

Background

During the NIH-sponsored Clinical Immersion Program at Arlington Fire Station 2, our team leader observed EMS personnel during real emergency responses. It was observed and interviewed that medication dosing in the field is slow, cognitively demanding, and error prone. Providers must look up protocols, perform weight-based calculations under pressure, and manually draw precise volumes into syringes. Small inconsistencies in plunger movement or misreading syringe markings can lead to incorrect dosing, especially during high-stress situations. These observations align with current literature. Medication dosing errors are common in prehospital EMS, even when reference tools are available. Studies report that paramedics correctly administer medications only 68.8% of the time, with pediatric dosing being particularly error-prone due to weight-based conversions. As a Senior Design team, these findings define our problem space: EMS providers need a faster, more reliable, and less error-prone method for calculating and administering medication doses in the field.

Need Statement

A way to provide accurate medication drawing assistance for firefighters/EMS personal in a medical emergency that accurately measures medication drawing in real time, shows recommended dosage based on patient intake and medical situation, and improves daily task performance.

Design Constraints

Size and Space Limitation – Enclosure needs to be compact to fit inside EMS bags and ambulance compartments.

Weight Restriction – Total weight needs to remain under 2.9 kg to maximize portability and ease of use in the field

Power and Electronics – Battery must supply enough power to all components and support a daily runtime of at least 1 hour.

Price – Total budget for project is \$1000. The design of the device prioritized using low-cost materials, electronic components, and fabrication costs.

Time – Timeline for this project is constrained by a semester-based course structure. Time is limited for physical prototyping, testing, and validation.

Physical Specifications

Class	Physical Specifications
Compatibility syringe/vial	Supports 1, 3, 5, 10 mL syringes and common medication vials
Temp. operation	Functions in 0–45 °C
Total weight	≤ 2.9 kg
Materials	ABS + carbon fiber
Sanitization	Resists ≥ 500 cycle wipe test
Dimensions	≤ 250 x 250 mm
Battery size	≤ 100 x 60 mm
Sensor Type	LP25-12-100R potentiometer

Functional Specifications

Class	Functional Specifications
User-Interface	Provide user-friendly protocol access with live feedback during syringe draw
Mechanical	Convert plunger displacement into volume and have a secure way to manually insert syringe/vial
Accuracy	±0.01 mL accuracy
EMS Protocols	Guide dosing of medication based on Arlington Fire Department (AFD) EMS protocols

Design and Prototype

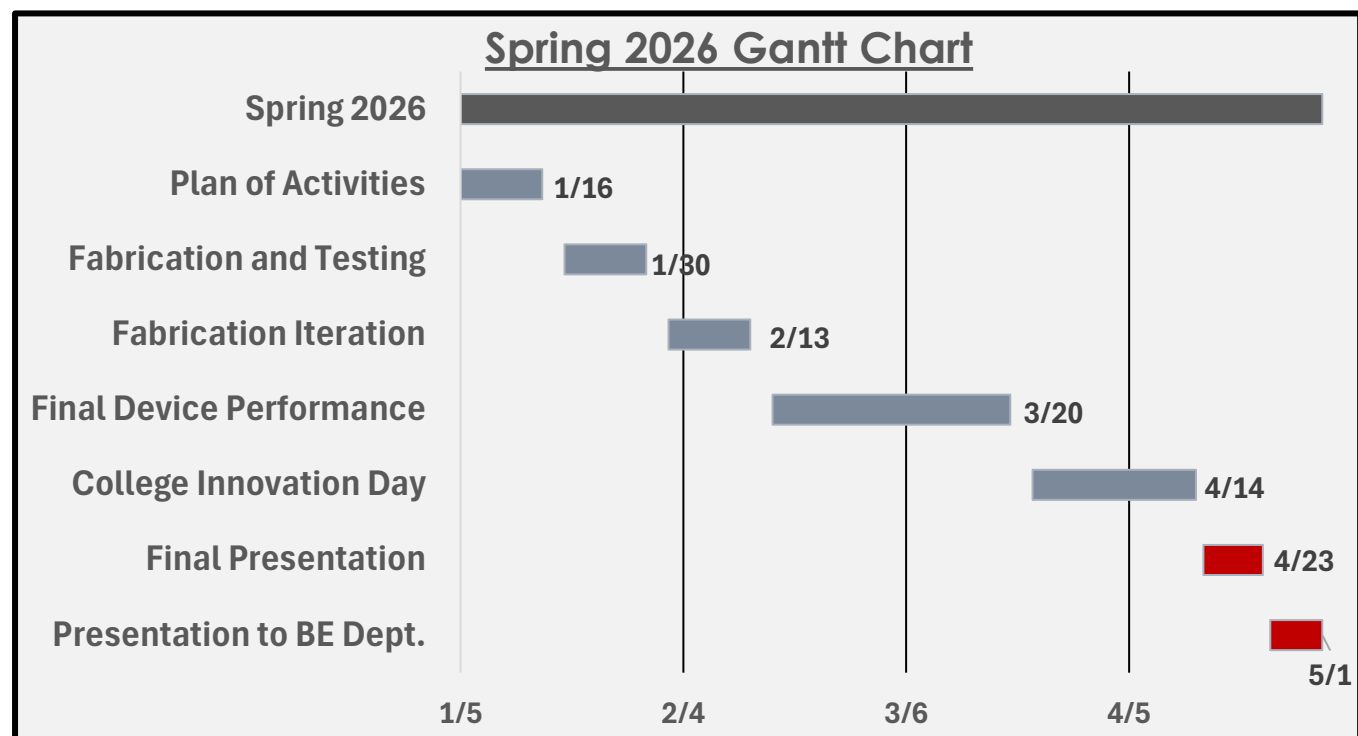


Figure 1: Gantt chart showing the progress and creation of our device

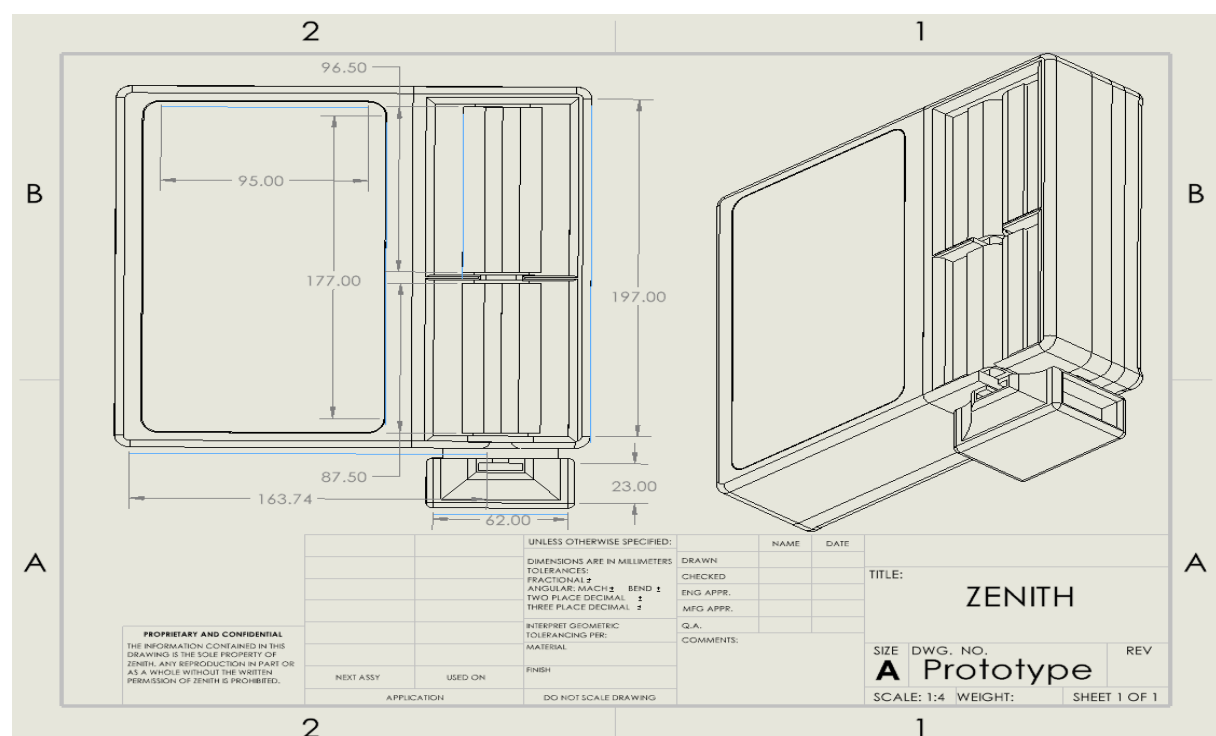


Figure 2: Orthographic drawing of our final design

Fabrication:

UTA Machine Shop

Moving parts: Carbon fiber
ABS

Stationary parts: ABS

Features:

AFD dosing protocols

Vial and syringe adjustable
insertion slots

Volume detection through
Linear

Potentiometers

Live display of fluid drawn
in mL

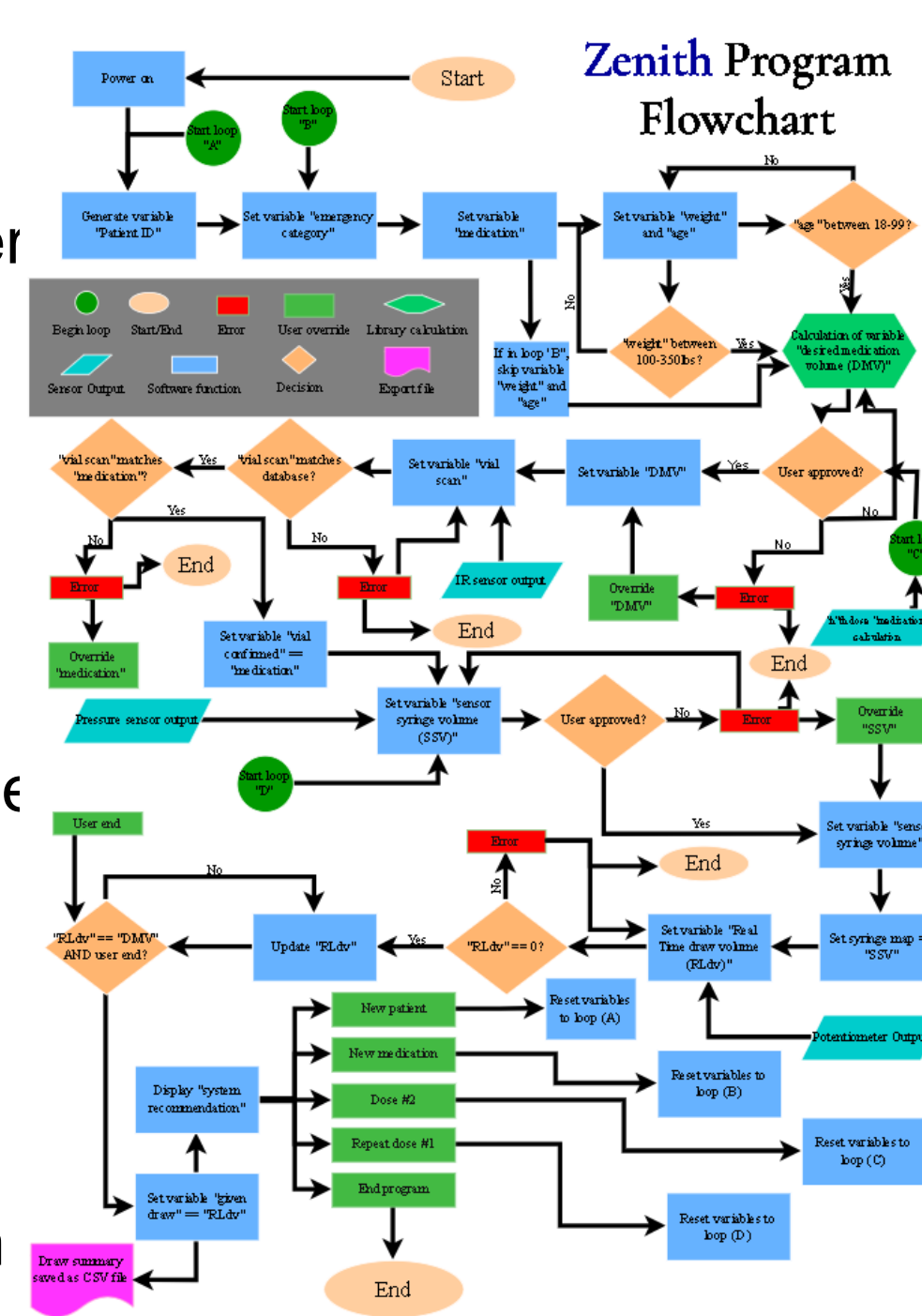


Figure 5: Coding Scheme of Zenith

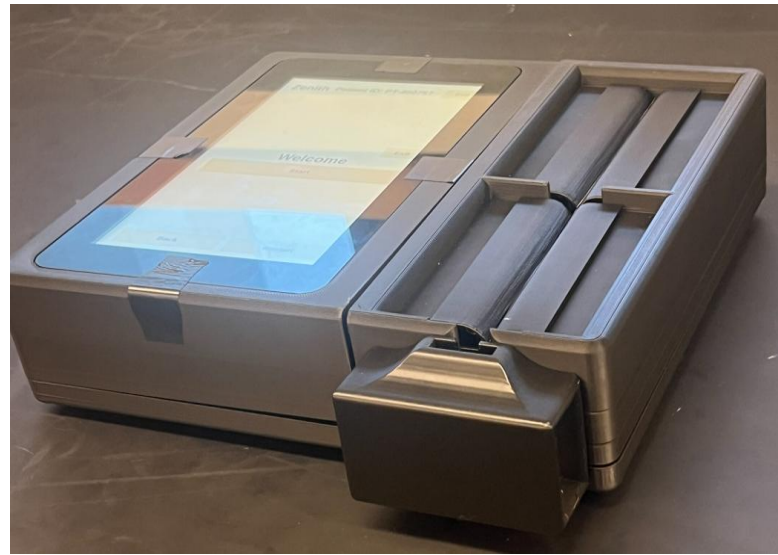


Figure 4: Image of fabricated final device

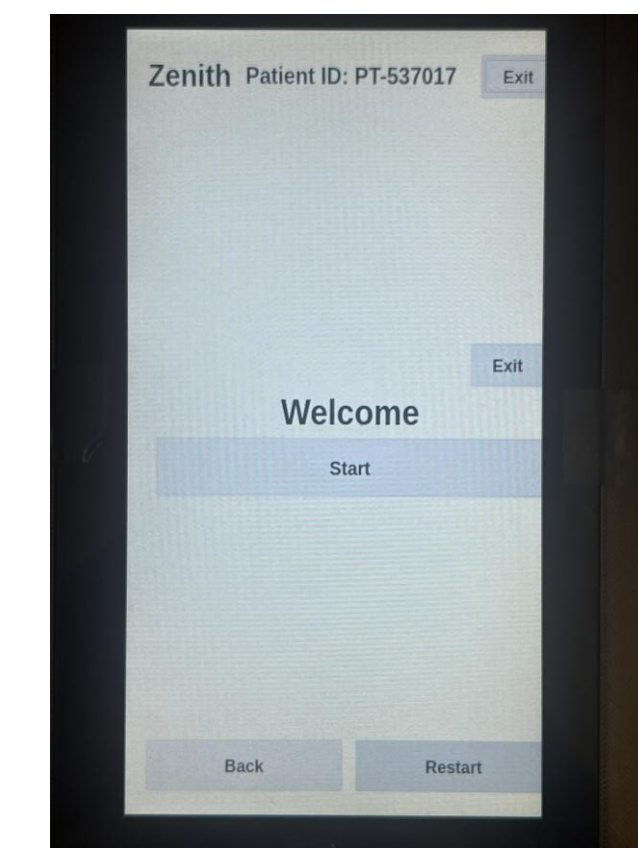


Figure 3: Image of software home page

Experimental Results

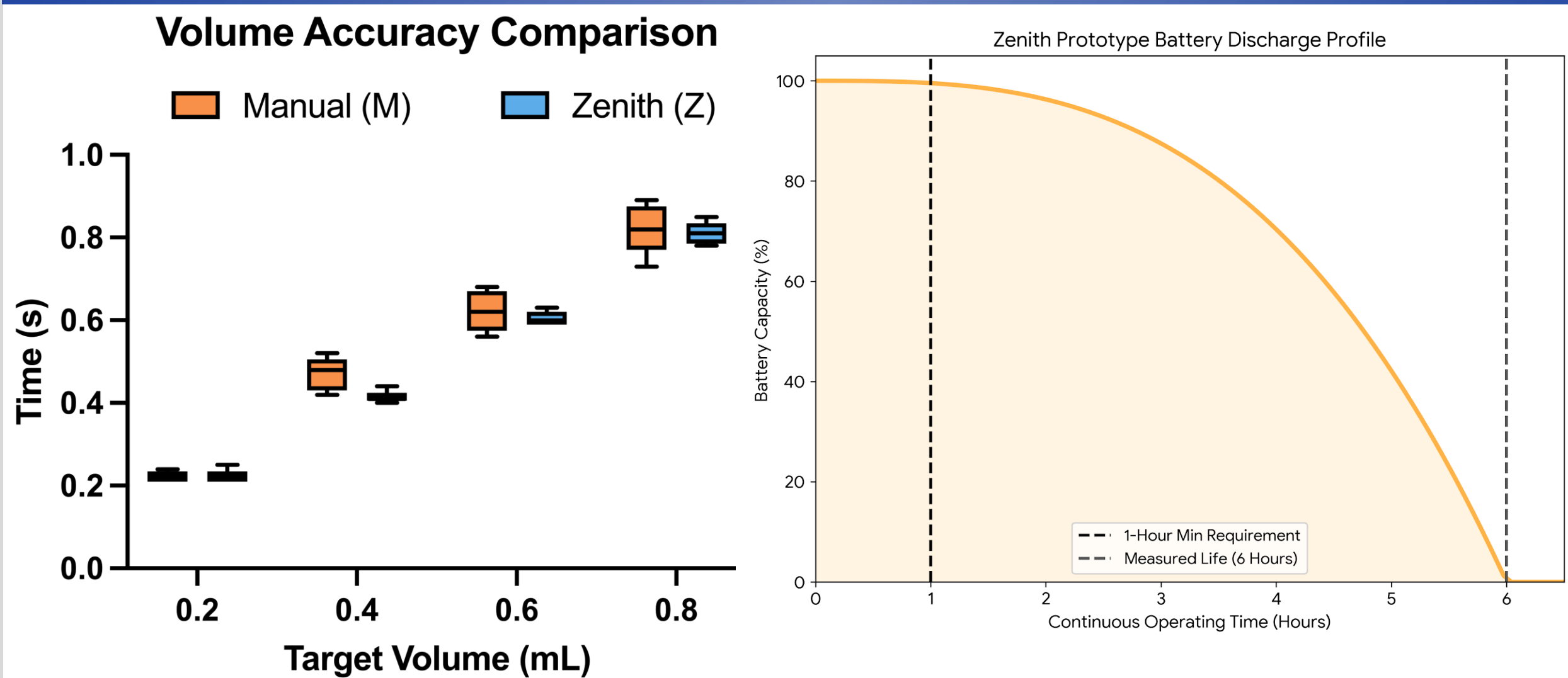


Figure 6: Volume Accuracy Comparison

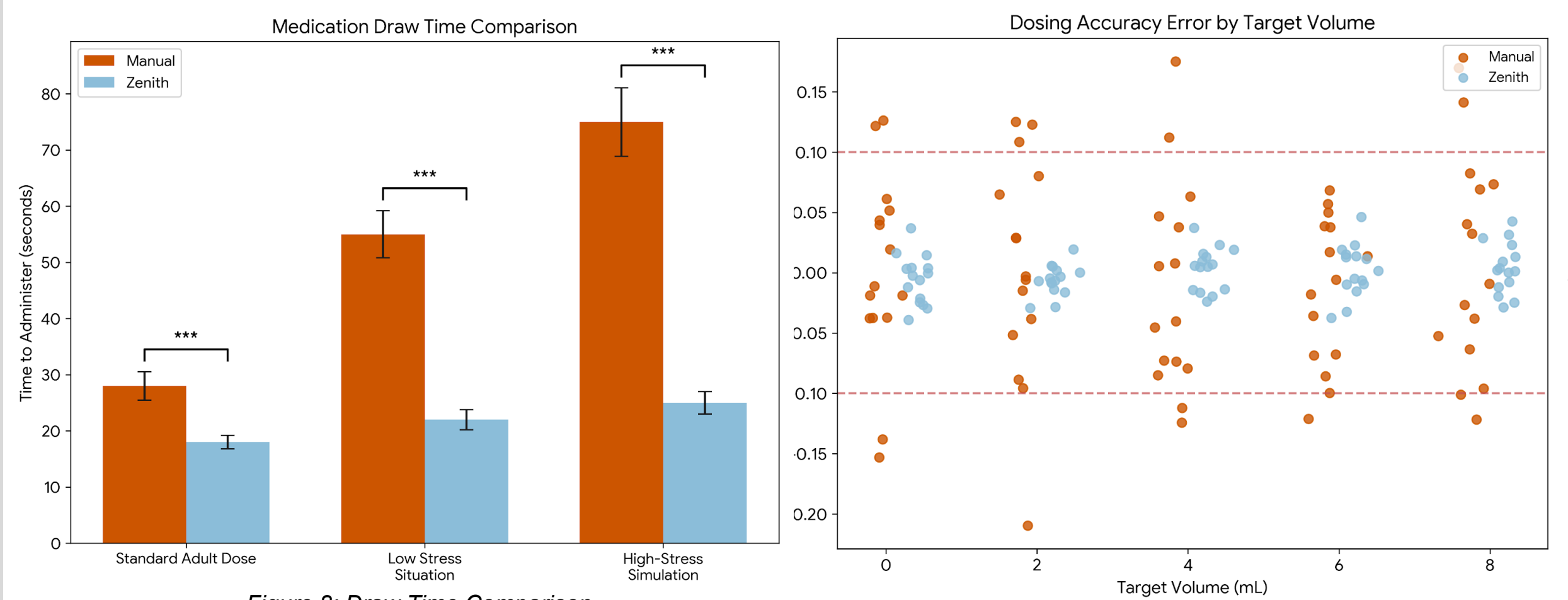


Figure 8: Draw Time Comparison

Figure 9: Percentage Dosing error at Target Volume

Traceability Matrix

User Req	Design Input	Design Output	Design Verification	Results
Functional Requirements				
Guide dosing	Based on AFD protocols	Protocol-based software (condition, med, dose)	Dual review + 10 test cases	Pending
User-friendly	≥ 80% of users rate easy	Step-by-step UI for protocol navigation	Usability survey (n=10)	Pending
Sensor feedback	Continuous real-time display	UI with syringe ID + mL display	20 live operation tests	Pass
Volume accuracy	±0.01 mL	Sensor alignment + calibrated software	Stepwise draw testing	Pending
Fast use	≤ manual method	Integrated CAD + software system	Timed live trials	Pending
Battery life	≥ 1 hour cont.	Li-ion battery system	Battery operation/life test	Pass (6 hours)

Physical Requirements

EMS fit	≤ 250 × 250 mm	CAD enclosure within size limit	Measure + compartment fit check	Pending
Syringe sizes	1, 3, 5, 10 mL	CAD design with spring-loaded insert	Fit + reach testing (all fit; 3,5 no reach)	Fail
Low weight	≤ 2.9 kg	Lightweight ABS enclosure	Mass measurement	Pass
Sanitizable	≥ 500 cycles	ABS + carbon fiber materials	500 wipe test	Pending
Durable	1 m drop	Impact-resistant CAD design	Drop test	Pass
Temperature	0–45 °C	ABS enclosure + enclosed electronics	Environmental testing	Pass
Handheld	≥ 80% comfort	Enclosure with rear hand strap	Survey (n=20 users)	Pass

Conclusion

From the specifications, constraints, and testing results, our device currently meets most of AFDs original goals. While some tests resulted in failures, there are still pending test results that may show the device can meet even more of their objectives. Some notable goals that the device currently achieves include operating effectively under EMS conditions, providing an interactive display for users, maintaining durability, and delivering accurate sensor feedback. One of the main lessons we learned during the design process was that having a limited budget restricted the types of sensors we could use. This often meant making trade-offs between device size and measurement accuracy. We also encountered several design challenges that were not fully addressed due to time constraints, but these issues can be improved in future iterations of the device.

Future Iterations

- Adjustable vial components to fit multiple vial sizes.
- Expanded syringe compatibility with auto-centering guides
- Slimmer, more ergonomic housing for easier field use

Standards

ISO 14971 – Risk management (prevents dosing errors)

ISO 13485 / FDA QMSR – Design controls & traceability

IEC 62304 – Software verification for dose calculations

IEC 60601 – Electrical safety & EMC in EMS environments

ISO 62366 – Usability engineering to reduce human error

References

- Sheridan, D. C., Meckler, G. D., Kennedy, A. M., Grabinsky, A., Blackwood, J., Vavilala, M. S., & Hansen, M. (2019). Dosing errors made by paramedics during pediatric patient simulations after implementation of a statewide pediatric drug dosing reference. *Prehospital Emergency Care*. <https://doi.org/10.1080/10903127.2019.1619002>
- Rappaport, L. D., Kennedy, C., Murphy, S., Eberhardt, M. H., & Wang, R. (2022). Medication errors in pediatric patients after implementation of a field guide with volume-based dosing. *Prehospital Emergency Care*. <https://doi.org/10.1080/10903127.2022.2025962>

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