Northeastern University
London

Cornerstone of Engineering II

Design Project Report

Part One

NU ID: 002364144

April 12, 2025

Northeastern University
London

Introduction:

The design project team set out to create a way of determining whether an area was safe for human habitation without the risk of harm to those running an assessment. Unexplored locations, areas impacted by natural or anthropogenic disasters, and remote sites can potentially threaten researchers, inhabitants, and anyone wanting to enter an area [1, 2, 3]. Probing an environment remotely is no new concept [4, 5, 6]; however, the existing solutions have limitations and gaps in the situations in which they can be deployed. The design project team believes this concept could fill in where current solutions cannot. Currently, to get on-location sensor data, there must be existing Environmental Monitoring Stations, or Unmanned Aerial Vehicles (UAVs) - like drones - can be used. Both solutions, however, have situations where they cannot be utilized. Fixed Environmental Monitoring Stations offer a long-term solution for monitoring an area with far fewer limitations on the equipment that can be used, allowing for the broadest range of simultaneously deployed sensors [7, 8, 9]. When towers are damaged or simply do not exist in an area, UAVs equipped with environmental sensors are an effective and proven way to collect data. Despite their versatility, their flaws are major: limited deployment time due to energy-hungry flight methods, High device cost, and the required trained operating team all limit where UAVs can be deployed [8, 10]. The design project team created a solution that can be deployed as a payload dropped from a manned or uncrewed aircraft. The simple and inexpensive deployment system allows for the safe stationing of the device in remote environments with rugged terrain, providing accuracy and long-term deployment with the advantage of versatile placement. Additionally, its simplicity opens the opportunity for larger-scale versions holding a wider range of sensors and/or extending the device's operational time with larger batteries; a problematic venture for current solutions.

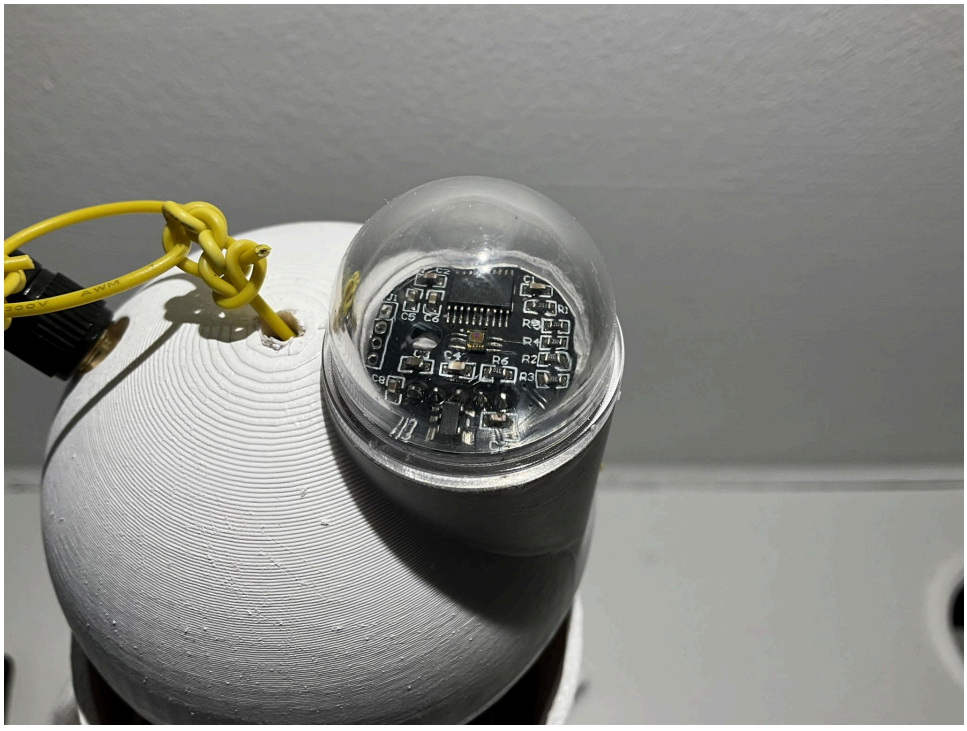
Acoem CAAQMS [9]

Swell Pro UK FD2 Sniffer Drone [10]

Design:

The initial phase of the team's design process entailed selecting key environmental data for analyzing an area's habitability for short and long periods. The chosen key data sets included air quality, temperature, humidity, light levels, and the presence of any harmful air pollutants. Preliminary research on available sensors identified two modules that collectively would fulfill the team's requirements.

The DFRobot Ambient Light Sensor (0-200klx) [11, 12] was chosen for ambient light level detection. Using an On-Chip photodiode, ambient light levels are accurately measured between 0 lux (lx) and 200,000 lux [11], a range greater than necessary in most environments, with average outdoor ambient light levels reaching an intensity of 100,000 lx [13]. The additional range provides the ability to detect light levels exceeding those typically experienced in direct sunlight, indicating potential hazards. Additionally, IR and UV blocking is used to eliminate possible interference, ensuring accuracy in its data [11]. In sum, the DFRobot Ambient Light Sensor (0-200klx) exceeds the needed range and provides the accuracy required for the project.



Light sensor attached to final device; Photo Taken By Author

The M5Stack ENV Pro Unit with Temperature, Humidity, Pressure, and Gas Sensor (BME688) [14, 15] fulfilled all remaining sensor requirements. Equipped with the BOSCH® BME688 sensor [16], the unit detects ambient temperature, gas resistance, and air pressure, as well as relative altitude and humidity [15].

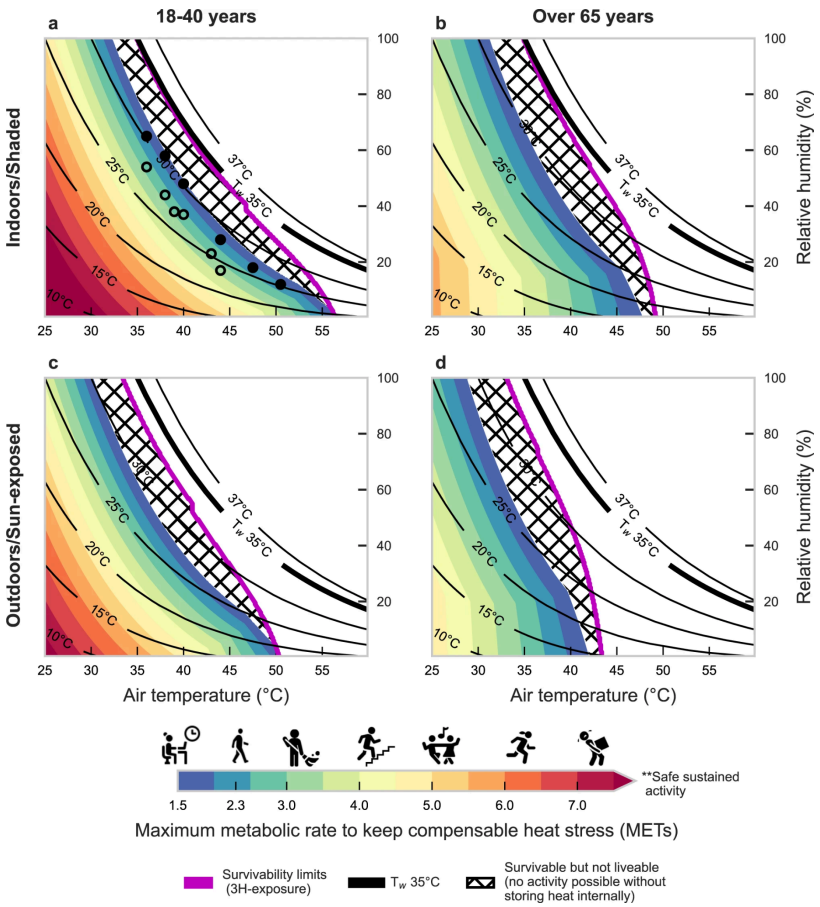
Extremes in temperature or humidity can be deadly, with survival levels varying depending on age [17, 18]. Maximum metabolic rates for safe, sustained activity can drastically decrease with higher relative humidity percentages and temperatures [17]. Extreme cold temperatures also limit survival time in the environment, depending on clothing and insulation, as seen in image 7 [18].

Gas resistance indicates the presence of volatile organic compounds (VOCs) in the air and other harmful air pollutants [16]; higher gas resistance indicates lower air quality. Depending on the severity of air pollution, long-term and short-term health risks are possible: research links exposure to cancer, respiratory disease, cardiovascular disease, stunted child development, and more [19].

Air pressure, in conjunction with other data collected by the BME688, allows the team to make predictions on weather and the likelihood of precipitation in the area. Understanding weather patterns over an extended period can help those conducting analysis better understand an environment.

Relative altitude data assists all measurements. Altitude impacts oxygen levels, temperature, and airflow. Keeping track of relative altitude allows a better understanding of what normal/expected data should be in an environment.

ENV Pro Unit attached to final device; Photos Taken By Author



Relative humidity against Air temperature with maximum metabolic rate. Shown at different age groups, indoor and outdoor, and exposure levels [17].

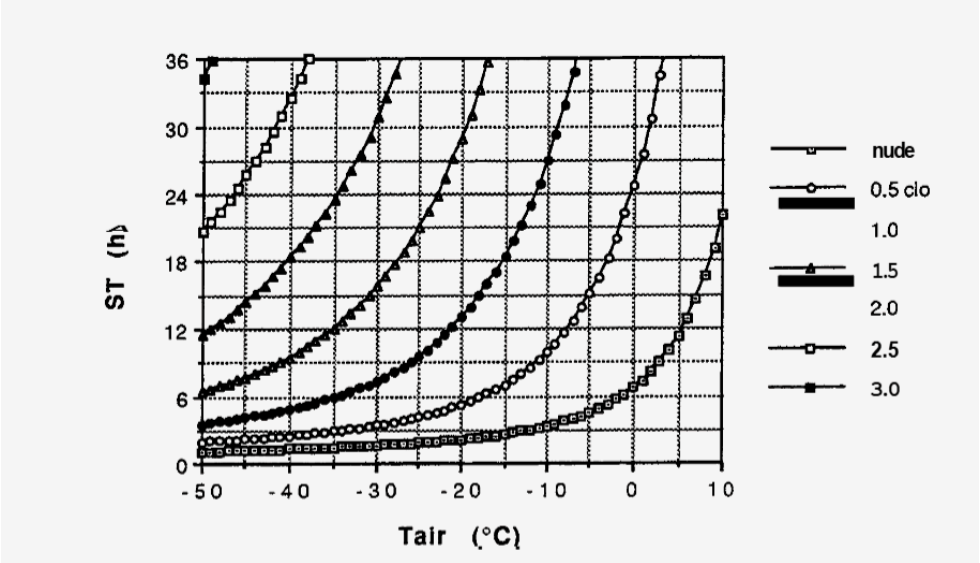
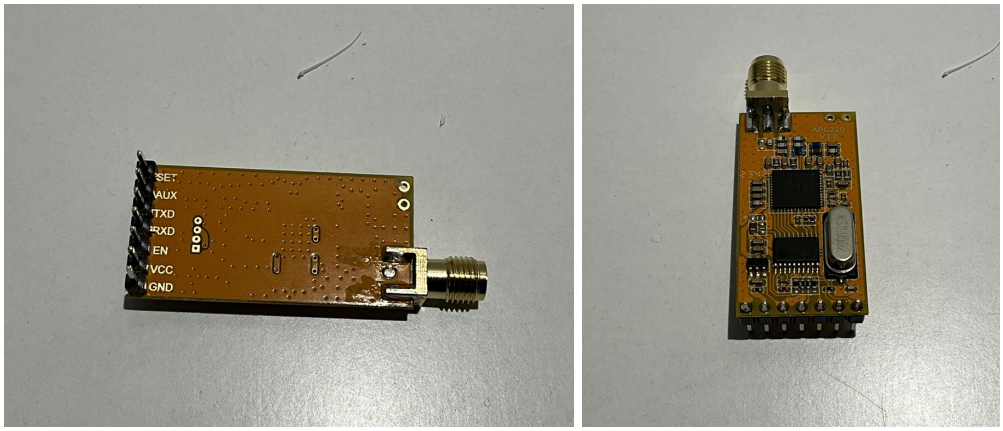
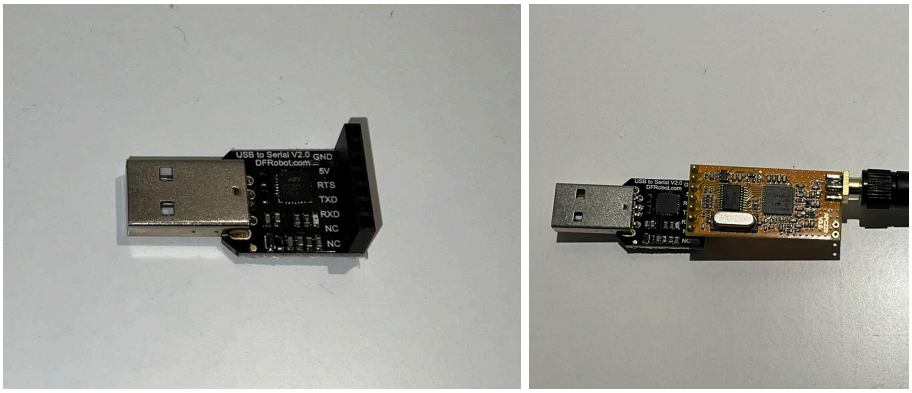


Image 7: Estimated survival time against Air temperature depending on insulation thickness [18].

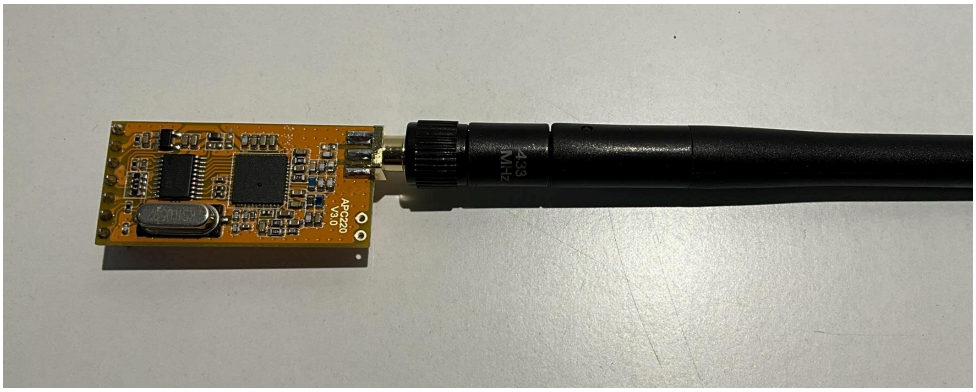
In potentially dangerous environments, receiving data over a distance is crucial for safe analysis. The design project team chose radio frequency (RF) as the wireless communication method because of its long and reliable range, low power consumption at moderate ranges, and independence from any existing network or infrastructure outside the team's control [20]. Other methods required additional equipment, lacked equivalent potential range, were inefficient in power consumption, or were too expensive for the economic goals of the team's design [21, 22, 23]. When using RF and selecting the necessary hardware, understanding what frequencies can be legally operated on is an important consideration. Nations have differing laws on where amateur and civilian users can operate [24, 25, 26]. In the UK, where the design project team developed and tested the device, 433 Hz is an accepted band for its intended use. The DFRobot APC220 Radio Communication Module [27, 28, 29] was chosen for its 433 Hz operating frequency, quoted 1000m - 1200m line of sight range, and lower power consumption [28]. Additionally, a DFRobot USB to TTL Converter (CP210) [32] was used to receive data on a notebook computer running Microsoft Windows 11 OS [30], RF Magic Software [28], and SerialPlot - Realtime Plotting Software [31].



DFRobot APC220 Radio Communication Module; Photos Taken By Author



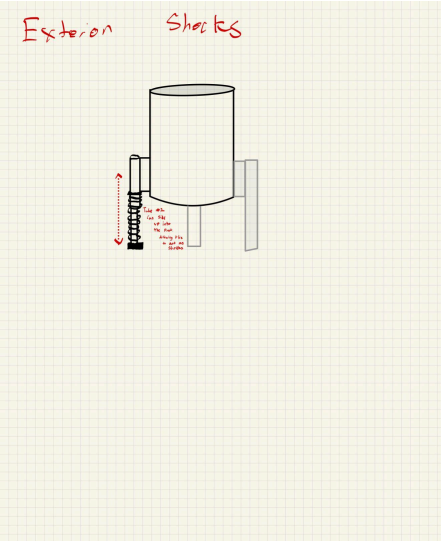
DFRobot USB to TTL Converter; Photos Taken By Author



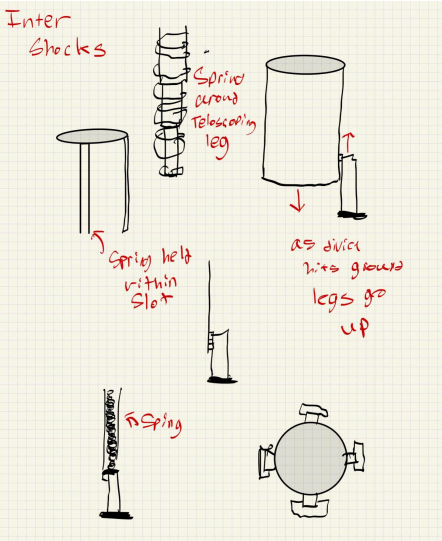
DFRobot APC220 Radio Communication Module & Antenna;
Photo Taken By Author

Inspired by Mars landers [34, 35], the device's descent to landing is slowed by a round, 49" solid canopy parachute. At landing, three equidistant dampers arranged in a triangular layout soften its impact. The telescoping legs have their compressions slowed by three layers of foam housed within the legs. Using the Parachute Size Calculator on RocketReviews.com, a well-known American model rocketry reviewer, the team found that a 49" canopy would be sufficient to slow the approximately 3 lbs payload to a reasonable speed by impact [33]. Original designs used springs rather than foam; however, in testing, the team found that the rebound from springs on impact could potentially result in tip-over. After impact testing ratios and volumes of four different foams, the team settled on a three-layer solution that maximizes impact absorption without excessive rebound. Smooth leg movement is created by sanding parts and using WD-40 Specialist® Silicone Lubricant [36].

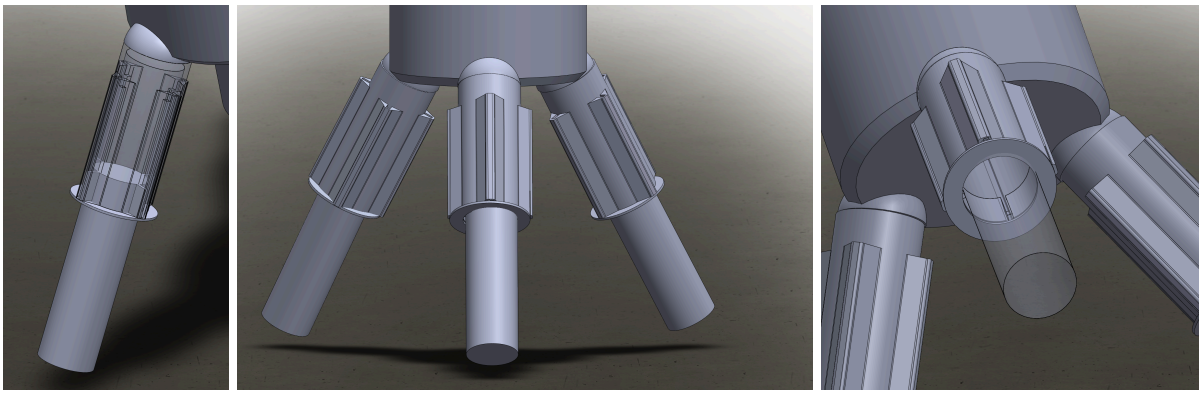
Original napkin drawings for device leg design; Created by Author.



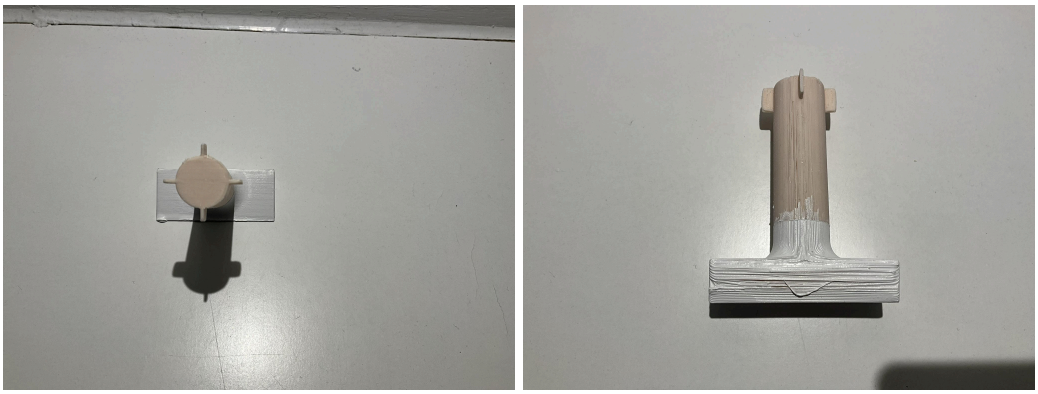
Exterior spring design.



Early version of final design.



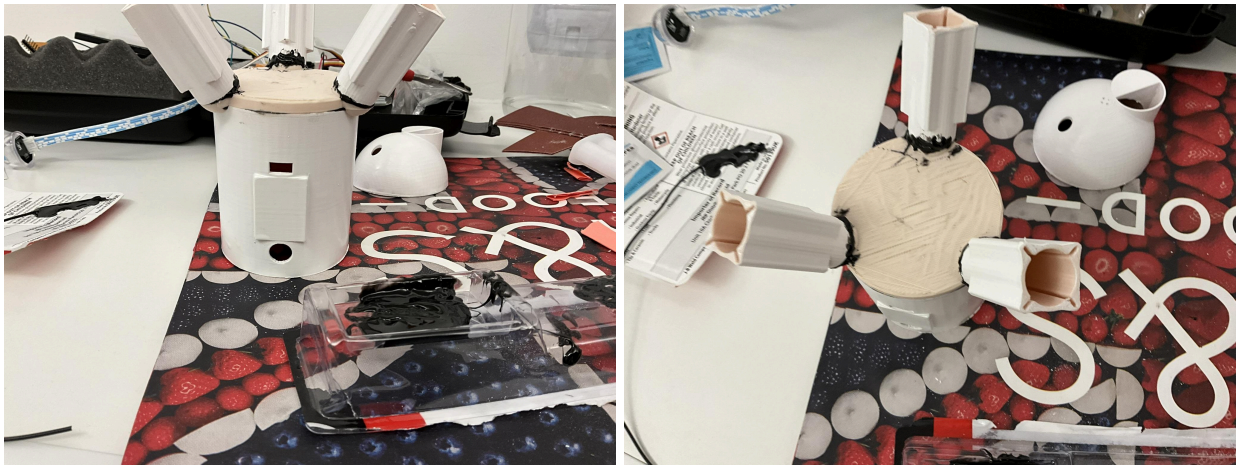
First version of SolidWorks modeled legs; Created by Author.



Final version of inner leg; Photos taken by Author.

Final version of outer leg; Photos taken by Author.

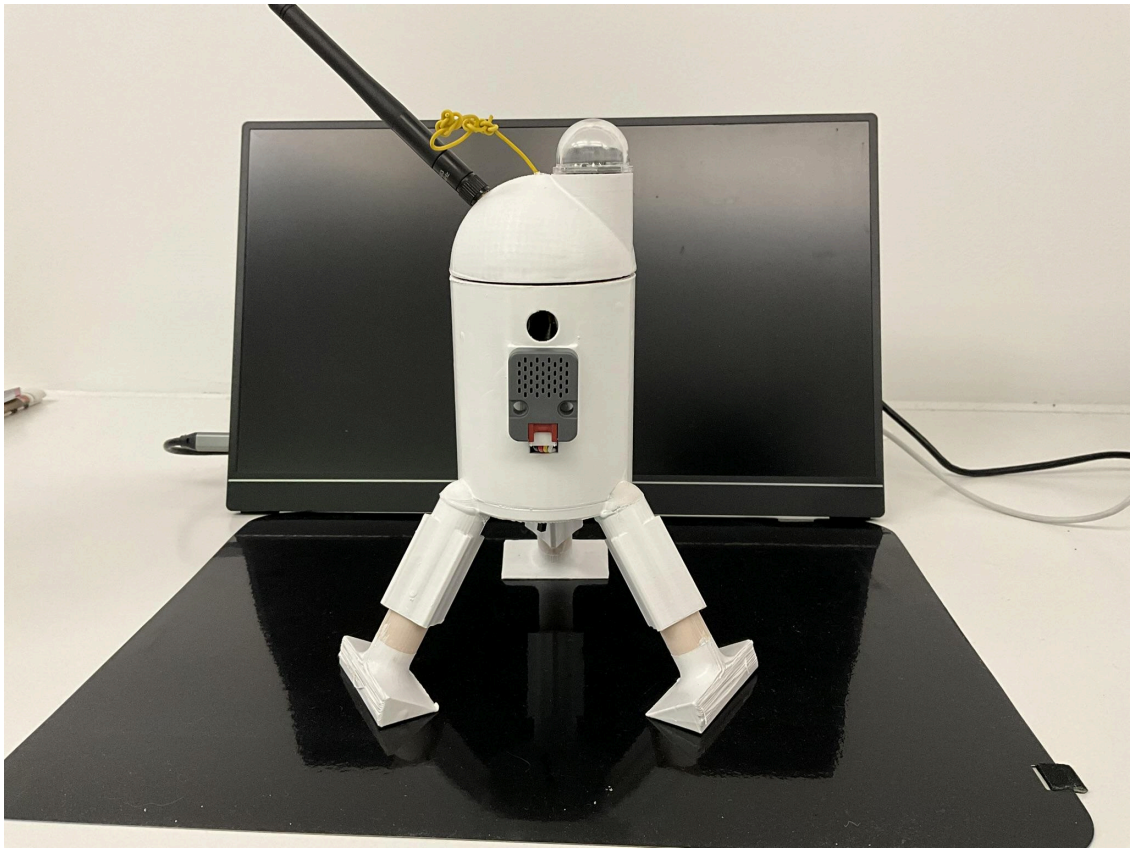
The final device was assembled using J-B Weld PlasticBonder™ and the J-B Weld PlasticBonder™ Syringe [37]. The device's exterior was finished with multiple coats of Fortress Trade White Satin Heat Resistant Radiator Spray Paint [38]. Both products were chosen for their heat-resistant and durable properties.



Final assembly process; Photos taken by Author.

Summary and Conclusion:

The design project team sought to develop a device for analyzing whether an environment was safe for human habitation, preventing risk of harm to those evaluating potentially dangerous or remote areas. The ability to collect a significant volume of crucial data from a distance, over long periods, all at an economical price, makes this concept a reliable alternative to existing environmental monitoring methods in some situations. Aimed to function when current solutions cannot, this concept does not replace other products but instead aims to sit as another tool in a collection of anyone conducting environmental monitoring. Scaling this model in size may allow for longer-term deployment and use in more extreme situations. The device purposely utilizes materials that increase durability and functionality in adverse situations; however, additional features such as parachute staging, additional water resistance, and stronger materials could bring the idea to real-world use. The project team theorized the potential use of hydraulic suspension systems for ground deployment and flotation devices for maritime use, replacing the current landing system and extending the scope of the device to additional areas.



Unsealed final version of the final device fully assembled; Photo taken by Author.

Northeastern University
London

Cornerstone of Engineering II

Design Project Report

Part Two

NU ID: 002364144

April 12, 2025

Introduction:

There is no agreed-upon "correct" answer to whether any action, situation, or idea is morally right or wrong; yet, philosophers have created theories to help guide moral judgment. Consequentialism, Deontology, and Virtue Ethics: all important ethical theories that can be collectively useful when analyzing the ethics of a subject.

Classic consequentialism states that an action is right or wrong based on its consequences, considering not what happens before the act but what happens after [39, 40].

Deontology provides moral rules that no action may violate the rights and dignity of any agent or hinder their autonomy [39, 41, 42, 43]. In a deontological view, any goal must treat all agents never as means to an end, but rather as independent ends [42]. Treating anyone as a means to a personal end/goal would infringe on their autonomy, making an action unethical [42]. Compared to Consequentialism, Deontology does not consider what happens after an action or its consequences, nor does it evaluate any context of the action. The importance is placed on whether the action follows moral duties and principles.

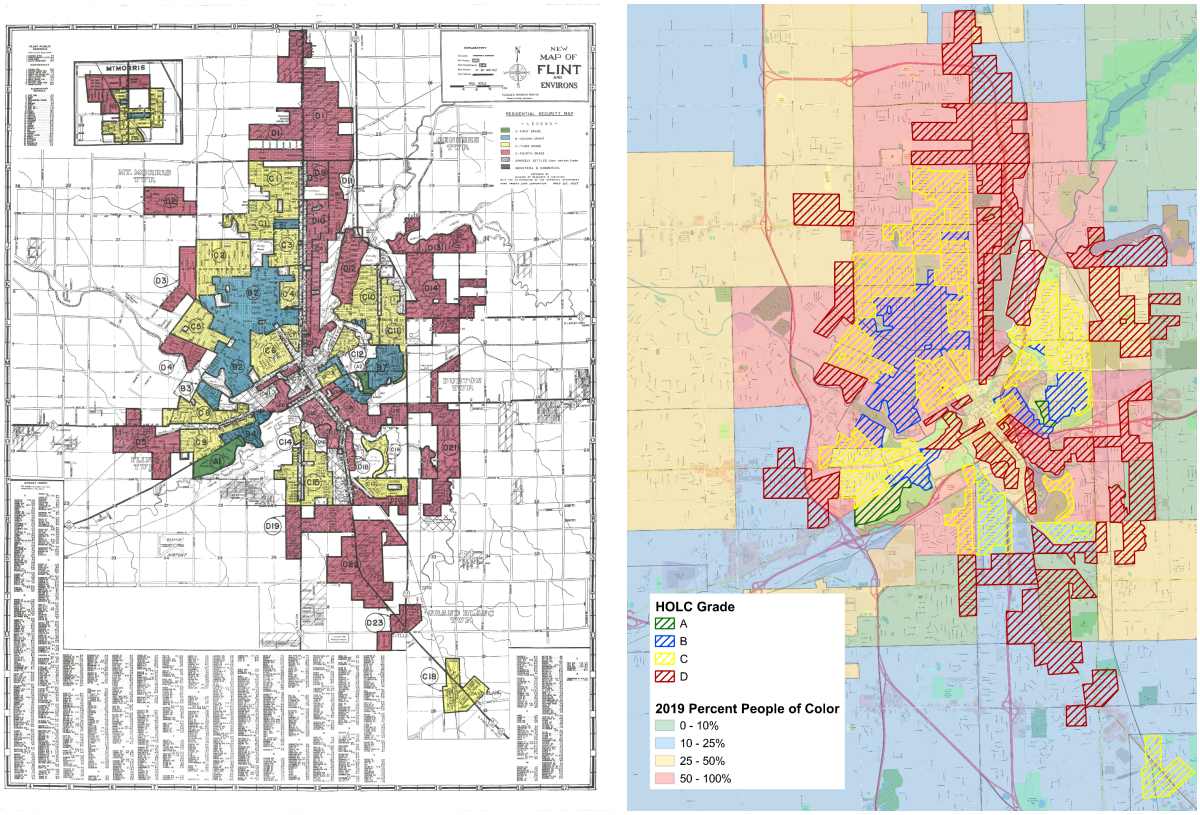
Unlike consequentialism and deontology, virtue ethics does not define ethical decision-making rules [39, 44]. Instead, developing positive character traits is emphasized. The morality of actions is determined by whether they align with those of an agent with virtuous traits. Actions must not only align with those of an agent posing positive traits, but of one who does not have excess or a lack in any traits. For example, too much generosity is wastefulness, while too little is greed [44].

The ethical focus in this report is on equity in environmental protection and monitoring. A key example that requires reflection and ethical discussion is the environmental injustice and systematic racism in the handling of the Flint, Michigan, water crisis. Despite early warnings from residents and officials, the prioritization of cost reduction over public health in a marginalized community [45, 46] highlights the importance of all communities receiving the protections and resources needed [46, 47, 48].

Analysis:

The water crisis devastated the population of an underserved community [48]. A predominantly Black and low-income area [49], Flint has long been neglected by all levels of government [56]. Exacerbated by a lack of adequate healthcare access, infrastructure, and education, people were left vulnerable to the long-term impacts of lead poisoning that were to come. Underfunded public services, deteriorating infrastructure, and the absence of political representation contributed to the crisis. The failure to act on expert advice and the subsequent mishandling of the following disaster deepened inequality in the area. By analyzing the crisis through each ethical theory individually, one can understand the situation more completely.

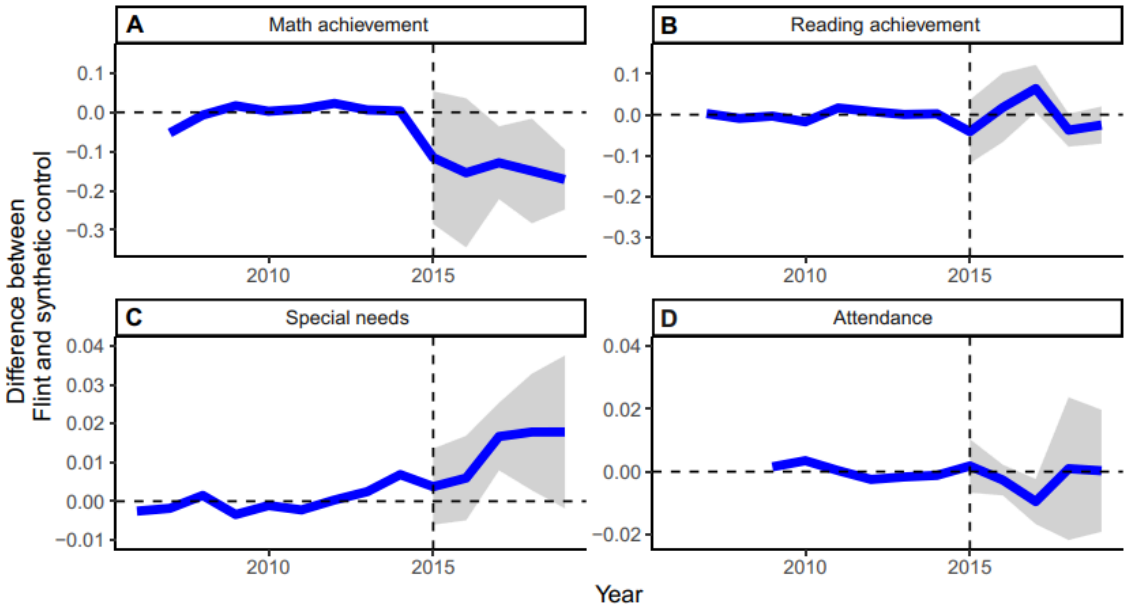
Images highlighting the history of redlining in Flint, Michigan.
A practice that has long-term effects on the socio-economic success of communities [55].



1937 HOLC map showing districting and 2020 Census Data compared to HOLC Map lines.

Starting with consequentialism, the consequences of the crisis, in summary, would be: a significant population with higher blood lead levels causing health complications, including skin

rashes, hair loss, and nausea [50]; a negative impact on the educational outcomes of school-age children in the area [51]; 350 million dollar cost to the state of Michigan [52]; a population decrease putting strain on already weak infrastructure [49, 53]; and a lack of running clean drinking water [53].



An estimate of student outcomes compared to synthetic control, where:
0 represents synthetic control outcome & shading is confidence interval [50].

Additionally, the well-documented systemic neglect of Flint's Black population [46], coupled with a manufactured lack of political power [55, 56], created an environment where their concerns were ignored and their well-being was prioritized after others. As a consequence, the mistreatment and lack of protections allowed officials to make unchecked decisions [46]. With no positive consequences resulting from the switch to the Flint River as a water source, and the disproportionate impact on those in communities most marginalized, the actions of those who made the decision are definitively unethical to a consequentialist.

The deontological analysis of the situation shifts focus away from consequences and to the decisions themselves. Despite being warned of potential 'big disasters down the road', the switch to a dangerous unprotected water plant was made [46]. The conscious prioritization of budget-cutting measures over the right to good health each person in the area has, is a decision that compromises the autonomy and rights of all agents impacted. Additionally, a press release assuring the public that "Flint water is safe to drink" is a misuse of public trust by elected

officials [46]. Through lying [54] and prioritizing personal goals over the well-being of others, the decisions that led to the Flint water crisis were unethical in deontology.

A virtue ethics analysis of the decisions leading to the Flint water crisis is the simplest to make of all normative ethical theories. The character traits of those involved were most notably careless, short-sighted, self-centered, and disingenuous. While one could argue that the foreseen benefits of such austerity measures [52] are a virtuous goal, a stubbornness that pushes past professional advice and constituents' complaints [46, 53] is not the trait of a moral person. A person with good character traits would prioritize the health and well-being of those they represent over all else and would have the dignity to follow advice from experts in areas where they have less experience.

Summary and Conclusion:

No "correct" answer exists regarding whether an action, situation, or idea is morally right. However, philosophers have created theories to help guide moral judgment. Consequentialism, Deontology, and Virtue Ethics: all valuable ethical theories that can be useful when analyzing the ethics of a subject.

The Flint, Michigan, water crisis devastated a marginalized community that was neglected by the systematically racist systems that formed it. Government failure, unchecked decision-making, and the mishandling of the ongoing crisis led to the poisoning and subsequent long-term health effects that have left a community recovering and fighting for justice towards those responsible [57].

Examining local government decisions and the disaster that followed through three different normative ethical theories gives a more complete picture of whether the situation was morally good or bad. The consequentialist focus on the results of decisions highlights the true extent to which individuals were impacted in isolation from any change in feeling context or intentions could have. Deontology and Virtue Ethics ignore consequences, focusing on the intentions and actions officials made. Combining analysis from each, the overwhelming conclusion is that the actions of those involved in the Flint, Michigan, water crisis were unethical and immoral. Their actions were selfish, irresponsible, corrupt, and short-sighted: none of which are character traits of a good person. The aforementioned actions led to pain and suffering of those entrusted them to represent and protect their communities. It would be difficult to argue in favor of those responsible, and the continued legal fight for reparations [57] underscores how American systems are still unjust and environmental protections are not equal. Low-income communities,

especially those whose populations predominantly consist of people of color, will continue to suffer at the hands of a system that requires their exploitation to function. Exploitation, across many ethical theories, is immoral and will only stop when members of the social class who benefit from exploitation stand up for those affected. Had environmental protections been present in Flint, Michigan, the decay of an entire community could have been prevented.