Final Design Report Team 13

Alec Hudson, Jenna Sapong, Myles Knot, Caleb Crunk, Jackson Lynd

Design Presentation

Executive Summary

This report details the IV bag height adjustment mechanism, an automated motorized IV pole with refill notification. It employs the following:

- Linear actuator for 5-7 ft height adjustment in <36 sec
- Load cell for fluid monitoring (alert at ~90 mL/0.09 kg)
- Arduino controls with joystick input
- Audible and Visual user feedback
- Stable and compact design

The design meets all DRS, costs $364.51, and outperforms manual poles in safety and efficiency. Trial readiness is proven through acceptance tests and performance metrics.

Machine Function

The device adjusts IV bag height (5-7 ft) via joystick and alerts via chime when fluid is low. It maximizes usability features across stakeholders of Users, Owners, Manufacturers and Support.

Design Requirement Specifications (DRS)

- Height: 5-7 ft in <36 sec.
- Load: 2.2-4.4 lbf (0.998 kg – 2kg).
- Alert at ~90 mL (0.09 kg).
- Budget: <$400.
- Alert Sound: >50 dB.
- Stability: No tipping/ease of transport.

Competitive Advantages

- Linear actuator chosen over rack/pinion or lever for off-the-shelf simplicity, constant velocity (1.34 in/s), and high load (89.9 lbf / 40.78 kg). Superior to manually lifting IV bags by reducing repetitive injuries, enabling single-user operation and auto-alert when bag is near empty.

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- This design is optimized for stability and ease of transport as it retracts to the lowest compact size possible (under 5 feet) making moving through doorways and onto elevators is much simpler.
- Eliminates all manual efforts of lifting IV bags resulting in reduction of repetitive injury claims

Proving Trial Readiness

Acceptance tests: Height adjustment 13.6 sec (pass); load to 4.4 lbf stable (pass); alert at 0.09 kg (pass); alert sound >50 dB (pass).

Performance Matrix

Requirement	Target	Performance	Status
Height	5-7 ft	5-7 ft (24” extension)	Pass
Time	<36 sec	17.9 sec	Pass
Load	2.2-4.4 lbf (0.998 kg – 2kg)	89.9 lbf (40.78 kg)	Pass
Change in Mass Sensitivity	0.005 kg	δ_m = 0.005 kg (10 kg cell)	Pass
Budget	<$400	$370.01	Pass
Sound	>50 dB	~90 dB	Pass

Cost Analysis

Bill of Materials

Component	OEM	Part Number	QTY	Cost/Unit	Total
Linear Actuator	JQDML	B0DH254XYJ	1	$104	$104.00
MicroController	Arduino	Uno Rev3	1	$27.60	$27.60
LED Wheel	Adafruit	LED Ring Light	1	$16.95	$16.95
Motor Shield	Arduino	Rev3	1	$28.40	$28.40
Thumb Joystick	Arduino	Grove	1	$6.00	$6.00
Audio Buzzer	Passive Buzzer	Naroote	1	$0.50	$0.50
Hanging Load Cell	DigiKey	1568-21669-ND	1	$23.10	$23.10
Plywood Base	Home Depot	24”x24”	1	$12.87	$12.87
PVC Tube Support	JM Eagle	6”x10 ft D2729	1	$26.31	$26.31

PVC Flange Mount	Jones Stephens	7 in. O.D.	1	$20.26	$20.26
PVC Tube Extender	IPEX	1/2 in. x10 ft SCH 40	2	$4.96	$9.92
PVC Connectors	Charlotte Pipe	1/2 in. Coupling	3	$0.70	$2.10
Caster Wheel Base	WEN	24”x24” Dolly	1	$54.60	$54.60
Handle	Manufactured	-	1	$20.00	$20.00
Position Encoder	Arduino	KY-040	1	$2.40	$2.40
Misc. Hardware	Home Depot	Bolts/Nuts/Washers	50	$0.18	$9.00
Total					**$364.51**

Final Design Overview

Key functionality for final IV Bag lift system that this design incorporates

- PVC/plywood base with casters for stability and low center of gravity
- Linear actuator for extension to required height, simple off-the-shelf components and compactness
- Load cell at top for weight/volume measurement providing required δ_m mass sensitivity
- Arduino controller with joystick user input.
- LED visual level and calibration indicator and audible alert chime.
- Automates height and alerts low and empty fluid levels.

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CAD Model

SolidWorks model: Retracted (5 ft) and extended (7 ft) views, labeled base, actuator, load cell, joystick, LCD, chime.

Figure 1: CAD

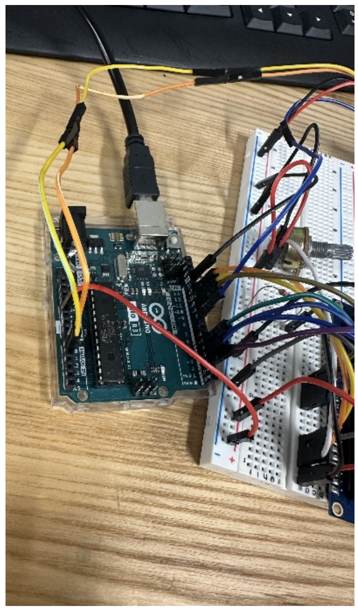

Figure 2: Wiring

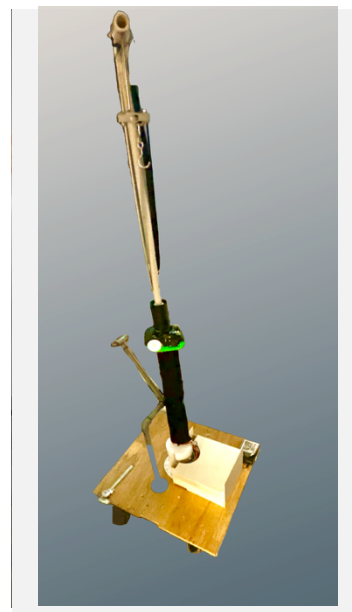

Figure 3: Machine as built

- Figure 1: Depicts the CAD model that was used to build and wire the actual Device.
- Figure 2: Shows the wiring on the Arduino microcontroller that combines all the components into one device.
- Figure 3: Pictures the working IV stand prototype, completed, tested and operational.

3-View Line Drawings

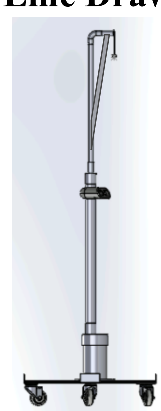

Figure 4: Side View

Figure 5: Top-Down view

Figure 6: Front view

- Figure 4: Depicts the side view providing a profile angle of the hook and loadcell showing 60-84” height range and caster mounting
- Figure 5: Shows the plan view which includes the profile of the IV stand and demonstrates the stable base with 24” square footprint
- Figure 6: shows the front view giving a good view of the user input control panel

Manufacturing Overview

Purchased Components	Fabricated Components
Arduino Controller/Wiring	3D printed parts
Linear actuator	Assembly
Switches	Transportation Handle
Materials	
Load Cell	

Assembling components together and developing the code for this project was the main challenge, once the code was developed manufacturing was straight forward to meet DRS goals.

Key Manufacturing Process Steps

1. Bolt casters to 24” square base
2. Mount PVC Base in center of base
3. Install actuator and 3D printed cap
4. Install additional PVC assembly to house actuator
5. Install Load Cell and Lifting Arm
6. Wire Arduino per Figure 2 and upload operating software
7. Test Assembly for performance to design requirement specs

Total assembly and test time ~2 hours

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Conclusion

The IV bag design prioritizes accuracy and ease of assembly, aiding medical staff and manufacturers through intuitive user interfaces and precise load sensing. It meets all design requirements and delivers optimal performance for the environment it services. Ass seen in the Proving Trail Readiness section, this design meets or exceeds all design requirment specifications.

Design Methodology

Problem Statement and Customer Needs

Manual IV pole adjustments cause repetitive stress injuries, inefficiency, and lost revenue due to unchecked fluid levels.

The customer needs are as follows:

- Automated IV Bag elevation that is easily adjustable and single-user capable (End-User)
- Efficient that requires no manual labor (reduced claims) and alerts for IV bags nearing/reaching empty (Owners)
- Easy to assemble and low cost (Manufacturers)
- Modular design and stability allows for easy transportation, maintenance and troubleshooting (Support)

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Functional Decomposition

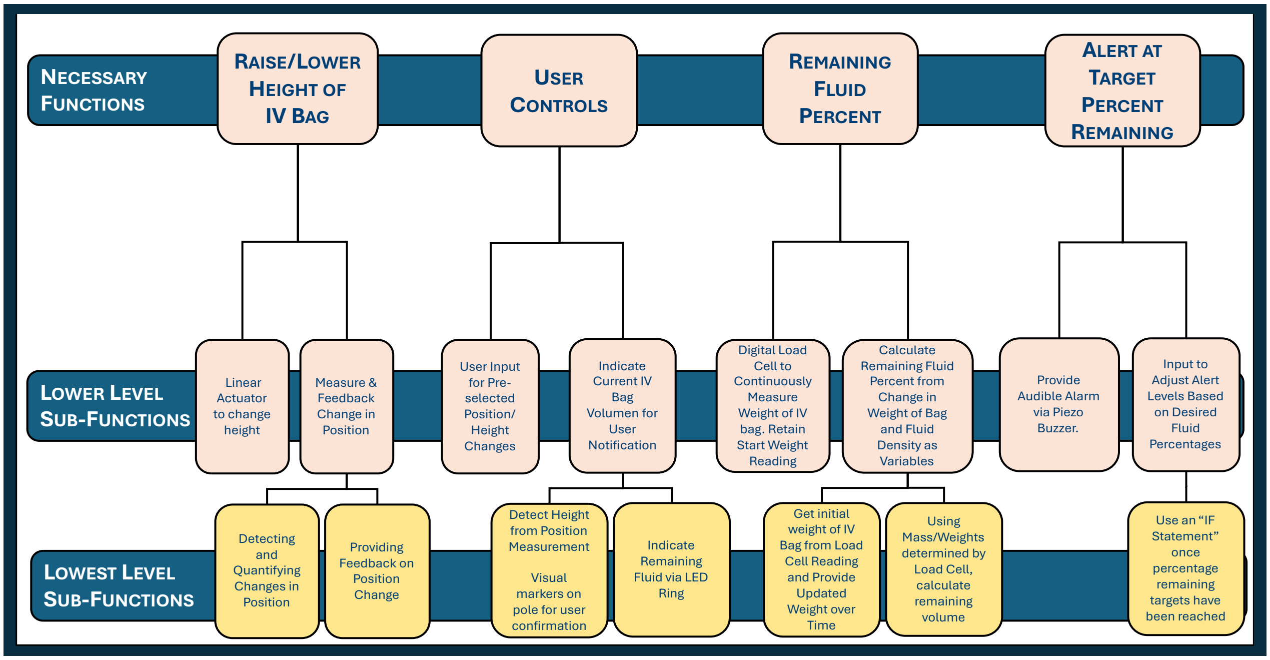

Figure 7: Function Tree Diagram – Adjust Height, Controls, Measure and Notify

Engineering Requirements/Specifications

Requirement	Target	Max Allowable
Height	5-7 ft	±0.1 ft
Time	<36 sec	Max 36 sec
Load	2.2-4.4 lbf	Min 2.2 lbf
Sensitivity (minimum mass change detection threshold)	δ_m=0.005 kg	Max 0.005 kg
Alert Sound	>50 dB	Max 100 dB
Budget	<$400	Max $400

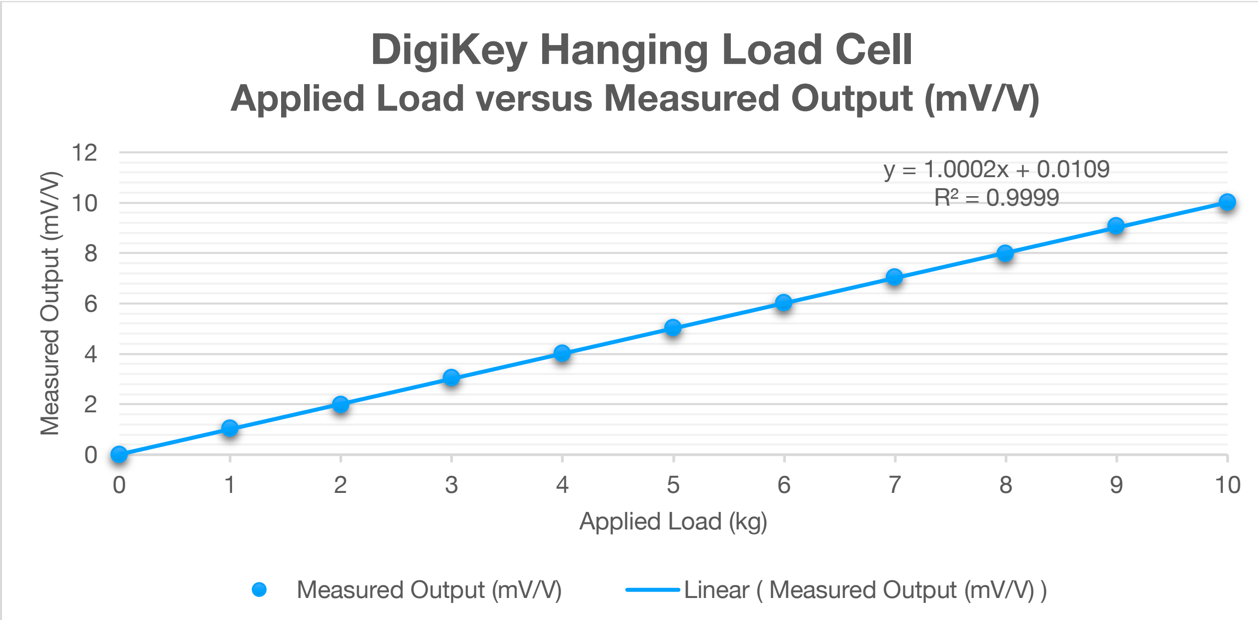

Chart1: Applied load versus voltage output for the DigiKey hanging load cell.

The load cell provides very predictable and stable voltage output across measured loads. This ensures reliability for calculating remaining fluid measured in the IV bag.

Based on the OEM specs of the load cell and expected loading use-cases, the hanging load cell will provide excellent resolution.

- 1 mL detectability on a 1L bag
- Provides the 0.05% mass change sensitivity accuracy and delivers required design precision up to 4,400mL (4.4 kg) load
- This system works for all common sizes of IV bags (50mL to 1,000mL) and can accommodate larger 3,000mL IV bags sometimes used in specialized trauma centers

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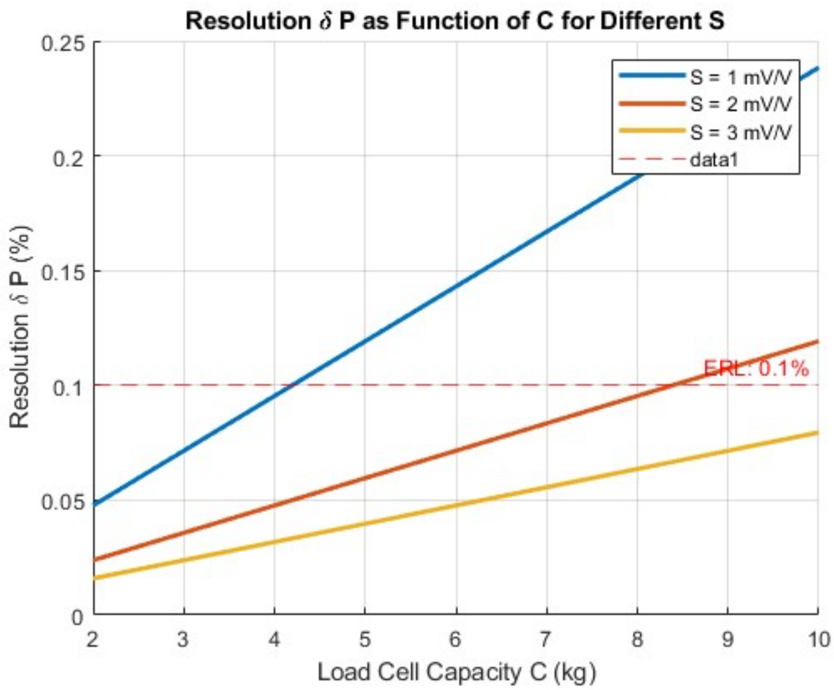
A parametric contour plot was generated using MATLAB and the OEM performance sheet data to visualize ERM uncertainty across the design space.



Line Color	Sensitivity S (mV/V)	Slope Behavior	Resolution at 10 kg
Blue	1 mV/V	Steepest	~0.10% (1 g)
Orange	2 mV/V	Medium	~0.05% (0.5 g)
Yellow	3 mV/V	Flattest	~0.033% (0.33 g)

- All lines are straight and rising → δP increases linearly with C
- Higher S = lower δP → better ability to detect small weight changes

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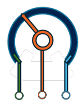
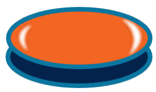
Concept Generation

The morphological matrix provides an overview of initial design concepts that were used to identify a preliminary solution.

LLSF	WP1	WP2	WP3
Raising and lowering	Screw Driven Motor 	Linear Actuator 	Lever to Move IV Pole Height 
Measuring Height	Potentiometer Sensor 	Optical Sensor 	Ultrasonic Rangefinder 
User Input and Feedback	Button 	Joystick 	LCD Light Ring 
Calculating Fluid Remaining	Load Cell 	Optical Sensor 	Timer 

From these, a weighted decision matrix was created to select the design to be manufactured.

Need	Weight	Concept Variation 1	Concept Variation 2	Concept Variation 3
Raising & Lowering	1.0	Linear Actuator S=1	Rack & Pinion S=0.8	Lever Arm S=0.25
Measuring height	0.5	JQDML Acutator Internal Potentiometer S=1	Constant Velocity Extention shaft S=.7	Optical Sensor S=0.25
Remaining IV Fluid Measurement	0.9	Load Cell S=1	Digital Scale S=0.6	Timer S=0.25

User Feedback/Alarm System	0.7	Chime S=1	Piezo Buzzer S=0.9	Speaker S=0.95
Ease of Transport, Stability	0.9	Ballast to the bottom S=1	Wide Base S=0.9	Bolt down /Locking S=0.7
Satisfaction Score		4.0	3.13	1.9

Final Design Solution and Single Alternative

Design Manufactured	Alternative
Linear Actuator Purchased	Lead screw to push up PVC- a lead screw would be rotated with a motor to push up the pvc pipe
Load Cell Purchased	Optical Sensor to measure fluid level- would see the level of fluid go down visually
Joystick & Position Encoder	Touch screen- to control machine and control function
LED ring light	LCD screen- would be used to display fluid level and linear actuator position
Passive Alarm	Active alarm- is one frequency, so pitch can't be changed

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Targeted design

Design Targets:	Status
IV stand moves up and down between 5ft and 7ft	**MET**
Loadcell tracks weight	**MET**
Buzzer goes off when loadcell reads lower than 20% weight	**MET**
Stability	**MET**

Design Development

Engineering Requirements Level Assurance

Requirement	Assurance
Height	• Height was measured from lowest point was equal to 5ft • Height was measured from highest point was equal to 7ft
Time	• Speed of linear actuator measured 1.34 in/s and extends the required 2 ft in 17.9 seconds
Load	• Supports the weight of a 1,000 mL IV bag (1 kg) and more. This was tested and verified with different weighted objects
Sensitivity	• Load cell was tested with two objects of slightly differing weight and was accurate within 1%
Sound Buzzer	• ~90 dB which was tested with an iPhone decibel reader
Budget	• Project stayed within the constraints of the budget and, is able to fulfil every engineering requirement

Design For Considerations (DFX)

DFX	Consideration or Goal
DFV: Designed for velocity	The linear actuator was selected to have the functionality of speed so it could complete position movements in less than 35 seconds. It's

	load capacity has a sufficiently high safety margin that speed is not affected under all expected loading use cases
DFS: Designed for Stability	The base was made with extremely low center of gravity, heavy and wide, to prevent any tipping. Additionally, design was optimized to allow for retraction to lowest height possible for transport and movement. These two design factors ensure the IV stand will not tip and cause damage or lost productivity. Passing through doorways and elevators was a major consideration for compactness.
DFM: Designed for Manufacturing	This was designed to use off the shelf components making manufacturing easy and reliable. Additionally, 3D printed components keep customized part cost extremely low and can be used to make molds for low-cost mass production.
DFS: Designed for Serviceability	All the wires and mechanical components are easy to troubleshoot, disassemble and replace making repairs simple and fast.

FMEA with Design Correction

Failure Mode	Severity	Occurrence	Detection	RPN	Action	Correction RPN
Actuator runs past 7ft	**3**	**5**	**1**	**15**	No action necessary, position reader added to code	**15**
Load cell stops reading fluid level	**10**	**4**	**10**	**400**	Add in alarm start if Load cell is not detected	**40**
Battery dies	**10**	**3**	**5**	**150**	Low power mode added for detection	**30**

Joystick Failure	**9**	**2**	**10**	**180**	Add secondary input selector button	**20**
Audible Feedback Failure	**3**	**1**	**10**	**30**	No Action Necessary, rely on LED Ring for feedback	**30**

Closes Loop Between Measured Performance and Engineering Specifications

- All Engineering Requirements are met and accounted for and are demonstrable via the first article assembly that was manufactured and presented.

- Measured Performance is as follows:
  - Extension time between 5 feet and 7 feet is 17.9 seconds (<36 required)
  - Change in mass sensitivity is 1 g (5g is requirement)
  - Visual feedback for changes in weight/volume remaining including 10% remaining fluid and when empty
  - Audible feedback at 10% remaining fluid and when empty

At-a-Glance

Meets all Design Requirement Specifications

Performance	Benefit
50% Faster Deployment	Efficiency Gains
9% Cheaper than budget	Cost Effective/More Profit
5 times more sensitive to changes in mass of IV Bag	Finer Fluid Level Monitoring
20x greater load capacity	Ensures robustness and can support multiple IV bags within same unit
Full IV Bag compatibility 50mL to 3,000 mL sizes	Covers 100% of standard and trauma-center applications; validated via load cell resolution
Compact and Stable Portabilty	98% of mass is within six inches to the ground, 24” square footprint with multi-surface capable casters
100% Functional Compliance	Passes all acceptance criteria for autonomous operation, height range 4-7 ft, and fluid monitoring and audible/visual alerts with easy-to-use UI/UX