Supply Activity Logger - Group 34

Trevor Murphy - Email: murphytr@oregonstate.edu
Jacob Collier - Email: collieja@oregonstate.edu
Ashwyn VanPelt - email: vanpeltz@oregonstate.edu

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Design Impact Statement

Public Health, Safety, and Welfare Impacts

The COVID-19 pandemic is an excellent example of medical products that need to be kept in stable environmental conditions to ensure efficacy. The consequences of a batch of vaccines being compromised due to environmental conditions, could end up with individuals thinking they are vaccinated, while still being at risk due to a compromised vaccine. [1]

Cultural and Social Impacts

Package tracking information could result in decreased trust in shipping partners, drivers, and warehouse workers, since disturbances in the package's condition, even trivial ones, could harm the reputation or social standing of these workers. Package delivery drivers already suffer from adverse conditions, and additional negative sentiment could be socially harmful. [2]

Embedded systems technology components use precious metals, which are unfortunately often derived from exploited communities. By buying these components, we make it harder to eliminate these practices.

Environmental Impacts

Our board, like any embedded systems project, will produce E-waste, due to its sensors, PCB, and batteries. E-waste is technically recyclable, but it is very difficult, being time and cost prohibitive. [3]

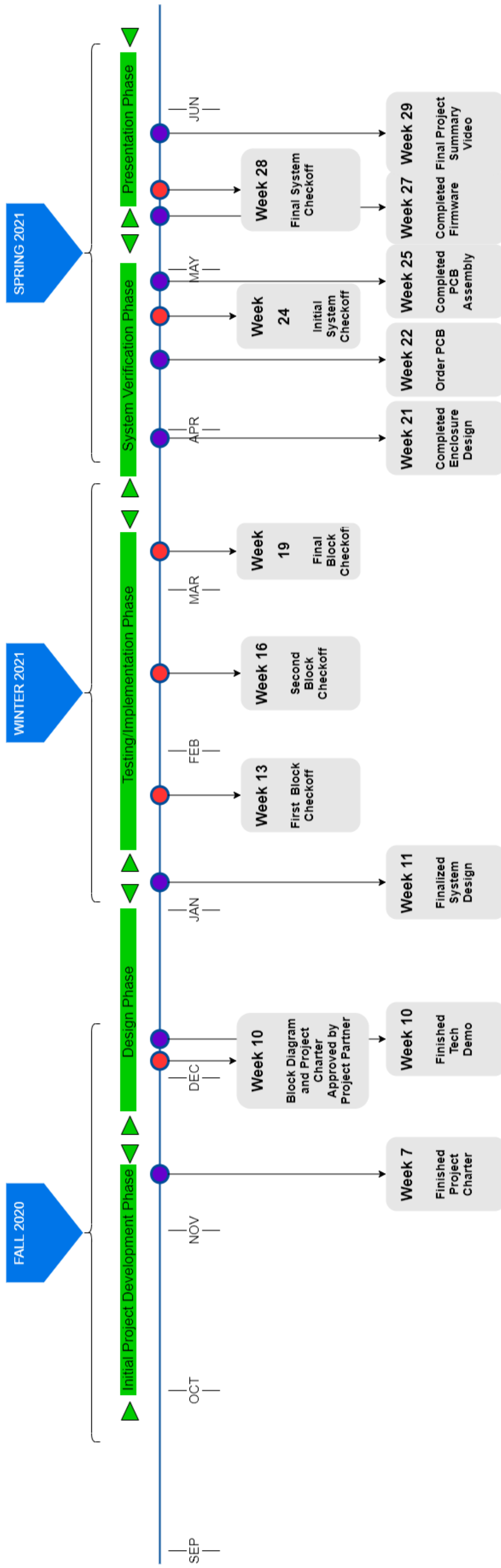
Nearly all facets of the shipping industry pollute the atmosphere and environment. By creating a supportive system for the shipping industry, our system will contribute to this pollution.

Economic Factors

Increased tracking information could also shift responsibility to the consumer, for resolving the damaged state of their package: the vendor can absolve themselves of responsibility, and force the consumer to take it up with the package handler instead. [4]

On the other hand, an individual or company knowing the possibly damaged state of a product can save time, effort, headache, and ultimately money in ascertaining the source of a product failure.

Project Timeline



Scope and Engineering Requirements Summary

Name	CR	ER	Verification Method	Test Process	Test Pass Condition	Evidence Link
Configurability	The system should be able to log data in various time intervals.	The system will have configurable time intervals between data logging events.	Demonstration	1) Choose a configuration setting. 2) Allow the system to run on the specified setting. 3) Examine the timestamps for each data log and measure elapsed time between results. 4) Verify that the elapsed time between logs matches the expectation of the chosen setting. 5) Repeat steps 1 - 4 for each configuration setting.	The system is configurable to allow for specified time intervals between data logging events.	https://youtu.be/I8sGLuYD3xU
Data Handoff	The logged data can be extracted at the package destination	The system will transfer its logged information to another device.	Inspection	1. Record data onto storage media 2. Remove storage media from system 3. Connect storage media to personal computer 4. Inspect storage media contents	If the logged system information transfers to another device, this condition passes.	https://youtu.be/MgshN3f57jw
Data Logging	The system should be able to record changes in various metrics including humidity, orientation, atmospheric pressure, and temperature.	The system will measure and log orientation within 1% accuracy, atmospheric pressure, and temperature within 3% accuracy, and humidity within 10% accuracy.	Test	The testing processes represent a consolidation of each of the previous requirements' tests and the new accuracy levels. To Test Humidity: 1) obtain a Hygrometer with <1% measurement error. 2) sample humidity measurements using the system sensor and a hygrometer in a moist outdoor environment. 3) sample humidity measurements using the system sensor and a hygrometer in a dry outdoor environment. 4) sample humidity measurements using the system sensor and a hygrometer in an indoor environment. 5) verify that the set of system measurements falls within 10% humidity of the hygrometer measurements for each environment. To Test Orientation: 1) Obtain a reliable digital level device with <1% measurement error. 2) Orient the system to be on a level surface, and record a measurement from it's orientation sensor. 3) Compare the recorded value to the value given by the digital levelling device. 4) Repeat steps 2 and 3 with the system oriented at a 45 degree angle. 5) Repeat steps 2 and 3 with the system oriented at a 90 degree angle. 6) Verify that the set of system measurements fall within 1% of the digital level device. To Test Pressure: 1) obtain a Barometer with <1% measurement error. 2) sample atmospheric pressure measurements using the system sensor and a barometer outdoors at OSU 3) sample atmospheric pressure measurements using the system sensor and a barometer at high pressure in a vacuum chamber 4) sample atmospheric pressure measurements using the system sensor and a barometer at low pressure in a vacuum chamber 5) verify that the set of system measurements falls within 3% of the barometer measurements for each environment. To Test Temperature: 1) obtain a thermometer with <1% measurement error. 2) sample temperature measurements using the system sensor and a thermometer in the morning outdoors at OSU. 3) sample temperature measurements using the system sensor and a thermometer in the afternoon outdoors at OSU. 4) sample temperature measurements using the system sensor and a thermometer in the evening outdoors at OSU. 5) verify that the set of system measurements falls within 3% temperature of the thermometer measurements for each environment.	The system measurements fall within their expected range of accuracy outlined in the associated part of the Engineering Requirement.	https://youtu.be/BP8hjaYh_-s
Form Factor	The system should be small.	The system will be no larger than: 9 x 5" x 2""	Inspection	1) Tape a square outline on a surface of 9 x 5" 2) Align a ruler vertically next to the square 3) Place the system in the square and verify that the height is lower than 2" and the system is entirely within the square.	The system is measured to be less than or equal to 9 x 5" x 2""	https://youtu.be/HEm8btAbFS4
GPS Capability	The system should be able to determine its physical location if possible.	The system will make multiple attempts to obtain its geographical location data for logging events, but stop retrying if a signal cannot be acquired.	Analysis	1) Run the system at a known location in the open, at a known location under cover that should block a GPS signal. 2) Have the system perform data logging events at both of the chosen locations. 3) Verify that GPS coordinates were measured and logged the location in the open, and that the system stopped retrying to acquire the GPS signal after the failed attempts at the covered location.	The system successfully measures and logs GPS data or stops attempting to do so after three failed attempts in each test environment.	https://youtu.be/M3QVbGEex94
Pilot Data Sets	Provide example data from live system tests in a practical field application.	Complete full system verification by week 18 and test system functionality by mailing the system to several locations within the United States.	Test	1) Ensure that the system verified by week 20 2) Package the system and send to 2 - 3 known recipients through the USPS. 3) Retrieve the system and verify that the system logged measured data as outlined in the Engineering Requirements, and did not sustain any damage and remains functional.	The system was completed by week 20, and provided example data sets through practical field testing.	https://youtu.be/BtlpRL246Xc
Power Consumption	The system should be functional for a shipping trip lasting at least a couple weeks.	The system will be functional for at least 3 weeks of operation, while completing a logging event once per hour.	Analysis	1) Identify the power characteristics of the chosen system battery. 2) Perform 24 data logging events over the course of at least 6 hours. 3) Measure net power consumption. 4) Analyze and extrapolate the data for a hypothetical 3 week shipping trip 5) Verify that the system will be able to run for this 3 week trip with the once-per-hour data logging frequency.	The system uses less than 4.8% of it's battery life (1 divided by 21, representing 3 weeks) over the 24+ logging events.	https://youtu.be/CY7uBMowEXw
Shock Response	The system should be able to detect significant shock events and turn on the logging system to log current state.	The system will detect shock events and log measurements.	Demonstration	1) turn on the system. 2) put system in a cardboard shipping box. 3) lift the system in the box and drop it from a height of 3ft onto a solid surface. 4) verify that shock event data is logged.	The system detects shock events and logs measurements.	https://youtu.be/06obbt7EHG8

Risk Register

Risk Description	**- Risk ID - Risk % - Severity**	**Risk Category**	**Performance Indicator**	**Responsible Party**	**Action Plan**
Board Failure	- HW1 - 10% - High	External/ Internal, Technical, Parts	The Board ceases to function, has reproducible failures, has visible damage	Trevor: handle consistently and carefully, note and communicate changes in behavior, note state upon receipt	Avoid: board will need to be reexamined and possibly redesigned if cause was not observable (physical damage, misuse)
Sensor Failure	- HW2 - 40% - Low	External/ Internal, Technical, Parts	A sensor ceases to function, has reproducible failures or inconsistencies, or has significant visible damage	Ash: handle consistently and carefully, note and communicate changes in behavior, note state upon receipt.	Retain: Keep an eye on sensor outputs and handle with care, but existing documentation and experience suggests that this is bound to happen, and impact is low
Sensor Spec Failure	- HW3 - 30% - Low	Internal, Technical, Docume-ntation	A sensor does perform to it's expected spec/ the spec was misunderstood by team members	Jacob: read and research part specs thoroughly before purchasing, ensure that the spec is well understood	Reduce: Ensuring that parts are vetted before purchase will reduce the likelihood of this occurring, and the impact severity if it does occur
Parts Delay	- TL1 - 50% - Medium	External, Timeline	A part arrives later than expected oris initially out of stock	Trevor: order parts well in advance	Retain: move timeline if required
Budgeting	- CT1 - 35% - Low	Internal, Cost	Parts required to meet spec are too expensive, or unexpected failures cause unforeseen costs	Trevor: budget out costs in advance to catch budgetary roadblocks early	Transfer: notify project partner and course instructor, request situational budget increase depending on source of cost

Risk Description	- Risk ID - Risk % - Severity	Risk Category	Performance Indicator	Responsible Party	Action Plan
Misaligned Inter-group expectations	- CM1 - 25% - Medium	Commun-ication	Ongoing communication difficulty between teams, misunderstandings between groups	Ash: ensure that teams are meeting periodically and verifying interfaces	Reduce: Periodic meetings and verification that we understand each others completion state and finished product goals
Data readability Failure	- SW1 - 20% - Medium	Internal, Software	Logged data is unreadable by or inconvenient for CS team to process	Trevor: ensure communication and cooperation with CS team on data storage, data logging	Transfer: Work with CS team to reach a middle ground/ help understand data Reduce: collab with CS team
Software Compatibility Failure	- SW2 - 15% - Medium	Internal, Software	CS team's programming and data is incompatible with hardware setup/data logging and transfer	Jacob: Ensure communication between teams on current platforms, verify and track compatibility in specs	Reduce: consistent communication with CS team, regular meetings to discuss format of data, hardware medium specifics, and data visualization
Code bugs and updates	- SW3 - 90% - Low	Internal, Software, Program-ming	Code does not work as it did before, fails	Ash: verify and track firmware updates, communicate with CS team	Retain: this is expected and is part of the development process
Reproducing Results Failure	- PD1 - 15% - High	Interal, Docume-ntation	Documentation for a project component is missing/out of date and needed to reproduce that component	Trevor: Document each and every step of project components	Reduce: Examine related documentation to recreate the missing or out of date documentation

The COVID pandemic had a much greater impact on the parts shipping industry than anticipated, which led to several issues such as delayed shipping and parts rapidly going out of stock. We did not include a risk about timeline management and this was a significant struggle for this project amidst the complications of the pandemic.

Future Recommendations

- **Increase Battery Life**
  - **Background:** We hoped for our system to last at least 3 weeks logging once per house, and we got it just under 2 weeks. Batteries already took up a significant portion of our design, and the system was beginning to get too heavy.
  - **Recommendation:** Optimize code to put sensors and systems into deeper sleep that conserves more power. Aim for <5mA current draw while not logging, as this should allow the system to run for longer than 3 weeks, and should be achievable with a true system sleep.
- **Prototype Early**
  - **Background:** Our system was not tested together, even on breakout boards, until the beginning of spring term. Putting the system together revealed many errors and oversights, which could have been resolved much sooner with more comprehensive choices and design changes, but this was not an option at the point when these errors were discovered.
  - **Recommendation:** Mock up a full system early winter term or as soon as possible, to examine errors, incompatibilities, and shortcomings. By doing this early, more wide reaching changes can be made, beyond band aid solutions or substitutions.
- **Communication Protocol Unification**
  - **Background:** Our sensors ended up using UART and I2C. Though it didn't cause insurmountable issues in our case, it certainly could have lengthened the time and increased the effort needed to get our design working
  - **Recommendation:** Unifying all sensors under one protocol, probably I2C, will make programming and PCB design significantly easier.
- **Microcontroller Programming Language and Compatibilities**
  - **Background:** Our system was initially going to be programmed with STM. After that proved too challenging, we shifted to Arduino, but elected to keep our board, since it should still be compatible with Arduino. It is likely that this was the source of many Arduino library incompatibilities that plagued the end of our project design cycle.
  - **Recommendation:** Select a language to program your microcontroller in, and a microcontroller, in conjunction with searching for support libraries. Ensure that your hardware and software are as neatly compatible as possible, to avoid late breaking errors that cannot be easily fixed without major redesigns.
- **Enclosure Blocks and 3D Printing Considerations**
  - **Background:** Our project partner asked us to 3D print an enclosure block, which ended up having large, flat components. Large and flat components of 3D printed designs tend to warp or lift.
  - **Recommendation:** Consider alternatives to 3D printing, or hybrid designs that get around the warping issue. It ultimately didn't affect our grade or design, but a change would have resulted in a cleaner and easier to use enclosure block.

- **System Finalization Cutoff**
  - **Background:** Throughout the course of the project, significant design changes were made to the project due to ironing out our Engineering Requirements page, constantly working with our project partner to refine the design and feature set of our system, and identifying potential flaws in the current state of the design. This consistently pushed back implementation, and added to the challenge of meeting our project timeline goals.
  - **Recommendation:** To avoid significant timeline challenges in the later stages of the project, we recommend to create a cutoff date well in advance of the system implementation stage of the project. If good forethought is put into this cutoff date, there should be plenty of time to implement the system that has been chosen.
- **Request Greater feedback on block checkoffs**
  - **Background:** During the Winter term, each team member was responsible for several system block checkoffs. Naturally, many of the functional blocks for this project were sensors. Because the block checkoffs focused on proving our interface properties of each block, many of our sensor blocks ended up being fairly functionally equivalent in terms of how one would operate them. Due to a certain level of 'redundancy' between many of our block checkoffs, we felt that a greater portion of block checkoff time could have been spent integrating each block into the system instead of verifying them independently.
  - **Recommendation:** To remedy this issue, we recommend to (as much as is possible) be in a position to at least partially integrate functional blocks into the system when it comes time to do block checkoffs for the class. This means that throughout Winter term, the team should be not only proving their block interface properties, but also be making progress on establishing a working system.
- **Clarify Engineering Requirements Early On**
  - **Background:** Confusion in regards to required work level, the agreed-upon meaning of specific terms that course instructors wanted us to use, and standards of proof for checkoffs, led to many, many iterations of engineering requirements.
  - **Recommendation:** Ask questions and get answers with regard to your engineering requirements as early and as often as possible. This will likely require that you communicate with your project partner and course instructor ina complicated game of telephone, to arrive at agreed upon standards for the project. Ensure that each requirement is something that you can implement as a team, something you can prove as a team, and something that meets the required work level. Missing one of these three will either result in late changes to your engineering requirements by necessity, or unfulfilled requirements at checkoff, if not both. For us, it was a little bit of both.

- **Communicate often with course instructors**
    - **Background:** As we worked on the system throughout the year, we encountered many issues with our project. These issues ranged from technical problems, to concerns about meeting course requirements, and more. Although we did meet with course instructors on several occasions throughout the year, we spent a far greater portion of time struggling with various aspects of the project that could have been greatly shortened by a quick conversation with the instructor.
    - **Recommendation:** Use instructor office hours frequently, and schedule meetings with them if necessary. Even having a recurring bi-weekly or monthly meeting time set aside to meet with instructors to discuss problems or even ask for recommendations on how to proceed could lead to more success in the project and in the course.

References

[1] Baskar, P., 2021. *What is A Cold Chain? And Why Do So Many Vaccines Need It?*. [online] Npr.org. Available at: <https://www.npr.org/sections/goatsandsoda/2021/02/24/965835993/what-is-a-cold-chain-and-why-do-so-many-vaccines-need-it> [Accessed 16 April 2021].

[2] H. Peterson, "Missing wages, grueling shifts, and bottles of urine: The disturbing accounts of Amazon delivery drivers may reveal the true human cost of 'free' shipping," *Business Insider*, 11-Sep-2018. [Online]. Available: https://www.businessinsider.com/amazon-delivery-drivers-reveal-claims-of-disturbing-work-conditions-2018-8. [Accessed: 17-Apr-2021].

[3] Ahmed, S., 2016. *The Global Cost of Electronic Waste*. [online] The Atlantic. Available at: <https://www.theatlantic.com/technology/archive/2016/09/the-global-cost-of-electronic-waste/502019/> [Accessed 16 April 2021].

[4] J. Bond, "2015 Warehouse/DC Equipment Survey: Smarter funding for the future," *Recently Filed RSS*, 01-Apr-2015. [Online]. Available: https://www.mmh.com/article/2015_warehouse_dc_equipment_survey_smarter_funding_for_the_future. [Accessed: 17-Apr-2021].