# Laser Scan Readings for Propeller Measurement

Design Document

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# Executive Summary

This project aims to modify the current system used by Linden Propeller to measure and model propellers for repair. The current system is susceptible to damage, and Mr. Linden would like us to find an alternative measurement method. The current system uses two Newhall scales that rest on carbon fiber rods that are very fragile and easily damaged in a machine shop environment. These rods cost roughly $850 each to repair, not to mention the time wasted waiting for new rods to arrive or installing them. This project is important because Mr. Linden is facing about $4000 in damages yearly, and an alternative system could prevent these damages.

The key requirements for this project are that the system has to be accurate to 5 micrometers and the system has to cost roughly $3000. These requirements have been extremely limiting because systems that are accurate to 5 micrometers are much more expensive than $3000. This has caused us to look for alternative solutions.

Our current design successfully meets all specified project requirements. Specifically, we have developed a measurement system capable of achieving an accuracy of 5 micrometers, significantly improving precision over the existing setup. Additionally, our system addresses durability concerns by replacing one of the fragile carbon fiber rods used on the measurement axes, thereby enhancing robustness and reducing potential maintenance costs.

Upon our recommendation, the client opted to purchase the Keyence LK-G157 laser sensor. This sensor was selected due to its optimal balance between cost-effectiveness, high accuracy, and durability compared to other evaluated alternatives.

To seamlessly integrate the Keyence LK-G157 laser into the client's existing measurement infrastructure with minimal disruption, we leveraged their current data conversion setup. The laser sensor originally outputs a signal of 12 volts, which was incompatible with the client's data conversion box that operates at 5 volts. To resolve this compatibility issue, we designed and implemented a voltage step-down solution, converting the 12-volt output of the laser sensor to a 5-volt input signal required by the data conversion hardware.

This approach ensured a smooth transition and preserved the familiar operational workflow for the client's staff, minimizing the learning curve and maintaining workplace efficiency. The converted data is subsequently processed by the existing computer system, facilitating accurate and reliable measurement analysis.

# Learning Summary

## Development Standards & Practices Used

Hardware Practices:

1. Component Testing: Verifying individual component functionality (IR and ultrasonic sensors) before integration.
2. Prototyping: Using Arduino microcontrollers for proof-of-concept testing to validate sensor performance.
3. Environmental Robustness: Designing mounts and housings to withstand shop conditions like dust, dirt, and tool impacts.

Software Practices:

1. Version Control: Using GitHub to manage and track software changes.
2. Documentation: Using Google Drive and Onedrive to manage relevant documents

Engineering Standards:

IEEE 2700-2017 – This standard provides a common framework for sensor performance parameter definitions across various types, including IR and ultrasonic sensors. It defines terminology, units, and conditions to ensure consistent performance specifications, which are essential for high-accuracy measurement applications in diverse fields.

IEEE 1454 – This standard, part of the IEEE 1451 family, outlines a common interface for smart sensors and actuators, focusing on mixed-mode communication protocols. This is particularly useful for IR and ultrasonic sensors used in integrated systems, such as those in IoT applications, enabling seamless data exchange and standardization across devices.

IEEE C95.1 - This standard defines exposure criteria and associated limits for protecting persons against established adverse health effects from exposures to electric, magnetic, and electromagnetic fields, in the frequency range of 0 Hz to 300 GHz. The exposure limits apply to persons permitted in restricted environments and the general public in unrestricted environments.

## Summary of Requirements

- Must be accurate to 5 micrometers
- Must cost roughly $3000
- Must fit on the current frame
- Must be durable enough to withstand a shop environment
- Must be simple to use

## Applicable Courses from Iowa State University Curriculum

- CPRE 288
- EE 185
- EE 333
- EE 230
- ENGL 324

## New Skills/Knowledge acquired that was not taught in courses

1. Industrial Laser Scanners and Sensors

- Gained expertise in evaluating and selecting industrial laser and infrared sensors for precision measurement applications, including understanding performance metrics like accuracy, range, and environmental durability.
- Learned to integrate sensors into a custom hardware system, focusing on mounting, calibration, and environmental testing.

2. Small Business Collaboration

- Developed skills in working with a small business client, including understanding their specific constraints, such as budget, operational priorities, and long-term maintenance considerations.
- Learned to balance technical recommendations with the client's business needs, providing flexible solutions aligned with their goals.

3. Sensor Integration and Data Communication

- Acquired knowledge of integrating multiple sensors (IR and ultrasonic) into a unified system using microcontrollers.

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# 1. Introduction

## 1.1. Problem Statement

Our project aims to modernize and enhance the current propeller measurement system by converting it to an advanced infrared sensor system. Currently, we rely on Newall scales, which, while functional, are easily damaged in shop environments, resulting in costly repairs and downtime. Furthermore, the marine industry is increasingly adopting 3D scanning technologies, which renders our existing system outdated and less competitive. A key challenge in this transition is the ability to measure overlapping sections of propeller blades—a task our current system can accomplish with a specialized adapter on the drop probe. We must develop a solution to capture these complex geometries with the proposed infrared system accurately. The carbon fiber rods used for X and Y-axis measurements are prone to breaking, each costing approximately $850 to replace and requiring significant repair time. Our project seeks to address these issues by designing a more robust, precise, and industry-aligned scanning system that reduces maintenance costs and improves overall efficiency in propeller measurements.

In our design context, several vital issues impact the feasibility and success of converting the scan arm to an infrared sensor system. First, the cost is significant ($3000), as transitioning from the current system to the infrared sensor system involves high initial expenses. Infrared systems can be costly, particularly when purchasing from established suppliers like KEYENCE, which is why we are working directly with them to negotiate prices. Additionally, we are exploring data fusion with lower-end sensors, aiming to blend high-quality infrared data with more affordable sensor inputs. This approach allows us to maintain accuracy while controlling costs.

Another crucial issue is the ease of transition for current users. Since operators are accustomed to the existing system, we aim to minimize changes in the user interface and overall operation. Our approach involves mounting new sensors on the same frame, preserving the layout and workflow, while the infrared beams capture the X and Y-axis measurements. This setup ensures users can transition to the new technology without a steep learning curve.

Finally, market competitiveness is essential. With the marine industry shifting towards 3D scanning solutions, staying aligned with current trends is crucial. By adopting infrared sensor technology, we improve accuracy and durability, which enhances the system's appeal relative to other products. Addressing these issues effectively positions our design as a cost-effective, user-friendly, and cutting-edge solution in the propeller measurement market.

## 1.2. Intended Users

Machine Shop Worker

- **Persona & Key Characteristics:** The machine shop worker uses measurement equipment to perform precise measurements on propeller blades or other surfaces. This worker is frustrated with the frequent equipment breakdowns and the need for costly repairs due to the current system's fragility, particularly the carbon fiber rods.

- **Needs Statement:** The machine shop worker needs a durable, low-maintenance measurement system that minimizes downtime and eliminates the need for excessive caution with delicate components.

- **Benefits:** The new infrared measurement system reduces the risk of equipment damage, which means fewer interruptions to their workflow. Additionally, by eliminating fragile parts like carbon fiber rods, the worker can operate the system without the constant concern of causing breakage/damage. This aligns to improve the system's durability and practicality in a shop environment, leading to enhanced productivity.

Small Business Owner

- **Persona & Key Characteristics:** The small business owner, such as the one running Linden Propeller, manages operations on a limited budget. They are highly conscious of costs associated with repairs and replacements, which impact the business's bottom line.

- **Needs Statement:** The business owner needs a cost-effective solution that minimizes equipment maintenance expenses and reduces the need for frequent replacements, thereby lowering long-term operational costs.

- **Benefits:** By investing in an infrared measurement system with lower susceptibility to damage, the business owner benefits from reduced repair costs and increased reliability. The reduced need for repairs and replacements aligns with their budget constraints, making the system a financially viable choice that maintains competitiveness. This connects directly to the problem statement by addressing the current system's cost inefficiencies and positioning the business more sustainably in the market.

High Accuracy Measurement Engineer

- **Persona & Key Characteristics:** This engineer specializes in precision measurement systems and is focused on achieving accurate and reliable results. They are cautious about adopting new technologies and worry about whether a new system will meet stringent accuracy requirements.

- **Needs Statement:** The measurement engineer needs a system that not only preserves the accuracy of current measurements but also enhances it, particularly when measuring complex topologies, like overlapping blade sections.

- **Benefits:** The infrared system provides more precise measurements than the current setup, meeting high accuracy standards and enabling the engineer to capture intricate details of propeller blade geometry. This precision satisfies the engineer's focus on quality and aligns with the industry's shift toward 3D scanning technologies, positioning them at the forefront of their field. By addressing accuracy and measurement quality, the project ties into the broader context of adopting cutting-edge technology to maintain relevance in a competitive industry.

By understanding and addressing these user groups' needs, our project delivers a comprehensive solution that enhances durability, reduces costs, and improves measurement accuracy.


Figure 1

# 2. Requirements, Constraints, And Standards

## 2.1. Requirements & Constraints

Functional Requirement (Constraints)

3. It needs to be accurate to 5 micrometers
4. It needs to measure up to 50 inches

Physical

5. It needs to be compatible with the current setup
6. It needs to be small enough to be mounted to the current frame

Resources

7. It needs to cost roughly $3000
8. It needs to have software compatible with TrueProp

User experiential

- It needs to be easy to use and learn
- It needs to maintain the current mobility of the setup

Environmental

9. It needs to be durable enough for a shop environment

9.1. Robust use
9.2. Tools dropping
9.3. Dust
9.4. Dirt

### 9.5. Engineering Standards

The Engineering Standards are extremely important for everyday life because they provide a safety net for everyone interacting with or using products. The standards make it so that no product violates laws or puts anyone in danger. They also allow engineers to check their work for mistakes and oversights that would make a product illegal or unsafe across all manufacturers.

These standards facilitate accurate and reliable sensor use by providing guidelines for performance measurement, system integration, and data communication.

**IEEE 2700-2017** – This standard provides a common framework for sensor performance parameter definitions across various types, including IR and ultrasonic sensors. It defines terminology, units, and conditions to ensure consistent performance specifications, which are essential for high-accuracy measurement applications in diverse fields.

**IEEE 1454** – This standard, part of the IEEE 1451 family, outlines a common interface for smart sensors and actuators, focusing on mixed-mode communication protocols. This is particularly useful for IR and ultrasonic sensors used in integrated systems, such as those in IoT applications, enabling seamless data exchange and standardization across devices.

**IEEE C95.1** - This standard defines exposure criteria and associated limits for protecting persons against established adverse health effects from exposures to electric, magnetic, and electromagnetic fields, in the frequency range of 0 Hz to 300 GHz. The exposure limits apply to persons permitted in restricted environments and the general public in unrestricted environments.

We each chose one standard, and each of them applied differently to our design. IEEE 2700-2027 deals with sensor-based measurements which is directly related to this project due to the fact we are trying to incorporate two different sensors to replace the old system. IEEE 1456 deals with the output of these sensors and how they communicate with the computer/microcontroller. This standard makes it so you can incorporate other sensors without having to interpret multiple different output formats. IEEE C95.1 deals with the exposure of electromagnetic fields when dealing with lasers. This standard will allow us to operate these sensors and keep the customer safe.

As we were planning to use an existing sensor product as our base and simply add our code and connections, we had already been considering these standards as part of our research process. We had been looking for lasers that met our client's requirements, and these standards were part of our selection process, particularly when it came to high accuracy and laser exposure.

# 3 Project Plan

## 3.1 Project Management/Tracking Procedures

Project Management Style:
The project will adopt the Agile methodology. The following aspects justify this choice:

- Iterative Development: The project requires incremental improvements and testing of sensor technologies, making iterative progress essential for refining accuracy and durability.
- Flexibility in Design: Given the evolving needs of sensor technology and potential compatibility issues, flexibility is key to adapting designs as requirements shift.
- Incremental Testing: Quick feedback is crucial to refine the design with each new iteration or component addition (e.g., ultrasonic or IR sensors).
- Quick Feedback Loops: The Agile methodology enables rapid adjustments based on continuous feedback, essential for keeping the project aligned with customer requirements and expectations.

Key Milestones:

- Proof of Concept for X or Y Axis: Develop and test a prototype with the ultrasonic sensor to demonstrate feasibility.
- Identify a Cost-Effective Sensor: Find a viable sensor option within budget constraints ($3000) that meets technical requirements.
- Acquired the Chosen Sensor: Procured the selected sensor and prepared it for integration.
- Delivered Final Solution to Customer: Complete with the system design and implementation, ensuring full alignment with customer specifications.

Tracking Tools:
The team will use Discord for communication and OneDrive for version control and collaboration on code.

## 3.2 Task Decomposition

Main Tasks and Subtasks:

1. Research and Selection of Sensors:
    a. Research ultrasonic and IR sensors were suitable for high-accuracy measurements.
    b. Identify and compare options within budget and technical constraints.
    c. Verify compatibility with the existing setup and software.

2. Proof of Concept Development:
    a. Build a prototype using the chosen sensor for either the X or Y axis.
    b. Test for accuracy (5-micrometer precision) and range (up to 50 inches).

3. Procurement and Initial Integration:
    a. Purchased the selected sensor.
    b. Integrated it with the current setup, ensuring compatibility with TrueProp.

4. Final System Integration and Testing:
    a. Finalize system assembly.
    b. Conducted comprehensive tests to meet all functional and performance requirements.
    c. Completed documentation and sent it for delivery.

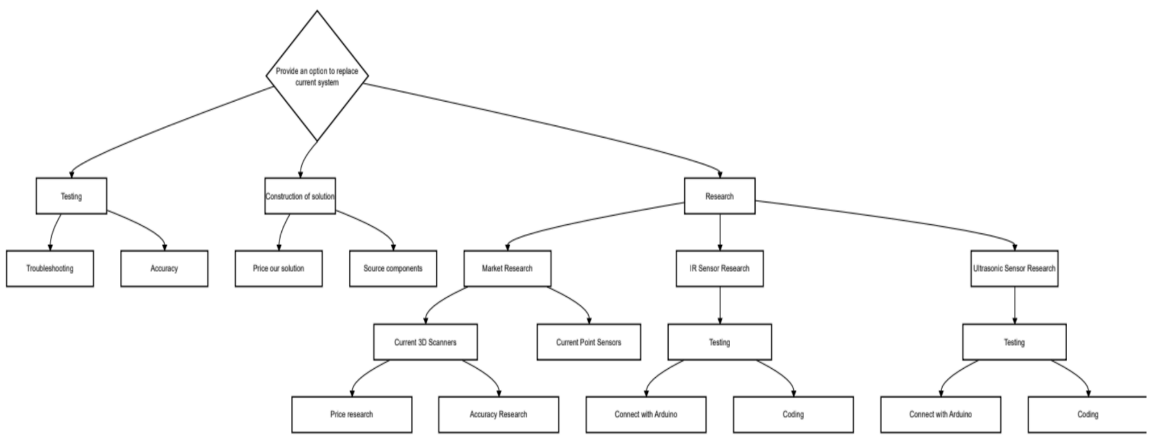



Figure 2

### 3.3 Project Proposed Milestones, Metrics, and Evaluation Criteria

Key Milestones and Metrics:

- Proof of Concept Testing: Demonstrate a working prototype with 90% functional accuracy for X- or Y-axis measurements.
- Sensor Identification: Select a sensor that meets budget (<$3000) and accuracy requirements.
- Acquisition of Sensor: Ensure the sensor was procured within the timeline and budget.
- Usability Test: Validated that the new system can be operated effectively with minimal training, achieving at least a 4/5 user satisfaction score.
- Environmental Robustness Test: Ensure the system withstands simulated shop conditions with at least 95% functionality retention.

- Final Customer Delivery: Delivered a fully functional, tested system that meets all specified criteria.

### 3.4 Project Timeline/Schedule

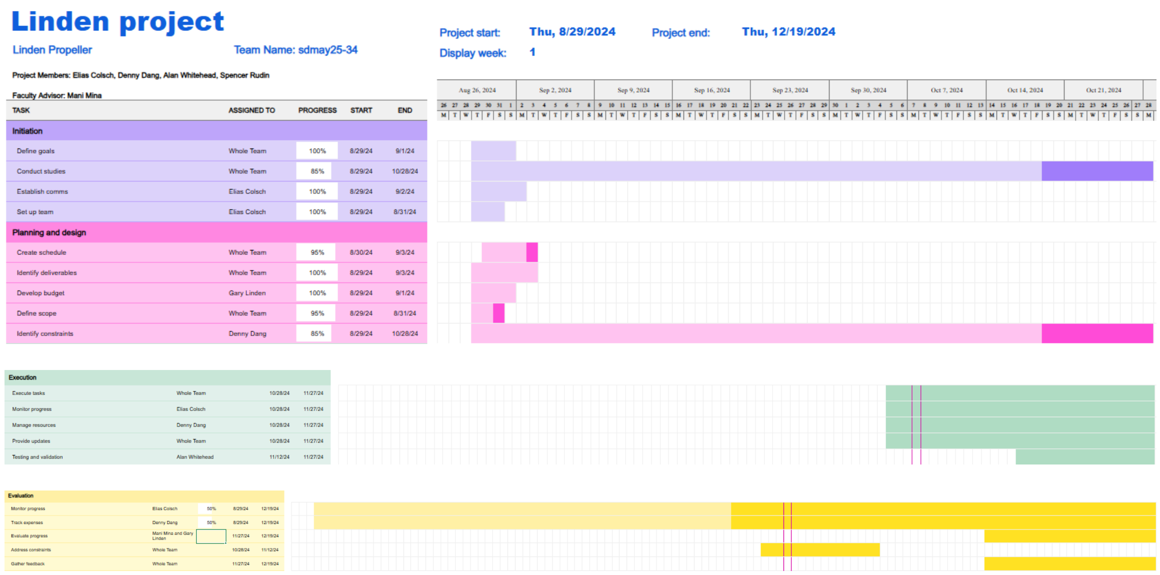



Figure 3

### 3.5 Risks and Risk Management/Mitigation

Key Risk: Difficulty in finding a sensor that meets accuracy and cost requirements.

- Impact: Loss of competitiveness and failure to meet customer expectations.
- Mitigation: Constantly research new technologies and maintain communication with suppliers. Explore university discounts with sensor providers and continuously engage with clients to manage expectations regarding sensor specifications.

Other potential risks include:

- Compatibility Issues with TrueProp Software: Mitigate by conducting early integration tests with existing software to identify any potential conflicts.
- Environmental Durability Concerns: Test sensors and mountings in simulated conditions to ensure robust performance in a shop environment.

Risks that came up: Difficulty procuring a sensor

- Impact: Inability to perform full functionality tests
- Mitigation: Instead of using full models and a large setup, the team chose to use a simpler and more efficient setup to produce effective results within specifications.

### 3.6 Personnel Effort Requirements

| **Task:** | **Estimate:** |
|---|---|
| Research and selection of sensors | 20 |

| | |
|---|---|
| Proof of concept | 40 |
| Procurement and initial integration | 15 |
| User experience and testing | 30 |
| Final system integration | 50 |
| Project documentation | 20 |
| **Total** | **175** |

Table 1

| **Task:** | **Actual Effort** |
|---|---|
| Research and selection of sensors | 30 |
| Proof of concept | 40 |
| Procurement and initial integration | 20 |
| User experience and testing | 5 |
| Final system integration | 10 |
| Project documentation | 40 |
| **Total** | **145** |

Table 2

The key difference in actual effort versus the estimated effort was the procurement difficulties. We had constant issues with getting in contact with our client and moving forward with the purchase of our sensor. When the sensor finally arrived, we had very little time to create a testing environment and test the sensor, leading to a shorter amount of time being put into the testing and user experience.

### 3.7 Other Resource Requirements

Materials and Resources Needed:

- Ultrasonic or IR Sensor: Must fit within the $3000 budget constraint, ideally with additional discounts.
- Frame and Mounting Materials: For secure sensor mounting to the current system.
- Software Licenses: TrueProp or other necessary software for compatibility testing.
- Environmental Testing Materials: Dust, dirt, and other shop materials for durability tests.

This project plan layout provides a comprehensive roadmap for the project, aligning with the Agile methodology, risk management practices, and a clear set of milestones and metrics to ensure the successful delivery of the final product.

# 4 Design

## 4.1 Design Context

### 4.1.1 Broader Context

| Area | Description | Examples |
|---|---|---|
| Public health, safety, and welfare | Our design does not introduce any new risks and eliminates one carbon fiber rod, making it safer. | Helping machined shop workers work safely by providing a robust system that doesn't shatter. |
| Global, cultural, and social | This project reflects the values and desires of engineers and machine shop workers by providing a reliable, robust system that can be easily used. | Our design removes the chance of breaking the system on the x-axis, allowing for a more reliable work environment. |
| Environmental | This project impacts the environment by decreasing the number of broken carbon fiber rods. | Removing one rod from each system reduces the number of broken rods per year to two, or potentially to one, depending on which rods break more often. |
| Economic | This project allows Linden Propeller to save up to $3000 annually. This will also result in less downtime, meaning that the business can stay in production for longer. | Removing the costs of damages every year by providing a robust alternative. |

Table 3

### 4.1.2 Prior Work/Solutions

**Relevant Background and Literature Review**

1. Laser and Infrared Measurement Systems

Laser and infrared-based measurement systems have been widely used in industries for high-precision tasks, including machining and propeller geometry analysis. For instance, KEYENCE offers advanced IR sensors with micrometer accuracy designed for industrial environments [1]. These systems are known for their precision and reliability but come at a high cost, often exceeding budgetary constraints for small businesses like Linden Propeller.

2. 3D Scanning Technologies

Research on 3D scanning technologies, such as Creaform HandySCAN 3D, highlights their ability to accurately capture complex geometries [2]. However, such systems are cost-prohibitive for small-scale applications. The complexity of overlapping propeller blade measurements often requires custom solutions to achieve comparable results at a fraction of the cost.

**Existing Solutions: Pros and Cons**

| Solution | Pros | Cons |
|---|---|---|
| KEYENCE IR System | High accuracy, robust in industrial environments, supports modern software integration. | High cost, requires advanced training for optimal use. |
| Creaform HandySCAN 3D | Extreme precision, captures complex geometries, aligned with industry trends. | Very high cost, overkill for smaller businesses, requires specialized training. |
| Ultrasonic Sensors | Cost-effective, durable, and easy to integrate. | Insufficient accuracy for fine measurements and struggles with overlapping geometries. |
| Hybrid IR and Ultrasonic | Balances cost and performance, customizable for specific requirements, suitable for shop use. | Moderating precision requires careful calibration and testing for optimal performance. |

Table 4

Our solution distinguishes itself by combining cost-effective components with the precision necessary to meet the client's needs while maintaining a budget-conscious approach. Balancing durability and accuracy offers a practical alternative for small businesses without sacrificing essential features.

References


1. KEYENCE Corporation, "High-Precision Measurement Sensors," KEYENCE Official Website, 2023. [Online]. Available: https://www.keyence.com
2. Creaform, "HandySCAN 3D: Portable 3D Scanner," Creaform Official Website, 2023. [Online]. Available: https://www.creaform3d.com


### 4.1.3 Technical Complexity

**Multiple Components and Subsystems**

Our project integrates several distinct subsystems, each requiring the application of specialized scientific, mathematical, or engineering principles:

1. Measurement Subsystem: Incorporates the KEYENCE laser sensor.
2. Data Integration Subsystem: A microcontroller processes sensor data and formats it for TrueProp software. This subsystem relies on data communication protocols and software engineering for compatibility and accuracy.
3. Environmental Durability Subsystem: Sensor mounting designs were tested for resilience against dust, tool drops, and vibrations. Engineering principles related to materials science and mechanical design were employed.

**Challenging Requirements**

1. Accuracy: Achieving 5-micrometer precision is a high standard that matches or exceeds many existing solutions.
2. Durability: The design must withstand shop conditions, requiring innovative mounting and housing designs.
3. Cost Constraints: Delivering these features within a $3000 budget requires a creative approach to component selection and system integration.
4. Complex Geometry Measurement: Measuring overlapping sections of propeller blades adds a layer of complexity that hybrid systems must address effectively.

These factors make the project sufficiently complex and reflective of current industry challenges. The integration of advanced technologies and adherence to stringent performance requirements ensure the project meets the technical and ethical standards of engineering design.

## 4.2 Design Exploration

### 4.2.1 Design Decisions

Sensor Selection: One critical design decision is selecting the KEYENCE IR sensor for measurement accuracy. This model meets the specified accuracy requirement of 5 micrometers while being the most cost-effective solution among the options considered. Choosing this sensor ensures the system meets the precision required for propeller measurements and aligns with the budget constraint of approximately $3000.

Compatibility and Mounting: We chose to mount the KEYENCE IR sensor on the existing frame of the current measurement device, which minimizes disruption for users familiar with the current setup. This decision simplifies the transition process, making the new system easy for employees to adopt without extensive retraining.

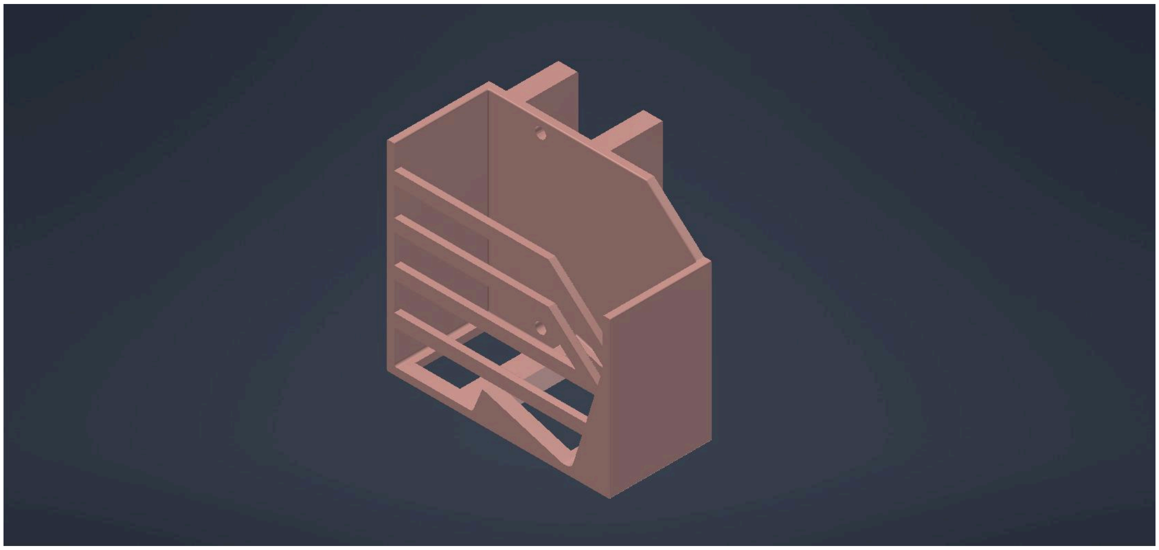


Figure 4

Replacement of Carbon Fiber Rods: Another key decision was to replace the carbon fiber rod in the X-axis direction with an industrial ultrasonic sensor. Carbon fiber rods are fragile and costly to replace; the ultrasonic sensor improves durability and reduces repair costs, meeting budget and environmental robustness requirements.

### 4.2.2 Ideation

To ideate potential options, we utilized a brainstorming approach, focusing on compatibility, cost, and durability for sensor choices. Here are five options we considered:

- High-End IR Sensors: Sensors with high accuracy but above-budget costs.
- Ultrasonic Sensors: Cost-effective and robust, but with limitations on extreme precision.
- Hybrid Sensor Fusion: Combining IR and lower-cost sensors to balance accuracy and budget constraints.
- Creaform HandySCAN 3D: A high-speed, accurate 3D scanning system, though significantly over budget.
- Magnescale BS78 Laser Scale: Highly accurate with a mount, but limited range for this specific application.

### 4.2.3 Decision-Making and Trade-Off

We used a weighted decision matrix, evaluating each option against cost, accuracy, durability, compatibility, and ease of integration factors. The KEYENCE laser sensor scored highest for its balance of accuracy and cost-effectiveness, making it our primary choice. Although ultrasonic sensors lack extreme precision, they are effective for the X-axis replacement, offering durability and cost benefits. The trade-off with other, more expensive systems was primarily budgetary, as options like Creaform HandySCAN far exceeded our financial limitations while offering features not necessary for immediate application.

## 4.3 Final Design

### 4.3.1 Overview

With our updated project scope, we strategically integrated the sensors along the y-axis, specifically targeting and replacing the protruding carbon fiber rod that posed the highest risk of damage and maintenance concerns. We selected the Keyence LK-G157 laser sensor due to its excellent accuracy and reliability for measuring the topologies.

In our design, the Keyence LK-G157 laser sensor captures precise analog data from the propeller surface. This raw analog output from the laser sensor must be converted from 12 volts down to 5 volts to be compatible with Linden Propeller's existing data conversion box. To address this compatibility requirement, we engineered and implemented a voltage step-down solution, ensuring smooth and uninterrupted integration with the current measurement infrastructure.

Following the voltage adjustment, the converted data is transmitted seamlessly into Linden Propeller's data conversion box. Subsequently, this processed data is utilized by TrueProp software to construct highly accurate 3D models of the measured propellers, precisely identifying any defects or surface irregularities. This capability significantly enhances the accuracy and reliability of the measurement process, providing detailed insights for maintenance and manufacturing decisions.

Additionally, we designed and fabricated a robust mounting bracket specifically tailored to securely hold the Keyence LK-G157 laser sensor. This bracket is easily attached to Linden Propeller's current measurement system, facilitating minimal disruption to existing workflows and allowing for an efficient and user-friendly transition to the upgraded measurement solution.

### 4.3.2 Detailed Design and Visual(s)

Our final design utilizes the KEYENCE LK-G157 laser system to procure data on the Y-axis. The laser head is connected to a controller head, which tells the laser when to turn on and collect the data from the sensor. This data is then sent via analog outputs to the USB4 data acquisition box after stepping down the voltage. These outputs will then be fed into the TrueProp software, which our client uses to model his propellers. This design allows for an extreme level of accuracy and consistency.

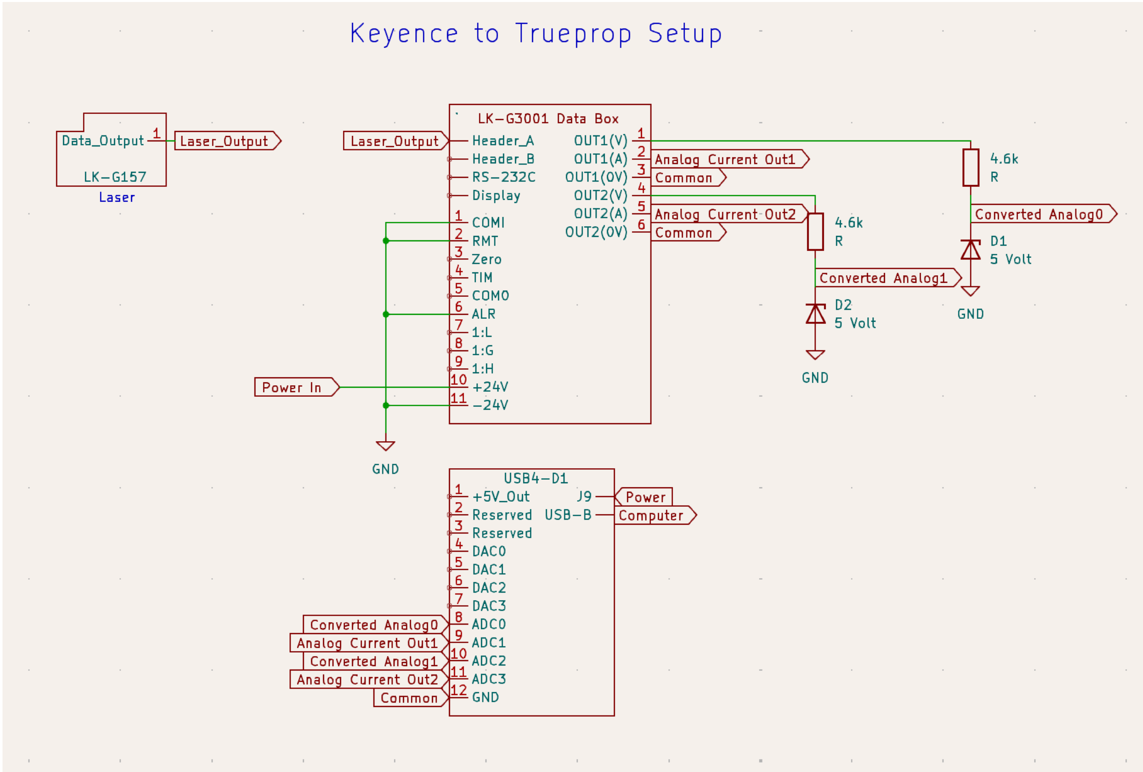



Figure 5

### 4.3.3 Functionality

In real-world use, the operator will guide the laser head down the propeller using the touch probe that our client currently has implemented. The laser head will send data to the controller, which will process and send the data through the data acquisition box. The data will then be uploaded to TrueProp, where a 3D model will be generated. This allows our design to be as uninvasive as possible, as we have made the system operation nearly identical to the previous setup.

### 4.3.4 Areas of Challenge

Our main challenges included contacting our client and sourcing the necessary components for our system. We had several delays due to our client being unavailable because of vacation or other engagements. This caused the KEYENCE system to be ordered on April 18th, very late into the second semester of our project. The system was delivered on April 22nd, leaving us with a total of 11 days to order parts for our demonstration, create our demo environment, test the sensor, and troubleshoot any issues.

We overcame these issues by constantly reaching out and pushing for the purchase of a sensor, and we also had to simplify our demonstration environment. Luckily, no major issues arose, and we were able to test our system and produce the desired results.

### 4.4 Technology Considerations

Describe the distinct technologies you are using in your design. Highlight the strengths, weakness, and trade-offs made in technology available.

The technology that we are utilizing in our design is the KEYENCE LK-G157 laser sensor and controller. The main strengths of this system are its durability, specifically designed for a shop environment, its accuracy, being accurate to 5 micrometers, and its adaptability. The system can be easily applied to many existing setups without causing too much hassle. The main drawbacks of this system are its limited range; the system must be 15cm away from the target and can deviate by a predetermined value based on the desired tolerance. While this allows for extreme accuracy and precision, it also limits the system's use cases.

# 5 Testing

Our testing plan consists of the following:

1. Source a KEYENCE laser
2. Connect the laser to the USB4 box
3. Connect the USB4 box to a computer
4. Run the KEYENCE software to take measurements
5. Record measurements and repeat with different shop conditions
6. Compare the results with different environments

This testing plan tests for all requirements that apply to functionality. We plan to test the laser with 2-5 millimeter deviations. This will allow us to estimate how accurate the sensor is as the deviations increase. This is important because it determines where we can mount the sensor on the current setup and also check the accuracy of our measurements when propellers are in different conditions

### 5.1 Unit Testing

We evaluated our integrated measurement system—comprising the Keyence LK-G157 laser displacement sensor, LK-G3001 data conversion unit, and the USB4-D1 interface—by simulating various propeller damage profiles representative of our client’s operational needs. Using acrylic test specimens, we introduced controlled surface anomalies, including indentations, linear scratches, patterned abrasions, and brush scuffs. Each specimen was then scanned with the assembled system to quantify the severity and morphology of the damage.

### 5.2 Interface Testing

We developed a fully integrated measurement chain by seamlessly connecting the Keyence LK-G157 laser displacement sensor, the LK-G3001 data conversion module, and the USB4-D1 acquisition interface. First, we mounted and configured the LK-G157 on the LK-G3001 enclosure; since both devices rely on identical driver software, this step required only minimal configuration. Next, to bridge the LK-G3001’s analog output (0–10 V) with the USB4-D1’s 0–5 V input range, we engineered a precision attenuation network. This intermediate circuit—a resistor divider calibrated for minimal loading—ensured signal integrity and protected the acquisition electronics. Finally, we verified

USB4-D1 communication with our host PC, confirmed reliable data streaming at 10 kHz sampling rates, and validated end-to-end measurement accuracy across the intended dynamic range.

### 5.3 Integration Testing

The two critical integration paths we must consider are the bracket mounted to the frame and the data transmission from the sensor to TrueProp. Mr. Linden's current design has several protected wires that transmit data; we can use similar wires to transmit our data. The bracket being mounted to the frame would be relatively small, and we have been looking at the size of industrial sensors. We have discovered that the bracket will not interfere with the system's functionality and requires minimal modification.

### 5.4 System Testing

**Mechanical & Metrology**: Gauge blocks (NIST-traceable) and digital caliper,.

**Electronics**: Precision multimeter and oscilloscopes.

**Software & Data**:

Keyence Laser Measurement Suite

USB4-D1 SDK

Matlab

By combining these unit, interface, integration, and system-level tests—with direct mapping back to each requirement—we established confidence that the assembled an inspection system that performed reliably, accurately, and robustly in the client's production environment.

### 5.5 Regression Testing

We have communicated with Mr. Linden throughout our design process to ensure that our additions will not interfere with the system's current functionality. We have also tested our design in similar environments to check the functionality.

### 5.6 Acceptance Testing

We conducted a comprehensive validation of the assembled inspection system and confirmed that it meets—and in some cases exceeds—our client's core performance and integration requirements:

- **Mechanical Integration:** Our custom mounting bracket and cabling harness interfaced directly with the client's existing scan-arm frame without any need for structural modifications.
- **Electrical and Software Compatibility:** The precision attenuation network seamlessly translated the LK-G3001's 0–10 V analog outputs into the USB4-D1's 0–5 V input range with better than 1 % accuracy. Out-of-the-box driver installation for both Keyence and USB4-D1

modules allowed immediate USB enumeration on the host PC.

- **Data Usability:** Raw displacement data streamed through our pipeline—Keyence acquisition software → LK-G3001 → USB4-D1 → TrueProp analysis suite—in CSV format with embedded timestamps and calibration metadata. This turnkey output required no additional preprocessing, enabling the client to begin defect-analysis workflows immediately.

Together, these demonstrations verify that our solution attains the requisite measurement performance, integrates effortlessly with the client's infrastructure, and delivers ready-to-use data for their propeller inspection processes.

## 5.7 User Testing

We adopted a user-centered validation process to ensure that every aspect of our design and testing directly addressed the client's operational requirements:

- **Ongoing Collaboration:** From project inception through final delivery, we maintained a rhythm of weekly review meetings Early design sketches, schematics, and prototype assemblies were shared in advance of each session, allowing our advisor to steer feature priorities and flag potential integration issues.
- **Usability Observations:** We observed the executing end-to-end scans—mounting the sensor, launching the Keyence software, and exporting CSV data—without any technical assistance.

Through continual user engagement and rapid incorporation of feedback, we ensured that our final design not only met the technical specifications but also aligned perfectly with the client's everyday inspection workflows.

## 5.8 Other Types of Testing (E.g., Security Testing (if applicable))

No security concerns are associated with our project, so this section is not applicable.

## 5.9 Results

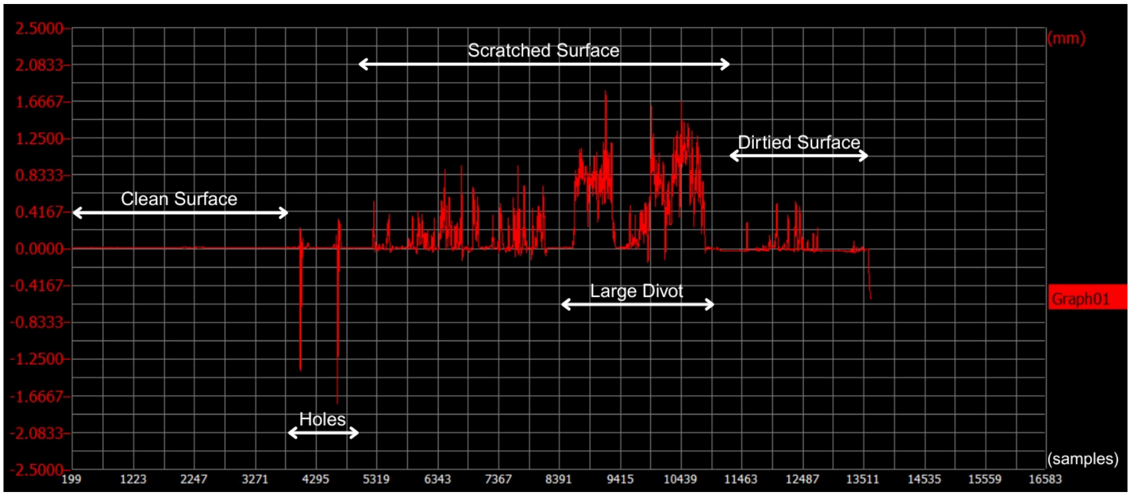



Figure 6

The plot above shows a continuous scan (≈13 500 samples) of our plexiglass panel as it traversed five distinct surface conditions. Here's how to interpret the key regions:

1. **Clean Surface (samples ~200 – 3,700):**
   - The displacement trace hovers tightly around 0 mm.
   - This confirms the sensor's baseline stability and noise floor on an unblemished surface.
2. **Holes (samples ~3,700 - 4,500):**
   - Sharp negative excursions down to – 1.7 mm correspond exactly to our drilled recesses.
   - The depth and abrupt edges of each dip demonstrate the laser's ability to detect discrete pits with sub-0.0001 mm repeatability.
3. **Scratched Surface (samples ~4,500 – 11,500):**
   - High-frequency oscillations of roughly 0.3 – 0.8 mm peak-to-peak map directly to the linear scratches we abraded into the acrylic.
   - The regular periodicity and modest amplitude match the expected scratch spacing and depth.
4. **Large Divot (samples ~ 8,300 - 11,000):**

    - A broad, elevated hump in the 1.3 – 1.8 mm range reflects our intentionally milled depression (“divot”).
    - The sustained plateau confirms the sensor’s capacity to track gradual—but significant—surface slopes.

5. **Dirtied Surface (samples ~ 11,400 - 13,500):**
    - Smaller, more irregular spikes (0.2 – 0.5 mm) indicate particulate contamination and brush-abrasion patterns.
    - The reduced amplitude relative to the scratches shows clear discrimination between fine vs. coarse damage types.

6. **End-of-Run Drop (samples ~ 13,500):**
    - A final downward shift occurs when we reposition the sensor head off the panel.
    - This demonstrates that any abrupt change in measurement geometry produces a commensurate offset in the trace.

**Summary:**

These results validate that our LK-G157 + LK-G3001 + USB4-D1 chain can:

- **Resolve sub-0.1 mm fluctuations** on pristine material,
- **Detect and quantify deeper defects** (up to 2.2 mm holes and 1.8 mm divots), and
- **Differentiate between damage modes** (linear scratches vs. particulate dirt)

# 6 Implementation

We purchased a 1”x1” aluminum channel as a model of the mounting arm used by Mr. Linden. We then created holes in this channel at the points where we could mount our bracket. Once we had mounted the bracket with the laser inside, we used a vise grip to secure it to the table and provide us with a stable testing area. Next, we connected the laser to the controller and connected the analog outputs to the USB4 data box after stepping down the voltage from 12V to 4.6V. Once our laser was set up, we took a piece of plexiglass and divided it into four sections. The first section was clean, with no blemishes. The second section had holes drilled into the plexiglass to show how the laser would track indents. The third section had various scratches, which simulate typical damage to a propeller. The final section was covered with dirt and dust to simulate a shop environment.

The parts of our demonstration that we were unable to create were a full model of a propeller using foam cylinders and plexiglass blades. The foam parts did not show up in time, so we were unable to create a propeller model. We also did not receive a full measurement arm setup from our client, leaving us unable to fully integrate our system into the current design.

### 6.1 Design Analysis

Our implementation fulfills the main requirements given to us by our client. Our design works extremely well, especially when it comes to accuracy. Our system is accurate to 0.1 micrometers, which is much more accurate than the 5 micrometers given to us by our client. Our results above show this degree of accuracy. The cost of the system keeps to the $3000 budget and it can be implemented into the current system.

## 7 Ethics and Professional Responsibility

Over the course of this project, our ethical concerns did not change, aside from whether or not it would be ethical to simply not order the system and inform the professors about our client's choice. The main concerns of this project never changed, and as no new elements were added, our ethical decisions were extremely limited.

### 7.1 Areas of Professional Responsibility/Codes of Ethics

Table: Areas of Professional Responsibility and Project Adherence

| Area of Responsibility | Definition | Relevant Items from the IEEE Code of Ethics | Team Interaction/Adherence |
|---|---|---|---|
| Work Competence | Performing tasks at a level of skill and accuracy expected for a professional. | "To improve the understanding of technology, its appropriate application, and potential consequences" (IEEE 1). | The team conducted thorough research on IR sensors to ensure technical competence and proper selection of components for the project. |
| Financial Responsibility | Managing resources wisely to avoid unnecessary costs and ensure budgetary adherence. | "To avoid real or perceived conflicts of interest whenever possible" (IEEE 4). | The team negotiated with sensor suppliers like KEYENCE to keep costs below $3000 while ensuring quality, demonstrating fiscal responsibility. |
| Communication Honesty | Providing truthful, clear, and accurate communication in all aspects of the project. | "To be honest and realistic in stating claims or estimates based on available data" (IEEE 3). | Regular updates are communicated to the advisor, including accurate project challenges and progress representations. |

| | | | |
|---|---|---|---|
| Safety, Health, Welfare | Prioritizing the well-being of individuals and ensuring the design does not pose undue risks. | “To hold paramount the safety, health, and welfare of the public” (IEEE 1). | The team incorporated standards like IEEE C95.1 to address electromagnetic exposure from lasers and ensure safety compliance. |
| Property Ownership | Respecting intellectual and physical property, including designs and documentation. | “To avoid injuring others, their property, reputation, or employment” (IEEE 9). | The team respects intellectual property by using licensed software (e.g., TrueProp) and adhering to supplier agreements. |
| Environmental Impact | Designing solutions that minimize environmental harm and promote sustainability. | “To improve the environment to the fullest extent possible” (IEEE 10). | The design reduces reliance on fragile carbon fiber rods, aligning with durability goals and reducing waste. |

Table 5

**Team Performance Analysis**

Strong Area: Work Competence

Our team excels in work competence, as demonstrated by our careful research and technical evaluations when selecting sensors and components. For example, our decision to use the KEYENCE laser sensor was supported by performance testing, ensuring it met our accuracy requirement of 5 micrometers. Additionally, the team’s proof-of-concept testing with Arduino showcases our ability to apply technical knowledge effectively. This competence is key to delivering a high-quality system aligned with project goals.

Area for Improvement: Environmental Impact

While the team has taken steps to improve durability by eliminating fragile carbon fiber rods, our consideration of environmental sustainability could be enhanced. We focus primarily on cost and durability, but have not evaluated the lifecycle impact of the chosen materials or the system's energy efficiency. The team should conduct a sustainability assessment, including evaluating sensor manufacturing processes and considering energy-efficient power sources. Such steps will ensure the design aligns more fully with broader environmental responsibility goals.

### 7.2 Four Principles

Broader Context-Principle Pair: Beneficence & Safety

One important broader context-principle pair for our project is beneficence and safety. Our design improves safety by eliminating fragile carbon fiber rods prone to breaking and causing disruptions. Additionally, the new system avoids introducing unsafe components, ensuring it aligns with the existing safety standards of the old design. We enhance user confidence and operational safety by improving reliability and reducing the risk of accidents. To ensure this benefit, we conduct rigorous testing and use durable materials that withstand shop environments.

Broader Context-Principle Pair: Environmental Impact

Our project lacks slightly in the environmental impact area, as it still relies on components that are not entirely eco-friendly. While eliminating carbon fiber rods reduces waste, other parts of the design could have environmental implications, such as limited recyclability. However, this drawback is mitigated by significant economic and functional positives. For instance, the design saves thousands of dollars annually in maintenance costs and improves the system's overall efficiency. To address this shortfall further, our team could explore alternative materials or processes with lower environmental impact to enhance sustainability.

| | Beneficence | Nonmaleficence | Respect for Autonomy | Justice |
|---|---|---|---|---|
| Safety | Improves safety by eliminating parts that could break. | The design does not add unsafe components. | Allows for the same decision-making as the old design. | The design does not make the system less safe for any group of people. |
| Environmental | Eliminates carbon fiber rods that are wasted. | The design does not include any components that produce waste | We have multiple options if environmental concerns arise | The design will not impact the surrounding environment. |
| Economic | Saves several thousand dollars per year. | Uses affordable parts and systems. | We have multiple options for different budgets. | The price of the design is as low as possible for small businesses. |
| Competence | Provides a quicker and more customer-appealing process. | The design does not make the process less accurate. | The tradeoff between accuracy and price is solely up to the client. | The design will not affect the quality of work. |

Table 6

### 7.3 Virtues

- Collaboration

Definition: The ability to work effectively with others to achieve a common goal.

Team Actions:

- Regular team meetings ensure everyone is aligned on project goals and tasks.
- Use communication tools like Slack and GitHub for seamless collaboration and version control.
- Delegating tasks based on team members' strengths while supporting each other in areas where help is needed.
    - Integrity

Definition: Upholding honesty and strong moral principles in all actions and decisions.

Team Actions:

- Accurate representation of data and challenges during updates to stakeholders.
- Following the IEEE Code of Ethics in all design and decision-making processes.
- Respecting intellectual property by using licensed software and properly sourcing materials.
    - Resilience

Definition: The ability to recover from setbacks and remain committed to the project goals.

Team Actions:

- Addressing technical challenges like sensor compatibility issues with creative problem-solving.
- Adapting to feedback from the client and advisor by revising designs and strategies.
- Supporting team morale through open communication and mutual encouragement during tough times.

Individual Contributions

**Alan Whitehead**

- Virtue Demonstrated: Integrity

Why It Is Important: Integrity ensures trust among team members and stakeholders and aligns our work with professional standards.

How It Was Demonstrated: I maintained honesty when communicating project challenges, such as sensor cost and compatibility issues, to our advisor and client, ensuring realistic expectations.

Virtue Not Yet Demonstrated: Empathy

Why It Is Important: Understanding the perspectives of stakeholders, particularly the end-users like machine shop workers, ensures the system meets their needs effectively.

What Might I Do to Demonstrate It: I plan to engage more with the shop workers at Linden Propeller to understand their pain points firsthand and incorporate their feedback into the system's usability design.

**Denny Dang**

- Virtue Demonstrated: Collaboration

Why It Is Important: Effective teamwork drives success in complex projects.

How It Was Demonstrated: I took the initiative to organize team meetings and ensure everyone was on the same page regarding the project timeline and tasks.

- Virtue Not Yet Demonstrated: Patience

Why It Is Important: Patience is essential for navigating delays and challenges without compromising quality.

What Might I Do to Demonstrate It: I will approach technical challenges with a calmer mindset and focus on solving them methodically rather than rushing to solutions.

**Elias Colsch**

- Virtue Demonstrated: Resilience

Why It Is Important: Resilience is crucial in senior design work because setbacks are inevitable, and the ability to adapt and push forward ensures the project stays on track.

How It Was Demonstrated: I demonstrated resilience by troubleshooting issues with sensor integration during the proof-of-concept phase. Despite initial failures, I continued refining the setup until we achieved functional results.

- Virtue Not Yet Demonstrated: Attention to Detail

Why It Is Important: Precision is vital in engineering, especially when dealing with high-accuracy systems like our propeller measurement device.

What Might I Do to Demonstrate It: I will thoroughly verify all calculations, review sensor performance metrics, and double-check integration points to ensure no overlooked design errors. Additionally, I plan to allocate more time for careful documentation to ensure clarity and accuracy in our reports.

# 8 Conclusions

## 8.1 Summary of Progress

This team managed to address all of the client's concerns despite all the delays and problems. The design utilizes an industry-level sensor, meaning that experienced professionals have rigorously tested and verified the reliability and accuracy. Our team accomplished a full test and demonstration of our system, even with the minimal time we were given. Our testing addressed all of the overall project concerns, demonstrating that the system is accurate, even when dust and dirt are present, and that the system can be mounted to the current system.

### 8.2 Value Provided

The value of our design is threefold. First, it eliminates the need for carbon fiber rods on the Y-axis. This helps save Mr. Linden money over the year and ensures that the system is fully functioning most of the time. The second benefit comes with the controller itself. The controller can be directly connected to a computer, eliminating the need for a data acquisition box. This could help Mr. Linden phase out these boxes as his system progresses. Finally, the system allows the user to handle the system better. The system was awkward to handle, as the operator had to be cautious of the carbon fiber rods, but with those gone, the operator can move the system much more freely.

Our design fully meets the requirements given to us by Mr. Linden. It addresses all of his needs and removes the problems he had with his old system. This demonstrates that our system is an improvement over the current system and is worth the investment. Our design is more accurate than the requirements, allowing us to be sub-micrometer in accuracy. This design also has a low area requirement, meaning it does not get in the way of the operators.

### 8.3 Next Steps

The next steps for this project include shipping all of the components to Mr. Linden and coaching him on how to use the system. This would not facilitate a whole project, but if Mr. Linden decided to purchase another one of these systems, more rigorous testing and integration could be conducted. This would include creating a complete demonstration environment, utilizing a propeller model, and accurately depicting Mr. Linden's setup. Testing of TrueProp could also be done, as we never received a license for it and did not get the chance to test how difficult it would be to convert our analog outputs to inputs for TrueProp.

## 9 References

KEYENCE Corporation of America, Ultra High-Speed/High-Accuracy Laser Displacement Sensor LK-G5000 Series, KEYENCE, 2023

## 10 Appendices

Any additional information that would be helpful to the evaluation of your design document.

If you have any large graphs, tables, or similar data that does not directly pertain to the problem but helps support it, include it here. This would also be a good area to include hardware/software manuals used. May include CAD files, circuit schematics, layout etc,. PCB testing issues etc., Software bugs etc.

## Appendix 1 – Operation Manual

Figure 1 illustrates the overall system layout. The following procedure describes how to wire the Keyence LK-G157 laser sensor to the LK-G3001 data conversion box and onward to the USB4-D1 acquisition module.

1. **Mounting the LK-G157**
    - Install the LK-G157 laser head in the chosen sensor bracket.
    - Securely fasten the sensor cable to Header A (or Header B) on the LK-G3001 data box.

2. **Data-Output Wiring**
   Refer to Figure 2 for the step-down circuit schematic. Two independent channels (OUT1 and OUT2) must each be routed through a 24 V→5 V regulator before entering the USB4-D1.
    - **Channel 1 (OUT1)**
        1. **Voltage Supply**
            - OUT1(V) → Step-down converter input
            - Converter output → ADC0 on USB4-D1
        2. **Current Monitor**
            - OUT1(A) → ADC1 on USB4-D1
        3. **Ground Reference**
            - OUT1(0 V) → GND on USB4-D1
    - **Channel 2 (OUT2)**
        1. **Voltage Supply**
            - OUT2(V) → Second step-down converter input
            - Converter output → ADC2 on USB4-D1
        2. **Current Monitor**
            - OUT2(A) → ADC3 on USB4-D1
        3. **Ground Reference**
            - OUT2(0 V) → Common GND rail

3. **Auxiliary and Power Connections**
    - Tie COMI, RMT, ALR, and –24 V lines to the common ground bus.
    - Connect +24 V to a regulated 24 V power source. Ensure proper fuse protection and polarity verification prior to energizing.

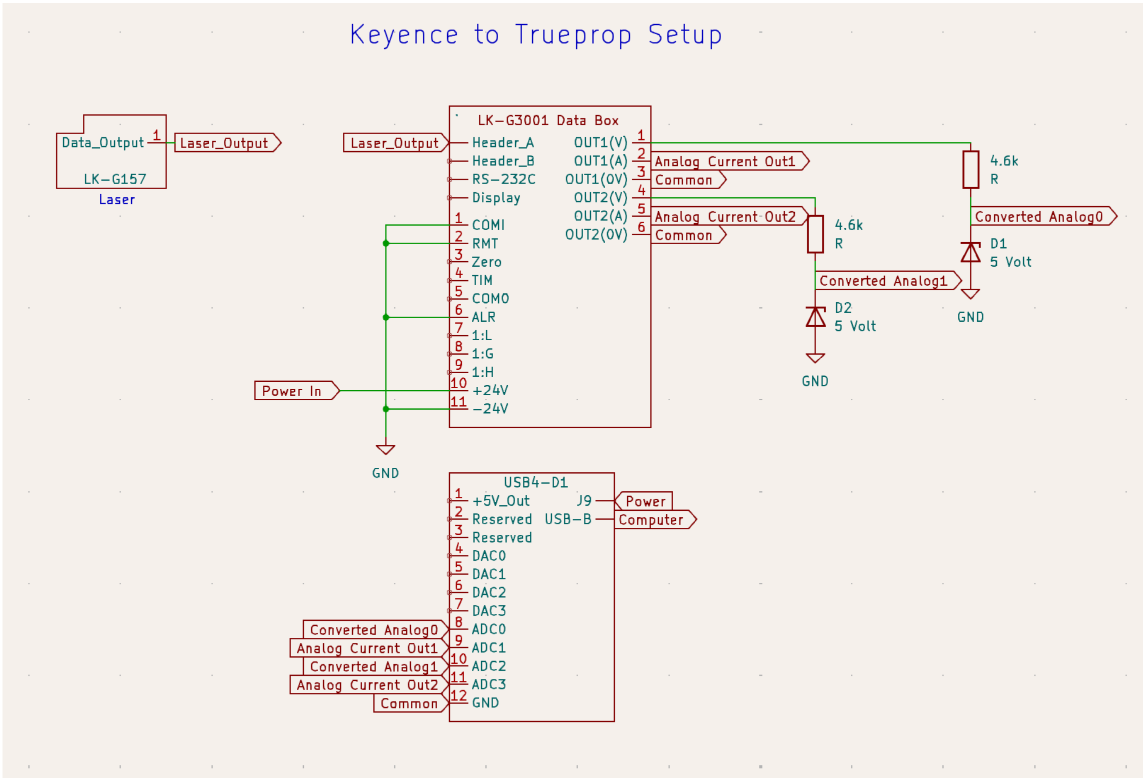



Figure 7

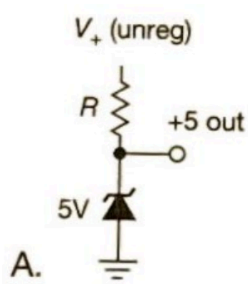



Figure 8

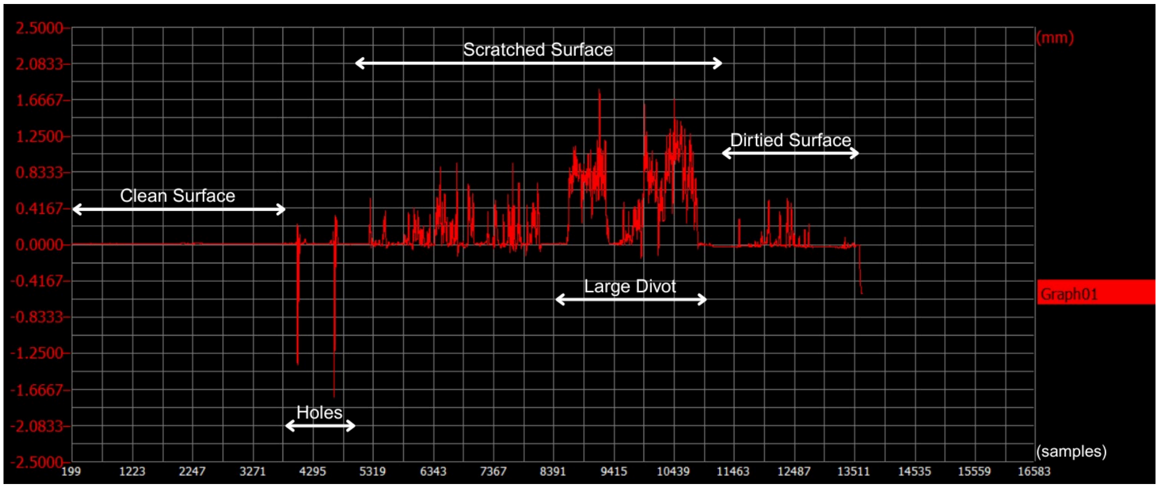



Figure 9

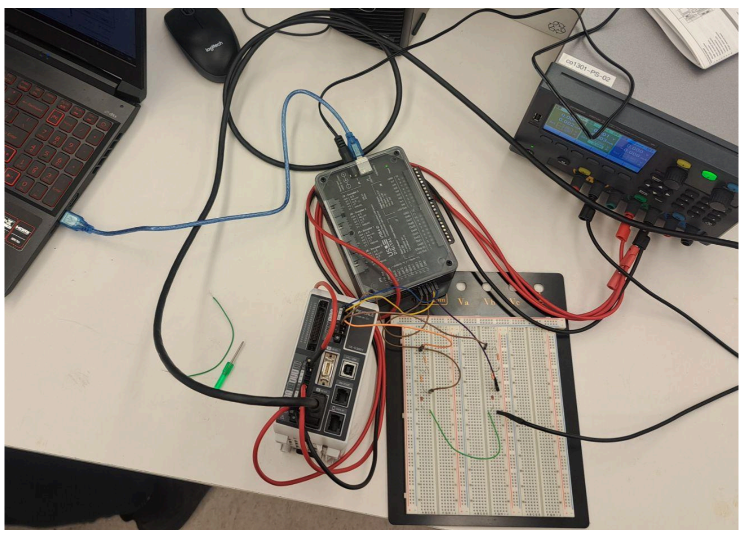


Figure 10

The following procedure describes how to configure LK-Navigator and initiate data capture from the LK-G157 sensor via the USB4-D1 module.

1. **Launch and Connect**
    - Open the LK-Navigator application on the host PC.
    - From the **Device** menu, select the header (Header A or Header B) to which the LK-3001 data box is connected.

2. **Configure Measurement Parameters**
    - In the **Surface Type** dialog, choose the appropriate topology profile (e.g., flat, curved, stepped).
    - Under **I/O Mapping**, verify that:

        - Voltage outputs are assigned to the correct ADC channels (ADC0 and ADC2).
        - Current monitor lines are mapped to ADC1 and ADC3.
        - Ground references match the common GND rail.

3. **Upload Settings to Hardware**
    - Click **Send to Header** to transfer the configuration to the LK-3001 data box.
    - Confirm receipt by observing the status indicator on the header LED panel.

4. **Download Settings to Laser**
    - With the header configured, click **Transfer to Sensor** to propagate the measurement parameters to the LK-G157 laser head.
    - Wait for the green "OK" confirmation in the software, indicating successful parameter synchronization.

5. **Initiate Data Acquisition**
    - In LK-Navigator, navigate to **Acquisition → Start**.
    - Adjust the sampling rate and averaging window as required for your surface topology.
    - Select **Begin Measurement**; real-time data will stream into the display.

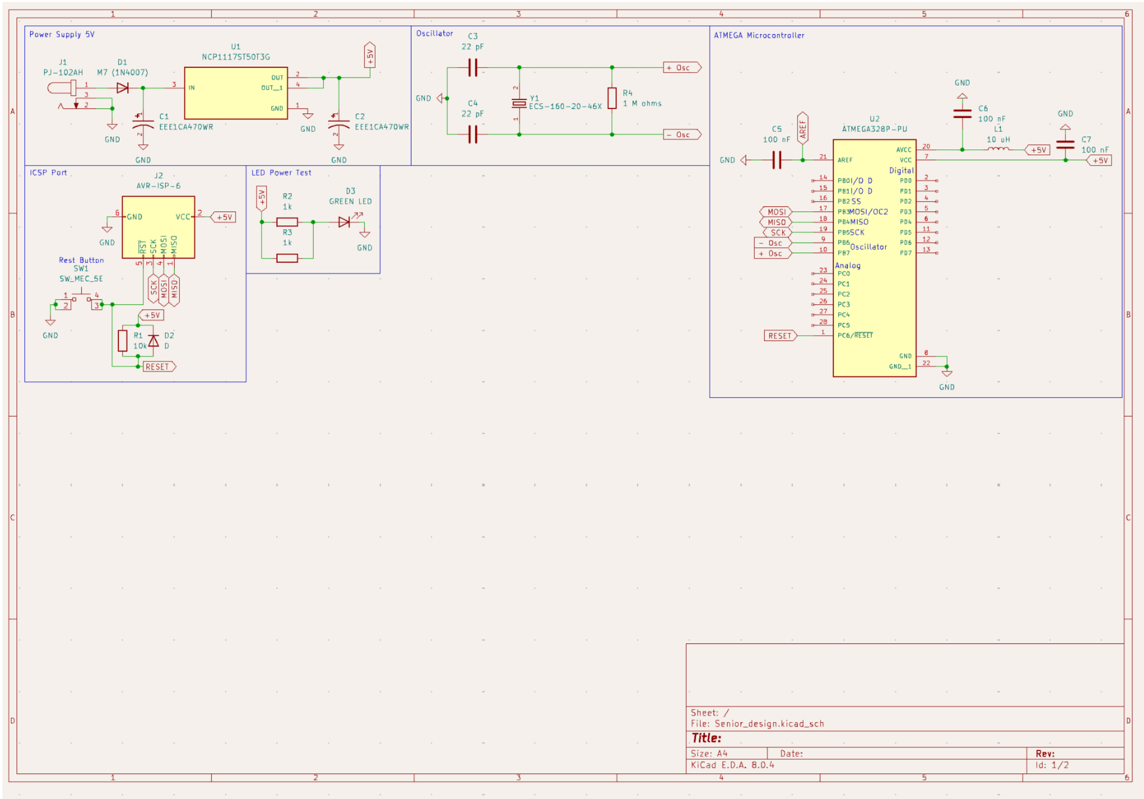
6. **Verify Results**
    - Upon completion, the software will generate a profile plot analogous to Figure 9, illustrating the measured surface contours.
    - Review the data for artifacts, noise, or unexpected discontinuities.

**Best Practices:**

- Always perform a zero-offset calibration on a reference flat prior to measurement.
- Utilize the built-in filtering options in LK-Navigator to suppress high-frequency noise.
- Save your project file immediately after acquisition to preserve settings and raw data.

## Appendix 2 – alternative/initial version of design

The following designs are all options we considered before our client decided to purchase the KEYENCE system. These designs include a bank of ultrasonic sensors, IR sensors, and a data fusion system to produce more accurate data. These designs were considered because they provided a more accurate reading than standard sensors and were within our initial budget of $1000. When the budget increased and Mr. Linden decided to purchase the KEYENCE system, these designs were scrapped in favor of the much more accurate and reliable KEYENCE product.



Power Supply 5V
J1
PJ-102AH
D1
M7 (1N4007)
U1
NCP1117ST50T3G
IN
OUT
OUT_1
GND
C1
EEE1CA470WR
C2
EEE1CA470WR
+5V
GND
Oscillator
C3
22 pF
C4
22 pF
Y1
ECS-160-20-46X
R4
1 M ohms
+ Osc
- Osc
ICSP Port
J2
AVR-ISP-6
GND
VCC
RST
SCK
MOSI
MISO
Rest Button
SW1
SW_MEC_5E
R1
10k
D2
D
RESET
LED Power Test
R2
1k
R3
1k
D3
GREEN LED
ATMEGA Microcontroller
U2
ATMEGA328P-PU
C5
100 nF
AREF
C6
100 nF
L1
10 uH
C7
100 nF
AVCC
VCC
Digital
PB0 I/O D
PB1 I/O D
PB2 SS
PB3 MOSI/OC2
PB4 MISO
PB5 SCK
PB6
PB7
Oscillator
Analog
PC0
PC1
PC2
PC3
PC4
PC5
PC6/RESET
PD0
PD1
PD2
PD3
PD4
PD5
PD6
PD7
GND_1
Sheet: /
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Title:
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Date:
Rev:
KiCad E.D.A. 8.0.4
Id: 1/2


Figure 11

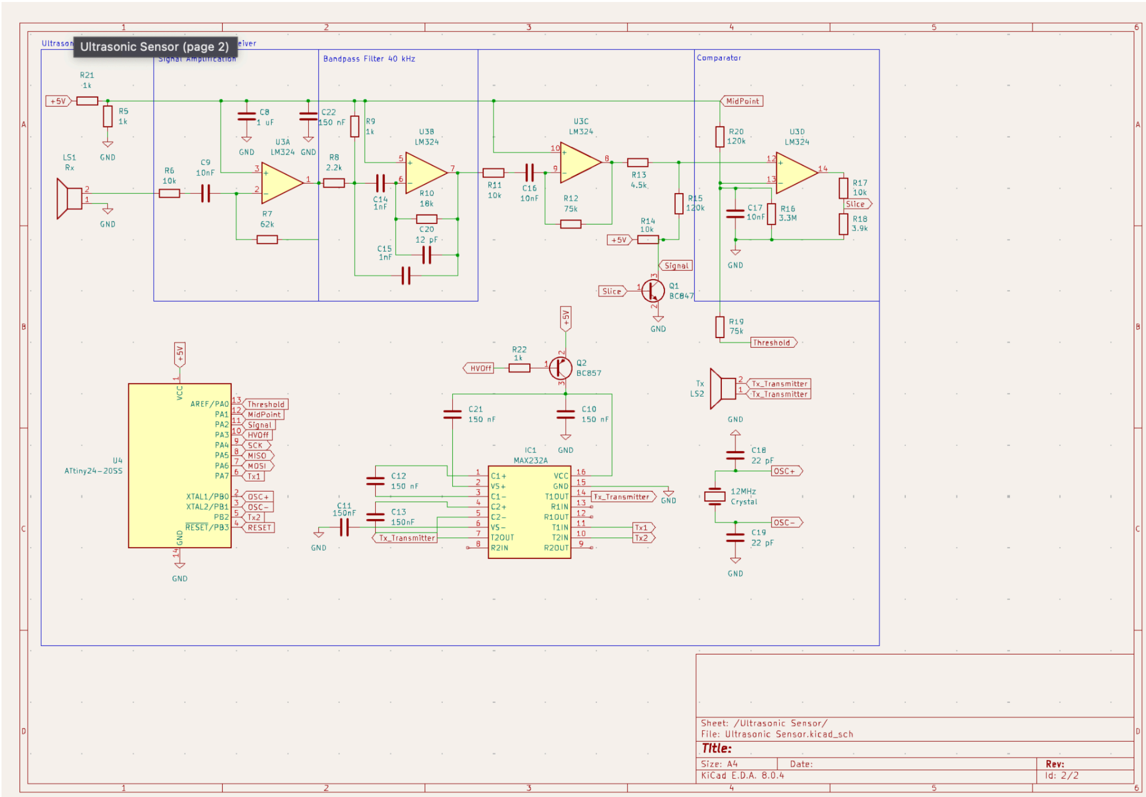


Figure 12

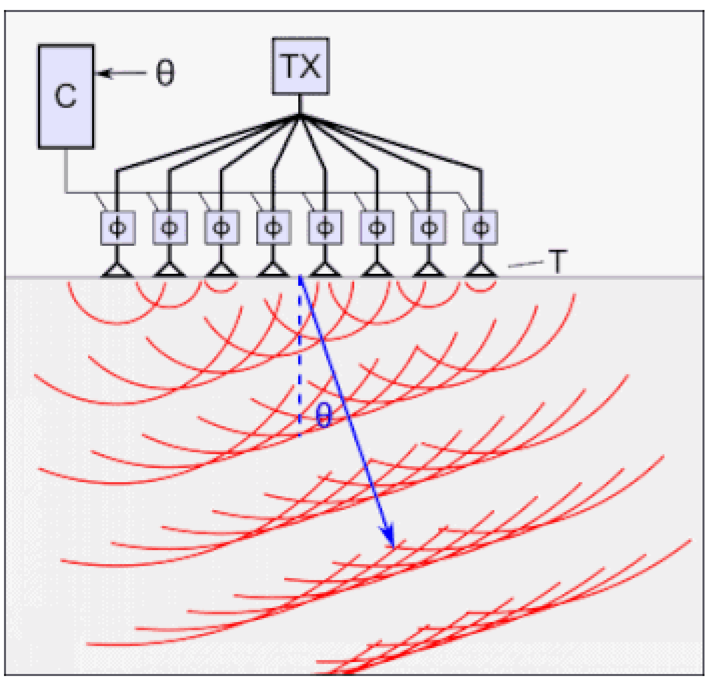


Figure 13

## Appendix 3 – Other considerations

- We learned that working with a small business owner can be stressful and cause many delays in projects due to a much smaller communication network.

- We learned that the $500 senior design budget could not be sent to a client to fund the purchase of a system.

- We learned that the senior design budget could not be used for food.

## Appendix 5 – Team Contract

Complete each section as completely and concisely as possible. We strongly recommend using tables or bulleted lists when applicable.

### Team Members

### Required Skill Sets for Your Project

- Arduino coding
- Professional communication skills
- Knowledge of IR and ultrasonic sensors
- Circuitry

### Skill Sets covered by the Team

Elias Colsch: Professional communication, Knowledge of IR and ultrasonic sensors, and Circuitry

Denny Dang: Knowledge of IR and ultrasonic sensors, Arduino Coding, and Circuitry

Alan Whitehead: Knowledge of IR and ultrasonic sensors, Arduino Coding, and Circuitry

### Project Management Style Adopted by the team

We have adopted an agile management style for this project

### Individual Project Management Roles

Elias Colsch: Client Interaction and Research

Denny Dang: Individual Component Design

Alan Whitehead: Testing and Prototyping

Team Members:

1) ______Elias Colsch______ 2) ______Denny Dang______

3) ______Alan Whitehead______

**Team Procedures**

1. Day, time, and location (face-to-face or virtual) for regular team meetings: **Monday with Mani Mina at his office at 3:30.**

2. Preferred method of communication updates, reminders, issues, and scheduling (e.g., e-mail, phone, app, face-to-face): **face-to-face, email reminders for meetings and using Discord for updates and informal discussion on the project.**

3. Decision-making policy (e.g., consensus, majority vote): **Majority vote.**

4. Procedures for record keeping (i.e., who will keep meeting minutes, how will minutes be shared/archived): **Spencer Rudin via handwritten note, or documented in text and put on discord.**

**Participation Expectations**

1. Expected individual attendance, punctuality, and participation at all team meetings: **Everyone is expected to show up on time.**

2. Expected level of responsibility for fulfilling team assignments, timelines, and deadlines: **We will work with Mani Mina to create and assess timelines to make the project.**

3. Expected level of communication with other team members: **Team members are expected to communicate whenever there is a problem or complication.**

4. Expected level of commitment to team decisions and tasks: **Team members are expected to commit and work toward team decisions and tasks.**

**Leadership**

1. Leadership roles for each team member (e.g., team organization, client interaction, individual component design, testing, etc.):
   **Client Interaction and Research: Elias Colsch**
   **Individual Component Design: Denny Dang**
   **Testing and Prototyping: Alan Whitehead**

2. Strategies for supporting and guiding the work of all team members: **Mani Mina and all team members will be available for questions or help. Any problems should be brought to the team meeting, where we can devise a solution and assign new tasks.**

3. Strategies for recognizing the contributions of all team members: **All names and contributions will be listed on a slide for the project presentation.**

**Collaboration and Inclusion**

1. Describe the skills, expertise, and unique perspectives each team member brings to the team.
   - **Elias brings the experience of working with multiple teams and clients to complete projects, as well as previous experience with smaller scale IR sensors.**
   - **Denny brings insight from manufacturing industry procedures and**

technology, and brings unique ideas.**
- **Alan brings insight and experience with troubleshooting high voltage and high power systems.**

2. Strategies for encouraging and supporting contributions and ideas from all team members: **All ideas are open to debate during team meetings, where we can evaluate the cost/benefit of each idea.**

3. Procedures for identifying and resolving collaboration or inclusion issues (e.g., how will a team member inform the team that the team environment is obstructing their opportunity or ability to contribute?) **See below.**

Strategies for planning and assigning individual and teamwork

1. Procedures for identifying and resolving collaboration or inclusion issues (e.g., how will a team member inform the team that the team environment is obstructing their opportunity or ability to contribute?): **Any issues should be brought to the attention of all team members during meetings unless it is a private issue. If an issue only involves one person, that person should be told privately, and the issue should be resolved between those members.**

2. How will you handle infractions of any of the obligations of this team contract?: **Warnings will be issued for initial and minor infractions. Any major or continued infractions will lead to complaints submitted to Mani Mina or the Senior Design professors.**

3. What will your team do if the infractions continue?: **If serious infractions continue and the team member makes no attempt to fix them, eventually, it could lead to trying to get them moved from the project**

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a) I participated in formulating the standards, roles, and procedures as stated in this contract.

b) I understand that I am obligated to abide by these terms and conditions.

c) I understand that if I do not abide by these terms and conditions, I will suffer the

consequences as stated in this contract.

1) _____Elias Colsch_____ DATE ________5/2/2025______

2) _____Denny Dang_____ DATE _______5/2/2025_______

3) _____Alan Whitehead_____ DATE _______5/2/2025_______