

EMS690U Integrated Design Project Assessment 1: Front End Group Design Report



<https://limbsandthings.com/media/deydkmnj/70250-colles-fracture-04.jpg?rmode=pad&width=800&height=450&format=webp&quality=80&v=1daa0572f8a1b70>

Project R2: Cast Application Trainer for Immobilising Fractures

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1. Introduction

1.1 Project Background

Through market research and discussions with medical experts, a critical gap in first-aid training was identified, specifically in limb fractures. Existing tools for teaching casting - particularly for distal radius fractures, one of the most common fractures in the UK [1] - are often expensive and lack realistic, hands-on experience. This deficiency leaves many medical students underprepared for clinical practice. As a result, improper casting techniques remain common and are linked to serious, well-documented complications such as thermal burns, compartment syndrome, and pressure sores [2]. These complications can lead to delayed healing, permanent disability, or the need for surgical intervention. The impact is significant, as fractures are associated with a 14% increase in mortality over the seven years following injury, with men at significantly higher risk [3]. Insufficient practical training increases the likelihood of improper immobilisation and complications, placing added strain on healthcare systems and worsening patient outcomes.

1.2 Project Aims

The primary aim of this project is to bridge the gap between theoretical learning and clinical application in fracture management by developing a high-fidelity, cost-effective simulator. The following solution, the “Interactive Fracture Immobilisation Trainer,” will move beyond static models by integrating physiological realism and active feedback. The largest static model like this on the market is currently the Colles’ Fracture Trainer, which costs £2000. [4] Unlike commercial alternatives, the device will prioritise accessibility to increase the number of trainees who benefit. To achieve this, the project is divided into five specialised work streams that will be integrated into a unified training platform:

1. Anatomical Core
2. Flow Pumping System
3. Haptic Feedback
4. Sensing
5. User Interface (UI)

1.3 Work Streams

1.3.1 Anatomical Core

To engineer the simulator’s chassis, an anatomically accurate, 1:1 scale forearm and hand will be produced. This serves as the integration platform for haptic actuators, sensors, and fluid channels within an intricate multi-layer tissue structure. Without a

realistic skeleton and soft tissue resistance, sensor data and haptic feedback would lack validity.

Aims:

1. Design an anatomically accurate forearm bone structure.
 - a. Bones will channel internally housed wiring and sensors.
 - b. Will simulate the fracture.
2. Engineer realistic ligaments to simulate physiological joint constraints.
3. Implement a dual-layer silicone system to replicate the distinct compliance of muscle and skin.

1.3.2 Flow Pumping System

A programmable pulsatile-flow pumping system will differentiate this trainer from competitors by accurately replicating human vascular physiology. This flow system contributes to the device's haptic feedback and sensing capabilities, ensuring trainees experience realistic physiological responses and are better prepared for real-world scenarios. The sub-system will provide reliable tactile cues and enhance the quality of medical training.

Aims:

1. Design and develop a cost-effective pulsatile-flow pumping system.
2. Accurately deliver realistic physiological responses.
3. Ensure compatibility with other work streams.
4. Measure physiological changes during casting.

1.3.3 Haptic Feedback

Current fracture models lack the dynamic response necessary to validate motor skills, forcing trainees to rely solely on visual inspection rather than tactile cues. To transform this product into a dynamic trainer, this work stream aims to develop a high-fidelity haptic system that functions as a responsive extension of the anatomical model. By embedding actuators within the synthetic soft tissue, the design should provide physiological cues and guidance without disrupting anatomical landmarks. This approach ensures trainees receive immediate, physical validation of their reduction techniques, transforming a passive model into an active training instrument.

Aims:

1. Combine vibrotactile cues with thermal (inflammation) and kinaesthetic feedback to create a cohesive and varied sensory environment.
2. Use appropriate actuators to achieve rapid response times and a wide frequency range.

3. Develop a “Guidance Gradient” algorithm that uses continuous feedback to modulate vibration frequency based on real-time sensor data.
4. Closely collaborate on the flow pumping system to provide a kinaesthetic response caused by the pulse and create inflammation spots near the fracture caused by warm fluid.
5. Incorporate data from the sensor system to trigger haptic events such as sharp pain vibrations.

1.3.4 Sensing

To provide the user with accurate and realistic feedback, it is important to design a multimodal sensory system. Information from the sensors could then be used to simulate pain response of a real patient and measure the performance of cast application by users. The sensing workstream is tasked with creating such system, the data from which will be used by other sub-systems in the complete product.

Aims:

1. Determine the set of main parameters that influence the pain response and quality of cast application.
2. For each parameter, find a way to sense it effectively, ensuring sensor placement does not impact the anatomical validity of the model.
3. Design an interface between the sensors and the main controller.
4. Combine the data from sensors to produce a pain metric and fracture alignment percentage, which can be used for feedback to the user.

1.3.5 User Interface

The UI’s main objective is to turn the sensory data into clear and understandable visual guidance during the practice and provide a performance summary at the end. The specific aim of the UI is to make the performance transparent, and the feedback will be detailed and actionable, presenting a clear path for trainees’ improvement.

Aims:

1. Guide the user step-by-step using a simple 3-column layout (Step / Instructions / Sensor Data).
2. Provide live safety feedback using three bold colours and text so the user knows if they are proceeding safely.
3. Deliver an objective report - overall score, checklist, and the timeline of unsafe moments.
4. Use a Raspberry Pi to run a custom website and display it to the user in an informative way.
5. Be accessible and user-friendly.

2. Research/design process

2.1 Methodology

An agile and modular methodology will be used throughout the development stage. This approach ensures continuous progress, adaptability to change, and effective risk management through frequent prototyping.

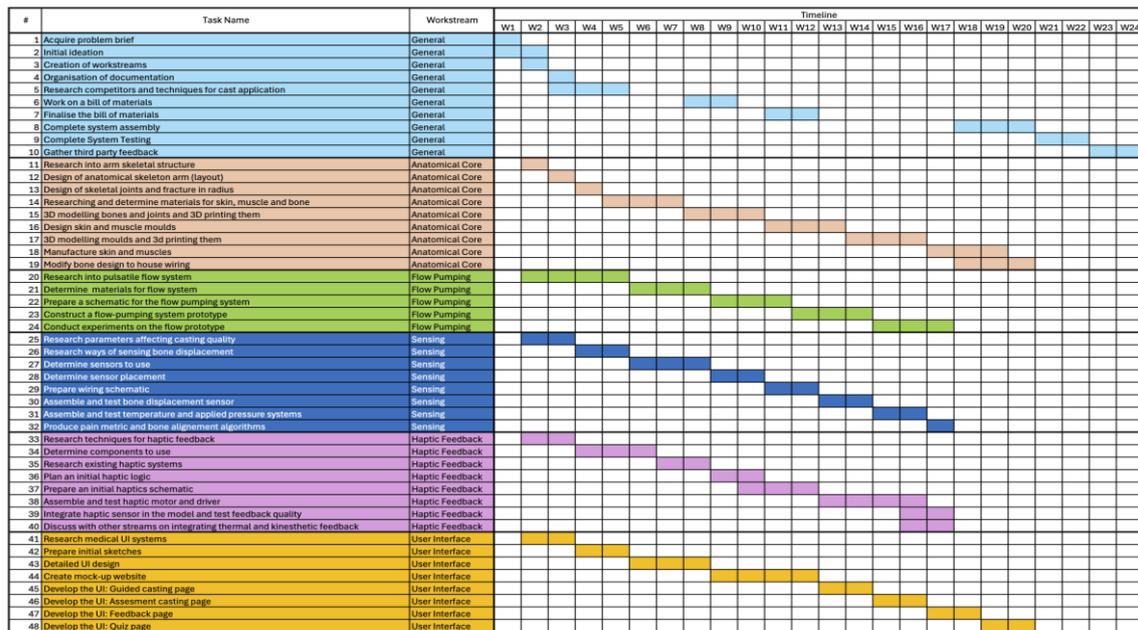


Figure 1 - Gantt Chart of Design Timeline

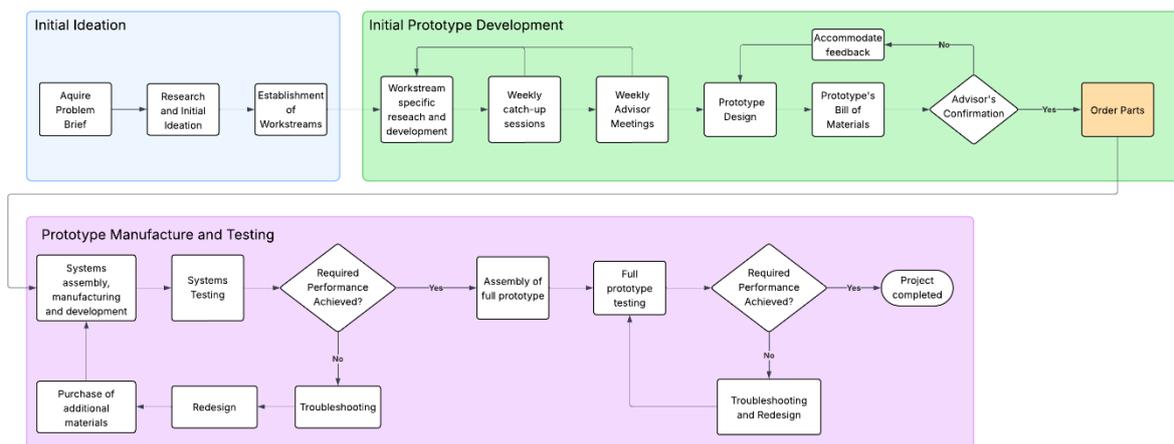


Figure 2 - Design Project Flowchart

Figures 1 and 2 illustrate the estimated development timeline and the flowchart of the overall design process, respectively.

2.2 Analysis of Design Problem

The design process began with a critical review of simulation deficiencies and patient concerns. The first step was to research whether deficiencies do in fact exist, and how beneficial designing a simulator would be. The team had an opportunity to interview an actual medical professional, Dr Hasnain Abbasi, with over a decade of experience in primary care and his tenure as Clinical Director of AT Medics. In this role, he oversaw the care of over 300,000 patients across London, a sample size that provides statistically significant data on musculoskeletal injuries and fracture management pathways. Dr Abbasi's insight allowed for the confirmation that filling the practical gap will be beneficial. [5]

Professionals in the medical field agree that patients become increasingly concerned that students and residents are 'practising' on them [6], and many medical journals mention the shift to use high-fidelity mannequin simulators instead [6,7,8]. This is exactly why the team plans to make the design put great emphasis on a simulator that will give realistic training, like it is done on a real patient, while addressing the concerns. While many current simulators in the field focus on virtual reality (VR) and augmented reality (AR) solutions [9,10], they base the design for larger-scale emergency response in critical situations and target first responders rather than medical trainees. Since the team plans to target the latter, a physical product rather than a virtual one and narrowing the scope to fractured limbs specifically is more appropriate.

To ensure this level of realism, research into pain response was conducted. The biggest cause of the immediate, sharp pain when breaking a limb is the mechanical distortion and activation of sensitive nerve fibres that densely innervate the bone's outer covering, the periosteum. [11] While this response is complex, a level of abstraction can be applied to create a varied sensor network to simulate it.

Literature indicates that while cost-effective 3D-printed models replicate reduction mechanics, they often lack the tactile nuance of real tissue [12]. A study [13] demonstrated that multi-layer physical models significantly improve perceived realism. This informed our decision to reject a single-pour silicone approach in favour of a dual-durometer system that simulates bone, muscle, and skin distinctness.

The simulator should be void of any gender, race, or body-specific characteristics, so the product does not raise ethical concerns. In designing the artificial limb, a neutral pigmentation will be used (such as grey), with the proportions being based on a real physical skeleton.



Figure 3 - Presented Product vs Competitors

2.3 Prototype Design and Simulations

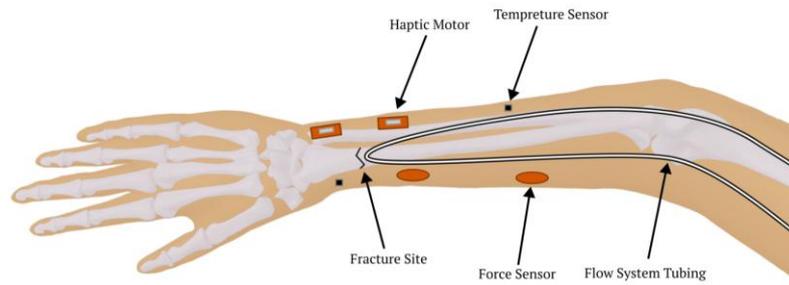


Figure 4 - Overall Model

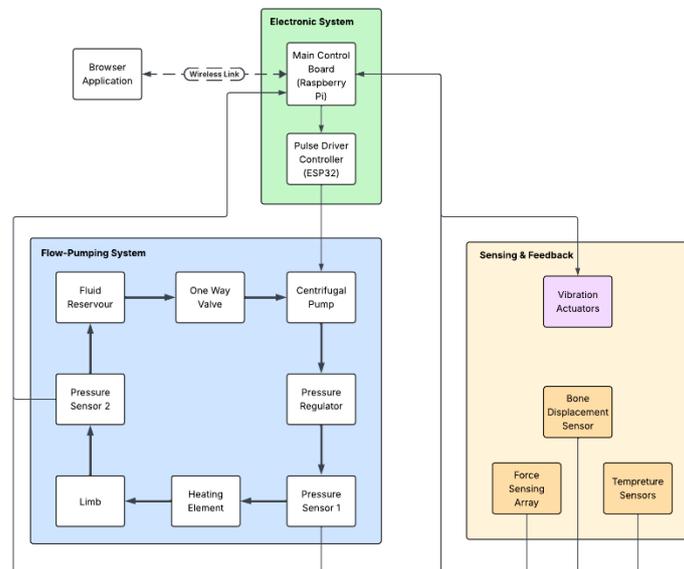


Figure 5 - Electronic Design

2.3.1 Anatomical Core

The anatomical core was made using Blender. An open-source DICOM mesh data was modified via Boolean subtraction to carve internal channels for tubing and motors. Initial stress testing showed standard PLA delaminated under pressure. While Acrylonitrile Butadiene Styrene (ABS) offered sufficient resilience, it was rejected due to manufacturing constraints, including warping, high failure rates, and toxic VOC emissions. Consequently, Polyethylene Terephthalate Glycol (PETG) was selected as the optimal compromise, providing structural durability with superior printability and safety.

FEATURE	PLA (PROTOTYPE)	ABS	PETG (RECOMMENDED)
Impact Resistance	Poor (Brittle)	Excellent	Excellent
Strength & Durability	Low	High (Tough)	High (Durable)
Printability	Easy	Difficult (Warp, Fumes)	Easy (No enclosure)
Anatomical Detail	Excellent	Good	Very Good

Figure 6 - Material Comparison Table

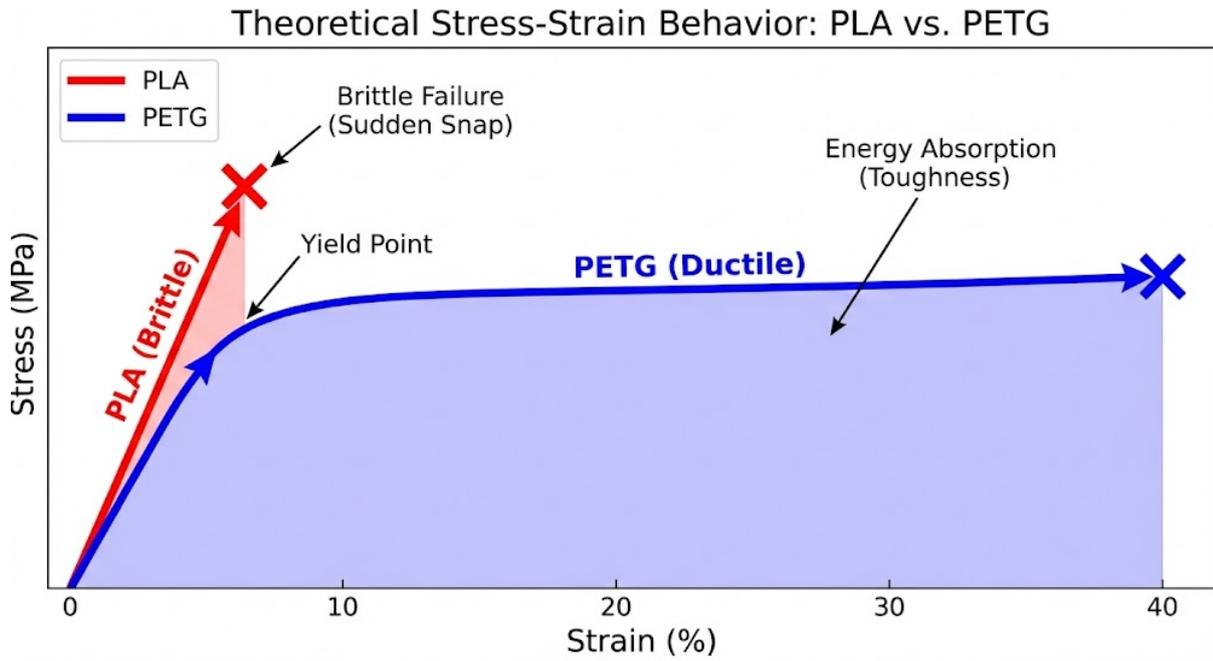


Figure 7 - Theoretical Stress-Strain Comparison Between PLA and PETG

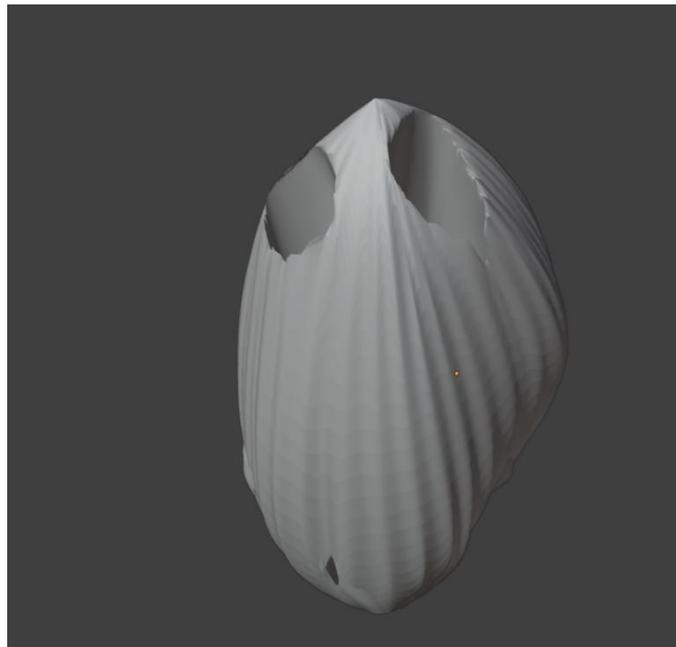


Figure 8 - Early-stage Design of Elbow Joint in Blender 4.5

One challenge was the radiocarpal joint, where flat TPU strip prototypes allowed unnatural rotation and were prone to tearing. We evolved the design to a "cup and knuckle" topography within a flexible TPU Socket Matrix (TPU 95A). This successfully restricts movement to accurate anatomical axes (flexion/extension).

To simulate realistic palpation, Smooth-On Ecoflex 00-30 was selected for the epidermis to mimic skin compliance, while Dragon Skin 30A was utilised for deep tissue to provide the firm elastic recoil necessary for identifying bony landmarks [11].

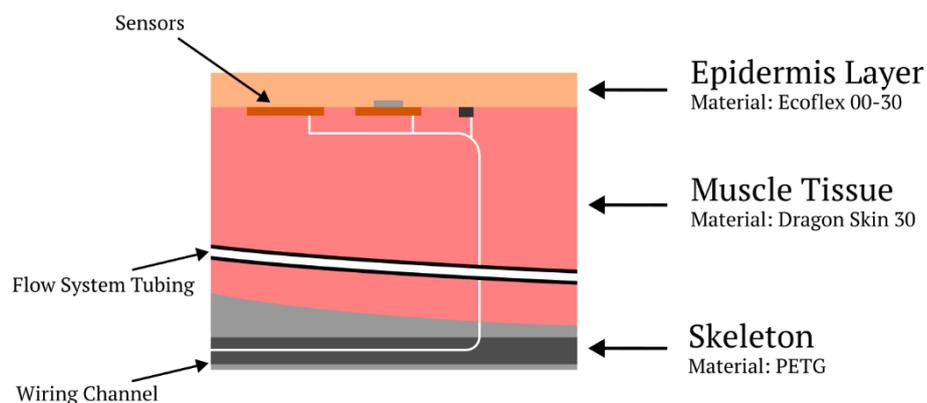


Figure 9 - Cross-sectional Schematic of the Multi-Layer Tissue Integration

Destructive compression testing (~50N) validated structural integrity. Initial PLA prototypes demonstrated brittle failure and Z-axis delamination whereas the PETG iteration displayed only minor elastic deformation without permanent yield, confirming the material toughness required to withstand the repeated loads of training.

Consultation with Dr. Hasnain Abbasi (GP) revealed that subjective "touch and feel" training often leads to complications like compartment syndrome [14]. He emphasised the critical need for objective safety metrics. This insight drove the requirement to engineer the anatomical core as a platform for sensor networks, rather than a passive static model.

2.3.2 Flow-Pumping System

The initial design of the flow-pumping system was inspired by cardiac simulation studies [15] that use an electromechanical pump driven by a linear actuator. While this approach allows precise control of stroke length and frequency, it results in increased complexity and cost. To overcome these limitations, this stream used a hybrid mock circulatory loop (MCL) approach that integrates computational modelling with

mechanical components - providing a realistic, reliable, and more cost-effective system [16].

The current prototype is based on a validated pulsatile flow system [17], which has demonstrated strong waveform accuracy and physiological relevance. This configuration enables the generation of realistic arterial pressure and flow waveforms while allowing key parameters, such as vascular resistance and compliance, to be adjusted computationally.

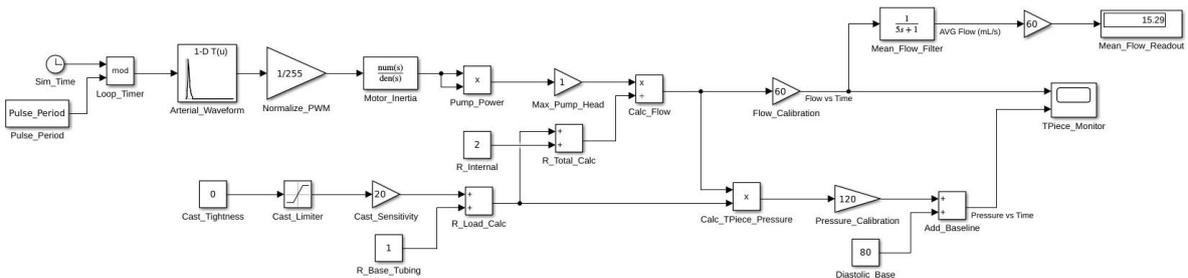


Figure 10 - Simulink Diagram + Scope + Mean Flow rate

Figure 10 illustrates the Simulink model of the flow-pumping system, including pump dynamics and the influence of an external cast used to model vascular compression. All parameters are normalised, with cast tightness defined from 0 (no cast) to 1 (maximum tightness).

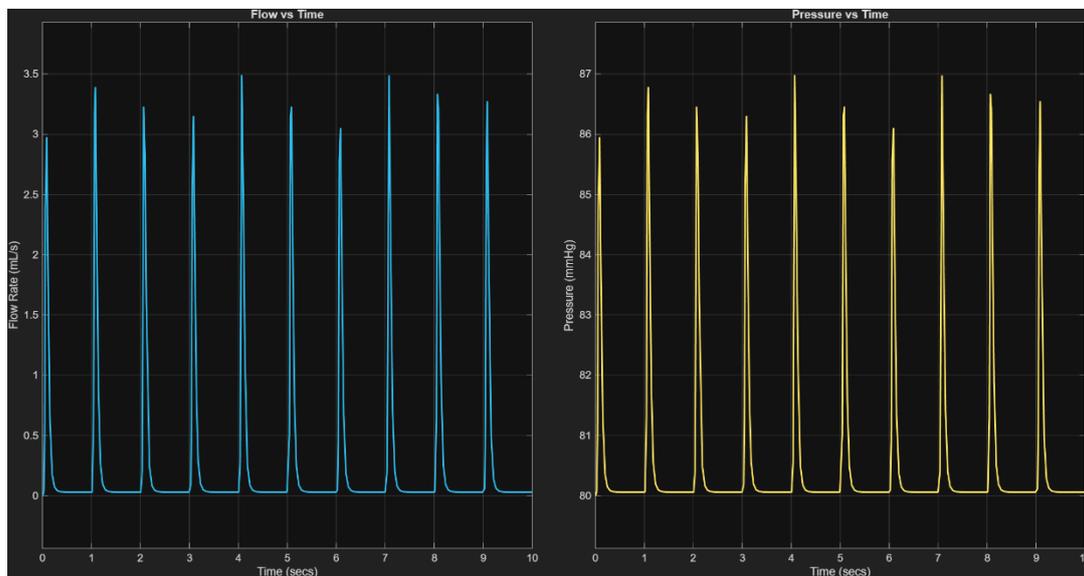


Figure 11 - Flow and Pressure Graph Before Casting is Applied

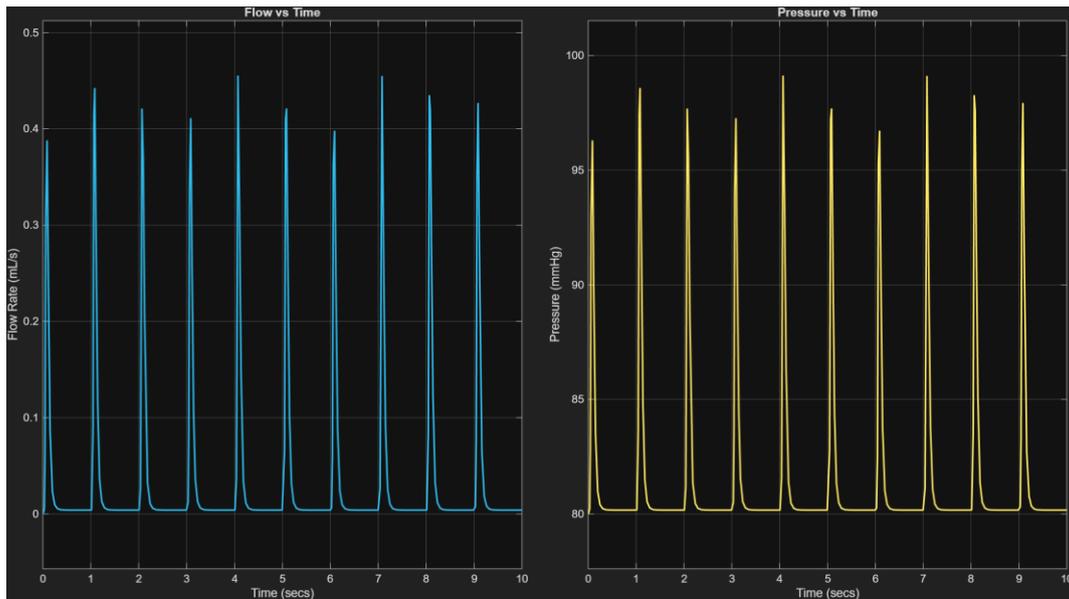


Figure 12 - Flow and Pressure Graph After Casting

The simulation results show that, when no cast is applied (Figure 11), the flow rate and pressure remain within the normal physiological range expected for a healthy adult at the radial artery - for example, average radial flows range from 0.9 to 15.3 ml/min [18], and our system's blood flow rate was calculated to be 15.29 ml/min. In contrast, applying a tight cast (Figure 12) leads to a reduction in flow followed by an increase in pressure. This pattern of diminished flow and elevated pressure is consistent with the hemodynamic changes observed in compartment syndrome [14], demonstrating that the hybrid MCL can realistically reproduce clinically relevant physiological conditions.

2.3.3 Sensory System

One of the main features of our design is its ability to provide real-time feedback to the trainee. This can be used to simulate the pain response a real person would feel during cast application or can be used retrospectively to rank the quality of procedure and highlight common problems.

Four main parameters were identified affecting the quality of the cast:

1. **Bone movement:** Changes in orientation of the fractured bone pieces.
2. **Skin Force:** Tactile sensations near the fracture site are perceived as painful.
3. **Skin Temperature:** As cast cures heat is generated, which might lead to skin burns. [19]
4. **Cast Tightness:** Tight cast applications may lead to problems with blood circulation.

Orientation of the broken bone piece could be determined using magnetic sensing. A small permanent tracer magnet could be mounted inside the mobile bone part, and several 3-axis magnetometers could be embedded into the static part of the bone. Knowing the characteristics of the magnetic field produced by the magnet and the

magnetic field measurements, it is possible to reliably measure the orientation and position of the tracer magnet. Such localisation methods were explored in [20,21], with the latter work achieving a high tracking accuracy of ~1mm positionally, and ~0.7° angularly.

For skin temperature and force measurements, sensors must be positioned close to the outermost skin layer. To make sensors less noticeable, placement, dimensions and materials of the sensors should be considered. For temperature sensors, ICs of small dimensions could be used, while stress sensors were picked to be force-sensitive resistors on a flexible base.

Cast tightness can be determined using information from the flow system. This can be achieved by comparing the differences in inflow and outflow blood pressure.

2.3.4 Haptic Feedback

To simulate the physiological cues of fracture immobilisation, specifically the transient "snap" of reduction (<10ms) and the continuous "grinding" texture of crepitus, a comparative analysis of vibrotactile technologies was conducted:

Type of actuator	Latency	Frequency range
Linear Resonant Actuator (LRA)	30ms	175 ± 10Hz
Eccentric Rotating Mass (ERM)	40-100ms	N/A (Frequency coupled to amplitude)
Piezoelectric	<5ms	0-500Hz

Table 1 - Vibration Actuator Comparison

Consequently, piezoelectric actuation was selected for its wide bandwidth (0-500Hz) and rapid response time (<5ms). The TDK PHUA8060-35A-33-000 actuator was specifically chosen for its unimorph structure; its ultra-thin profile (0.35mm) allows for seamless embedding between the synthetic muscle and skin layers, preserving anatomical realism while delivering perceivable force (55µm displacement at 24V). [22]

Driving high-capacitance piezoelectric actuators requires a high-voltage differential signal ($24V_{p-p}$), necessitating a specialised boost driver.

Driver	Form-factor	Cost	Size
MikroE Piezo Driver Click	Commercial Off-The-Shelf (COTS)	~£13	43mm x 25mm
TI DRV8662	Very-Thin-Profile Quad Flat No-Lead (VQFN)	£2.08	4mm x 4mm
BOS0614	Wafer Level Chip Scale Package (WLCSP)	£4.28	2.1mm x 2.5mm

Table 2 - Piezo Driver Comparison

The design pivoted to a discrete implementation using the Texas Instruments DRV8662. This component was selected over the industry-standard Boréas BOS0614 solely due to manufacturing constraints; the BOS0614's requires advanced PCB fabrication incompatible with rapid prototyping. In contrast, the DRV8662's VQFN package permits the manual fabrication of custom breakout boards.

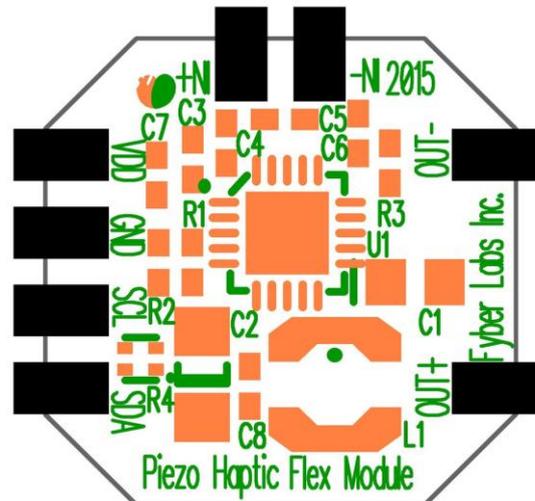


Figure 13 - Piezo Haptic Flex Module from Fyber Labs. Source: <https://www.tindie.com/products/fyberlabs/piezo-haptic-flex-module/>

Market analysis of the Fyber Labs Piezo Haptic Flex Module [23] (utilising the related DRV2667) serves as a functional precedent for integrating haptic driver topology into a flexible form factor. Although the project employs the analogue-input DRV8662, the miniaturisation of this comparable architecture validates that the required driver circuitry can be deployed with minimal external components. This commercial benchmark confirms that a high-voltage driver solution can be achieved within a footprint suitable for the project's anatomical constraints, informing the layout strategy for the custom breakout board.

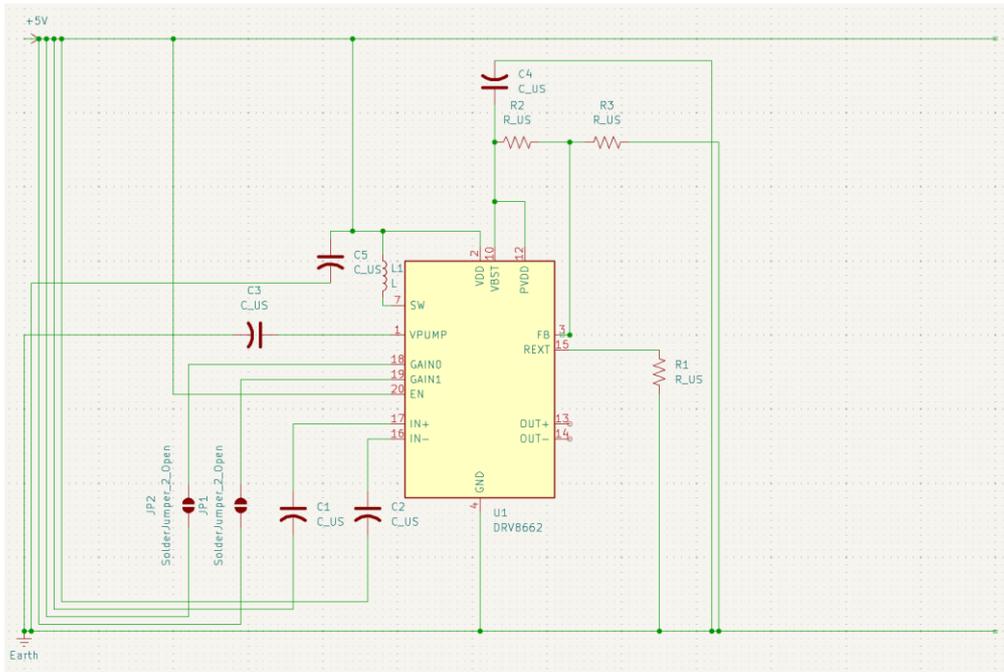


Figure 14 - Electrical Diagram for Driver Circuit

Moving forward, a schematic made in KiCad was made to visualise the layout needed for the driver circuit (Figure 14), which will make it easier for prototyping later.

2.3.5 User Interface

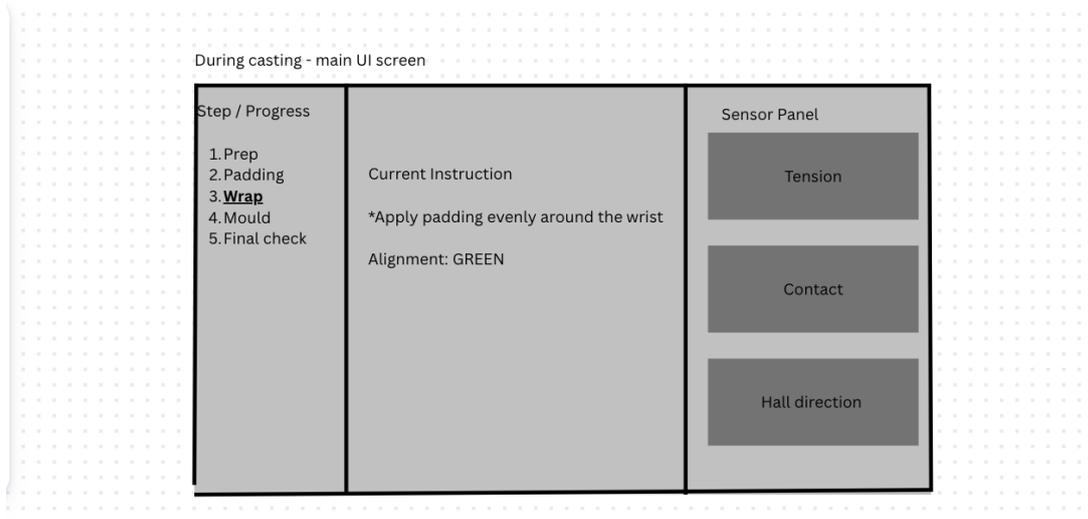


Figure 15 – Initial UI Design

The user interface is designed to be simple and intuitive. The primary screen uses a three-column layout, allowing users to follow the process easily and act with confidence. As shown in Figure 15, the interface is divided into three sections, applying the rule of threes to create a clear and balanced structure.

The left column presents a progress list showing the casting workflow, with the current step clearly highlighted. The centre column displays a single, focused instruction for

the active step, supported by an explicit safety status. A three-colour system is used: green indicates safe conditions, amber signals a warning, and red represents failure or unsafe operation. The right column contains a sensor panel that mirrors the physical hardware, including a tension bar showing cast tightness, contact indicators, and an alignment direction cue. Only essential live data is shown to maintain focus and reduce cognitive load.

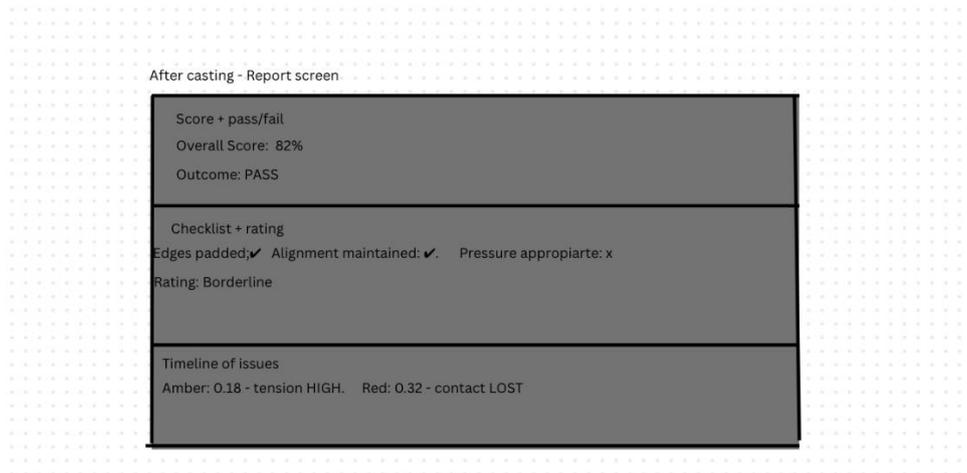


Figure 16 - Feedback Report Page

After each attempt, the system generates a feedback report (Figure 16). The header displays the overall score and pass/fail outcome. The central panel shows checklist results with ticks or crosses and a single rating. A timeline at the bottom highlights time-stamped amber and red events, allowing users and tutors to identify exactly what went wrong and when. This approach ensures feedback is objective, quick to review, and actionable for subsequent attempts, while maintaining high contrast, bold labels, and visual clarity throughout.

3. Discussion

3.1 Justification & Achievement

3.1.1 Anatomical Core

Material, Equipment, Technology or Process	Item/Technology	Description	Justifications	Limitations
Material	PETG	Printed material for bone	Strength without brittleness, easy to manufacture.	Has more flexibility than a real bone
Material	TPU	Printed material for joints	Flexibility for realistic ligament feel.	Can be difficult to print
Material	Ecoflex 30	Soft silicone for the skin layer	Soft and elastic replicating human skin accurately.	Durability may be an issue long-term, so replacements could be needed
Material	DragonSkin 30A	Firmer Silicone for the tensed muscle layer	Firmer feel to replicate muscles accurately.	Can stick to Ecoflex so cornstarch may be needed in between
Process	3D Printing	Process used for making the skeleton	Quick for manufacturing. Accurate and cheap printing. Easy to access in labs and work can be done from home.	Requires a good initial model

Table 3 - Justification Table for Anatomical Core

The primary achievement of this work stream was the engineering of a robust integration chassis capable of unifying the project's haptic, sensing, and fluidic subsystems. This directly enables the project's core aim of delivering "active feedback"; without this anatomically accurate housing, the sensor networks would lack the physiological context required to generate valid safety metrics. Furthermore, the

successful implementation of the dual-durometer silicone system achieved the aim of physiological realism, replicating the non-linear compliance of real tissue that mono-material competitors fail to provide.

3.1.2 Flow Pumping System

Material, Equipment, Technology or Process	Item/Technology	Description	Justifications	Limitations
Technology	Centrifugal Pump	12V pump that can deliver up to 2.1 GPM with a max head of 3M.	Due to its ability to change speed quickly, it is suitable for simulating an arterial waveform.	This does not prevent backflow, requiring the use of check valves
Technology	Pressure Transducer	Measure the pressure of the system	When casting is applied, the pressure changes, and a pressure transducer is used to detect this change.	The threaded design requires a fitting for installation.
Technology	ESP32	Real-time controller	It is used for real-time processing and is well-suited for generating PWM signals.	Soldering is required
Technology	Motor Driver	Function as the interface between the ESP32 and the motor	Effective control of the pump using PWM.	Soldering is required. Cost.
Process	Assembly	Connects all the part together to form the system.	Begins the process of prototyping	The system references a research paper [17], which notes a limitation: the pump has not

				been tested under varying fluid viscosities.
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Table 4 - Justification Table for Flow Pumping

The primary achievement of this stream has been the successful MATLAB simulation. MATLAB was used to model the selected components as accurately as possible, and the results confirm that the chosen parts are suitable for the intended design. The simulation was able to replicate key measurable parameters, including flow rate and pressure within the radial artery. It also demonstrated the expected system behaviour during casting, showing a rise in pressure and a corresponding decrease in blood flow.

3.1.3 Sensor System

Material, Equipment Technology or Process	Item/ Technology	Description	Justifications	Limitations
Technology	Magnetic Sensing	Technique for determining an object's position and location	Resulting system will be lightweight and fairly accurate. The main advantage of this system would be the lack of physical linkage between two bone pieces. Having a linkage, would allow for easier sensing, however, would make the design more complex and less realistic.	Limited resolution, susceptible to magnetic noise, requires regular calibration.
Technology	Digital Thermal Sensor (STS4L-AD1B-R3)	Digital thermal IC with I2C interfacing	Small dimensions will make it less noticeable during	Even with small dimensions, the sensor can still be noticeable during palpation. A better

			palpation. Digital interface ensures convenience to take measurements from, without requiring additional analogue to digital converters	approach would be to use soft thermal sensors; however, these are not commercially available or are expensive.
Technology	Force Sensitive Resistor Cell	A thin flexible load sensor, with a measuring range from 30g to 1.5kg	Form factor allows to put it beneath the skin. Appropriate measuring range.	Could still be noticed during palpation, especially if located near a joint, or a part that experiences a lot of tension/compression.

Table 5 - Justification Table for Sensing

The sensing workstream managed to complete research and preliminary design of the system. This required a lot of collaboration with other workstreams, since sensor data is widely used throughout the project. In collaboration with Haptic Feedback, positioning of the sensors inside the arm were determined. Overall, the work stream managed to achieve all tasks set out to achieve before week twelve.

3.1.4 Haptic Feedback

Material, Equipment, Technology or Process	Item/Technology	Description	Justifications	Limitations
Technology	Piezoelectric Actuator (TDK PHUA8060)	Multilayer ceramic actuator with 0.35mm profile.	<4ms response time allows for instantaneous guidance. 0-500Hz range enables "Guidance Gradient" logic. Ultra-thin profile integrates into silicone skin without	Requires an additional driver circuit. Ceramic element is brittle; requires protective casing. Higher unit cost.

			physical artefacts.	
Technology	High-Voltage Driver (TI DRV8662)	Piezo driver with integrated boost converter (24V).	Allows direct PWM control for real-time frequency modulation. Drives piezo to full 55µm displacement from 3.3V logic. VQFN allows manual breakout fabrication (unlike WLCSP).	VQFN package and small size makes it difficult to hand-solder. Boost converter generates heat; requires thermal management considerations.
Process	Manual Breakout Fabrication	Custom soldering of VQFN chips to DIP adapter boards.	Enables immediate prototyping without waiting for custom PCB manufacturing. Allows individual driver testing before full system integration.	Connections are less durable than printed PCBs. High risk of bridging pins during soldering. Manually soldering pins to each contact point has limited scalability

Table 6 - Justification Table for Haptic Feedback

To mitigate the risks associated with high-voltage actuation in a handheld device, the actuators will be sealed within the dielectric silicone skin layer. Furthermore, to address neurodiverse sensory thresholds, the system software includes an intensity calibration feature, ensuring equitable training accessibility. Commercially, TDK actuators' solid-state longevity reduces long-term maintenance costs, aligning with NHS sustainability targets.

The Haptic Feedback work stream has successfully defined the hardware architecture and control logic required to transition the simulator from a static model to a responsive training platform. Key achievements include:

- Section 2.3.4 confirmed the selection of the TDK PHUA8060 piezoelectric actuator over conventional ERM/LRA alternatives. This achievement establishes the system's capability to deliver the <5ms response time required for

simulating bone-on-bone crepitus, a critical project milestone for ensuring high-fidelity realism.

- The technical risk posed by the WLCSP packaging was mitigated by specifying the DRV8662. A manufacturing strategy utilising a custom breakout interface for the VQFN package has been validated against commercial precedents, ensuring the system is compatible with the project's rapid prototyping constraints.

These achievements directly address the primary project aim of bridging the gap between theoretical knowledge and clinical skill. By securing a high-bandwidth actuation method, this work stream provides the physical interface necessary for the Sensor Network and Flow Pumping to communicate meaningfully with the user.

3.1.5 User Interface

Material, Equipment, Technology or Process	Item/Technology	Description	Justifications	Limitations
Technology	Raspberry Pi	A small computer for controlling hardware with GPIO capabilities	The Raspberry Pi can host the user interface while controlling I/O, with easy sensor integration via GPIO and standard communication protocols.	High Cost and limited output voltage

Table 7 - Justification Table for User Interface

A Linux-based web architecture was chosen for the front end to ensure portability, allowing the interface to be accessed wirelessly via any laptop for simplified maintenance.

The user interface design is justified by its alignment with medical-device HMI guidelines [24]. High-contrast visuals, bold labels, and clear status indicators are employed to reduce the likelihood of user error and to support accessibility, including users with colour-vision deficiencies. This design prioritises rapid, consistent feedback while minimising cognitive load, which is consistent with healthcare research on effective and safe clinical training interfaces.

Overall, this stream has successfully delivered an initial interface design that follows HMI best practices, enhances accessibility for all users, and remains flexible to integrate with and support the requirements of the other work streams.

3.2 Combined Risk Assessment

Hazard	Risk	Likelihood (1-10)	Mitigation
Soldering	Burns	5	Leave plenty of space to rest arms. Wear protective gloves.
Power Supplies, components, PCBs, electronics	Electric Shock	2	Always keep grounded when working with high voltages.
Inhaling solder fumes	Toxic poisoning	6	Solder in a well-ventilated area. Use an extractor tube. Use lead-free solder.
3D Printing (bed, nozzle)	Thermal Burns	3	Allow print bed to cool to below 40°C before getting parts.
Sharp/mechanical tools i.e., deburring tool	Cuts/mechanical injuries	6	Cut resistant gloves, using correct tools safely according to guidance.
Hazardous Chemicals	Toxicity, burns	4	Ventilated areas when printing or using chemicals.
Water Spillage	Short Circuit, Electric Shock	6	Stores water separately from electronic components.

Table 8 - Risk Assessment Table

3.3 Future Work

The next phase focuses on physical manufacture and electronic integration:

- **Chassis Fabrication:** Print the final radius and ulna in PETG, smoothing the joint surfaces to ensure fluid articulation.
- **Sensor & Actuator Embedding:** During the silicone casting process, the TDK actuators and magnetometer sensors will be embedded directly into the model. This ensures they are protected while remaining close enough to the surface for effective haptic feedback and position tracking.
- **Final Assembly:** We will mount the cured soft tissue onto the rigid skeletal chassis, connecting the internal wiring to the main controller to complete the physical build.

4. Conclusion

This project effectively designed the Interactive Fracture Immobilisation Trainer, an exceptionally realistic simulator that allowing trainees practise how to treat distal radius fractures. The design goes beyond traditional static models by combining five specialised work streams to make a training platform that is responsive and accurate to how the body works.

The anatomical core and flow pumping system make things more realistic by modelling complicated conditions like compartment syndrome. The sensing and haptic feedback networks turn subjective palpation into objective safety metrics. The user interface combines this information into useful advice, culminating in detailed reports.

The initial design shows that high-performance simulation does not have to be expensive; at an estimated £500 per unit, it is a scalable alternative to the £2,000 Limbs & Things alternative. This design sets the stage for lowering clinical mistakes and raising the standards of emergency orthopaedic care by giving medical students a safe, repeatable place to learn a complicated procedure.

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Appendix



CERTIFICATE of ACHIEVEMENT

This is to certify that

Doanh Le

has completed the course

Academic Integrity at Queen Mary 2025/26



CERTIFICATE of ACHIEVEMENT

This is to certify that

Bohdan Skulimovskyi

has completed the course

Academic Integrity at Queen Mary 2025/26



CERTIFICATE of ACHIEVEMENT

This is to certify that

Yuvraj Singh Panesar

has completed the course

Academic Integrity at Queen Mary 2025/26

