Medtronic — Optimized Robotic Surgery System — dc DESIGN CENTER COLORADO

Ben Smitherman, Cheng Zhou, Christopher Adami-Sampson, Elyjah Toledo, Garrett Miller, Gregory Reilly, Kalysa Christopher, Timothy Teh, Zak Chehadi

BACKGROUND

Medtronic's HUGO™ Robotic-Assisted Surgery (RAS) system enables surgeons by providing high tolerance minimally invasive surgical operations, though the current version has areas for improvement.

Project Objectives:
- ARM REDESIGN
- SURGICAL DRAPE
- CABLE MANAGEMENT
- HAPTIC FEEDBACK

Medtronic HUGO RAS Device

ARM REDESIGN

OBJECTIVES:
- ☑ Reduce the width of the arm from 8" to under 5"
- ☑ Replicate linear "Z-slide" motion using joints
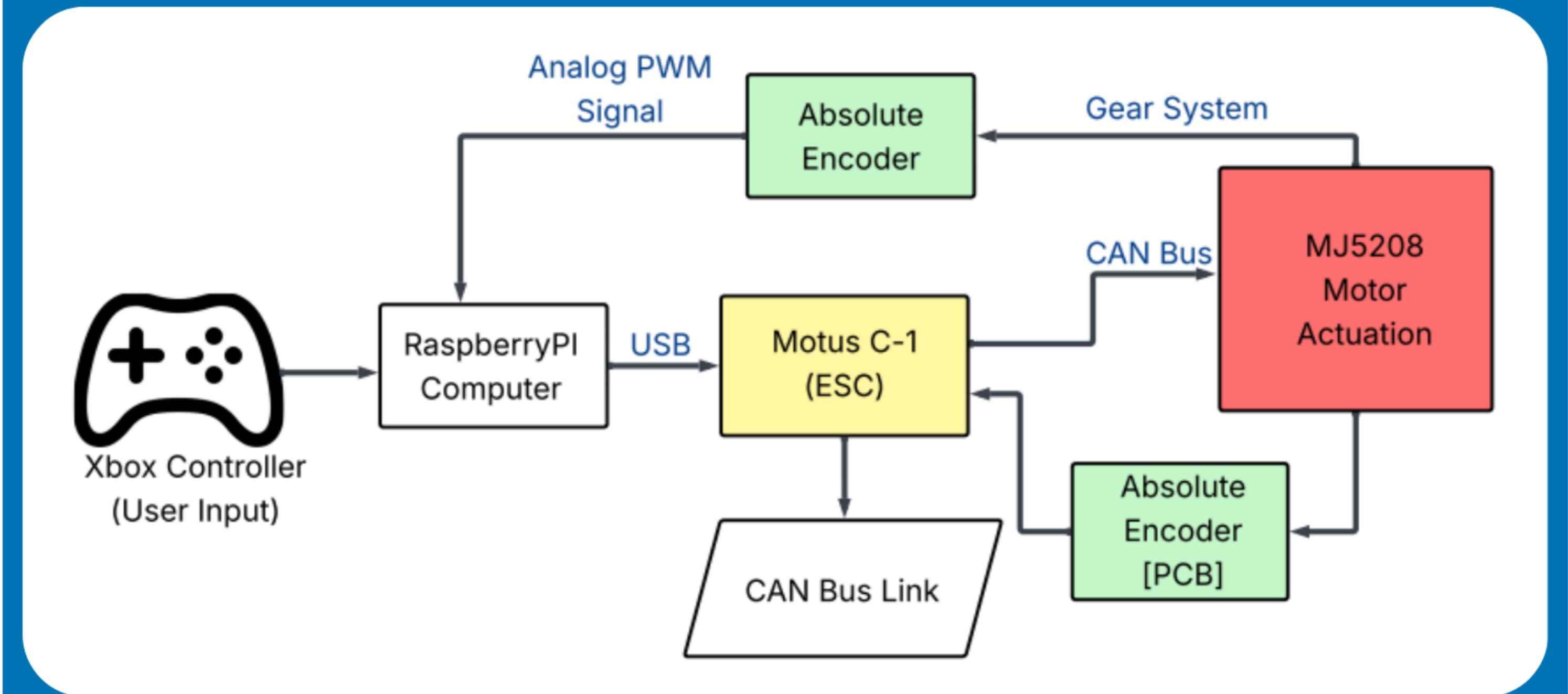- ☑ Implement Harmonic Drive gearboxes

MECHANICAL SYSTEM

- Concentricity ensures vibration resistance
- Replicated Z-slide motion via joint actuation
- Compact joints fit arm width constraints
- Harmonic Drives 80:1 gear ratio, precise
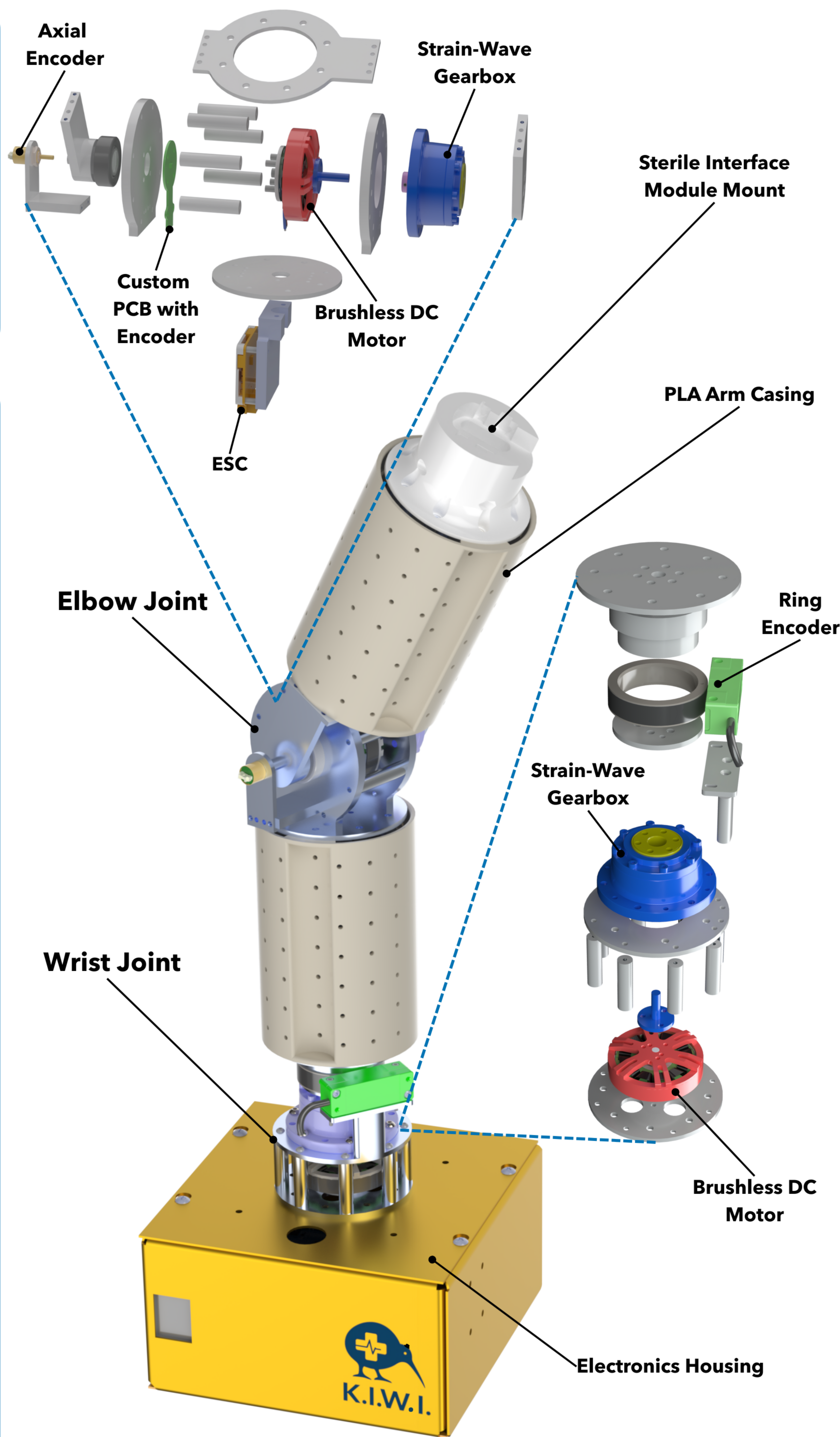- Arm profile reduced 50% (8" → ~4")

K.I.W.I. Aluminum Endoskeleton

ELECTRICAL SYSTEM

OBJECTIVES:
- ☑ Articulate both joints with a controller
- ☑ Integrate CAN Bus for serial communication
- ☑ Confirm 1:1 output encoder response

Analog PWM Signal → Absolute Encoder → Gear System
Xbox Controller (User Input) → RaspberryPI Computer → Motus C-1 (ESC) → CAN Bus → MJ5208 Motor Actuation
RaspberryPI Computer — USB — Motus C-1 (ESC)
Motus C-1 (ESC) → CAN Bus Link
Absolute Encoder [PCB]

- Brushless DC motors enable joint articulation (~303 in³)
- Electronic Speed Controllers (ESC) dictate speed & position
- Custom PCB with MA600 encoder integrated into elbow joint
- Absolute encoders provide feedback for absolute positioning

Exploded diagram labels

- Axial Encoder
- Strain-Wave Gearbox
- Custom PCB with Encoder
- Brushless DC Motor
- ESC
- Sterile Interface Module Mount
- PLA Arm Casing
- Elbow Joint
- Ring Encoder
- Strain-Wave Gearbox
- Wrist Joint
- Brushless DC Motor
- Electronics Housing
- K.I.W.I.

SURGICAL DRAPE

OBJECTIVE:
- ☑ Reduce the form/size of the surgical drape
- Vacuum system secures drape to arm
- Fan off during motion; on when stationary
- Streamlined shape for easy installation

CABLE MANAGEMENT

OBJECTIVE:
- ☑ House end-effector cables along length of arm
- Internal C-channels route cables with minimal protrusion
- Bi-stable spring cuffs secure cables in place

K.I.W.I. PLA Exoskeleton

HAPTIC FEEDBACK

OBJECTIVE:
- ☑ Provide 1:1 tactile response to surgeon
- Two Brushless DC motors, magnetic sensors, and dual motor drivers
- Arduino with Field-Oriented Control (FOC): precisely regulates torque via real-time feedback

Before Applied Force   After Applied Force

TESTING

Quarter-scale Model	Verifies ROM of the full arm?	✓
Surgical Drape	Decreases form and does not restrict movement?	✓
Cable Management	Routes cables along arm and does not restrict movement?	✓
Torque Requirement	Does it provide min 45 ft-lbs?	✓
Movement Accuracy	Does the joint move between angle locations accurately?	✓
Haptic Feedback	Does reciprocal motor provide same load within +/- 0.5 lbs?	?

FUTURE OUTCOMES

- Re-verify motion range with added joints
- Expand software for multi-joint control
- Implement 4-arm overhead gantry
- Integrate haptic feedback in console