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Preliminary Design: IceAlign: Aligning Your Path to Success

Revisions

Revision	Author	Changes	Date
001	Sina Shaban	<list of changes, e.g., "Initial Release" for 1st version>	2025-02-08

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Acronyms

IoT	Internet of Things
IR LED	Infrared LED
MID	Minimum Implementation Design
FRs	Functional Requirement
PRs	Performance Requirement
SPI	Serial Peripheral Interface
UART	Universal Asynchronous Receiver-Transmitter
ADC	Analog-to-Digital Converter
Op-amp	Operational Amplifier
MCU	Microcontroller Unit

References

[1]

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1 Purpose

This document describes the preliminary design for the Curling assistant for visually impaired people (IceAlign).

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2 Concept of Operation

The high-level operation of the IceAlign is illustrated by the following user stories and use cases.

2.1 User Stories

1) User Story 1
   I am a Skip. I rotate my broom until it is aligned with the thrower's stone. When I am aligned, I immediately receive audio or tactile feedback. I am able to align with the thrower without needing verbal cues.
2) User Story 2
   I am a Thrower. I prepare to release the curling stone. The sweeper's broom has an LED which I can see from a few metres away. I aim toward the LED and release the stone accurately toward the LED that corresponds to the final target.
3) User Story 3
   I am a Sweeper. I try to position my broom to block the aligned infrared LED between the skip and thrower. As I move the broom and it blocks the alignment between skip and thrower , the Light on my broom activates. The activated light is bright enough. The thrower, even if visually impaired or in a noisy or brightly lit environment, knows exactly where to aim the stone.
4) User Story 4
   I am a User. The system operates continuously for 6–8 hours on a single charge, and it notifies me when it's running low . It withstands physical impacts and wet/icy conditions during gameplay. It remains reliable throughout the match without frequent maintenance.

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2.2 Use Cases

Figure 2.2.1 Use Cases Diagram

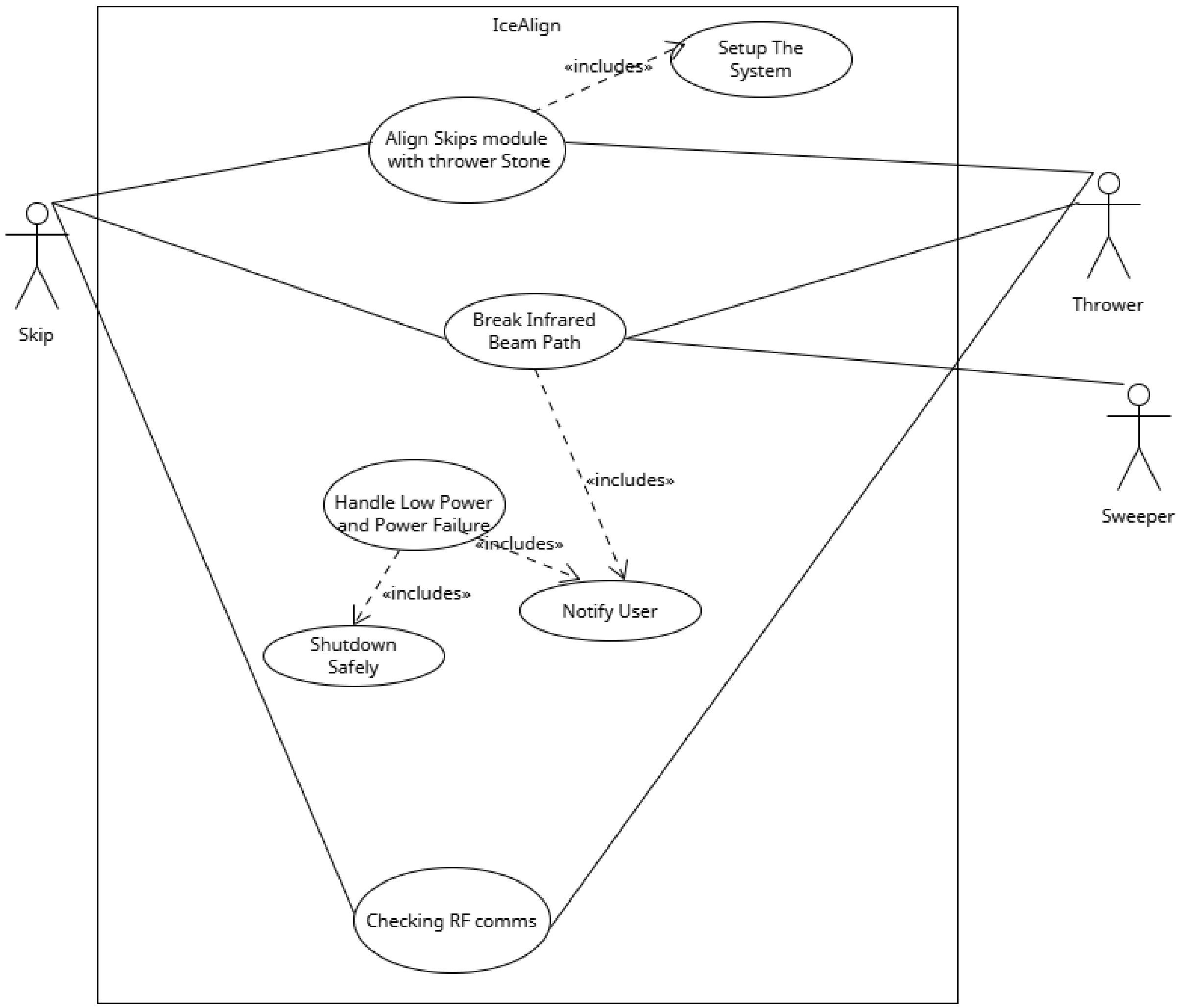

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Table 2.2.1 Use Case – Aligning Skip and the thrower

Use Case Description and Details	
Number	UC-001
Name (action)	Aligning Skip and the thrower
System	IceAlign
Actors	1. Thrower 2. Skip
Use Case Goal	To enable the skip to align their emitter module with the thrower accurately.
Primary Actor	skip
Preconditions	1. The skip and thrower are in their respective positions. 2. The IceAlign system is properly set up.
Postconditions	1. The skip's emitter module is accurately aligned with the thrower. 2. The thrower module is able to receive the beam from Skips module 3. The skip receives confirmation of proper alignment. 4. Skip is able to keep the module mounted on their broom steadily.
Basic flow	1. The skip turns on the emitter module mounted on their broom . 2. The emitter module sends an IR LED beam to the thrower's receiver module. 3. The thrower's receiver module detects the IR LED beam and sends feedback to the skip's module. 4. The skip's module receives the feedback and provides alignment confirmation to the skip
Alternate flows	A. IR beam not detected 1. The skip turns his broom around but does not receive feedback on alignment 2. The skip retries the alignment by turning the broom 3. If the alignment is successful, the skip receives audio/tactile feedback
Exceptions	Possible exception includes: 1. Loss of power, batteries are discharged

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Table 2.2.2 Use Case – Power Supply Failure

Use Case Description and Details	
Number	UC-002
Name (action)	Power Supply Failure/Battery Discharged
System	IceAlign
Actors	1. Thrower 2. Skip 3. Sweeper
Use Case Goal	To handle power supply failure and regain power
Primary Actor	skip, thrower, sweeper
Preconditions	1. The IceAlign system is in use and looses power 2. The IceAlign system does not power on
Postconditions	1. The IceAlign system is safely shut down.
Basic flow	1. The Ice Align system loses power 2. The IceAlign system detects the power supply failure and shuts down. 3. The users can see this by the power light turning off 4. The user replaces the batteries
Alternate flows	1. Loose wiring: a. When initiating battery replacement, if the user notices loose wiring, the user reinserts the power cables into the battery as well as the IceAlign module 2. Battery recharging: a. the user recharges them using an external power source. b. the user return to the game
Exceptions	

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Table 2.2.3 Use Case – Breaking the IR Beam after alignment

Use Case Description and Details	
Number	UC-003
Name (action)	Breaking the IR Beam after alignment
System	IceAlign
Actors	1. Sweeper 2. Skip 3. Thrower
Use Case Goal	Sweeper to accurately block the IR beam emitted by the skip's emitter module from reaching the thrower
Primary Actor	sweeper
Preconditions	1. The IceAlign system is properly set up and calibrated. 2. The skip's emitter module is aligned with the thrower (UC-001). 3. The sweeper is in position to break the IR beam with his module turned on
Postconditions	1. The IR beam is successfully blocked by the sweeper. 2. The sweeper's LED is activated, providing visual feedback
Basic flow	1. The sweeper moves their broom into the path of the IR beam. 2. The IR beam is broken, triggering the sweeper's LED to activate. 3. The sweeper receives visual feedback from their LED, confirming the IR beam break.
Alternate flows	3. The sweeper’s LED does not light up: a. The Sweeper retries breaking the alignment b. If successful upon retrying, the sweeper’s LED turns on
Exceptions	1. The alignment does not break if the sweepers broom is parallel to the alignment between skip and thrower 2. The sweeper’s LED does not turn on due to the throwers module receiving IR reflected from another surface

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Table 2.2.4 Use Case – Set up the system

Use Case Description and Details	
Number	UC-004
Name (action)	Turning on the system
System	IceAlign
Actors	1. Thrower 2. Skip 3. Sweeper
Use Case Goal	To enable the curlers to power on their respective systems
Primary Actor	skip, sweeper, curler
Preconditions	1. The skip, thrower and curler have their batteries charged
Postconditions	1. The IceAlign modules of the skip, thrower and curler are powered on, with the power light turned on.
Basic flow	1. The skip, curler and sweeper place their charged batteries into the battery holder 2. They plug in the power cable from battery to their respective Ice Align module 3. all user turns on the system
Alternate flows	1. the system did not turns on a. the user check the battery b. the user change the battery c. system turns on
Exceptions	1. The batteries are discharged and hence the IceAlign system does not power on

Table 2.2.5 Use Case – Check RF communication

Use Case Description and Details	
Number	UC-005

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Name (action)	Check RF communication
System	IceAlign
Actors	1. Skip 2. Sweeper 3. Thrower
Use Case Goal	To ensure RF comms are operational
Primary Actor	Thrower, Skip
Preconditions	1. The IceAlign system is turned on 2. The skip and the sweeper are close to each other.
Postconditions	1. The users can confirm the IR emitters, IR receivers, FM transmitters and FM receivers are all working.
Basic flow	1. The the thrower's module is placed right in front of the skip's module such that the IR detector is right in front of the IR emitter. 2. The skip's module gives visual/tactile feedback indicating alignment and confirming the RF comms are working.
Alternate flows	1. The the thrower's module is placed right in front of the skip's module such that the IR detector is right in front of the IR emitter. 2. The skip's module does not give visual/tactile feedback indicating an issue with the RF communication, or with the IR receiver and IR emitter
Exceptions	RF communication may be interrupted in cases of high RF noise

Table 2.2.6 Use Case – Notify User

Use Case Description and Details	
Number	UC-006
Name (action)	Notify User
System	IceAlign
Actors	1. Thrower 2. Skip 3. Sweeper
Use Case Goal	To notify user incase of powerfailure
Primary Actor	IceAlign

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Preconditions	1. The Ice Align system is in use 2. One or multiple Ice Align modules run out of power
Postconditions	The affected module safely shuts down to prevent malfunction. The user is notified via a blinking LED, indicating the low battery status.
Basic flow	1. A module detects low battery levels. 2. The LED starts blinking to alert the corresponding user. 3. If power continues to drop, the module shuts down safely to prevent data loss or hardware damage.
Alternate flows	If the battery stabilizes (e.g., due to external power input), the LED stops blinking and normal operation resumes.
Exceptions	If the LED indicator fails, a sudden loss of power may occur

3 Functional and Performance Requirements

Table 3.1 Functional Requirements

FR #	Functional Requirement Description
FR-01	The system must emit a **vertical planar Infrared LED beam** from the skip's broom for alignment.
FR-02	system provide **immediate audio/tactile feedback** to the skip when aligned with the thrower's stone within 10 ms
FR-03	The system must activate a **bright LED with > 5000mcd brightness** on the sweeper's broom when the Infrared beam is blocked.
FR-04	The system must operate within a **temperature range of -10°C to +40°C**
FR-05	The system must be **battery-powered** with a minimum runtime of 6–8 hours
FR-06	The system must withstand **rapid broom movements** and physical impacts during gameplay
FR-07	The system must use **eye-safe infrared wavelengths** (e.g., 940nm) with power levels below safety thresholds comply with IEC 62471 standards.
FR-08	The system must be **easy to use**, requiring minimal training for visually impaired players.
FR-09	The sweeper's LED must remain visible in bright curling ring condition.

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FR-10	The system must allow the thrower to **aim accurately** toward the sweeper's activated LED.
FR-11	The system must maintain reliable communication between modules (Skip, Thrower, Sweeper) with automatic error recovery
FR-12	All modules must be securely mounted to withstand broom vibrations and impacts
FR-13	The system must provide low-battery alerts (audio/tactile) and activate power-saving mode at ≤20% battery
FR-14	Components must be waterproof to operate in icy/wet conditions.
FR-15	The thrower's module must confirm alignment accuracy (±5cm) with the sweeper's LED before sweepers block the infrared beam
FR-16	The system must use modular connectors for easy battery replacement/recharging.
FR-17	Feedback signals (audio/tactile) must be unique to avoid confusion (e.g., distinct tones for alignment vs. errors).

Table 3.2 Performance Requirements

PR #	Performance Requirement Description	Related FRs
PR-01	The IR beam must maintain alignment accuracy (±5cm) at a range of ≥50 meters	FR-01
PR-02	The audio/tactile feedback for the skip must have a response time of <10ms from alignment detection to confirmation.	FR-02
PR-03	The sweeper's LED must emit light with a brightness of >5000mcd and an audible buzzer at 85dB (±5dB) to ensure visibility	FR-03, FR-09
PR-04	The system must maintain **stable operation** across the specified temperature range (-10°C to +40°C).	FR-04
PR-05	The battery must provide **6–8 hours of continuous operation** under normal gameplay conditions.	FR-05
PR-06	The system must withstand **> 1000 rapid sweeping motions** without damage	FR-06
PR-07	The IR emitter must operate at **< 1W power** to ensure eye safety and comply with IEC62471 standards.	FR-07
PR-08	The system must require **< 30 minutes of training** for visually impaired users to operate effectively	FR-08

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PR-09	The sweeper's LED must emit **audible feedback (e.g., beep)** in addition to visual feedback to ensure that sweeper knows that they had indeed block the IR beam	FR-09 , FR-03
PR-10	The thrower must be able to **aim within ±5cm accuracy** toward the sweeper's LED.	FR-10,FR-03
PR-11	FM communication between modules must achieve ≥95% signal integrity at 50m range, with automatic retries for lost packets.	FR-11
PR-12	Low-battery alerts (audio/tactile) must activate at ≤20% capacity, extending runtime by 30% in power-saving mo	FR-13
PR-13	All modules must pass waterproofing and earth drop tests	FR-14

4 System Design

The Visually Impaired Curling Assistance System (IceAlign) comprises three main subsystems: the Thrower's Module, the Sweeper's Module, and the Skip's Module. These interconnected subsystems work together to provide accurate alignment assistance and real-time feedback to visually impaired curlers, enabling them to improve their game performance. The following sections outline the major nodes and components of each subsystem, including hardware, software, and firmware components, and their relationships

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4.1 System Architecture

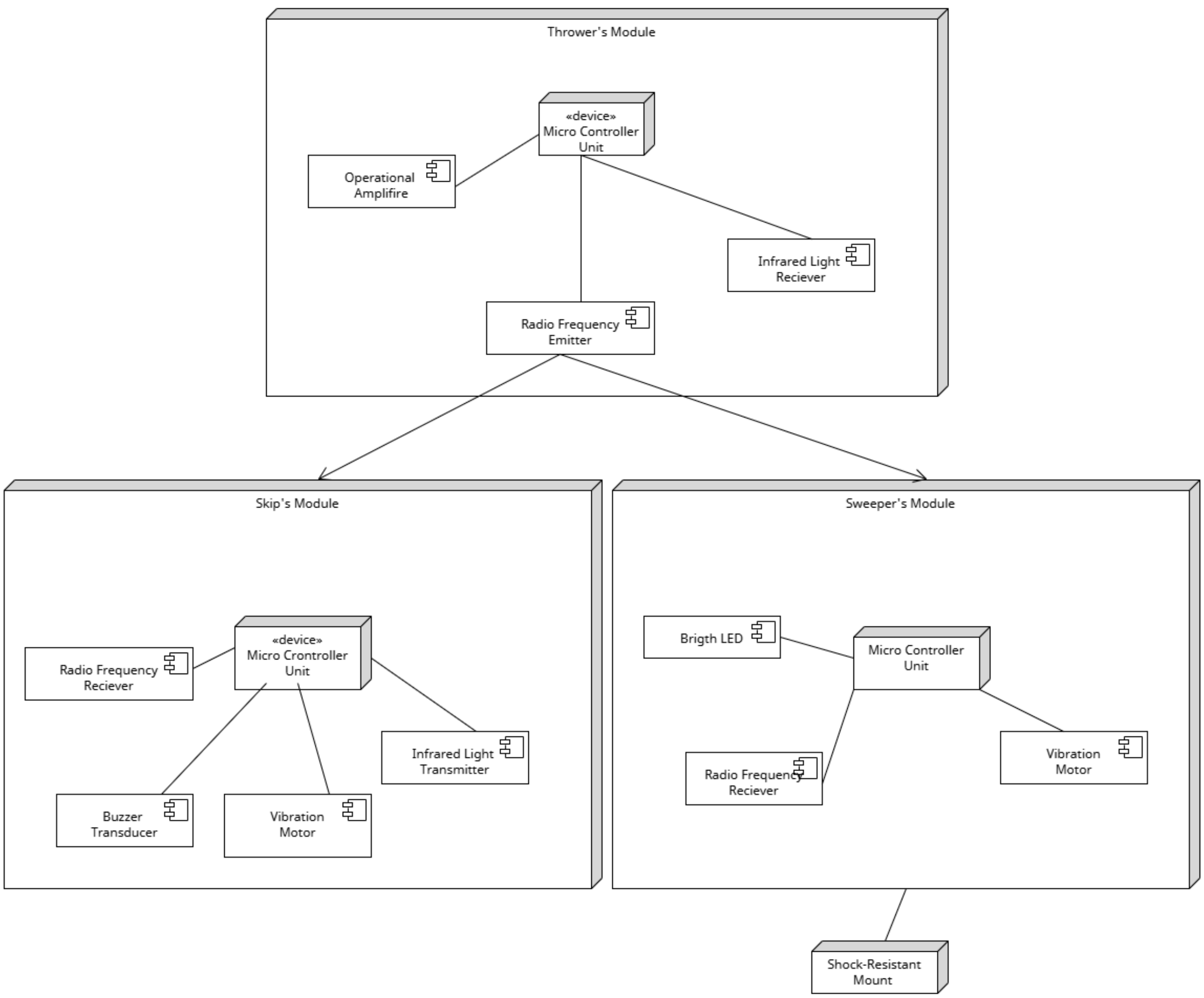

Figure 4.1.1 : This figure shows the major Hardware components its made of three main nodes that correspond to skip , thrower and sweepers modules.

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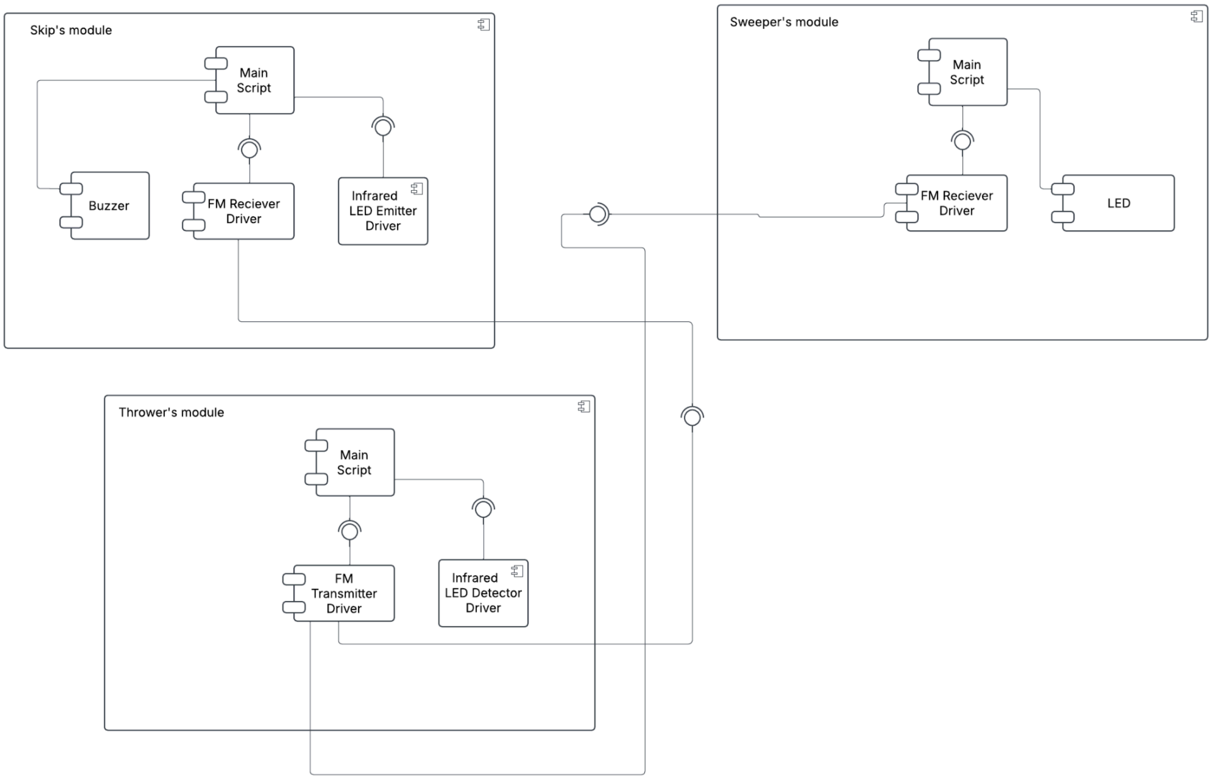

Figure 4.1.2 : This figure shows the high level software and firmware architecture of the system

4.1.1 Hardware Components

Table 4.1.1.1 Emitter module hardware components

CM #	Component	Description
CM -01	IR LED (940nm)	TSAL6100 IR emitter; vertical planar beam (50m range, <1W power)
CM -02	Microcontroller	Controls IR modulation and processes alignment confirmation signals
CM -03	FM Receiver Module	433MHz RF receiver ; receives alignment confirmation
CM -04	Battery	3.7V Li-ion (2000mAh); powers Skip's module for 6–8 hours.

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CM -05	Vibration Motor	.5G vibration motor for tactile alignment feedback to Skip

Table 4.1.1.2 Receiver module hardware components

CM #	Component	Description
CM -01	Photodiode	Detects the IR beam from the Emitter (e.g., TSOP3443).
CM -02	Microcontroller	Processes photodiode signals and triggers FM transmission
CM -03	FM Transmitter Module	433MHz RF transmitter; sends alignment data to Skip/Sweeper
CM -04	Battery	3.7V Li-ion (2000mAh); powers Thrower's module
CM -05	Signal Conditioning	LM318 op-amp + LPF/BPF filters; reduces noise in photodiode signals.
CM -06	Buzzer	85dB buzzer; provides audible alignment confirmation

Table 4.1.1.3 sweeper module hardware components

CM #	Component	Description
CM -01	IR-Blocking Plate	Physically interrupts the IR beam to set the target position.
CM -02	Microcontroller	Activates the LED upon receiving FM signals
CM -03	FM Receiver Module	433MHz RF receiver receives activation signals
CM -04	Battery	3.7V Li-ion (1000mAh); powers Sweeper's module

CM -05	LED + Buzzer	5000mcd LED + 85dB buzzer; activated when IR beam is blocked.
CM -06	Shock-Resistant Mount	Rubberized mount; withstands >1000 sweeps (1.5G force).

4.1.2 Software/Firmware Components

Table 4.1.2.1 Sweeper Module software and firmware components

CM #	Component	Description
CM -01	Pi OS Lite	Runs Python python interpreter and allows us to interface with the GPIO ports of the Pi Zero 2W
CM -02	Python script	Controls the LED and takes decisions based on the data from the FM receiver driver
CM -03	FM Detector Driver	Processes and decodes the signal received and to extract the original data

Table 4.1.2.2 Skip module software and firmware components

CM #	Component	Description
CM -01	Pi OS Lite	Runs Python python interpreter and allows us to interface with the GPIO ports of the Pi Zero 2W
CM-02	Python script	Controls the Infrared emitter to send pulsed infrared beams at a frequency o, controls the Buzzer/LED based on the data from the FM receiver driver
CM-03	FM Detector Driver	Processes and decodes the signal received and to extract the original data

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CM-04	Infrared LED Emitter driver	Responsible to interface with the main script and control the Infrared LEDs

Table 4.1.2.3 Thrower module software and firmware components

CM #	Component	Description
CM -01	Pi OS Lite	Runs Python python interpreter and allows us to interface with the GPIO ports of the Pi Zero 2W
CM -02	Python script	Interfaces with the Infrared receiver driver and processes the data from the Infrared detection module. It also controls interfaces with the FM transmitter driver to send the alignment information to other modules
CM -03	FM Transmitter Driver	Receives the alignment information from the main script, encodes the information and transmits it
CM -04	Infrared Detector Driver	Receives the amplified analog infrared signal and passes digital alignment information to the main script

5 System Requirements

The high level system requirement of our system IceAlign is as follows

Table 5.1 System Requirements

SR #	System Requirement Desc	FR#	PR#	Notes
SR-01	IR LED emitting at 940nm wavelength with <1W power, compliant with IEC 62471 eye-safety standards.	FR-07	PR-07	Ensures eye safety and regulatory compliance.
SR-02	Microcontroller with low-power sleep mode.	FR-05	PR-05	Extends battery life to 6–8 hours

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SR-03	FM Transmitter/Receiver modules using 433MHz band with ≥95% signal integrity at 50m range	FR-11	PR-11	Enables reliable alignment signaling between Skip, Thrower, and Sweeper
SR-04	Photodiode with 50m detection range.	FR-01	PR-01, PR-10	Detects IR beam and ensures precise thrower alignment.
SR-05	LED (5000mcd) paired with 85dB buzzer on sweeper	FR-09	PR-03, PR-09	Ensures visibility in bright/noisy environments.
SR-06	Vibration motor with 1.5G intensity for tactile alignment confirmation to the skip.	FR-02	PR-02	Provides immediate feedback (<10ms latency) for alignment accuracy.
SR-07	Li-ion battery (3.7V, 2000mAh) for all modules	FR-06	PR-05	Meets 6–8 hour runtime requirement, and activates power-saving mode at ≤20% capacity
SR-08	All components rated for stable operation at -10°C to +40°C and ≤90% humidity	FR-04	PR-04	Ensures reliability in curling environments
SR-09	Durable mounts tested for >1000 sweep	FR-08	PR-06	Withstands gameplay wear-and-tear.
SR-10	Retroreflective mirror with >90% reflectivity	FR-07	PR-07	Break Ir LED beam from getting to receivers module

6 Minimum Design

The Minimum Design, also known as the "walking skeleton," is a critical component of our design process. It represents the bare minimum functionality required to demonstrate the viability of our IceAlign system. In this section, we will outline the key features and functions that will be implemented in the first development iteration.

Our Minimum Design focuses on delivering a functional system that can demonstrate end-to-end alignment between the skip, thrower, and sweeper. The key features and functions

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that will be implemented include IR beam emission and detection, alignment confirmation, communication through RM/FM transmitter and receiver, and a basic user interface for a system with a range of about 10m. These features will be implemented using a combination of hardware and software components on a simple breadboard, including the skip's emitter module, thrower's receiver module, alignment confirmation system, and basic feedback system. For the minimum design, we plan on using a wired DC power supply instead of batteries for the Minimum design.

Table 6.1 minimum Initial Design

MID #	Functional Block	Key design Point	implementation detail	Contribution to End-to-End Functionality
MID -01	IR Emitter Module	- Emits a vertical IR beam at 940 nm . - Provides the initial signal for alignment.	IR LED(TSAL 6210) with a dedicated driver circuit on the Skip's module	Initiates the alignment process by emitting the beam that triggers detection in downstream modules.
MID -02	IR receiver Module & Signal Conditioning	Detects the IR beam reliably. - Uses noise reduction for accurate signal capture.	IR receiver (e.g TSOP 3448) paired with LM318 op-amp and active filters	Receives and processes the IR signal, ensuring that the correct alignment data is captured for further processing.
MID -03	Communication Module	Provides wireless data transfer between modules using FM signals	FM transmitter (on the Thrower's module) and FM receiver (on the Skip's/Sweeper's modules) interfaced with the MCU	Bridges the sensor and processing stages by transmitting the alignment data, enabling the system to work as a unified whole.

MID -04	Microcontroller Unit (MCU)	Centralizes signal processing and system control		Integrates inputs from the sensor and communication modules and triggers the user feedback
MID -05	User Feedback System	Provides immediate visual/audio/tactile feedback (target response < 100 ms).	Feedback devices mounted on the respective modules (e.g., high-brightness LED, buzzer, and/or vibration motor) activated by the MCU.	Notifies users (skip, thrower, or sweeper) of proper alignment, thereby completing the end-to-end demonstration of system functionality

7.High-level Hardware Design

Table 7.1: Skip's Module Hardware Design

HD #	Component	Connection	Function	Notes
HD-01	IR LED (940nm) + Driver	Controlled via GPIO port from microprocessor	Emits IR beam for alignment	Ensures eye safety (<1W power)
HD-02	FM Receiver Module	Connected to MCU via SPI Or UART	Receives alignment confirmation signals	Enables real-time feedback

HD-03	Buzzer / Vibration Motor	MCU digital output	Provides feedback to Skip	Ensures alignment confirmation
HD-04	Li-ion Battery (3.7V) + Regulator	Powers all components	Provides stable power supply	Ensures 6–8 hours of operation

Table 7.2: Thrower's Module Hardware Design

HD #	Component	Connection	Function	Notes
HD-01	Photodiode + LM318 Op-amp	Signal processed via active filters & MCU ADC	Detects IR beam and confirms alignment	Ensures ±5cm accuracy
HD-02	FM Receiver Module	Connected to MCU via SPI Or UART	Sends alignment signals to Skip/Sweeper	Enables communication

HD-03	Li-ion Battery (3.7V) + Regulator	Powers all components	Provides stable power supply	Ensures 6–8 hours of operation

Table 7.3: Sweeper's Module Hardware Design

HD #	Component	Connection	Function	Notes
HD-01	High-brightness LED (5000mcd) & Buzzer (85dB)	MCU digital/PWM output	Provides visual & audio feedback	Ensures visibility in noisy conditions
HD-02	FM Receiver Module	Connected to MCU via SPI Or UART	Receives alignment signals	Enables communication
HD-03	Li-ion Battery (3.7V) + Regulator	Powers all components	Provides stable power supply	Ensures 6–8 hours of operation
HD-04	IR-blocking Plate	Passive physical component	Disrupts IR beam when alignment is achieved	Marks target position

6 High-level Software/Firmware Design

Sweeper Module

1. **Pi OS Lite (CM-01)**
   - Runs on the **Raspberry Pi Zero 2W**, providing a minimal **Linux environment** with GPIO support.
   - Enables execution of the Python script and communication with hardware interfaces.
2. **Python Script (CM-02)**

- Handles **LED control** and **decision-making** based on the processed FM data.
- Interfaces with the **FM Detector Driver** to receive data from the Skip module.

3. **FM Detector Driver (CM-03)**
   - **Receives and decodes** FM signals transmitted by the Thrower module.
   - Extracts **alignment data** and passes it to the Python script for processing.

Skip Module

1. **Pi OS Lite (CM-01)**
   - Provides a **Python execution environment** and GPIO support for interfacing with IR emitters, LEDs, and buzzers.
2. **Python Script (CM-02)**
   - **Controls the IR emitter** to send pulsed beams at a specified frequency.
   - **Interprets FM signals** received via the **FM Detector Driver** and triggers LED/Buzzer alerts for guidance.
3. **FM Detector Driver (CM-03)**
   - Decodes FM transmissions received from the **Thrower module**, ensuring accurate data interpretation.
   - Sends extracted information to the **Python script** to adjust guidance signals accordingly.
4. **Infrared LED Emitter Driver (CM-04)**
   - **Controls the IR LED pulses**, ensuring **precise signal timing** for alignment guidance.
   - Works with the **Python script** to adjust the **pulse frequency** based on detected alignment.

Thrower Module

1. **Pi OS Lite (CM-01)**
   - Provides the **base system** for running scripts and managing hardware peripherals.
2. **Python Script (CM-02)**
   - **Processes data** from the **Infrared Detector Driver** to determine alignment status.
   - **Interfaces with the FM Transmitter Driver** to send alignment information to the **Sweeper and Skip modules**.
3. **FM Transmitter Driver (CM-03)**
   - Encodes **alignment information** from the Python script and **transmits it wirelessly** via FM signals.
   - Ensures **signal integrity** and reliable communication with the **FM Detector Drivers** in the **Skip and Sweeper modules**.
4. **Infrared Detector Driver (CM-04)**
   - Converts **analog IR signals** into digital alignment data.
   - Sends processed data to the **Python script**, which determines whether the **thrower is properly aligned**.

7 Prototype Budget

Table 7.1 System Budget (ROM)

Component	Mfr P/N	Mfr	Qty	Unit Price	Extended Price
Infrared (IR) Emitter 940nm	TSAL6100	Vishay Semiconductor Opto Division	5	0.54	2.7
THRU-BEAM SENSOR 508MM	2168	Adafruit Industries LLC	2	9.03	18.06
RASPBERRY PI ZERO 2W	SC0721	Raspberry Pi	3	27.3	81.9
10F Microcontroller IC	PIC10F200-I/P	Microchip Technology	1	1.23	1.23
Transducer Buzzers	PS1240P02BT	TDK Corporation	5	0.73	3.65
Wireless Transceiver Module	NRF24L01	10Gtek	1	13.99	13.99
Reflector Pane	CAXUSD	CAXUSD	1	8.98	8.98
				Total Cost	130.47

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10 Alpha System Design

<Introduce the alpha design. Mention in general terms how the alpha design will differ from the prototype and why. Mention the scope and aim of this section; are there major or minor changes to the architecture, hardware, software, and other aspect? State any assumptions about how the alpha system will be deployed and used, especially if that differs from the prototype.

In the case where there could be a market for a product based on the prototype, describe briefly how the changes improve the SWaP+C, usability (the user experience), and manufacturability. Other issues like maintenance, recyclability, social impact, and more will be discussed in the final report.

If your project really does not lend itself to a product, for example it is a custom, one of a kind device built for your client or it's more of an R&D project to prove a technology for possible future products, take a different approach here. Describe how a second iteration of the prototype can be designed that incorporates the improvements you have identified to this point. These may be things that you'd like to have included, but there is no time for or the parts can't be obtained now. Discuss how the prototype can be made more extensible, e.g., by defining an API for future researcher/users. Maybe speculate on how certain aspects can be updated when technology gets better, e.g., like a processor upgrade to provide better machine learning capabilities, more sensor inputs, etc. Same as for a prototype that can become a product, leave other issues like maintenance, recyclability, social impact, and more for the final report.>

10.1 System Architecture

<The architecture may not change between the prototype and the alpha product. If so, note this explicitly and provide an explanation based on the updated PDD prototype architecture.

Otherwise, provide new deployment and component diagrams that show the differences clearly and discuss the changes in paragraphs following the figures. Be sure to reference the figures in those descriptions.>

10.2 Block Diagram

<Here, provide a block diagram that shows the major hardware components, like MCU, memory, sensors, LEDs, connectors, and power supply, with the main interconnections. For example, if an Arduino is used for the prototype, probably all that is really needed is the ATMEGA328 chip and a clock. Unless critical, things like resistors and capacitors can be ignored at this level of

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diagram; they will be captured in a detailed hardware design that is likely done using CAD tools like Altium or KiCAD. Focus on the key components that meet the system requirements for the alpha product.

See the lecture notes for an example of the toddler monitor block diagram.

If your project doesn't really lead to a "product", try to invent one. For example, if your project relies on a SoC and you are using a dev board, consider only those hardware components needed for the functionality of your system. For example, if you use a Zybo that is connected to a motor driver to control a stepper, obviously there is no real need for the PMOD connectors, RGB and mono-colour LEDs, and other things. Just the Zynq chip, some GPIOs, and a power subsystem is required. Start with that for the block diagram.

If you are really stuck, talk to Steven.>

11 System Budget

<Based on the Block Diagram, create a system budget that provides the order of magnitude landed production cost of the Alpha product. Review the lecture notes for a Toddler Monitor example. Explain the main cost drivers for each aspect, such as yield and returns, packaging, and NREs. If you are not sure of the actual NREs , assume 100% of the cost of a single unit, and 1% of the cost for 1000 units.

Consider costs for 1 unit and 1000 units at a minimum.

To get a better feel for things, sign up for a free account at macrofab.com. There will be a few example products and if you look at them on the "dashboard" Quote & Order tab, you can begin to get a feel for the NREs involved vs the cost per unit differences for 1 unit vs 1000 units. What are the main cost drivers? How does this relate to your Alpha product if, say, there was a demand for 1000, 5000, or 1000.? Discuss following your System Budget table.>