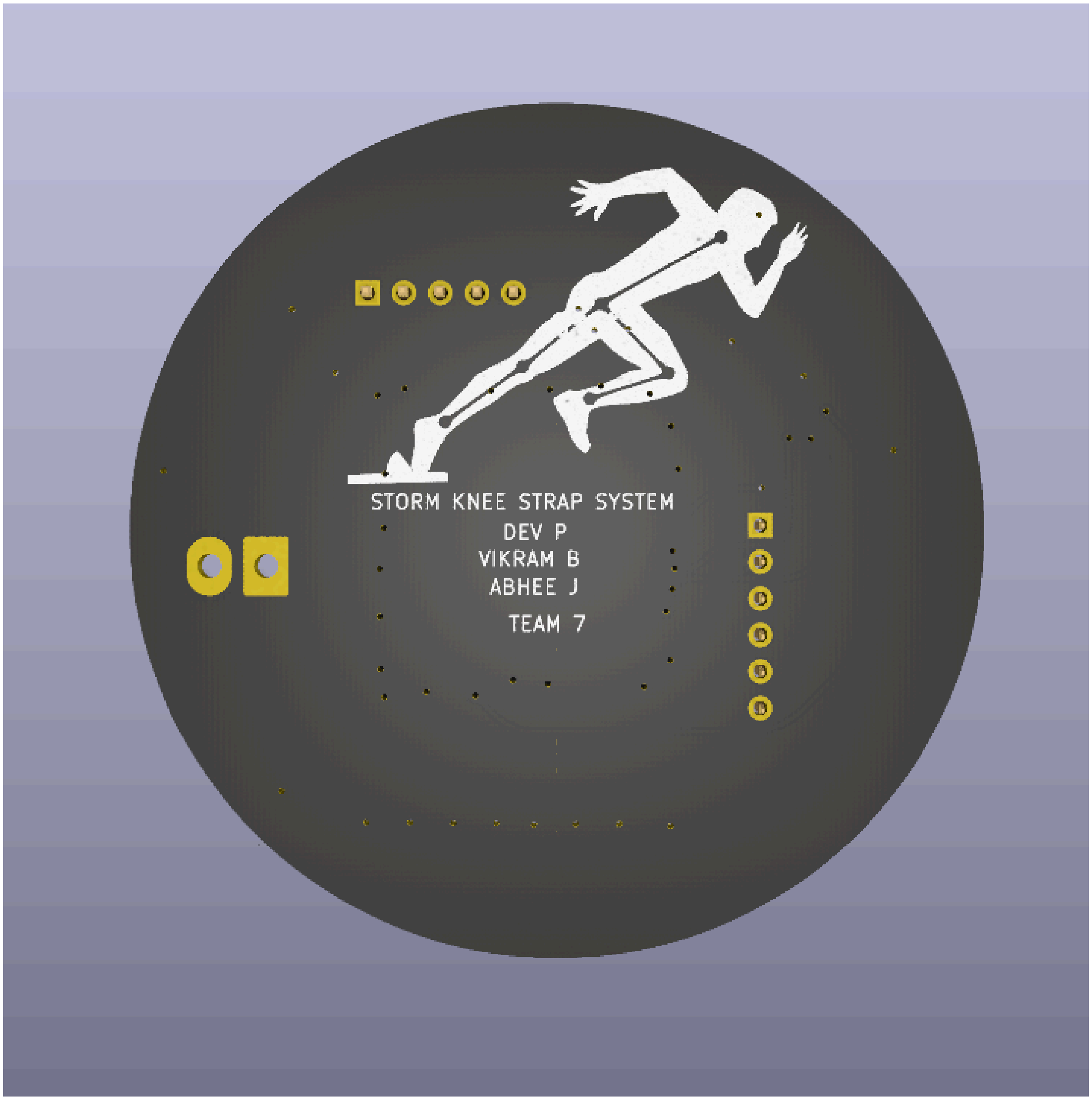


We utilized power plane pours for Ground and Power to reduce parasitic capacitances and ensure better power/signal integrity in our designs. We also minimized junctions in our PCB design to avoid possible signal integrity issues, and attempted to place components as close to the respective pinouts. The components reside in a circle with a radius of 30mm (about 1.2 inches). One thing to note is that the HC05 module is a separate component that will connect to the 5 pin connector labeled HC-05. This means that it will extend outside the edge cut of the knee strap system. We made this design decision to allow for flexibility in bluetooth module positioning to ensure proper signal integrity during our testing phase. J2 is our battery connector. We aim to mount the lithium cell along the knee band instead of on the PCB. This decision was made for several reasons. First, it allows us to keep the PCB light and avoid weight imbalance along the knee. It also allows us to design a 3D printed case for the board, which along with conformal coating will help protect the PCB from the elements. The battery will connect to the system from connector J2, which is connected to the rest of the power stages and LDOS.

We have attached renders of the proposed system below:



The front view is shown above.

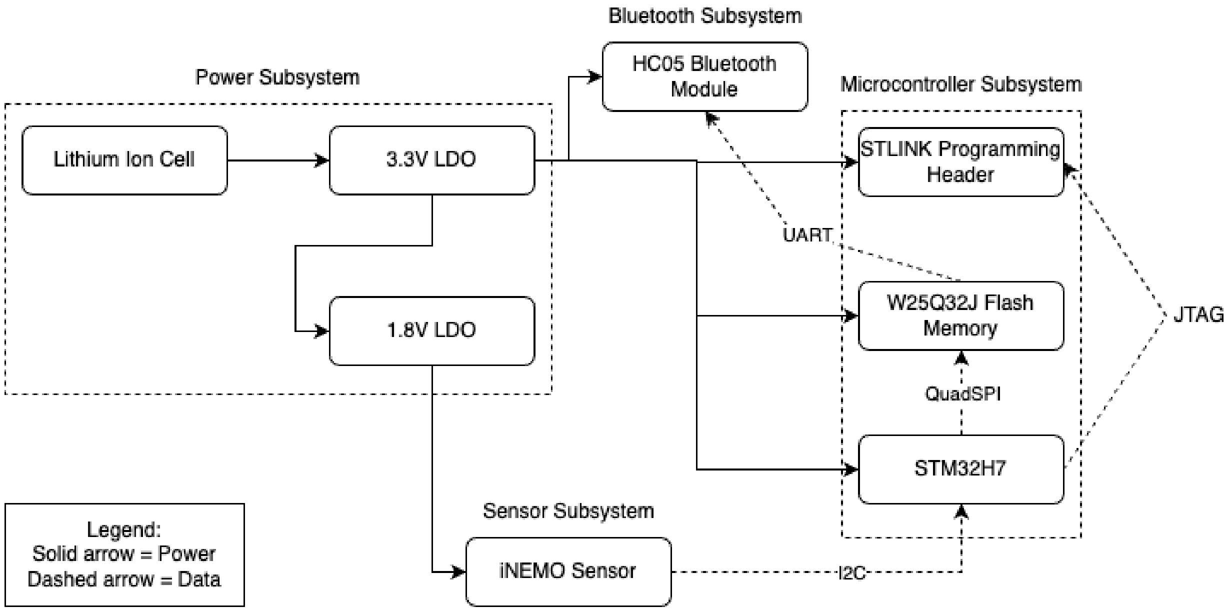


The rear view of the system is shown below.

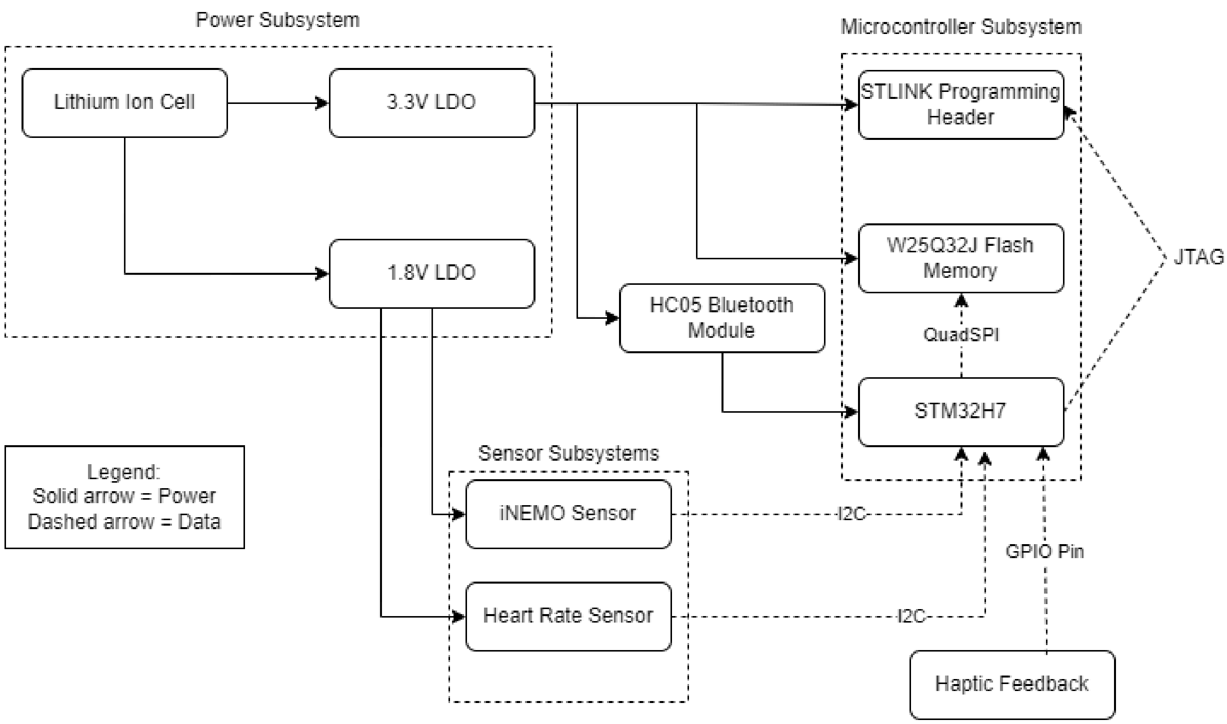
In summary, the physical design of the knee strap will include the PCB, a 3D printed case (radial offset of 2mm, so 32mm radius for the case), and the cloth straps. The battery will be mounted along the strap, and the HC05 will extend outside of the PCB enclosure to allow us to test signal integrity and minimize noise and latency in our data streaming.

2.4 Physical Subsystem Flow Charts

2.4.1 Knee-Strap Subsystem



2.4.3 Chest-Strap Subsystem



2.5 Subsystem Requirements and Verification

2.5.1 Knee-Strap Subsystem

The knee strap subsystem is responsible for capturing and processing biomechanical data during sprints. It includes sensors that monitor key leg-movement specific metrics, ensuring both accuracy and durability in typical training conditions. Data collection and transmission will be handled efficiently, allowing athletes to review performance metrics promptly post-workout.

Subsystem	Requirements	Verification
Power	• The 3.3V LDO must provide at least 500 mA of current, ensuring reliable operation of	• Equipment: Multimeter, adjustable power supply, stopwatch.

	the microcontroller and Bluetooth module. ● The 1.8V LDO must supply at least 150 mA with similar voltage tolerance to avoid sensor inaccuracies. ● The battery must support at least 2 hours of continuous operation, with a capacity of at least 500 mAh to power all subsystems during a typical running session.	● Test Procedures: Connect the multimeter to measure current draw from the 3.3V LDO. Power the system using an adjustable power supply and measure the current when the system is running the microcontroller and Bluetooth module. Ensure the 3.3V LDO provides at least 500 mA of current. Repeat the procedure for the 1.8V LDO, ensuring it provides at least 150 mA. Use the stopwatch to measure the duration of operation with a fully charged battery. ● Presentation of Results: Record current measurements and operation duration in a table.
Microcontroller	● The STM32H7 must run at least 200 MHz to make sure it is processing near real-time data. ● The microcontroller must be able to handle SPI/I2C communication at high speeds (at least 10 MHz for SPI) to avoid bottlenecks during sensor data acquisition.	● Equipment: Oscilloscope, logic analyzer. ● Test Procedures: Connect the oscilloscope to the timer pins of the microcontroller and verify it operates at 200 MHz. Use a logic analyzer to capture SPI/I2C communications and ensure the data rate exceeds 10 MHz. ● Presentation of Results: Show screenshots of the clock frequency and logic analyzer waveforms.

Bluetooth	• The Bluetooth module must maintain a transmission range of at least 5 meters to ensure data can be transferred from the knee strap to the mobile phone when requested. • The Bluetooth module must be able to handle continuous data transmission at a rate of at least 20 kB/s to ensure efficient transfer.	• Equipment: Bluetooth-enabled device, stopwatch. • Test Procedures: Set up a Bluetooth connection between the knee strap and a device. Move the devices apart and measure the maximum distance at which the connection is maintained. Use the stopwatch to measure the time taken to transmit a known data packet and verify it exceeds 20 kB/s. • Presentation of Results: Record transmission distances and data rates in a table.
Sensor	• The IMU must be able to measure angular velocity up to ±1000°/s to capture the full range of running movements, from sprints to slower jogs. • The IMU must have a sampling rate of at least 100 Hz to ensure real-time data collection.	• Equipment: Accelerometer test platform, car tire, oscilloscope. • Test Procedures: Rotate the IMU on a car wheel and verify the angular velocity measurements up to ±1000°/s. Verify the sampling rate using an oscilloscope connected to the data output lines. • Presentation of Results: Present the sensor output in a graph, showing accelerations and angular velocities captured at various rates.

2.5.2 Mobile App Subsystem

The mobile app subsystem is used to interface between the athlete and the biomechanical data collected by the knee strap subsystem. It will present the collected sprint metrics in a clear, user-friendly format and provide insights on performance, progress tracking, and AI-driven training recommendations. The app will ensure that data is processed and displayed with minimal delay, while allowing users to view their progress over multiple training sessions. Additionally, it will enable efficient data transmission from the knee strap and offer personalized training recommendations based on user statistics.

Subsystem	Requirements	Verification
Bluetooth API	• The Bluetooth API must support data transmission at a minimum rate of 20 kB/s to avoid delays.	• Equipment: Bluetooth debugging tool, stopwatch. • Test Procedures: Use a Bluetooth debugging tool to monitor the data transmission rate between the knee strap and mobile app. Ensure the data is transmitted at a rate of at least 20 kB/s by timing the transmission of a large dataset using the stopwatch. • Presentation of Results: Record data transmission rates and present them in a table. Include time logs and any packet loss details.
Cloud and Data Storage	• The mobile app must be able to sync data with AWS at least every 5 minutes during training sessions to ensure no data loss. • MongoDB should handle at least 100MB of local storage, enabling users to store multiple training sessions without immediate cloud sync. • AWS services must handle processing and storing up to	• Equipment: AWS CloudWatch logs, network analysis tool. • Test Procedures: Use CloudWatch to verify that the app syncs data with AWS every 5 minutes during training. Upload a dataset of 100 MB to MongoDB and AWS services and measure the response time. • Presentation of Results: Provide sync interval logs

	100 MB of biomechanical data per session.	from CloudWatch and screenshots showing the successful storage of 100 MB in MongoDB and AWS.
Frontend	● The data visualization subsystem must render performance metrics in under 5 seconds to provide a smooth user experience. ● The app must display time-series graphs with a minimum resolution of 10 data points per second to ensure detailed tracking of performance changes. ● The interface must be simple and intuitive.	● Equipment: Stopwatch. ● Test Procedures: Load a dataset of 5MB in size into the app and measure the time it takes to render the performance metrics. Verify that time-series graphs display at a minimum resolution of 10 data points per second. ● Presentation of Results: Record the rendering time and resolution data in a table.
AI Analysis	● The AI subsystem must process biomechanical data and generate recommendations within 1 minute of the session's conclusion. ● The machine learning models must deliver accurate recommendations and insights based on the latest technical sprint literature. This requirement will be verified subjectively by our team, using our educated judgment and domain knowledge.	● Equipment: Backend logs, stopwatch. ● Test Procedures: Measure the time taken by the AI subsystem to process the biomechanical data after a training session. Compare the AI's recommendations with known sports research to evaluate its accuracy. ● Presentation of Results: Present the AI processing times in a table and summarize the accuracy of its recommendations.

2.5.3 Chest-Strap Subsystem (Stretch Goal)

The chest strap subsystem is nearly identical to the knee strap because it captures and processes biomechanical data during sprints, along with the added functionality of monitoring cardiovascular metrics and providing haptic feedback. In addition to the IMU used to track metrics like overall body position and speed, the chest strap includes heart rate sensors to offer insights into cardiovascular performance. A haptic feedback motor is incorporated to notify athletes when their heart rate drops to a level indicating full recovery between efforts, enabling more efficient training sessions.

Subsystem	Requirements	Verification
Sensor	• The IMU must be able to measure accelerations up to ±16g and angular velocity up to ±1000°/s to capture the full range of running movements, from sprints to slower jogs. • The IMU must have a sampling rate of at least 100 Hz to ensure real-time data collection. • The heart rate sensor must be able to measure heart rates from 30 BPM to 220 BPM with an accuracy of ±4 BPM to cover all phases of training. This will be verified by comparison with industry standards like the Apple Watch. • The heart rate sensor must sample at a minimum rate of 1 Hz to provide near real-time feedback on heart rate changes during and after exercise. • The haptic feedback motor must be capable of generating tactile signals that are strong enough to be felt through typical training	**IMU Testing:** • Equipment: Car Tire Test • Test Procedure: The IMU will be rotated on a car tire moving at a constant velocity to verify that it can measure accelerations up to ±16g and angular velocity up to ±1000°/s • Presentation of results: Present sensor outputs in a table showing results from different speeds and measuring consistency **Heart Rate Sensor Testing:** • Equipment: Apple Watch • Test Procedure: compare the readings of the chest strap's heart rate sensor with the Apple Watch to confirm accuracy within ±4 BPM across a range of 30 to 220 BPM • Presentation of results: record heart rate measurements in a

	clothing layers. This will be verified by in-field testing by our team. ● The haptic motor must be able to deliver feedback within 2 seconds of receiving the signal to ensure prompt notification when the athlete's heart rate drops to the desired recovery level.	table and compare them to industry standards **Haptic Motor Testing:** ● Equipment:Testing over athletic clothing ● Test Procedure: Wear chest strap during training to ensure haptic motor can be felt ● Presentation of results: Document feedback responsive from multiple people in different training environments and clothing
All other subsystems	See 2.3.1	

2.7 Tolerance Analysis

Our project shows multiple tolerance issues. The three we are choosing to address are given below:

1. We will need to account for the IMU component overestimating or underestimating strides due to the difference in the user's heights and motion states.
2. We will need to account for the knee subsystem to overdraw the current from the onboard linear regulator (MCP1702 3.3V) causing it to overheat.
3. We will need to account for the lack of precise start and end times for the sprint by adjusting for drift velocities.

2.7.1 Inaccuracy in Step Length For Different User Heights and Motion States

To have the most effective athletic training monitoring, we will need to ensure the accuracy of the step lengths have the least variance as possible. We employ the following model to estimate step length and compare the iNEMO's values:

$$S_{Li} = h \cdot (A \cdot f_i + B \cdot var_i + C) + D$$

In this equation, SL_i represents the step length for the ith step, h represents the user's height, f_i is the stride frequency, and var_i is the vertical acceleration variance. To calculate for f_i, the stride frequency, we can incorporate the equation:

$$f_i = \frac{1}{t_i - t_{i-1}}$$

In this equation, t_i and t_{i-1} represent the corresponding times between two adjacently detected steps. To calculate for var_i, the stride frequency, we can incorporate the equation:

$$var_i = \frac{1}{N-1} \sum_{t=t_i-1}^{t_i} (a_t - a_i)^2$$

In this equation, a_t represents the acceleration at time t, and a_i represents the average acceleration. N in this example is the number of samples taken during the step. This variance helps in understanding the consistency for each step. The coefficients *A, B, and C* are determined using the least squares method (minimizes the sum of the squared deviations between observed and predicted step lengths).

2.7.2 Overheating from Excessive Power Draw

One of the biggest concerns in this project is safety, specifically of overheating components, which could occur with the voltage regulator (MCP1702 and AP7312) and thus we would need to account for its prevention. The table below shows the potential current drawn from each of our components and the potential thermal impact it can have:

Component	Typical Current Draw
STM32H7	200 mA
HC05 Bluetooth Module	3 mA
STM iNEMO LSM6D032X	0.38 mA
Flash Memory: W25Q32JVSSIQ TR	28 mA

We are using 2 voltage regulators for this project. The MCP1702 3.3V and the AP7312 1.8 V. The STM iNEMO will connect to the AP7312 while the other components will connect to the MCP1702. These MCP1702 and AP7312 will have the following ratings respectively:

MCP1702:

Property	Values
Absolute Maximum output current	500 mA
Absolute Maximum operating temperature	150℃
Maximum Thermal resistance per Package	336℃/W

AP7312:

Property	Values
Maximum output current	300 mA
Maximum operating temperature	150℃
Thermal resistance	140℃/W

We utilize the MCP1702 voltage regulator with a thermal resistance of *125°C/W* and a maximum junction temperature of *150°C*. The maximum power dissipation is calculated using:

$$P_{MPC1702}=(V_{in}-V_{out})\cdot I=(5V-3.3V)\cdot 0.250A\approx 0.425W$$

$$P_{\mathrm{AP7312}}=(V_{in}-V_{out})\cdot I=(5V-1.8V)\cdot 0.300A\approx 0.960W$$

This yields an estimated theoretical maximum temperature of:

$$Tmax=P_{MPC1702} \cdot R_{thermal\text{-}max}=0.425W \cdot 336°C/W=142.8°C$$

$$Tmax=P_{\mathrm{AP7312}} \cdot R_{thermal}=0.960W \cdot 140°C/W=134.4°C$$

Keep in mind these maximum temperature ratings are based on the theoretical absolute maximum output values from the LDO. Since our design will never actually pull 250mA of current from the LDO, nor will it operate at the maximum junction temperature (ambient knee is approximately 36℃), nor will the thermal package resistance be 336℃/W (we are not using a four-layer PCB), there should be no risk of reaching 142.8℃, or 134.4℃. Overall there should be stable operation with our project without the need for worrying about overheating.

2.7.3 Precise Detection of the Start and End of a Sprint

It is vital for sprinters to have the exact start and end time for a sprint without worrying about potential offsets. These inaccuracies due to either the sensor delay or potential noise could cause overall inaccuracies in our analysis. We resolve this with double integration for acceleration calculations (from acceleration to velocity and finally displacement) and accounting for drift velocities to decipher from the sprint and the sprinter simply adjusting or moving themselves.

In addition, the drift during a moving period is calculated as the difference between the velocity estimates at the end and the start of that period. This is given by:

$$Drift\ rate = \frac{Ve - Vb}{e-b}$$

Here, V_e and V_b represent the velocities at the end and beginning of the movement, while e and b denote the respective times of these velocity measurements. Each velocity sample within the period is adjusted to remove the calculated drift, which reflects the true movement more accurately.

$$V_{corrected} = v_{ti} - drift\ rate \times (t_i - t_b)$$

3 Cost and Schedule

3.1 Cost Analysis

Labor Costs

We assume a reasonable hourly rate for a graduate from the ECE program at the UIUC to estimate the labor costs. Based on industry standards that we researched, we concluded at an hourly rate of $40/hour. The multiplier of 2.5 accounts for other overhead costs such as benefits and administrative expenses which are typically found in the graduate work programs:

Team Member	**Hourly Rate**	**Hours to Complete**	**Multiplier**	**Total Cost**
Abhee Jani	40$/hr	150	2.5	15,000$
Trivikram Battalapali	40$/hr	150	2.5	15,000$
Dev Patel	40$/hr	150	2.5	15,000$
Total Labor Costs:				45,000$

Part Description	Manufacturer	Part Number	Quantity	Unit Cost	Total Cost
STM32H7 Microcontroller	STMicroelectronics	STM32H743	1	14.15$	14.15$
Flash Memory 32mb	Winbond	W25Q32JVSSIQ TR	3	0.50$	1.50$
Lithium-Ion Battery 3.7V 500mAh	Adafruit	Li-Polymer 503035	2	7.95$	7.95$
3.3V LDO Voltage Regulator	Microchip	MCP1702	3	0.65$	1.95$

1.8V LDO Voltage Regulator	Diodes Inc.	AP7312	3	0.68$	2.04$
Bluetooth Module	HC Wireless	HC-05	2	7.75$	15.50$
iNEMO IMU Sensor	STMicroelectronics	LSM6DS3	2	9.95$	19.90$
Cloud Services	Amazon Web Services	-	1	~50$	50$
Velcro Strap	-	-	1	~5.00$	5.00$
Total Parts Cost					117.99$

Labor Costs: 45,000$

Part Costs: 105.04$

Final Cost: 45,117.99$

3.2 Schedule

Week of October 2

- Finalize Design Document:
  - **All Members:** Collaborate to complete the design document.
    - **Dev:** Focus on the Mobile App Subsystem.
    - **Vikram:** Focus on the Knee-Strap Subsystem.
    - **Abhee:** Work on the Tolerance Analysis and Ethics and Safety sections.
- Continue PCB Design:
  - **Dev (Lead):** Start schematic capture and PCB layout for the knee strap subsystem as well as starting the layout for the chest strap subsystem
  - **Abhee, Vikram:** Assist with component selection and schematic verification.

Week of October 9

- Design Review Preparation:
  - **All Members:** Prepare presentation materials for the design review.
    - **Dev:** Prepare topics on the Mobile App Subsystem.
    - **Vikram:** Prepare topics on hardware design.
    - **Abhee:** Prepare topics on Tolerance Analysis and Ethics.

- Design Review Execution:
    - **All Members:** Present to instructors and TAs.
- Continue PCB Design:
    - **Dev:** Incorporate feedback from the design review into the PCB design.
    - **Abhee, Vikram:** Review PCB layout for errors.

Week of October 16

- First Round PCB Orders:
    - **Deadline:** October 14 by 4:45 PM.
    - **Dev (Lead):** Finalize PCB design and submit for audit.
    - **Abhee:** Assist with the audit process.
- Order Components:
    - **Dev:** Compile Bill of Materials (BOM).
    - **Vikram and Abhee:** Place orders for all components.
- Begin Firmware Development:
    - **Dev (Lead):** Set up development environment for STM32H7 microcontroller.
    - **Abhee:** Assist with writing initial firmware for sensor interfacing.
- Begin Mobile App Development:
    - **Vikram (Lead):** Set up React Native project structure.

Week of October 23

- Receive PCBs and Components:
    - **All Members:** Verify and inventory received items.
- Assemble Hardware Components:
    - **Dev (Lead):** Oversee soldering and assembly of PCBs.
    - **Vikram, Abhee:** Assist with assembly and testing.
- Continue Firmware Development:
    - **Abhee:** Develop code for data acquisition and storage.
    - **Trivikram:** Implement Bluetooth communication protocols.
- Continue Mobile App Development:
    - **Abhee:** Develop UI components and initial screens.
    - **Vikram:** Assist with backend setup.

Week of October 30

- Initial Testing of Subsystems:
  - **Dev (Lead):** Test microcontroller functionality and sensor readings.
  - **Vikram:** Test power subsystem stability.
  - **Abhee:** Test basic app functionality.
- Debugging:
  - **All Members:** Collaborate to identify and fix issues.
- Integrate Bluetooth Communication:
  - **Dev:** Implement Bluetooth module in firmware.
  - **Abhee:** Implement Bluetooth connectivity in the app.

Week of November 6

- Subsystem Integration:
  - **All Members:** Integrate hardware, firmware, and mobile app components.
- Integration Testing:
  - **Dev:** Verify data transmission from hardware to app.
  - **Abhee:** Ensure the app displays data correctly.
  - **Trivikram:** Monitor hardware performance under integrated conditions.
- Refine Prototype:
  - **All Members:** Make improvements based on test results.

Week of November 13

- Prepare for Mock Demo:
  - **All Members:** Finalize prototype and prepare demonstration.
  - **Dev:** Ensure firmware stability.
  - **Abhee:** Refine app interface.
  - **Trivikram:** Ensure hardware reliability.

Week of December 2

- Final Demo Preparation:
  - **All Members:** Address any issues identified during the mock demo.
  - **Dev:** Final firmware adjustments.
  - **Abhee:** Final app refinements.
  - **Trivikram:** Final hardware checks + testing final project.
- Final Demo Execution:

- **Dates:** December 2-4.
- **All Members:** Present to instructors and TAs.

4 Ethics and Safety

For us to maintain the ethical and safety code of conduct, we are pledging to the IEEE code of ethics while building this sprint optimization system, and specifically section III where it states: “We will avoid injuring others, their property, data, reputation, or employment by false or malicious action”.

4.1 Ethical Concerns

4.1.1 Transparency of Algorithmic Decisions

With STORM, we ensure that the algorithm used for the sprinter performance and recommendations to better their sprints are transparent and understandable. This is vital for athletes and even coaches to understand how the decisions are made by our system. Ensuring that these algorithms don’t create biases or favor specific demographics (mainly height), is critical to maintaining the ethical deployment of our technology.

4.2 Safety

We commit to adhering to specific industry standards and regulatory guidelines to uphold the highest standards of safety in the development and deployment of Project STORM,

4.2.1 Compliance with Sports Equipment Standards

ASTM Standards for Sports Equipment: Project STORM will adhere to ASTM standards, such as ASTM F2276-10(2019), which provides the standard specification for fitness equipment and its safety and performance requirements. This ensures that all hardware components used in our monitoring system are safe, reliable, and pose no risk to the users.

4.2.2 Safety Concerns

Our primary safety concerns involve ensuring the physical security and reliability of the sensor systems used in STORM:

To eliminate the risks associated with electronic failures, which could include overheating of components or battery malfunctions mainly, our design will conform to the IEC 60068 series on Environmental Testing for electronics. This series provides guidelines on how to assess the durability and operational safety of electronic components under various environmental conditions.

4.2.2 Additional References

This guide provides instructions on the handling and storage of lithium Ion batteries. It goes over the potential hazards we could face, such as short circuiting and overheating, as well as their preventative measures: such as using protective circuits and temperature monitoring.

- https://batteryuniversity.com/learn/article/safety_concerns_with_li_ion

This guide provides insight into the dangers of human exposure to RF Electromagnetic Fields. This especially helps due its outline of the maximum permissible exposure to wireless communicative devices. We will use this to ensure our bluetooth module and other components are within this guideline throughout the project life cycle.

- https://www.fcc.gov/general/radio-frequency-safety-0

Finally, we will ensure that the data collected from this application and device will be stored and used properly as per the General Data Protection Regulation (GDPR) compliance guidelines. These guidelines outline requirements for user consent, data encryption, and the ability for users to delete their data.

- https://ec.europa.eu/info/law/law-topic/data-protection/eu-data-protection-rules_en

5 References

[1] D. Jaén-Carrillo, A. Pérez-Castilla, and F. García-Pinillos, “Wearable and portable devices in sport biomechanics and training science,” *Sensors*, vol. 24, no. 14, p. 4616, Jul. 2024. doi:10.3390/s24144616

[2] IEEE Code of Conduct, https://www.ieee.org/content/dam/ieee-org/ieee/web/org/about/ieee_code_of_conduct.pdf (accessed Sep. 19, 2024).

[3] P. M. S. Ribeiro, A. C. Matos, P. H. Santos, and J. S. Cardoso, “Machine learning improvements to human motion tracking with Imus,” Sensors (Basel, Switzerland), http://www.ncbi.nlm.nih.gov/pmc/articles/PMC7664954/ (accessed Sep. 19, 2024).

[4] Y. Zhang et al., “The height-adaptive parameterized step length measurement method and experiment based on motion parameters,” Sensors (Basel, Switzerland), http://www.ncbi.nlm.nih.gov/pmc/articles/PMC5948631/ (accessed Sep. 19, 2024).

[5] “Standard specification for fitness equipment,” F2276, https://www.astm.org/f2276-10r15.html (accessed Sep. 19, 2024).