Review the assignment due date

IoT Venture Pitch

ESE5180: IoT Wireless, Security, & Scaling

Team Name: Gatorade

Team Member Name	Email Address
James Steeman	jsteeman@seas.upenn.edu
Joaquin Revello Lerena	joaquinr@seas.upenn.edu
Chirag Satapathy	csat28@seas.upenn.edu

Weekly Meeting: Wednesday 7pm

GitHub Repository URL: https://github.com/ese5180/iot-venture-f25-gatorade

Concept Development

Product Function

Our smart HVAC system will integrate permanent sensors at key nodes throughout ductwork to continuously monitor air quality, VOC, humidity, then alert operators to deploy an AI-guided mobile robot for chemical-free cleaning using UV-C sterilization and adaptive brushing to achieve 99.99% pathogen elimination. The sensor network will predict contamination issues and guide operators to exact problem locations, while the lightweight bot will provide superior cleaning results in 30 minutes versus 2-3 hours for competitors. This intelligent system will deliver better performance at lower cost by combining continuous monitoring with smart operator guidance for targeted, efficient cleaning.

Target Market & Demographics

Who will be using your product?

- Facility managers at commercial buildings (offices, hospitals, schools, retail)
- HVAC technicians who will operate the AI-guided cleaning bot
- Building maintenance staff monitoring the sensor network dashboard
- Property managers overseeing multiple buildings

Who will be purchasing your product?

- Commercial building owners (office buildings, shopping centers, hotels)
- Healthcare facility administrators (hospitals, clinics, care facilities)
- Educational institutions (universities, school districts)
- Property management companies managing multiple commercial properties
- Data center operators requiring precise environmental control

Where in the world would you deploy your product?

- Primary markets: North America (US, Canada) - strict indoor air quality regulations
- Secondary markets: Europe (UK, Germany, Nordic countries) - high environmental standards
- Growth markets: Australia, Japan, Singapore - advanced building management adoption
- Future expansion: Major commercial centers in developing markets (Dubai, Hong Kong, major Chinese cities)

How large is the market you're targeting?

- Global HVAC services market: ~$200 billion annually
- Building management systems: ~$20 billion annually
- Indoor air quality monitoring: ~$5 billion annually growing 8%+ yearly
- Serviceable addressable market: ~$15-25 billion (commercial buildings with centralized HVAC)
- Target segment (50,000+ sq ft commercial): ~$8-12 billion annually

How much of that market do you expect to capture?

- Year 1-2: 0.01% = $1-2 million (pilot customers, proof of concept)
- Year 3-5: 0.1% = $10-25 million (regional expansion, established product)

- Year 5-10: 1-2% = $100-250 million (national presence, market leadership)
- Long-term potential: 5-10% = $500M—1.2B (dominant platform with international expansion)

What competitors are already in the space?

Direct Competitors

- Teinnova Multibot - Professional duct cleaning robots ($50K+ equipment)
- JettyRobot S - Industrial pipeline inspection/maintenance ($100K+ systems)

Indirect Competitors

- Traditional HVAC cleaning services - Manual cleaning companies
- Smart building management systems - Johnson Controls, Honeywell, Siemens
- Indoor air quality monitors - Airthings, PurpleAir, Awair
- Smart HVAC filters - 3M Filtrete, Nordic Pure smart filters

Key Differentiation

No existing competitor combines continuous sensor monitoring with AI-guided mobile cleaning and chemical-free UV-C sterilization in a comprehensive building health management platform.

Stakeholders

We have reached out to several stakeholders, including emailing EOS at UPenn, and submitting web contact forms for LG and Hitachi, but have not solidified any individual stakeholder at this point.

Student Project: Request for Feedback on HVAC Inspection & Monitoring Concept

James Steeman <jsteeman@seas.upenn.edu> Thu, Sep 25, 12:42 PM (1 day ago)
to EOS, Chirag, Joaquin

Hello,

My name is James, and I'm part of a student team in SEAS (the ESE 5180 course) considering an engineering project related to HVAC inspection and maintenance. As part of the project, we're looking for feedback to help us refine the idea and understand what aspects are most valuable (and what might be unnecessary). If someone on your team is available to share some thoughts, we'd greatly appreciate it.

The inspection portion of the idea is a robot that navigates through HVAC ducts to detect issues such as mold, debris, blockages, corrosion, and wear. It would then generate or update a system map and prepare work orders. This could also be equipped with cleaning elements like a brush or vacuum unit for dust/debris removal, and perhaps a UV cleaning element.

Additionally, the robot would place compact sensor nodes throughout the system to provide real-time and continuous monitoring of temperature, humidity, vibration, or other desired parameters to help identify developing issues, support air quality compliance, and enable predictive maintenance.

We believe that this could both help with maintenance of newer systems and reduce costs by proving that older HVAC systems can remain in service with targeted maintenance, rather than requiring full replacement. It could also offer facility managers more information to use in decision making processes

Since we don't have any experience working with or maintaining such systems, we're hoping to better understand which parts of this idea would be most useful in practice, and what challenges it could face in real-world deployment? Are there already techniques used to facilitate inspection and monitoring tasks, and if so, how might this idea fit in with those?

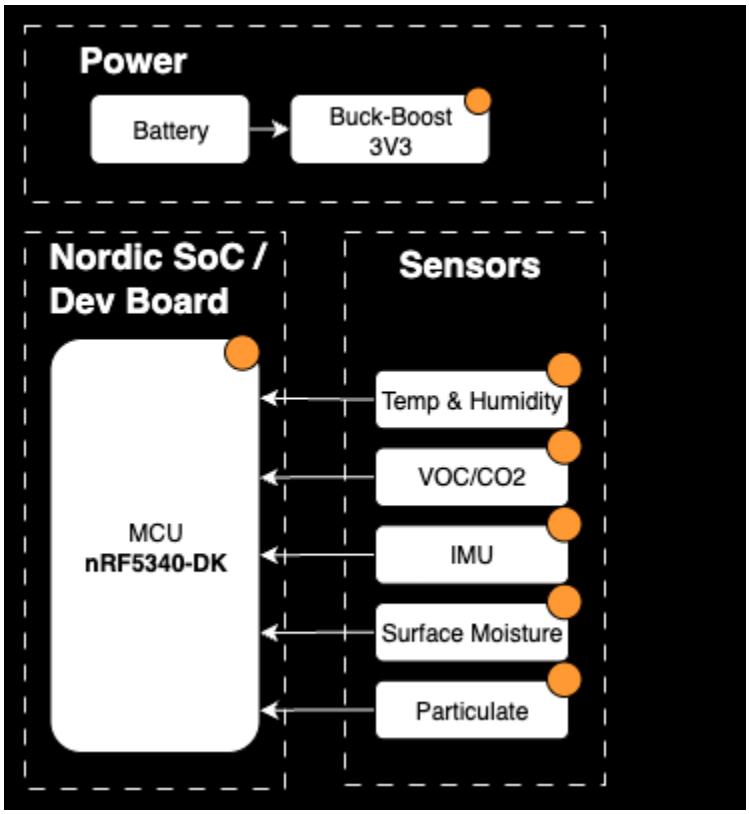
Thank you for your time and help!

Best,
James Steeman
EE '26

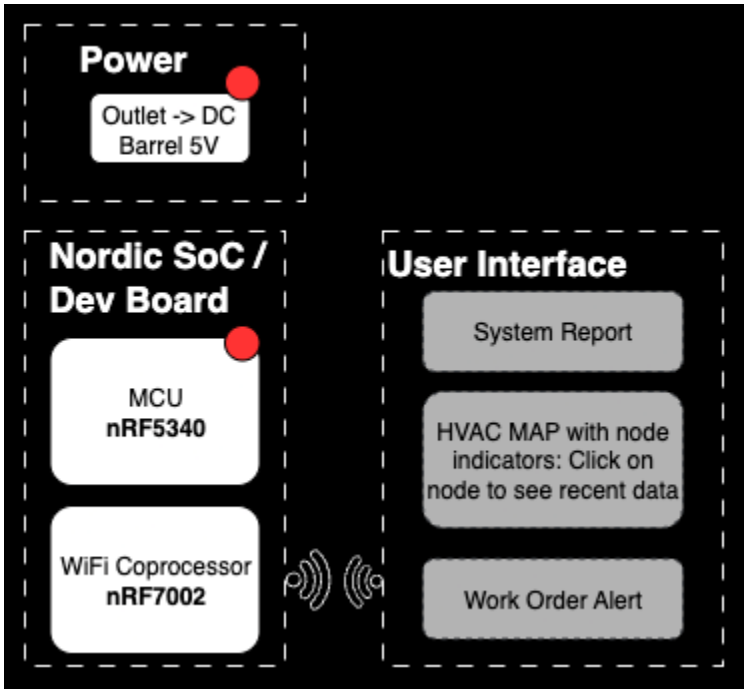
Since we believe the current idea of our product will be more directed towards HVAC companies and building managment than maintenance staff, we continuing to reach out to additional companies (through sales departments) for feedback on our idea.

System-Level Diagrams

Sensor Node

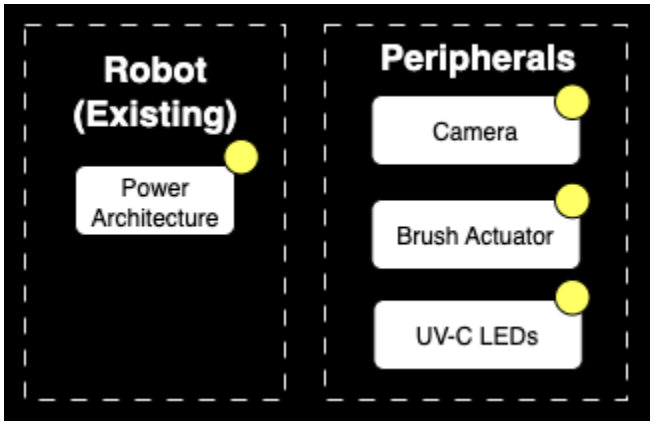


Gateway



Robot

We will start by leveraging an existing robot and prototyping on top/hacking the robot to add cleaning functionality. Below is a very simple diagram indicating our added peripherals, which we will first attempt to power from the robot's power architecture, but add external battery/ power management if necessary.



Security Requirements Specification

Security Overview

The system will ensure data, communications, and firmware integrity are protected from tampering, eavesdropping, and unauthorized access. Security measures particularly focus on safeguarding the gateway and nodes, which are in continuous operation and not always being observed.

Security Definitions, Abbreviations

- OTA: Over the air firmware updates
- GUI: Graphic User Interface

Security Functionality

Requirement ID	Requirement Title	Description	Rationale
SEC 01	Gateway Firmware Integrity	Gateway shall run only firmware from signed OTA	The gateway acts as a bridge between the sensor node mesh network and the cloud (data

Requirement ID	Requirement Title	Description	Rationale
		updates, and shall securely store keys	portal etc.), and compromise here could expose the client's network and leave them vulnerable to attacks and breaches
SEC 02	Autheticate Nodes	Each sensor node shall authenticate in the mesh network using unique key/ certification and ignore messages from tampered systems	This prevents unauthorized devices from disrupting the mesh or tampering with the data at the hardware level. It also protects from counterfit devices being added to our network
SEC 03	Data Encryption	Communication from nodes, gateway and GUI interface shall be encrypted	This protects potentially sensitive IAQ and predictive maintenance data from eavesdropping and tampering at the data level

Hardware Requirements Specification

Hardware Overview

The system contains a mobile robot for HVAC navigation, duct cleaning operations and sensor node depolyment. Low power sensor nodes will be deployed in the HVAC system for data collection to identify system issues and enable predictive mainenance. There will also be a gateway node.

Hardware Definitions, Abbreviations

- HVAC: Heating, Ventilation, and Air Conditioning

- VOCs: Volatile Organic Compounds
- UV-C: Ultraviolet C - short-wavelength UV light used for chemical-free disinfection and sterilization

Hardware Functionality

Requirement ID	Requirement Title	Description	Rationale
HRS 01	Bot Size and Weight	The mobile bot shall be maximum 300mm x 100mm x 100mm (can change) and weigh less than 5kg to fit through standard commercial ductwork.	Must navigate existing HVAC systems without modifications or damage.
HRS 02	UV-C Sterilization	The bot shall include UV-C LEDs with 360-degree coverage to achieve 99.99% pathogen elimination.	UV-C sterilization is the core technology differentiator for chemical-free cleaning.
HRS 03	Sensor Durability	Sensor nodes shall operate in -10°C to +70°C, 0-95% humidity with IP65 protection, VOC and 12+ month battery life.	HVAC environments are harsh; sensors must survive without frequent maintenance.
HRS 04	Wireless Communication	System shall maintain mesh networking with 100m range and <2 second response time between sensors and bot.	Real-time monitoring and response is critical for building health management.
HRS 05	Camera System	The bot shall include HD cameras with LED illumination for visual	Visual documentation and AI analysis are

Requirement ID	Requirement Title	Description	Rationale
		inspection and AI-powered contamination detection in low-light ductwork environments.	essential for contamination identification and compliance reporting.

Software Requirements Specification

Software Overview

The node/gateway software shall collect, process, and transmit sensor data HVAC sensor nodes to a centralized gateway. It shall manage sensor feature toggling, battery optimization, and secure communications across BLE mesh and Wi-Fi networks.

The robot software shall collect and process real time controls and data for navitagion and cleaning operations.

Software Users

- Facility managers at commercial buildings (offices, hospitals, schools, retail) using IoT dashboard
- HVAC technicians operating cleaning robot
- Building maintenance staff monitoring the IoT dashboard
- Property manager

Software Abbreviations

- MCU: Microcontroller Unit

Software Functionality

Requirement ID	Requirement Title	Description	Rationale
SRS 01	Battery	Software shall use MCU low	It is important to

Requirement ID	Requirement Title	Description	Rationale
	Optimization	power modes, intermmittent sensing and transmission to extend battery life to at least one year	maximize sensor lifetime to minimize disruptions and maintenance on the network
SRS 02	Robot Deployment/ Guidance	IoT dashboard shall alert operators to provide precise contamination or fault locations for targeted cleaning/work orders	Reduces manual inspection time and system downtime

Pitch 1

Course Pitch 1 Slides

Wireless Demo

Gateway Repo

Mesh Node Repo

We have pulled and compiled the code on the different machines.

We have ordered sensors and the seeed studio XIAO nRF54L15 (s) for our ble mesh nodes.