FAMU-FSU College of Engineering

Team 523:
Mixed Reality Wearable for 3D Body Tracking

Team Introductions

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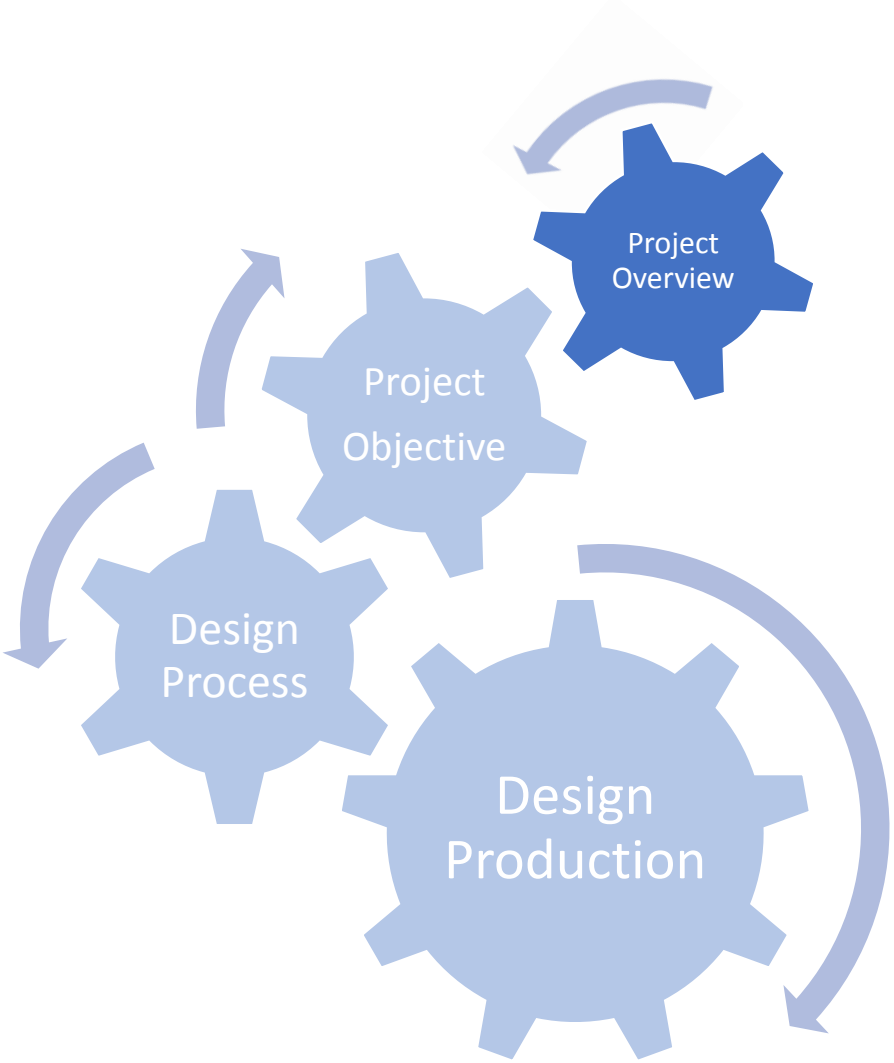
Project Overview



Project Overview

- Anthropometry is the measurement of the size and proportions of the human body

- Anthropometric scans typically output a 3D figure that can be used for body measurements and for Engineering design

Figure 1: 3D cad image of different hand views

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Project Overview (cont.)

- Currently, scan participants are given verbal instructions on where and how to position and orient themselves for an anthropometric scan

- This process is tedious and time consuming for the scan technician

Figure 2: Example of 3D scanning

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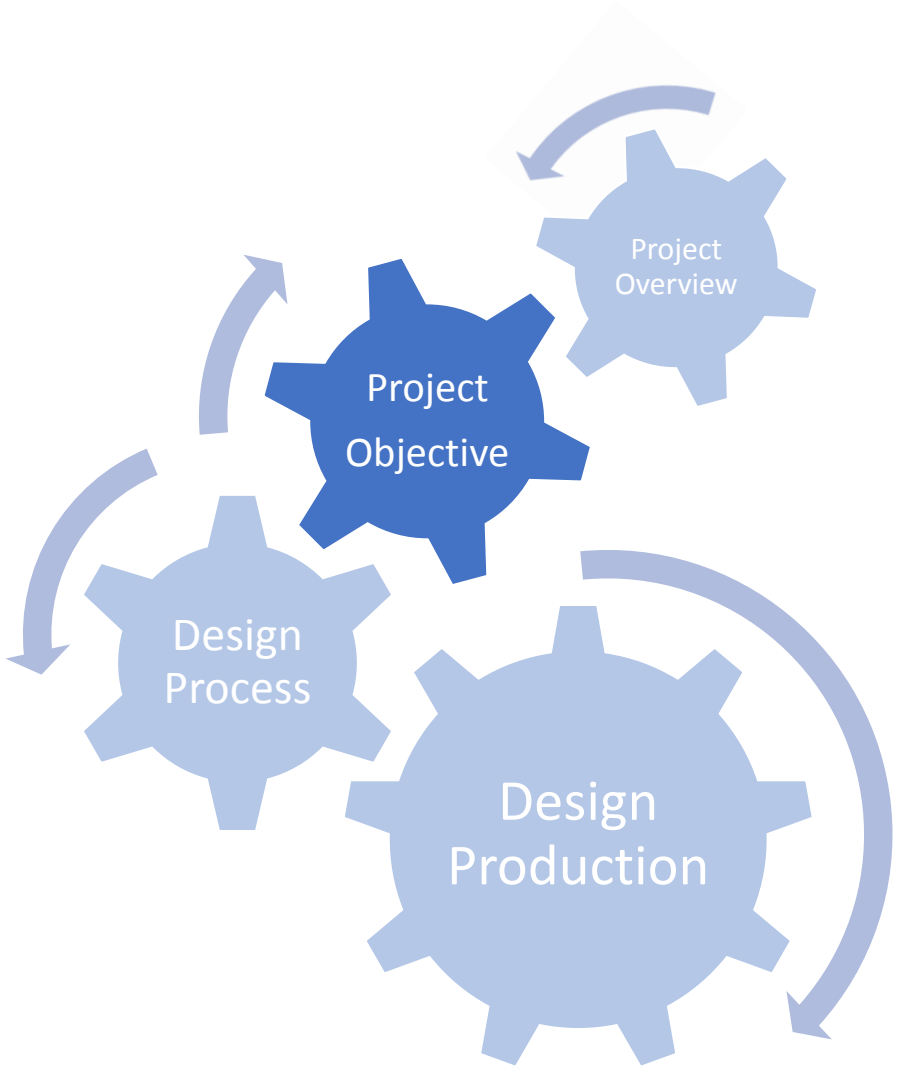
Project Objective



Objective

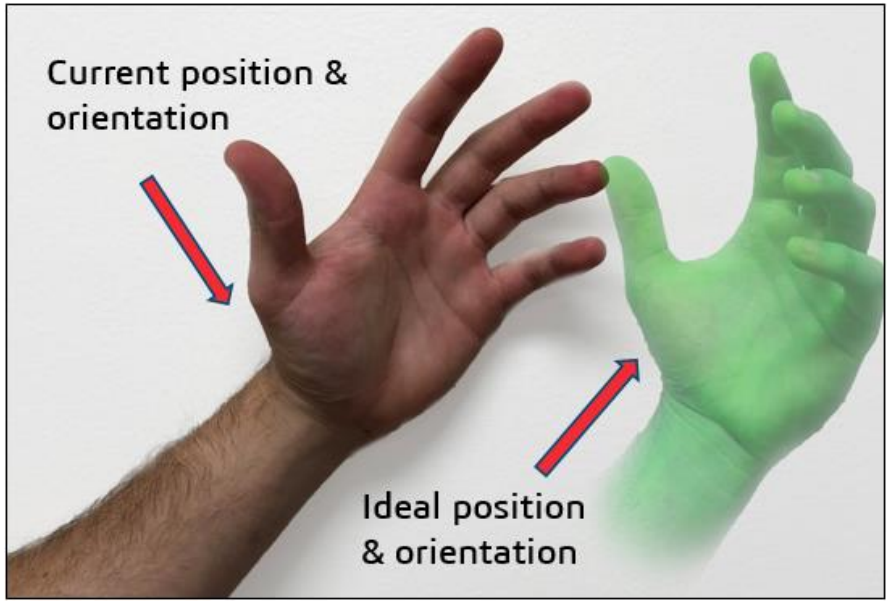


Figure 3: Example of a visualization

The objective of this project is to provide a user interface for a participant in a 3D body scan environment in order to shorten the duration of the overall process by reducing the amount of instructions given by the scan technician to position/orient the participant.

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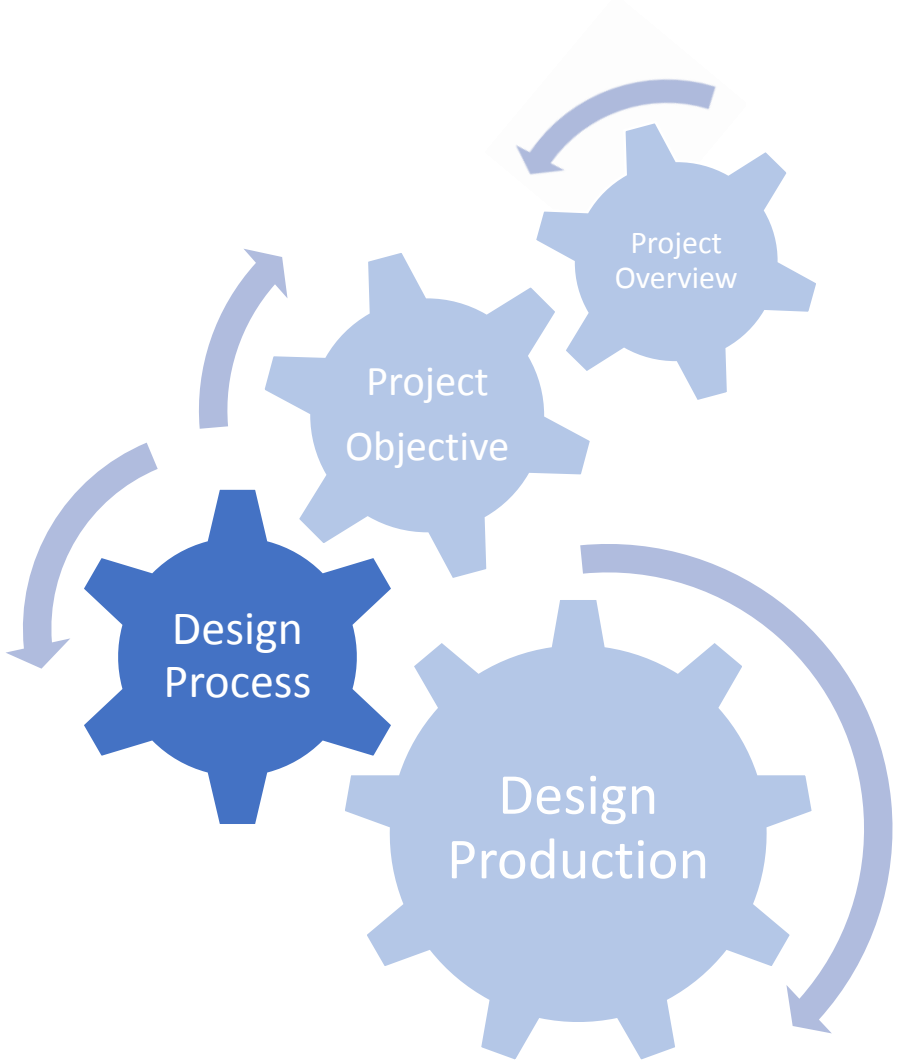
Design Process



Customer Needs

Table 1: Customer needs table

#	CUSTOMER STATEMENTS	INTEPRETED NEED
1	It would be beneficial if the device could indicate to the user when the “ideal scan location” is filled	If possible, the device will be able to notify the user to hold the current orientation of the participant’s head/hand
2	The device must not interfere with the scanner	The device must cease operating upon successful fulfillment of the ideal pose
3	Project something into space for the participant to aim their head/hand	The device must indicate to the participant the ideal location and orientation for accurate scans
4	The device must be a stand-alone system	The device must complete its intended function without the assistance of other devices
5	The device must be able to be powered remotely	The device requires a method for power control
6	The device must not create any safety hazards	The device must minimally impact the participant

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Functional Decomp.

- Functional Decomposition acted as a funnel for the ideation process
- From top to bottom, the boxes become more and more specific

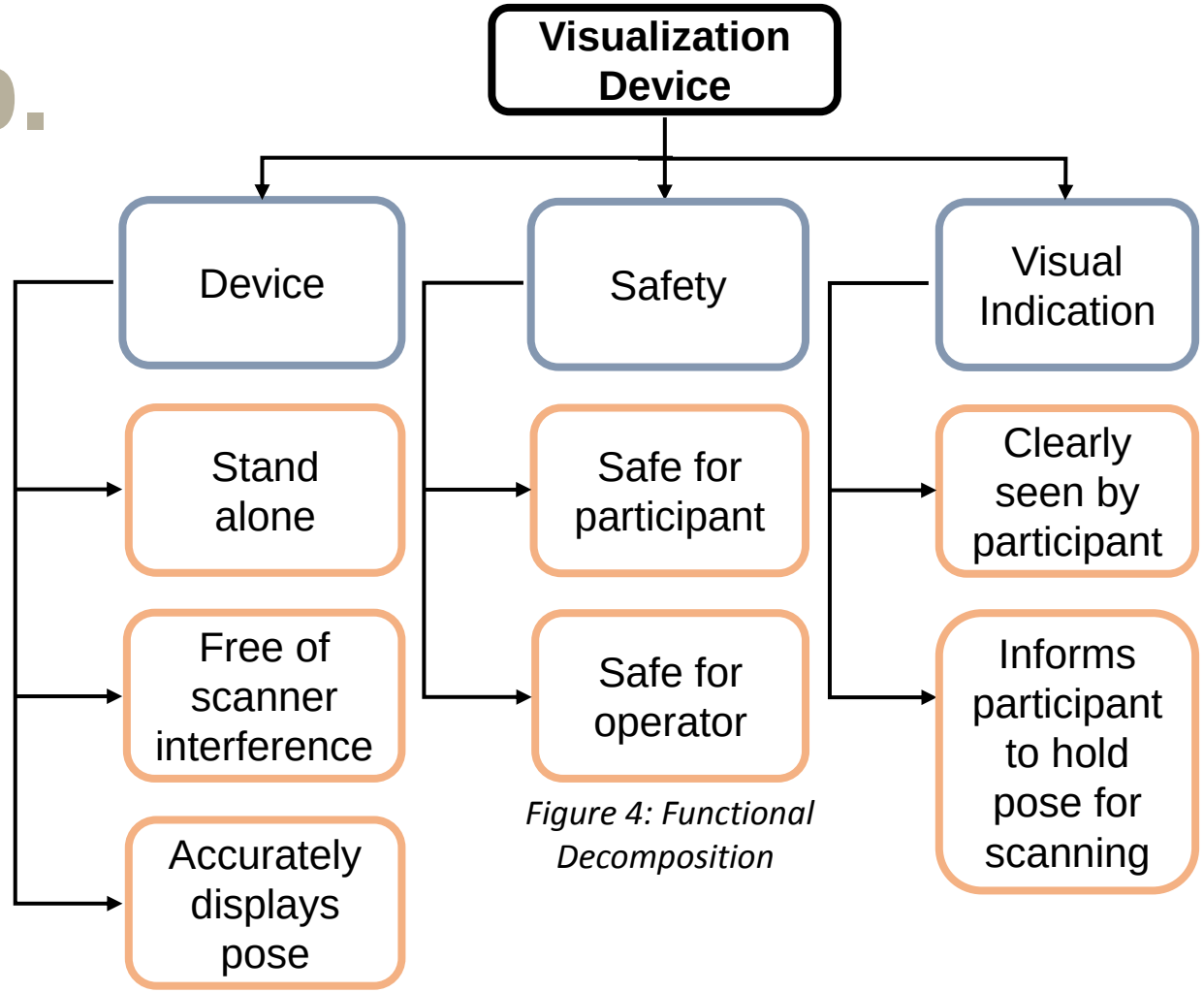

Figure 4: Functional Decomposition

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Targets & Metrics

- Functional decomposition led to a large set of targets & metrics (T&M) that was determined to be necessary for a successful design

- These are the most important T&M from the original list
  - They satisfy industry/governmental standards

Table 2: Customer needs table

Mixed Reality Wearable For Body Tracking			
Main Functions	Sub-Functions	Metrics	Targets
Device	Self-Contained	Dimensions (in)	≤ 30 x 30 x 30
		Weight (lbs)	≤ 25
	Free of Interfernece	Distance From Scanner (m)	~ 1
Safety	Safe For Participant	Brightness Level (Lumens)	≤ 200
Visual Indication	Signals Participant to Hold Position	Time in designated location and Orientation (Seconds)	< 30

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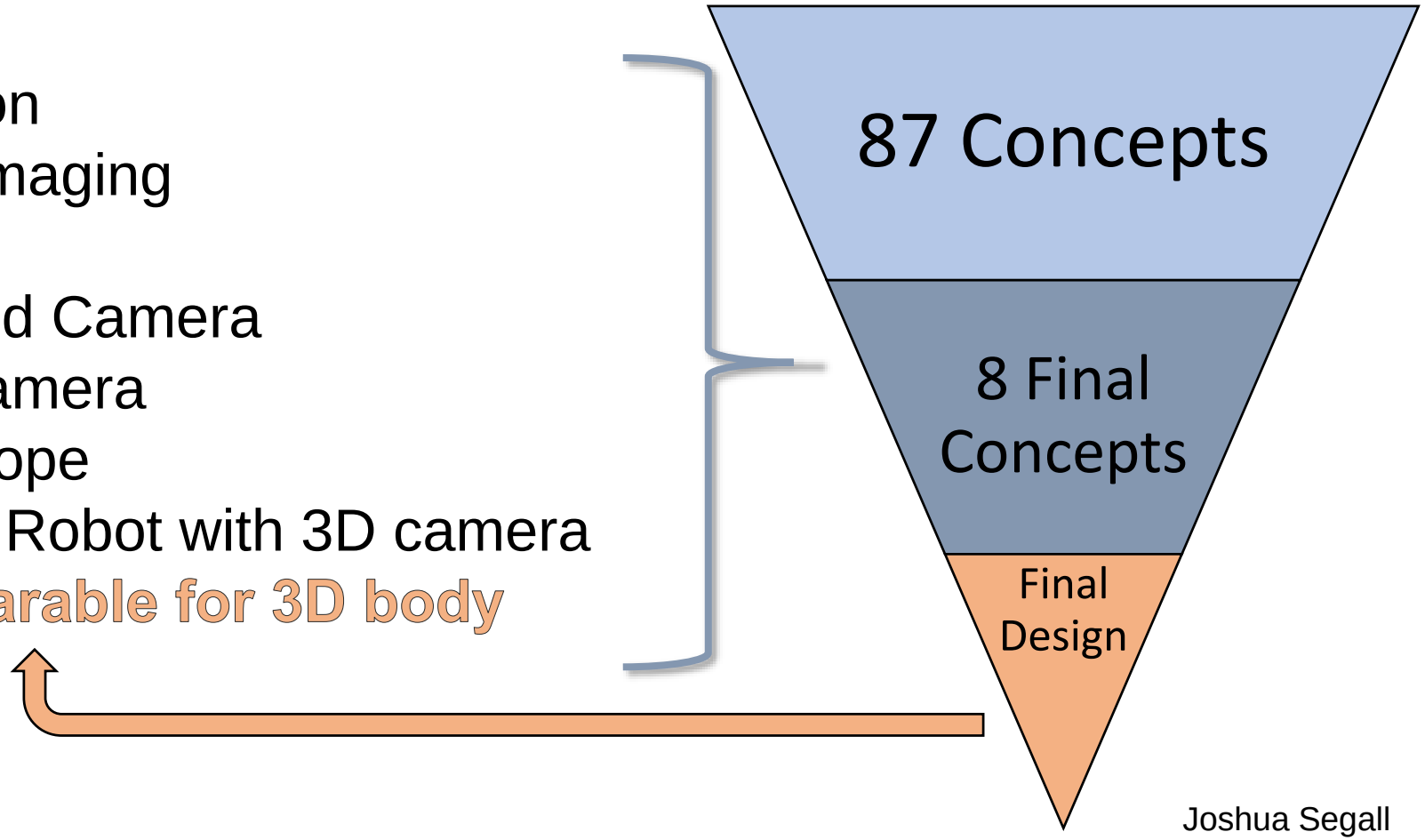
Concept Generation: Overall Design

1. AR and Leap Motion
2. Mirage/Schlieren Imaging
3. BMW Holo-Touch
4. 3D Image Live Feed Camera
5. Adafruit with 3D Camera
6. Illumination Mirascope
7. Semi-Autonomous Robot with 3D camera
8. **Mixed Reality Wearable for 3D body tracking**



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Concept Selection: Overall Design

- AHP shows the results of our re-calculated concept selection
- Final selection found that the Mixed Reality Wearable was in fact the best selection

Table 3: Analytical Hierarchy Process

SELECTION:	Mixed Reality Wearable	Adafruit w/ 3D Camera	Semi-Automatis Robot w/ 3D Camera
Design Volume	0.64	0.36	0.10
Weight	0.45	0.10	0.45
Distance from Scanner	0.45	0.23	0.22
Tolerance of Depth Measurement	0.57	0.15	0.29
Brightness Level/Intesity Level	0.60	0.20	0.20
Operationg Temperature:	0.70	0.10	0.10
Resolution	0.60	0.20	0.20
Operating Time	0.43	0.36	0.30
SUM	4.44	1.70	1.86

Table 4: Final Selection

FINAL CONCEPT WEIGHTED	
Mixed Reality Wearable	0.56
Adafruit w/ 3D Camera	0.21
Semi-Autonomous Robot w/ 3D Camera	0.23

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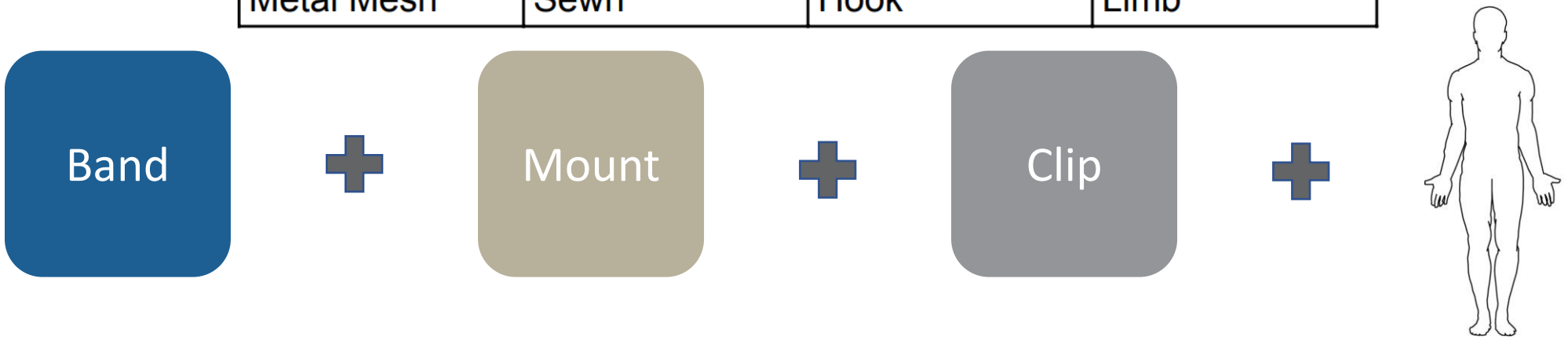
Concept Generation: Wearable

Table 5: Various Wearable concepts

Bands	AprilTag Mount	Clip Style	Body Part (1-4)
Velcro	Magnets	Traditonal	Hand
Elastic	Clip	Dove tail	Head
Fabric	Addhesive	Magnetic	Wrist
Metal Mesh	Sewn	Hook	Limb



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Concept Selection: Wearable Design

Table 6: Wearable Concept Selection

		Scale (1,3,6)											
Needs:	Weight:	Idea 1	I 1	Idea 2	I 2	Idea 3	I 3	Idea 4	I 4	Idea 5	I 5	Idea 6	I 6
Multiple Tags	6	6	36	6	36	3	18	6	36	3	18	6	36
Easy Removal	12	6	72	1	12	3	36	6	72	1	12	6	72
Consistant Placement	10	6	60	3	30	3	30	6	60	6	60	3	30
Aesthetics	2	3	6	3	6	9	18	1	2	3	6	6	12
Versatile Placement	4	6	24	1	4	3	12	6	24	3	12	3	12
Easy to put on/tighten	8	6	48	3	24	3	24	6	48	6	48	3	24
	Totals	246		112		138		242		156		186	
	Rank	1		6		5		2		4		3	

Figure 5: 3D printed hand with wearable attached

Winner:

Elastic Band with AprilTags Clipping on, with Dove Tail release

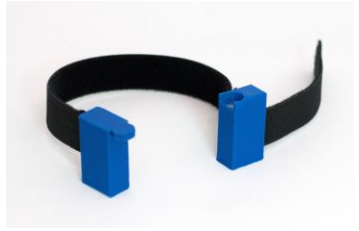

Figure 6: 3D printed wearable

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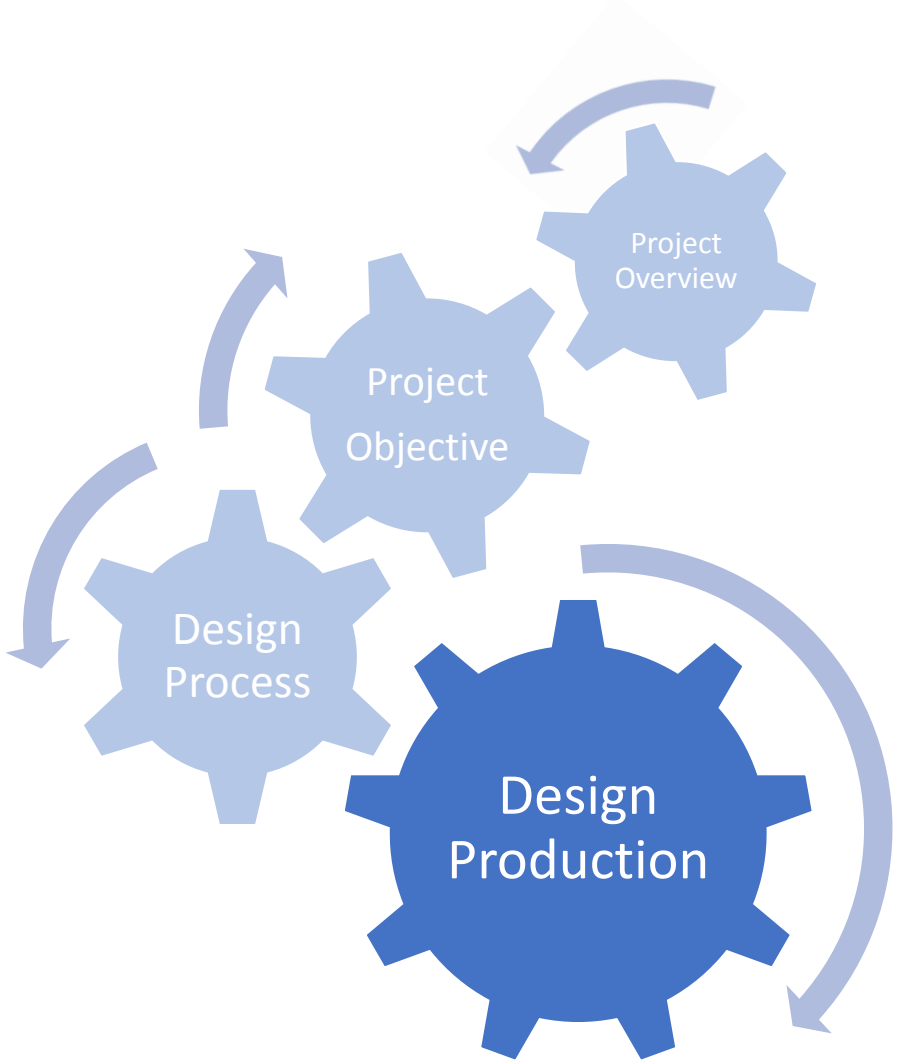
Design Production



Design Components

1) ZED Mini
   - 3D Camera
2) Wearable
   - Apriltag(s) attach to it
3) NVIDIA Jetson TX2 – Computer
   - Tracks Apriltag with Robot Operating System (ROS)
4) Steady State Monitor
   - Information is displayed through Rviz/Gazebo (virtual worlds)

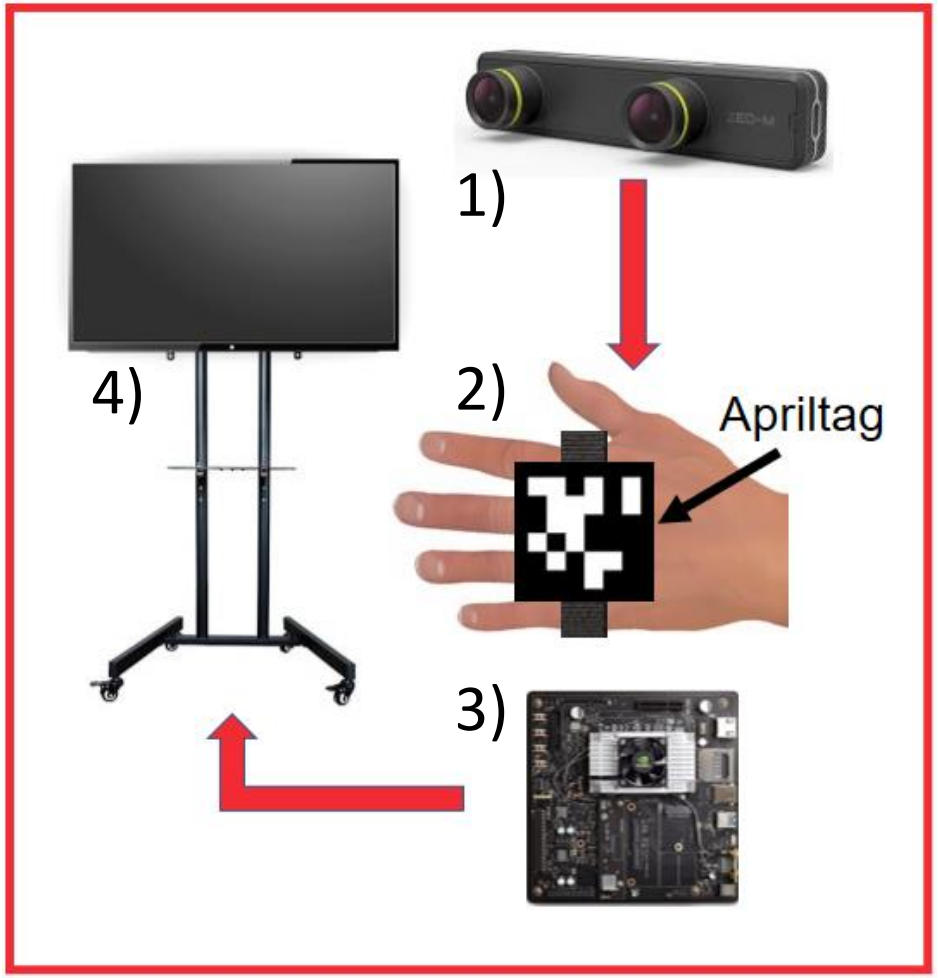


Figure 7: Overall design setup

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Progress: ROS

- Can track/display the position & the orientation of the ZED Mini within Rviz

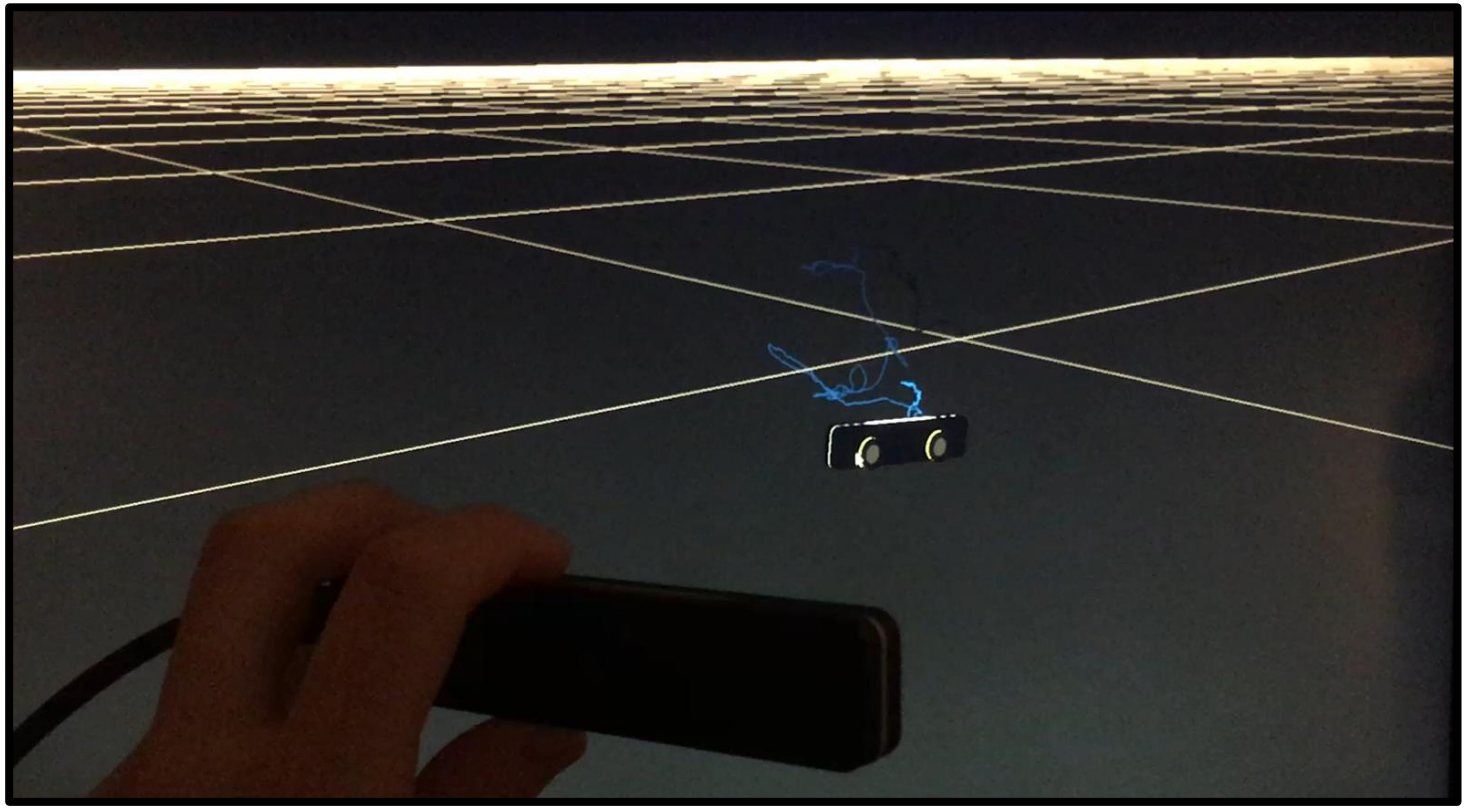

Figure 8: Video of the ZED Mini's pose being tracked in Rviz

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Progress: ROS (Cont.)

- Need to finalize 2 input parameters in order to use the “AprilTags2” node within ROS
  - Nodes are executables that communicate with other nodes within ROS

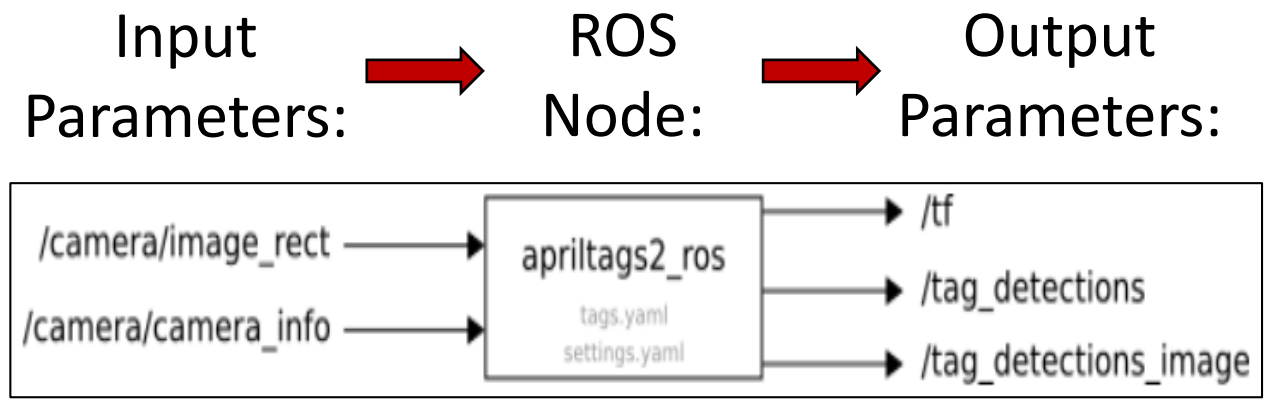

Figure 9: Inputs and outputs of the “apriltags2_ros” node

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Wearable Iterations

Figure 10: Apple Watch concept

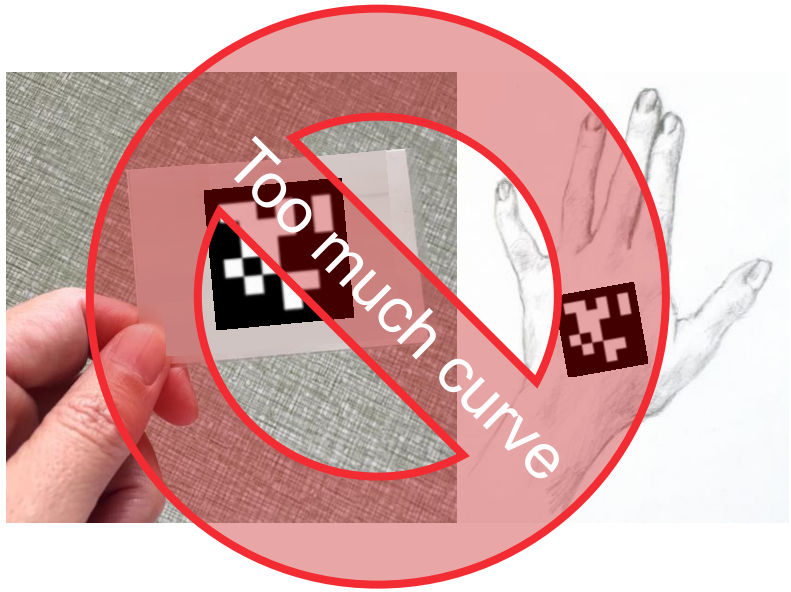

Figure 11: Temporary tattoo concept

Figure 12: Magnetic bracelet concept

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Future Testing

Future Testing

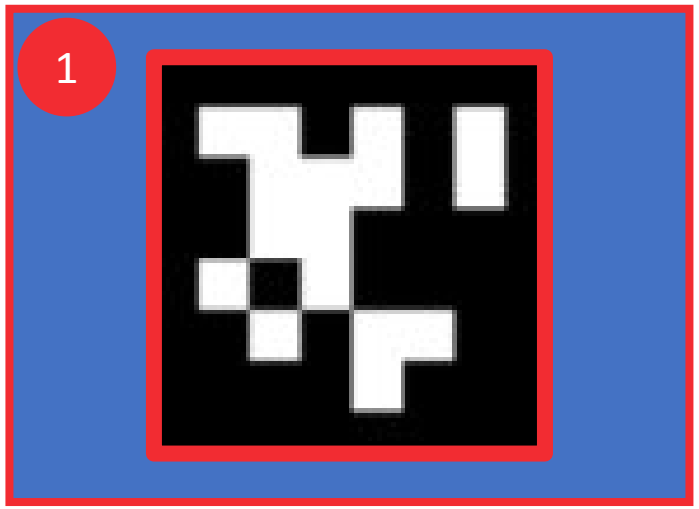

Figure 13: AprilTag pose tracking

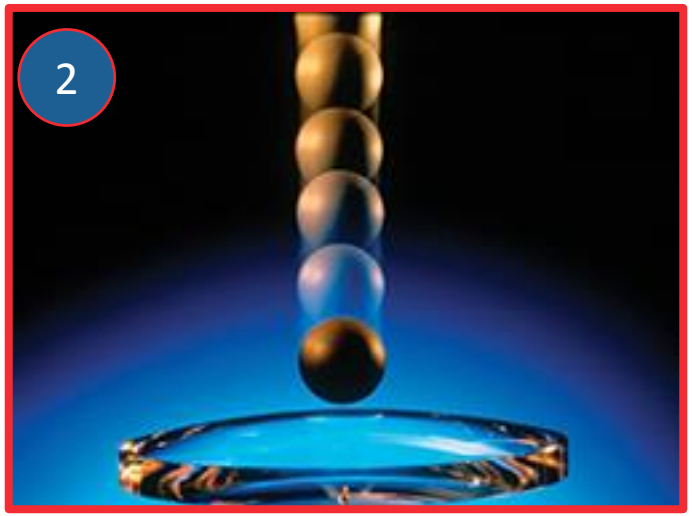

Figure 14: Drop and impact testing

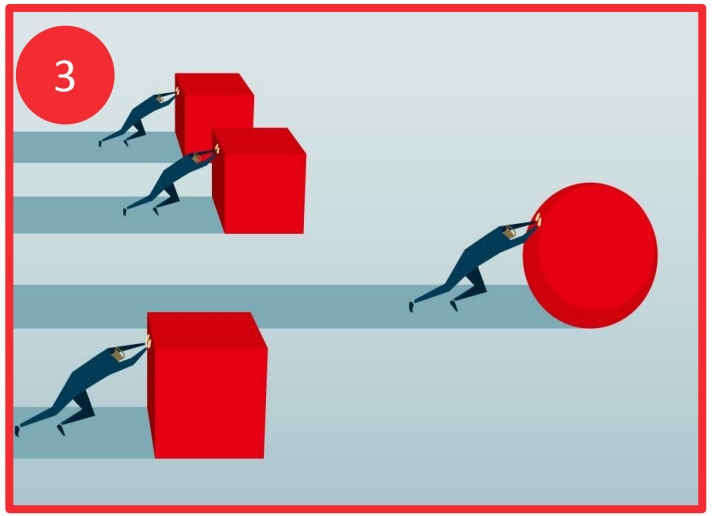

Figure 15: Increasing efficiency

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Main Takeaways

Most Important Points

1. Can currently track/display the pose of the ZED Mini in Rviz
2. Have a functional/versatile wearable design
3. Need to finalize the 2 input parameters for the ROS node
4. Need to order a mobile monitor adjustable mount (~$56)
5. Need to attribute a 3D image to an AprilTag within Rviz or Gazebo
6. Need to place a stationary 3D image in an ideal pose within Rviz or Gazebo

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Lessons Learned

1. Everything that can go wrong…
2. Continue to think about splitting up workloads evenly so that nobody has to be working on the project until 4:00am
    - Quality of work goes down at this time of hour
3. Transforming multiple moving 3D frames into a camera frame is incredibly challenging
4. Wearable design needs to have a balance between satisfying the problem as well as sparking interest in the participant/customer

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References

1. Garrido-Jurado, S., Muñoz-Salinas, R., Madrid-Cuevas, F., & Marín-Jiménez, M. (2014). "Automatic generation and detection of highly reliable fiducial markers under occlusion," *Pattern Recognition,47*(6), 2280-2292. doi:10.1016/j.patcog.2014.01.005
2. Malyuta, D. (2017). "Navigation, Control and Mission Logic for Quadrotor Full-cycle Autonomy," Master thesis, Jet Propulsion Laboratory, 4800 Oak Grove Drive, Pasadena, CA 91109, USA.
3. Romero-Ramirez, F. J., Muñoz-Salinas, R., & Medina-Carnicer, R. (2018). "Speeded up detection of squared fiducial markers," *Image and Vision Computing,76*, 38-47. doi:10.1016/j.imavis.2018.05.004
4. Wang, J. & Olson, E. (2016). "AprilTag 2: Efficient and robust fiducial detection," in *Proceedings of the IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS).*

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Questions?

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Backup Slides

Functional Decomp Backup

Targets and Metrics Backup

Targets and Metrics

Table #:Full Targets and Metrics Table

Ideal Location Indicator For Anthropometric Scanners			
Main Function	Sub-Functions	Metrics	Targets
Device	Self-Contained	Dimensions (in)	≤ 30 x 30 x 30
		*Weight (lb.)	≤ 25
	Free of Scanner Interference	*Distance from Scanner (m)	~ 1
	Accurately displays location and orientation	*Tolerance of depth Measurement (cm)	≤ 4
Safety	Safe for participant	*Brightness level (Lumen)	< 200
		Intensity level (Lux)	< 200
	Safe for operator	Operating temperature (°F)	< 150
Visual Indication	Clearly seen by participant	Perceived Brightness level (Lux)	100 - 200
		Resolution (Pixel)	≥ 480
	Signals participant to hold position	*Time in designated Location & Orientation (Second)	< 30
Power	Power supply	Power consumption (Watts)	< 11
		Operating voltage (Volts)	≤ 55

Targets and Metrics: Device

- The device must be self contained
- Does not interfere with the scanner
- Accurately displays where the participant should be and how they should be orientated

Table #: Targets and Metrics Table Row 2

Ideal Location Indicator For Anthropometric Scanners			
Main Function	Sub-Functions	Metrics	Targets
Device	Self-Contained	Dimensions (in)	≤ 30 x 30 x 30
		*Weight (lb.)	≤ 25
	Free of Scanner Interference	*Distance from Scanner (m)	~ 1
	Accurately displays location and orientation	*Tolerance of depth Measurement (cm)	≤ 4

Targets and Metrics: Safety

- The device should be safe for the participant and the operator

Table #: Targets and Metrics Table Row 2

Ideal Location Indicator For Anthropometric Scanners			
Main Function	Sub-Functions	Metrics	Targets
Safety	Safe for participant	*Brightness level (Lumen)	< 200
		Intensity level (Lux)	< 200
	Safe for operator	Operating temperature (°F)	< 150

Targets and Metrics: Visual Indication

- The “sweet spot” must be clearly seen by the participant
- Device will signal them to hold the current position

Table #: Targets and Metrics Table Row 3

Ideal Location Indicator For Anthropometric Scanners			
Main Function	Sub-Functions	Metrics	Targets
Visual Indication	Clearly seen by participant	Perceived Brightness level (Lux)	100 - 200
		Resolution (Pixel)	≥ 480
	Signals participant to hold position	*Time in designated Location & Orientation (Second)	< 30

Targets and Metrics: Power

- Power is important for
  - Safety
  - Efficiency

Table #: Targets and Metrics Table Row 4

"Sweet Spot" Indicator For Anthropometric Scanners			
Main Function	Sub-Functions	Metrics	Targets
Power	Power supply	Power consumption (Watts)	< 11
		Operating voltage (Volts)	≤ 55

Concept Selection Backup

Concept Selection: Pair Wise Comparison

Concept Selection Process:
Pair Wise Comparison

Table #: Pair Wise Comparison Results for Customer Requirements

Customer Requirements	Weight	Importance
1) Self Contained	1	6
2) Doesn't interfere with scanner	4	1
5) Clearly seen by participant	4	2
3) Accurately displays "Sweet Spot" Location	2	3
6) Signals to hold position and orientation	2	4
4) Accurately displays desired orientation	2	5

Concept Selection: House of Quality

Concept Selection Process:
House of Quality

Table # : House of Quality

		Engineering Characteristics							
	Improvement Direction	↓	↓	-	↑	-	↓	↑	↓
	Units	in³	lbf	m	cm	Lumen/Lux	°F	Pixel	Sec
Customer Requirements	WF	Design Volume	Weight	Distance from Scanner	Tolerance of Depth	Brightness Level/Intesity	Operating Temperature	Resolution	Operating Time
Self Contained	1	9	3	3			3		
Does Not Interfere with the Scanner	4	9		9	3	9	1		
Accurately Displays the "Sweet Spot" Location	3			9	9	9	1	9	3
Accurately Displays the Desired Orientation	2			9	9	9	1	9	3
"Sweet Spot" clearly Seen by the Participant	4			9	3	9	1	9	9
Signals to the Participant to Hold/Update Position and Orientation	2			3		9	1	9	9
Raw Score	564	45	3	126	69	135	18	99	69
Percentage	(%)	7.98	0.53	22.34	12.23	23.94	3.19	17.55	12.23
Rank		5	7	2	4	1	6	3	4

Concept Selection: Pugh Matrix Round 1

Concept Selection Process:
Pugh Matrix

Table #: First Pugh Chart for final 8 concepts

Selection Criteria	DATUM: Hypervsn Wall	AR & Leap Motion	Mirage/ Schlieren	BMW Holo-Touch	3D Image Live Feed Camera	Cast of Hand/Head	Adafruit w/ 3D Camera	Illuminating Mirascope	Semi-Automatic Robot w/ 3D Camera
1) Self Contained		+	-	+	-	+	S	+	+
2) Does Not Interfere with the Scanner		+	-	S	+	S	S	+	+
3) Accurately Displays the "Sweet Spot" Location		+	-	+	+	+	+	S	+
4) Accurately Displays the Desired Orientation		+	-	+	+	+	+	+	+
5) "Sweet Spot" clearly Seen by the Participant		S	-	-	+	+	+	-	-
6) Signals to the Participant to Hold/Update Position and Orientation		+	-	+	+	-	+	+	S
7) Price		+	+	+	+	+	+	+	+
# of Pluses (+)		6	1	5	6	5	5	5	5
# of Minuses (-)		0	6	1	1	1	0	1	1

"S" – Similar "+" – Concept plus "-" - Concept negative

Concept Selection: AHP #1

Concept Selection Process:
AHP

Table #: Analytical Hierarchy Process

				Normalized [C]									
Evaluation Criteria	**Design Volume**	**Weight**	**Distance from Scanner**	**Tolerance of Depth Measurement**	**Brightness Level/Intesity Level**	**Operating Temperature**	**Resolution**	**Operating Time**	**Weight Factor**	**WS**	**Consistency**		
Design Volume	0.060	0.100	0.041	0.115	0.029	0.150	0.056	0.115	0.083	0.726	8.717	Lambda	8.956
Weight	0.020	0.033	0.029	0.038	0.016	0.050	0.056	0.038	0.035	0.300	8.543		
Distance from Scanner	0.300	0.233	0.205	0.346	0.146	0.150	0.167	0.115	0.208	1.919	9.231	CI	0.137
Tolerance of Depth Measurement	0.060	0.100	0.068	0.115	0.438	0.050	0.167	0.115	0.139	1.370	9.837	CR	0.098
Brightness Level/Intesity Level	0.300	0.300	0.205	0.038	0.146	0.250	0.167	0.346	0.219	1.954	8.918		
Operating Temperature	0.020	0.033	0.041	0.115	0.029	0.050	0.056	0.038	0.048	0.425	8.870		
Resolution	0.180	0.100	0.205	0.115	0.146	0.150	0.167	0.115	0.147	1.333	9.046		
Operating Time	0.060	0.100	0.205	0.115	0.049	0.150	0.167	0.115	0.120	1.020	8.490		
	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000				

Reference

CR < 0.10

Concept Selection: AHP #1 Continued

Concept Selection Process:
AHP

- The final concept was determined using multiple pair wise comparisons for each engineering characteristic
- The output is the weighted number ranking of the final 3 selections

Table #: Analytical Hierarchy Process

	pi		
SELECTION:	Semi-Automatic Robot w/ 3D Camera	Adafruit w/ 3D Camera	3D Image Live Feed Camera
Design Volume	0.11	0.26	0.63
Weight	0.09	0.45	0.45
Distance from Scanner	0.23	0.32	0.45
Tolerance of Depth Measurement	0.57	0.29	0.14
Brightness Level/Intesity Level	0.60	0.20	0.20
Operationg Temperature:	0.60	0.20	0.20
Resolution	0.60	0.20	0.20
Operating Time	0.14	0.43	0.43
SUM	2.94	2.35	2.71

Table #: Final Selection

FINAL CONCEPT WEIGHT	
Semi-Automatic Robot w/ 3D Camera	0.40
Adafruit w/ 3D Camera	0.28
3D Image Live Feed Camera	0.32

Concept Selection: Pugh Matrix Round 2

Concept Selection Process:
Pugh Matrix

Table #: Pugh Matrix including the Mixed Reality Wearable

Selection Criteria		BMW Holo-Touch	Mixed Reality Wearable	Cast of Hand/Head	Adafruit w/ 3D Camera	Illuminating Mirascope	Semi-Automatic Robot w/ 3D Camera
1) Self Contained	New Datum AR & Leap Motion	-	+	S	+	+	+
2) Does Not Interfere with the Scanner		-	+	+	-	-	S
3) Accurately Displays the "Sweet Spot" Location		-	+	-	S	-	S
4) Accurately Displays the Desired Orientation		S	+	-	S	S	S
5) "Sweet Spot" clearly Seen by the Participant		-	+	S	S	-	-
6) Signals to the Participant to Hold/Update Position and Orientation		S	S	-	S	S	S
7) Price		+	+	+	+	+	+
8) Multi Purposed		+	+	+	+	+	+
# of Pluses (+)		2	7	3	3	3	3
# of Minuses (-)		4	1	3	1	3	1

Bill of Materials: Preliminary Part 1

Table #: Part 1 of the Preliminary BoM

TEAM 523 - Ideal Location Indicator BILL OF MATERIALS							
Part #	Part Name	Description	Quantity	Vendor	Price	Price (after 7.5% tax)	BoM Maturity
1	Base Plate	Plytanium 15/32" CAT PS1-09 Pine Sanded Plywood, 4' x 8'	1	Lowe's	$27.85	$29.94	50%
2	Linear Actuator	Okin Refined Power Recliner Motor Actuator Model JLDQ-11	1	Sears	$121.71	$130.84	50%
4	AL 8020 T-slotted Bar	Single Rail, Silver, 30 mm High x 30 mm Wide, Hollow	4	McMaster-Carr	$159.76	$171.74	50%
5	M4 Screw	Alloy Steel Low-Profile Socket Head Screw	32	McMaster-Carr	$10.83	$11.64	50%
6	M4 Washer	18-8 Stainless Steel Washer for M4 Screw Size, 4.3 mm ID, 9 mm OD	32	McMaster-Carr	$1.86	$2.00	50%
7	M4 Nut	Steel Hex Nut, Medium-Strength, Class 8, M4 x 0.7 mm Thread	32	McMaster-Carr	$1.32	$1.42	50%
8	M3 Screw	Alloy Steel Low-Profile Socket Head Screw	12	McMaster-Carr	$7.00	$7.53	50%
9	Inside Corner Bracket	10pcs Of 3030 Corner Fitting Angle 30x30 Decorative Brackets Aluminum Profile Accessories L Connector	1	Aliexpress	$7.79	$8.37	50%
10	Idler Pulley	GT2 5mm Bore Aluminum Toothless Timing Belt Idler Pulley	4	DHgate	$11.00	$11.83	50%
11	Timing Belt Pulley	Aluminum GT2 Timing Pulley - 6mm Belt - 20 Tooth - 8mm Bore	4	Adafruit	$31.80	$34.19	50%
12	Timing Belt Tensioner	Tensioner Locking Spring for GT2 Timing Belt (pack of 50)	1	Adafruit	$2.75	$2.96	50%
13	Timing Belt	Timing Belt GT2 Profile - 2mm pitch - 6mm wide 1164mm long	1	Adafruit	$9.95	$10.70	50%
14	Motor Mount Kit	Mounting bracket chassis mount for timing belt motors	2	Digi-Key Electronics	$15.98	$17.18	50%

Table #: View of Full Preliminary BoM

Bill of Materials: Preliminary Part 2

Table #: Part 2 of the Preliminary BoM

15	Wheel Motors	Cytron Power Window Motors w/ 5" Wheels (Pair)	2	Robotshop	$125.00	$134.38	50%
16	Timing Belt Motor	Brushed DC Motor Gearmotor	4	Digi-key Electronics	$79.96	$85.96	50%
17	3D Printer Filament	1.75 mm and 1 kg per Spool	1	Hatchbox	$23.99	$25.79	50%
18	3D Camera	ZED Camera High-Resolution and High Frame-rate 3D Video Capture	1	Stereolabs	$449.00	$482.68	50%
19	LCD Display	7" 1024 x 600 IPS Display	1	DFRobot	$34.00	$36.55	50%
20	Microcontroller	Raspberry Pi 3 Model B	1	Raspberry Pi	$27.49	$29.55	50%
21	LED Lights	5mm LEDs assortied colors (Yellow, Green & Red)	1	MS Direct	$12.99	$13.96	50%
22	Motor Driver for Robot Wheel	Sabertooth Dual 2x32A 6V-24V Regenerative Motor Driver	1	Robot Shop	$119.99	$128.99	50%
23	Motor Driver for V-Wheels	L298 Dual H-Bridge DC Motor Controller	2	Robot Shop	$15.76	$16.94	50%
24	Jumper Wires	SIM&NAT 12inch / 30cm 40 Pin Male to Female Dupont Wire, 40 Pin Male to Male, 40 Pin Female to Female Breadboard Jumper wire Ribbon Cables kit	1	Newegg	$7.49	$8.05	50%
25	Battery Pack for Microcontroller	5200mAh battery pack w/ micro USB	1	Grainger	$33.20	$35.69	50%
26	Battery Pack for Wheels	12V DC Battery Power Supply- 8 Cell D Battery Holder	1	SuperBrightLEDs	$3.49	$3.75	50%
27	Aluminum Plate	Mounting for LCD screen; 1/8th inch thickness	1	Online Metals	$16.67	$17.92	50%
28	Electrical Tape	Scotch Super 33+ 66-ft Electrical Tape	1	Lowes	$3.98	$4.28	50%
29	V-Wheel Kit	V-Wheel Kit B	1	ServoCity	$29.99	$32.24	50%
					Total:	$1,497.05	

Table #: View of Full Preliminary BoM

Bill of Materials: Final Design BoM

Table #: Final Design BoM

Table #: View of Full Preliminary BoM

TEAM 523 - Mixed Reality Wearable for 3D Body Tracking BILL OF MATERIALS							
Part #	Part Name	Description	Quantity	Vendor	Price	Price (after 7.5% tax)	BoM Maturity
1	3D Camera	Zed mini	1	Stereolabs	$449.00	$469.00	100%
2	Computer Processor	NVIDIA Jetson TX2 Developer Kit (with Educational Discount)	1	NVIDIA	$299.00	$310.96	100%
4	3D Printer Filament	Hatchbox PLA 3D Printer Filament: 1kg spool, 1.75mm, black	1	Amazon	$19.99	$21.49	100%
5	USB Flash Drive	SanDisk Extreme Pro 128 GB	1	TheImagingWorld (Amazon)	$47.60	$48.67	100%
6	USB Port Hub	Anker 10 Port 60W Data Hub with 7 USB 3.0 Ports	1	AnkerDirect (Amazon)	$42.99	$44.06	100%
7	Keyboard Wrist Rest	CushionCare Keyboard Wrist Rest Pad	1	CushionCare (Amazon)	$13.87	$14.94	100%
8	HDMI to VGA adapter	VicTsing HDMI to VGA Adapter Converter: black	1	VicTsingDirect (Amazon)	$7.59	$12.45	100%
9							
10							
					Total:	$921.58	

Detailed Math Backup