Tech-fit

Proof of Concept Demo

ENSC 405W: Capstone A

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Luke Gair
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Allan Tsai
Johnston Yang

01

Project Overview

Guardian Sight™

Guardian Sight™ aims to improve a user's form and posture when performing at-home workout routines to reduce the number of injuries arising from improper form. The prototype informs the user when an exercise is executed properly or when adjustments need to be made. This is achieved using computer vision and sensors to determine the user's posture and other physiological data.

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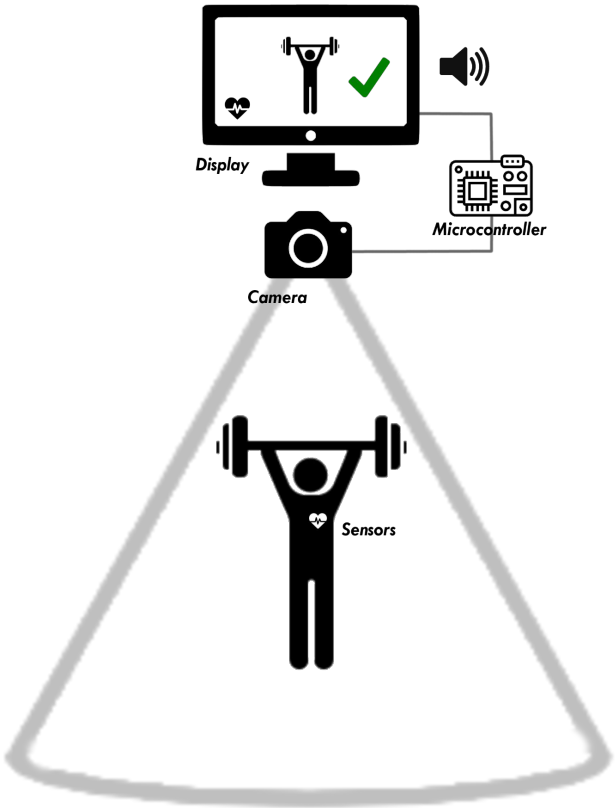
Technical Case

High-level Description



- Camera system will provide user pose capturing
- Sensor system will provide heart rate feedback
- Central controller system will analyze camera and sensor system data
  - Upload to a local database
  - Display relevant details to the LCD monitor
    - Repetition count
    - Indication of a good or bad repetitions
    - Suggested improvements
    - Heart rate

Materials

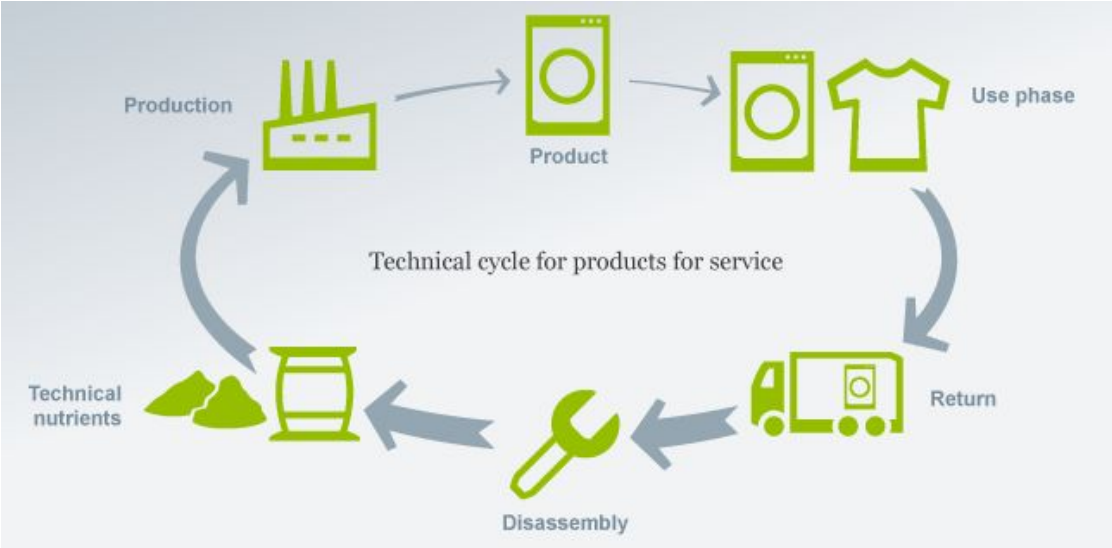
405W PoC
- Raspberry Pi 4
- MAX30102 heart rate sensor
- Arduino Uno
- Camera
- LCD Monitor

In preparation for 440
- 3D printed Jetson casing
- Nvidia Jetson

Materials to get
- 3D printed heart rate sensor casing
- Heart rate sensor batteries
- Arduino Flora
- Bluetooth module

Cradle to Cradle Design

- Electronic component which can be recycled at Return-it Electronics
- Rechargeable and recyclable batteries



Changes in Scope and Design

Dual Camera System

- Limitations in posture correction using single camera image
- Moving to two camera setup by either:
  - Running two instances of MediaPipe
  - Using alternate machine learning framework
- Switching to webcams from Jetson e-CAM30_CUTX1

Posture Correction Overlay

- Reconsidering using a skeleton overlay to correct posture

Main Microcontroller Enclosure

- Initially designed to be small in form factor and able to withstand a drop from waist high
- Enclosure will no longer be shock absorbent. It is unnecessary since it should be stationary

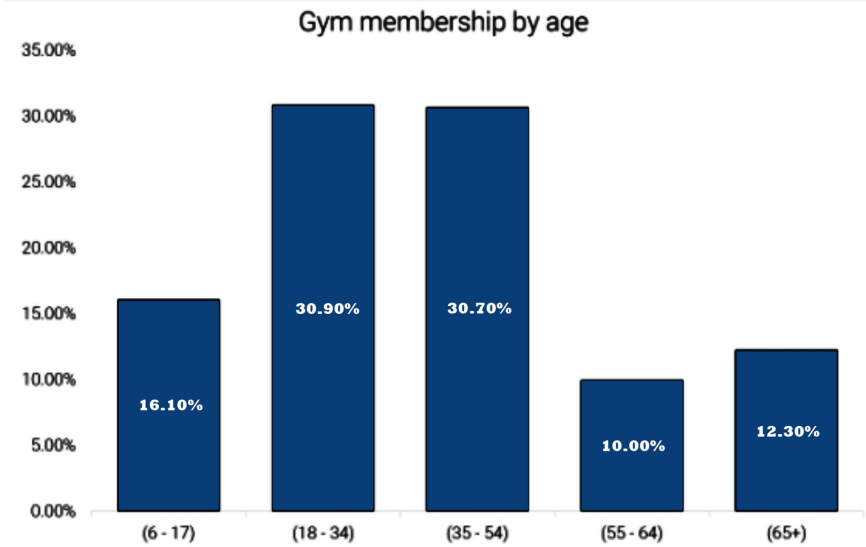
Heart Rate Sensor

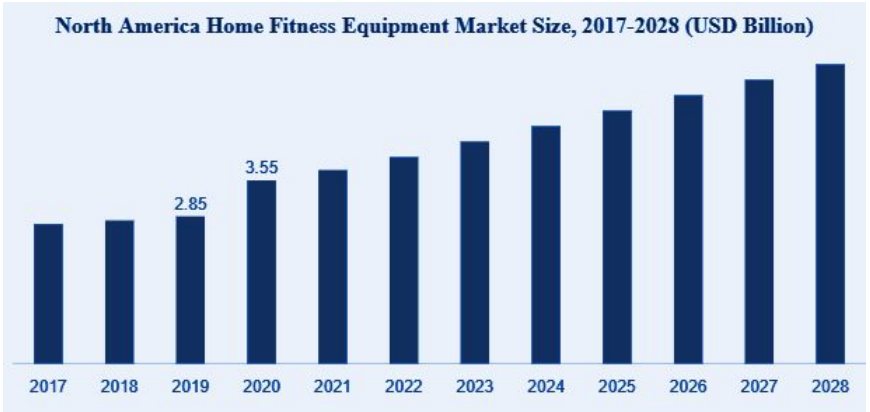
- Sensors has difficulty detecting heart rate on wrists
- Potentially switching to a new ones with green LEDs

03

Business Case

Market


Gym membership by age
35.00%
30.00%
25.00%
20.00%
15.00%
10.00%
5.00%
0.00%
16.10%
30.90%
30.70%
10.00%
12.30%
(6 - 17)
(18 - 34)
(35 - 54)
(55 - 64)
(65+)


North America Home Fitness Equipment Market Size, 2017-2028 (USD Billion)
2.85
3.55
2017
2018
2019
2020
2021
2022
2023
2024
2025
2026
2027
2028

Cost Breakdown

Component	Cost (CAD)
Nvidia Jetson TX2	$250
Monitor	$120*
Arduino FLORA	$25
Camera x2	$100
Flora Wearable Bluefruit LE Module	$20
Lithium Ion Polymer Battery	$20
Enclosures	$5
Total Cost without Monitor	**$420**
Total Cost with Monitor	**$540**

Competition

VERA by Reflection Health

- Avatar coach guides users through rehabilitation exercises
  - Specifically for people with injuries
- 3D scans user to track progress with exercises

Tempo Studio by Tempo

- Uses 3D camera to capture user’s movement
- Provides real time feedback to correct form
- Expensive
  - $3000

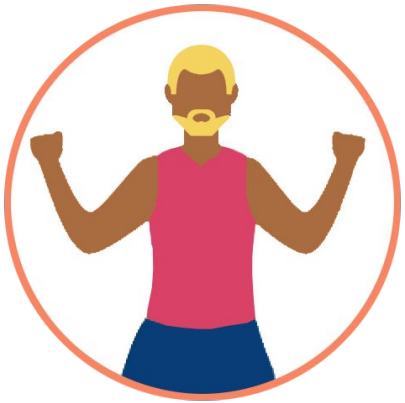
Ideal Customers

Home Workout Holly

- Age: 18-52
- Familiar with using a computer or smartphone
- Looking for affordable at home fitness solutions
- Has space to work out in their home

Commercial Gym Carl

- Commercial Gym Owner
- Looking to provide low cost alternatives to personal trainers
- Looking to reduce the number of personal trainers required on the gym floor



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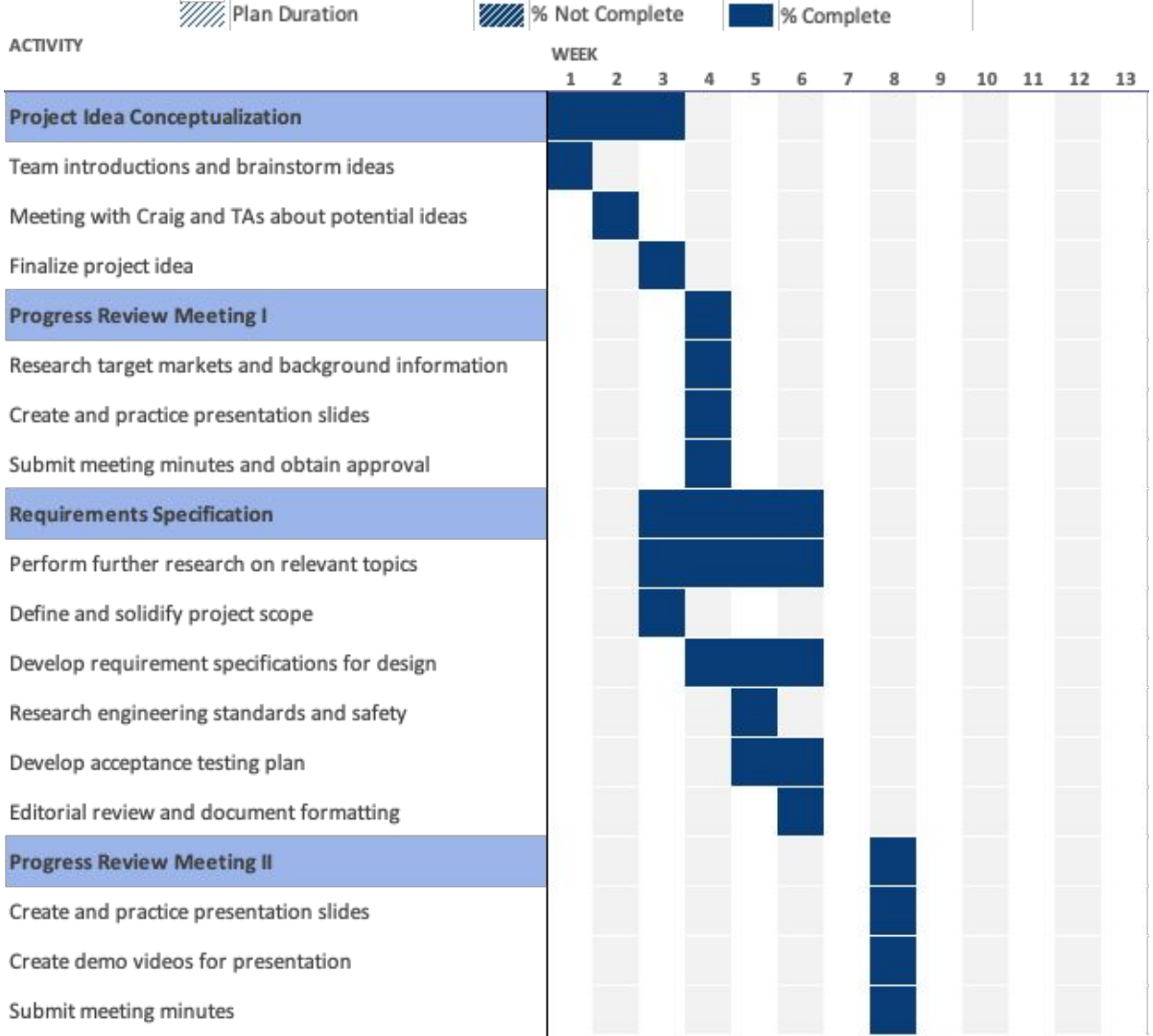
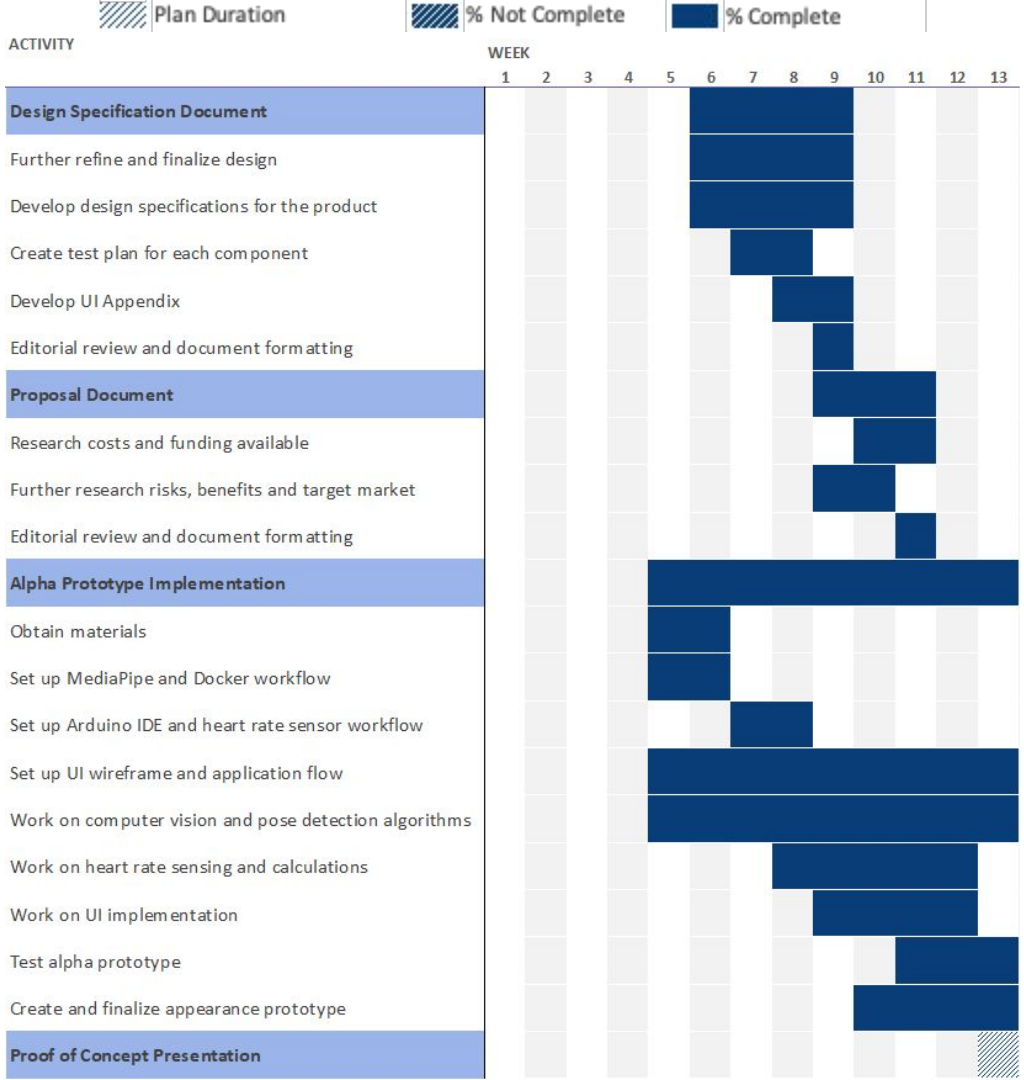
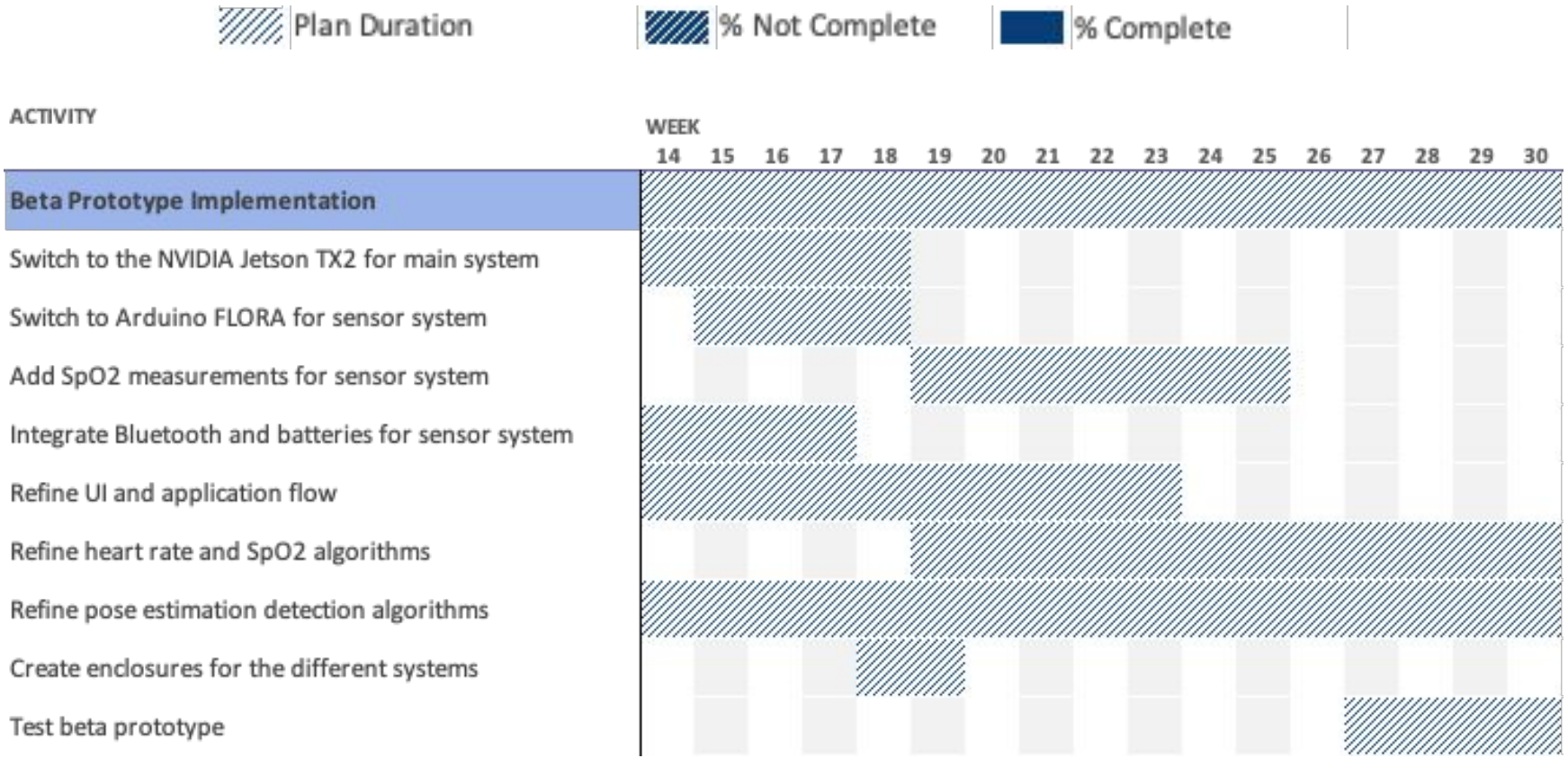
Schedule for 440


Plan Duration
% Not Complete
% Complete
ACTIVITY
WEEK
1 2 3 4 5 6 7 8 9 10 11 12 13
Project Idea Conceptualization
Team introductions and brainstorm ideas
Meeting with Craig and TAs about potential ideas
Finalize project idea
Progress Review Meeting I
Research target markets and background information
Create and practice presentation slides
Submit meeting minutes and obtain approval
Requirements Specification
Perform further research on relevant topics
Define and solidify project scope
Develop requirement specifications for design
Research engineering standards and safety
Develop acceptance testing plan
Editorial review and document formatting
Progress Review Meeting II
Create and practice presentation slides
Create demo videos for presentation
Submit meeting minutes


Plan Duration
% Not Complete
% Complete
ACTIVITY
WEEK
1 2 3 4 5 6 7 8 9 10 11 12 13
Design Specification Document
Further refine and finalize design
Develop design specifications for the product
Create test plan for each component
Develop UI Appendix
Editorial review and document formatting
Proposal Document
Research costs and funding available
Further research risks, benefits and target market
Editorial review and document formatting
Alpha Prototype Implementation
Obtain materials
Set up MediaPipe and Docker workflow
Set up Arduino IDE and heart rate sensor workflow
Set up UI wireframe and application flow
Work on computer vision and pose detection algorithms
Work on heart rate sensing and calculations
Work on UI implementation
Test alpha prototype
Create and finalize appearance prototype
Proof of Concept Presentation


Plan Duration
% Not Complete
% Complete
ACTIVITY
WEEK
14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
Beta Prototype Implementation
Switch to the NVIDIA Jetson TX2 for main system
Switch to Arduino FLORA for sensor system
Add SpO2 measurements for sensor system
Integrate Bluetooth and batteries for sensor system
Refine UI and application flow
Refine heart rate and SpO2 algorithms
Refine pose estimation detection algorithms
Create enclosures for the different systems
Test beta prototype

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Team and Self-reflection

TechFit Team

ANDREW CHEN

Chief Operating Officer (COO)

Mechanical Design Lead

LUKE GAIR

Chief Executive Officer (CEO)

Testing Lead

HAMLET JIANG SU

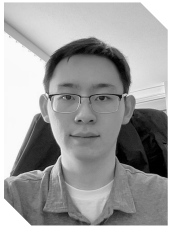
Chief Technology Officer (CTO)

Hardware Lead

LANDON REEVES

Chief Communications Officer (CCO)

Product Manager



ALLAN TSAI

Chief Analytics Officer (CAO)

Computer Vision Lead

JOHNSTON YANG

Chief Financial Officer (CFO)

UI/UX Lead

Team Dynamics

Meetings

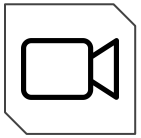
- Meetings mostly remote: difficult to organize and keep on track
- Will transition to in-person meeting whenever possible

Development Processes

- Development has been fragmented due to availability of hardware
  - One or two people working on a major component of the system
- Will create more dedicated in-person development times

Time Management

- Managing tasks have been difficult due to everyone's unique schedules
- Will be improved by having more productive meetings and keeping a calendar of everyone's availability



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Demo

Testing

Acceptance Test Plan

Acceptance Test Plan			
Purpose	**Test Description**	**Acceptance Criteria**	**Notes**
Camera output image valid up to 2 meters distance.	Take pictures of an object at varying distances.	The camera must produce a clear image of the target.	Camera provides clear image of subject, tested on a variety of webcams.
Validate heart rate sensor system.	Increase a person's heart rate through stimulation. Test the system on one arm, compare against third party sensors on the other arm.	The system's sensors must match other sensors within a range of 5 beats per minute.	Alpha heart rate sensor within 5 BPM of other third party sensors.
Validate microcontroller is able to detect if the user has improper form.	User does an exercise with improper form and have the microcontroller detect if the user has improper form	The microcontroller must be able to detect if the user has the incorrect form. Verify output results from the system with Kinesiology.	Basic functionality of incorrect pose identification in place
Validate microcontroller is able to detect if the user has proper form.	User does an exercise with proper form and have the microcontroller detect if the user has proper form.	The microcontroller must be able to detect if the user has the correct form. Verify output results from the system with Kinesiology.	Microcontroller can correctly identify workout exercise, accuracy yet to be verified.
Validate wireless connection between heart rate sensor and microcontroller.	Connect sensor to microcontroller.	The proper heart rate must be shown on the display while the sensor is connected.	Heart rate BPM actively shown on display while connected and worn.
Validate battery life of heart rate sensors.	Leave on heart rate sensor and measure how accurate the heart rate measurement is.	Use the heart rate system for 3 hours straight and compare the measurement from when the user started to the measurement after 3 hours.	Alpha heart rate sensor hardware last for over three hours, however battery and design still subject to change.
Validate system can output audio.	The system will output audio depending on whether the user has done the exercise correctly or incorrectly.	User does exercise incorrectly and must hear the audio cue.	Device can sucsessfully output audio cue for incorrect form
Validate heart rate sensors durability.	Drop the heart rate sensor, varying heights, 250cm maximum. Compare the heart rate to a third party sensor to determine the accuracy.	The heart rate sensor can survive a drop from up to 250cm. The heart rate sensor is within the third party heart rate sensor by 5 beats per minute.	Heart rate sensor functions correctly and within margin of error after drop test.

Testing

Software Testing

Software Test Plan

Test Number	Test Description	Expected Outcome	Pass/Fail	Actual Outcome
A.2.1	After pressing the power button, Guardian Sight™ will power on.	Guardian Sight™ will turn on within 5 seconds.	PASS	Gaurdian Sight starts within a second of running the application.
A.2.2	The initial screen after turning on Guardian Sight™ will show the main page.	Guardian Sight™ will show the user the screen with Main Menu.	PASS	Main Menu successfully displayed when Guardian Sight is first started.
A.2.3	When performing exercises on Guardian Sight™, the display will show the appropriate heartbeat measurement.	Guardian Sight will show the correct heartbeat measurement on the display when the user is using Guardian Sight™.	PASS	Heartbeat displayed correctly and verified with third party sensor.
A.2.4	On the initial screen, Guardian Sight™ will overlay the pose with the landmarks from MediaPipe.	Guardian Sight™ will overlay the landmarks with the pose on the screen.	Tentative PASS	Pose landmarks are visible on person, proper overlay not implemented at this time.
A.2.5	When the user is using Guardian Sight™, the correct angles of the elbows are shown during exercises.	The angle of the elbows will be shown on the display. We can confirm the angle by using a protractor.	Tentative PASS	Angles are measured correctly but are not shown on screen, program is capable of printing the angle on the terminal.
A.2.6	When the user is using Guardian Sight™, the correct angles of the knees are shown during exercises.	The angle of the knees will be shown on the display. We can confirm the angle using a protractor.	Tentative PASS	Angles are measured correctly but are not shown on screen at this time, verified by looking up in SW. Camera angle needs to be considered in order to capture whole body.

Testing

Hardware Testing

Hardware Test Plan

Test Number	Test Description	Expected Outcome	Pass/Fail	Actual Outcome
A.3.1	The MAX30102 sensor shall measure the heartbeat correctly while the user is using Guardian Sight™.	The MAX30102 sensor shows the correct heartbeat by comparing it to a third party heartbeat sensor.	PASS	The heart rate shows the correct heart rate within 5 BPM when used on the fingertip. Verified with third party sensor.
A.3.2	The e-CAM30_CUTX1 camera shall display the correct output of the user when Guardian Sight™ is in use.	The user shall see themselves when they are using Guardian Sight™ using the camera.	PASS	Camera output is correctly displayed but will need to re-verify once the camera is finalized in beta phase.
A.3.3	The e-CAM30_CUTX1 camera shall be able to detect the user with a luminance of 0.5 lux.	The microcontroller shall be able to detect the user and provide the correct posture.	N/A	Test not conducted as camera is not yet finalized in alpha prototype.
A.3.4	When users are wearing the MAX30102 sensor, make sure that the microcontroller is still connected to the MAX30102 sensor.	The MAX30102 sensor is connected to the microcontroller from 2 metres away from the microcontroller.	N/A	Task deferred to beta.
A.3.6	When using the MAX30102 sensor, test the battery life of the sensor.	Have the MAX30102 sensor run for a maximum of 3 hours. Verify the heart rate to a third party sensor.	Tentative PASS	Device runs for over three hours while maintaining functionality, alpha prototype however not final hardware design.

Testing

Mechanical Testing

Mechanical Test Plan				
Test Number	**Test Description**	**Expected Outcome**	**Pass/Fail**	**Actual Outcome**
A.4.1	When users are wearing the MAX30102 sensor, drop the sensor to ensure that the sensor is durable.	Drop the MAX30102 sensor from a maximum of 150cm to test durability and verify the heart rate to a third party sensor.	PASS	The device sensor was dropped from recommended height and remained functional.
A.3.2	Adjustability of the MAX30102 wearable sensor wrist strap.	The MAX30102 sensor is able to fit on the wrists of people of different sizes.	N/A	Task deferred to beta.
A.3.3	Durability of the main enclosure.	Drop the main enclosure from a height of 75cm to test durability and verify that the electronics function correctly.	N/A	Test to be removed.

Testing

Analytical Useability Testing

Useability Testing				
Test Number	**Test Description**	**Expected Outcome**	**Pass/Fail**	**Actual Outcome**
B.5.1	Power on the system and proceed to calibrate the system to basic functionality.	Setup and calibration to be completed in 25 minutes or less.	N/A	Calibration deferred to beta phase.
B.5.2	Power on the system, and wait for the system to arrive at main functionality.	Main functionality reached in 1 minute or less.	PASS	Main program is functional within a couple seconds. Test to be re-done for beta phase on Jetson board.
B.5.3	Traverse menus and any infographics.	Interface does not significantly lag.	PASS	Interface operates as expected.
B.5.4	Traverse menus and any infographics.	Interface does not experience any significant bugs or crashes.	PASS	Existing menus and infographics operate as expected.
B.5.5	Operate camera under normal conditions, disconnect camera.	The device should display a black screen on the output device. After 1 minute with no signal, shutdown.	N/A	Deferred to beta phase.
B.5.6	Traverse menus and any infographics and attempt to break the system under normal use conditions.	Unexpected design or coding flaws revealed.	TENTATIVE PASS	Total system menu and infographics not complete. Existing work passes, but there exists some scaling issues.

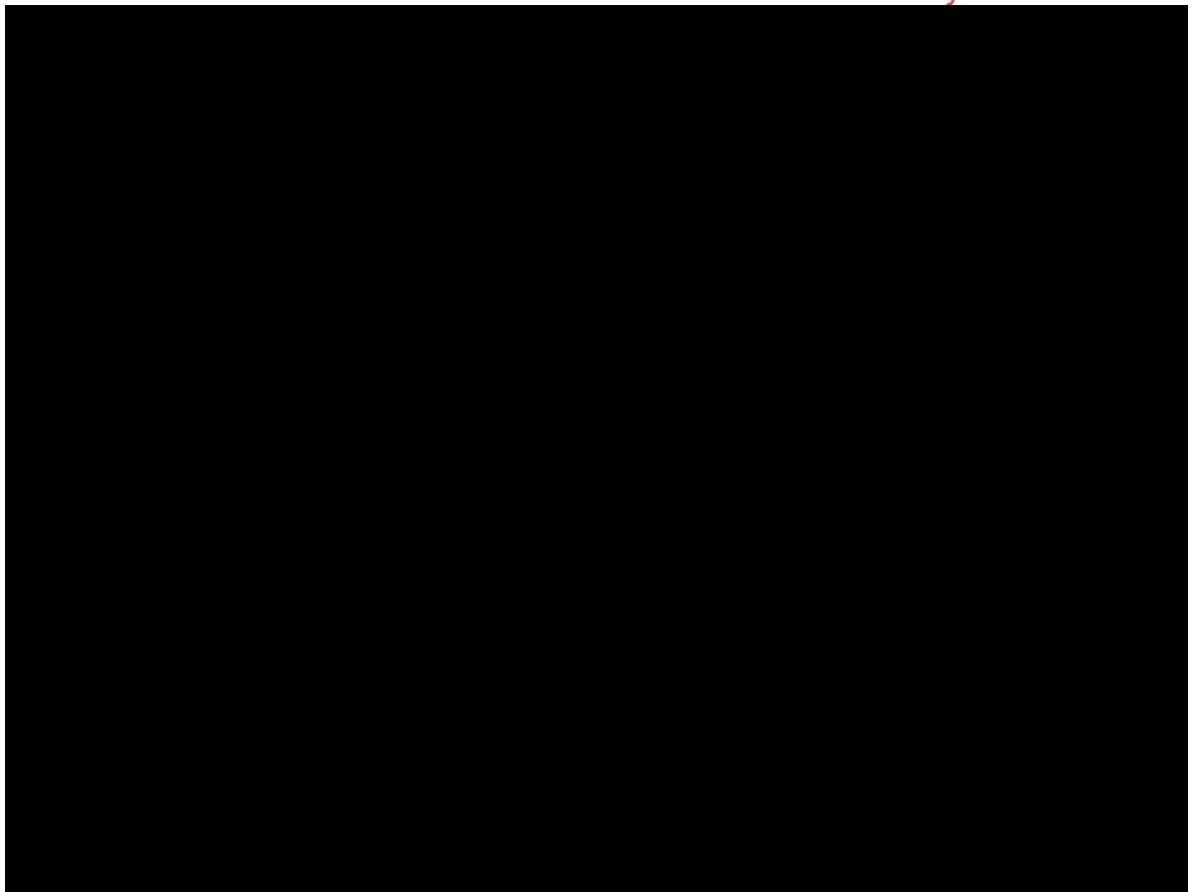
Testing

Empirical Useability Testing

Empirical Useability Testing				
Test Number	**End User Activity**	**Questionnaire**	**Expected Outcome**	**Pass/Fail**
B.5.7	Perform an exercise routine with Guardian Sight™ for 10-15 minutes	Was it clear that Guardian Sight™ was active and functioning correctly during the routine	Guardian Sight™ displays accurate real time pose analysis on the display	N/A
		How accurate was Guardian Sight™ pose estimation	Software gives accurate pose estimation and feedback	N/A
		How easy was it to engage and disengage Guardian Sight™ before and after the routine	Routines should start and stop when the user tells the system through the use of a UI button	N/A
B.5.8	Use Guardian Sight™ with the heart rate monitor	How does the heart rate monitor affect your ability when its on your wrist	The heart rate monitor does not inhibit the user	N/A
		How heavy does the heart rate monitor feel on your wrist while using Guardian Sight™	The heart rate monitor does not induce fatigue or discomfort in the user	N/A
		Does the heart rate monitor pair easily with the main Guardian Sight™ device	The Bluetooth connection does not introduce unnecessary delay during the Guardian Sight™ pairing process	N/A
B.5.9	Use Guardian Sight™ application	Was Guardian Sight™'s design intuitive and easy to navigate	Interface and button placements do not inhibit the user	N/A
		Were Guardian Sight™'s menus and buttons easy to locate and select	Interface and button placements are easily visible and selectable	N/A
		Was the Guardian Sight™ set up process easy to perform and calibrate	Guardian Sight™ set-up and calibration process will be easy and intuitive through the use of infographics in combination with brief tutorials	N/A

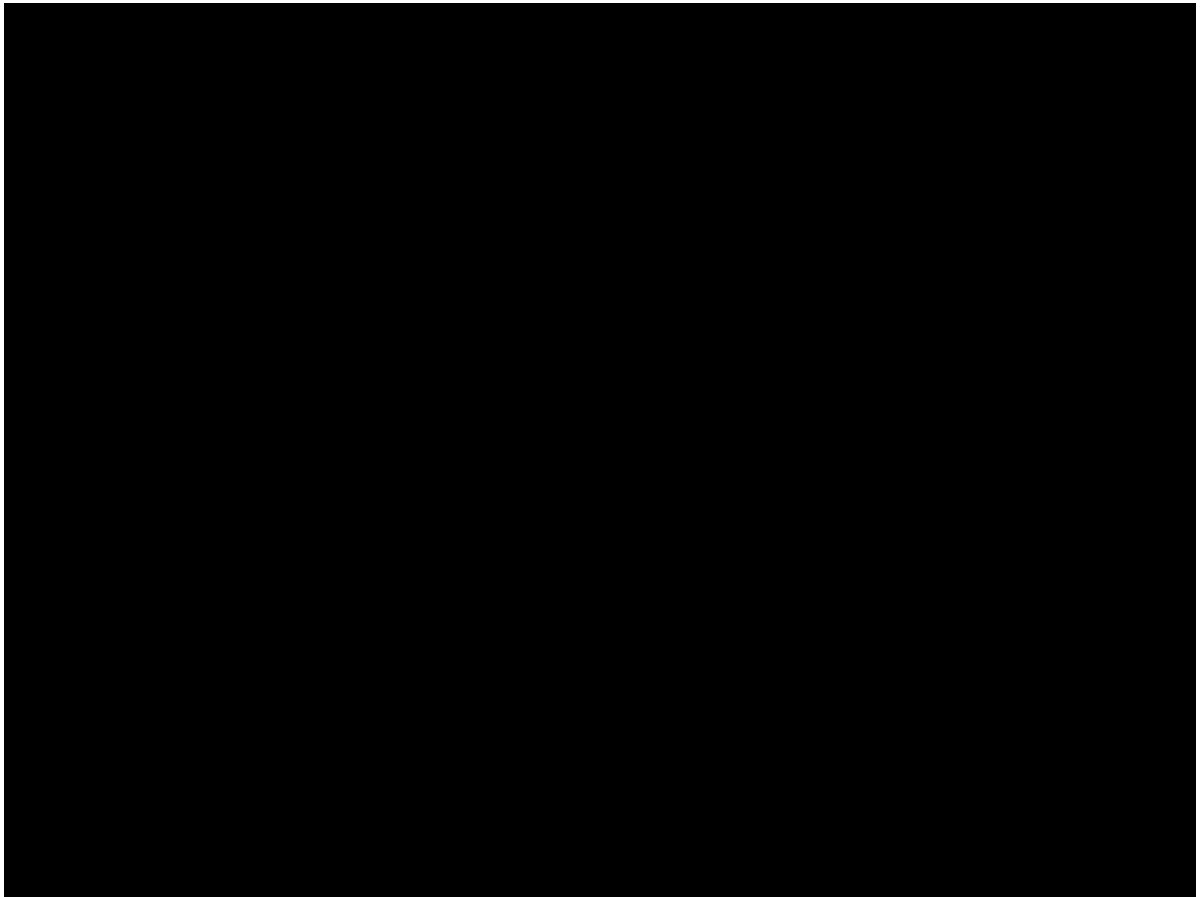
Concept

Audible Feedback & Heart Rate Functionality



Concept

Use Case & User Interface



Feedback Received

Hardware

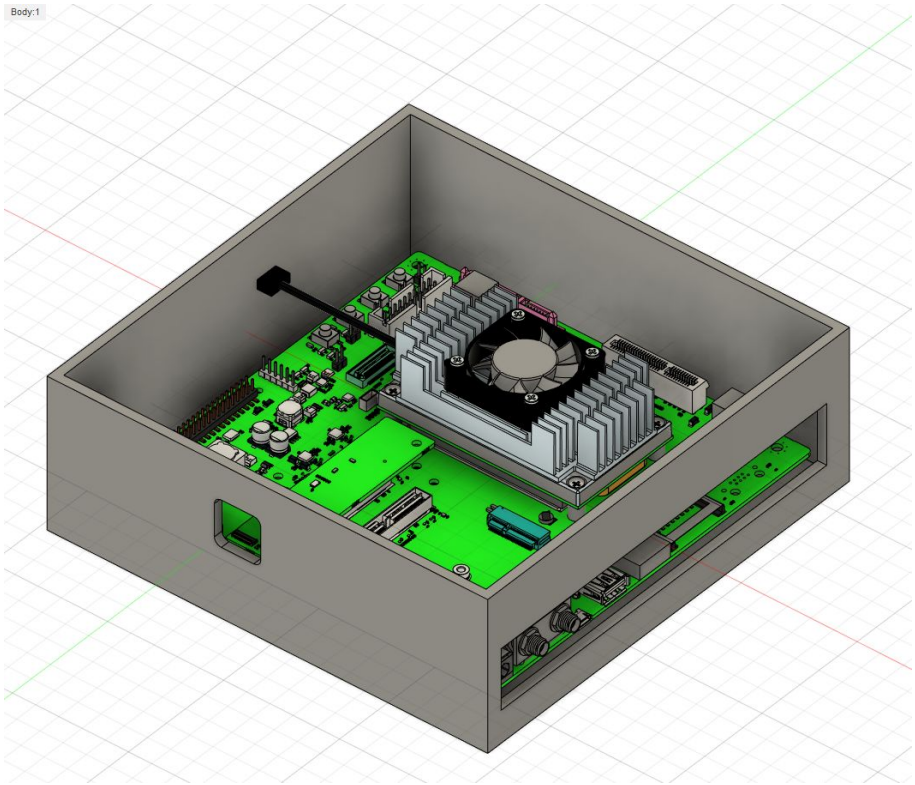
- Incorporating physiological measurements *(Andrew Rawicz)*
  - Using heart rate sensor to obtain heart rate and SpO2 readings
- Using more powerful hardware *(Craig Scratchley)*
  - Moving to Jetson TX2 in the beta phase for increased performance
- Using multi-camera setup *(Timothy Yu, Craig Scratchley)*
  - Moving to dual camera setup for beta phase
- Heart rate mounting location and its effectiveness *(Craig Scratchley)*
  - Testing with current sensor is more optimal on fingertips, obtaining a sensor with green LEDs would increase effectiveness when worn on the wrist

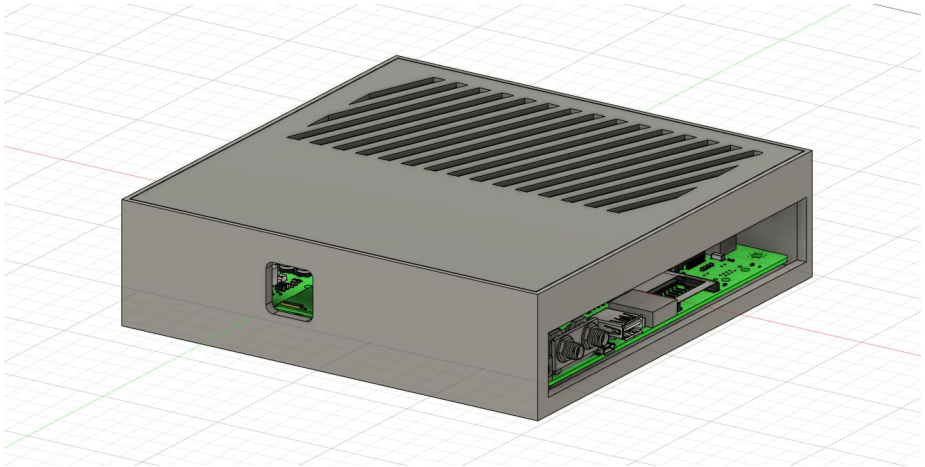
Software

- Calibrating camera(s) & user's optimal position *(Timothy Yu, Srishti Yadav)*
  - Using software to calibrate cameras and ensure that they can properly see the user

Appearance

Look and feel



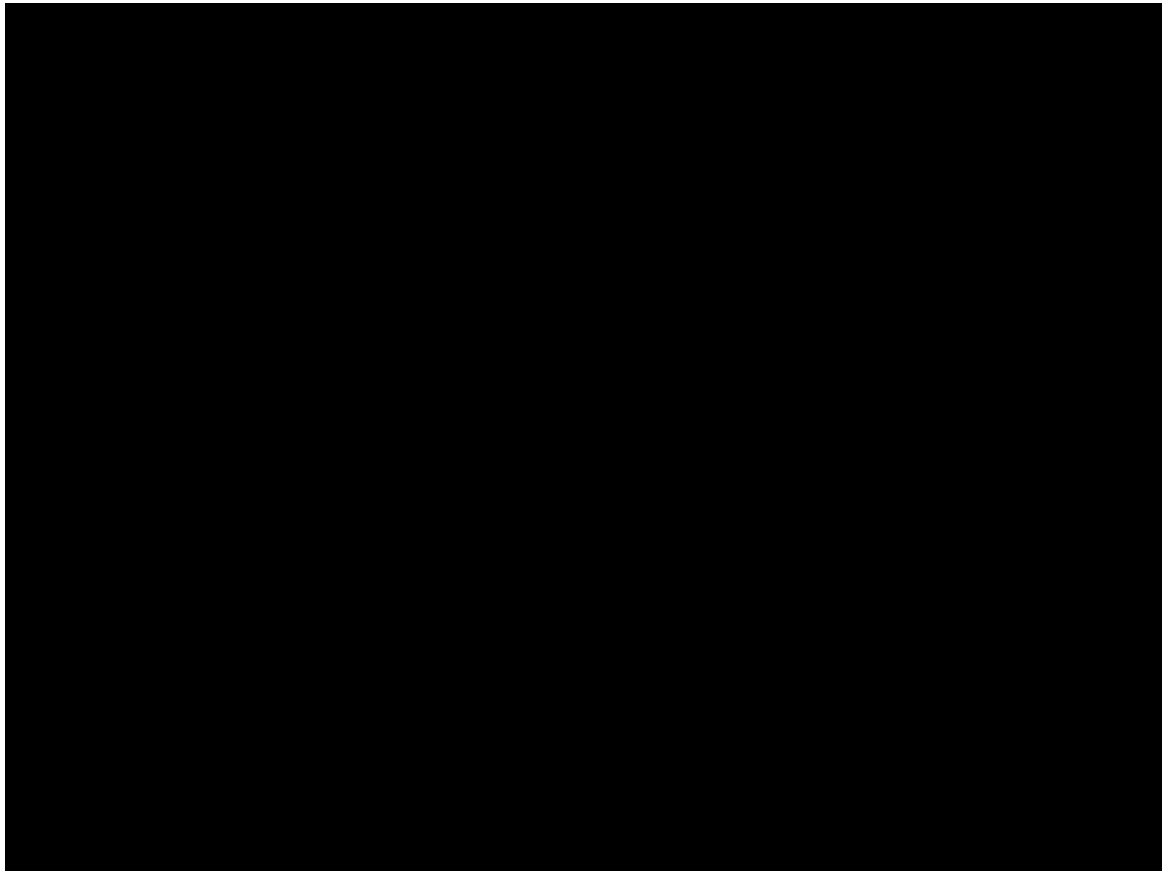


Appearance

Look and feel

Technical Design

Exploration & Research



07

REFERENCES

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QUESTIONS?