MITACS SUMMER PROJECT FINAL PRESENTATION

- TDCR LEARNING KIT FOR OPENCR PROJECT
- IFAS – FAS AS A MANUAL INPUT DEVICE

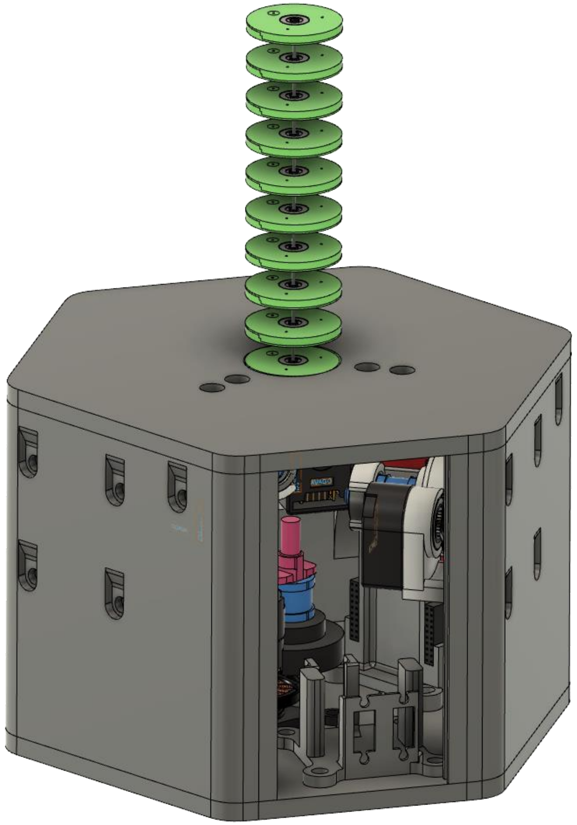
BY ANKIT AGGARWAL

UNIVERSITY OF TORONTO Robotics Institute

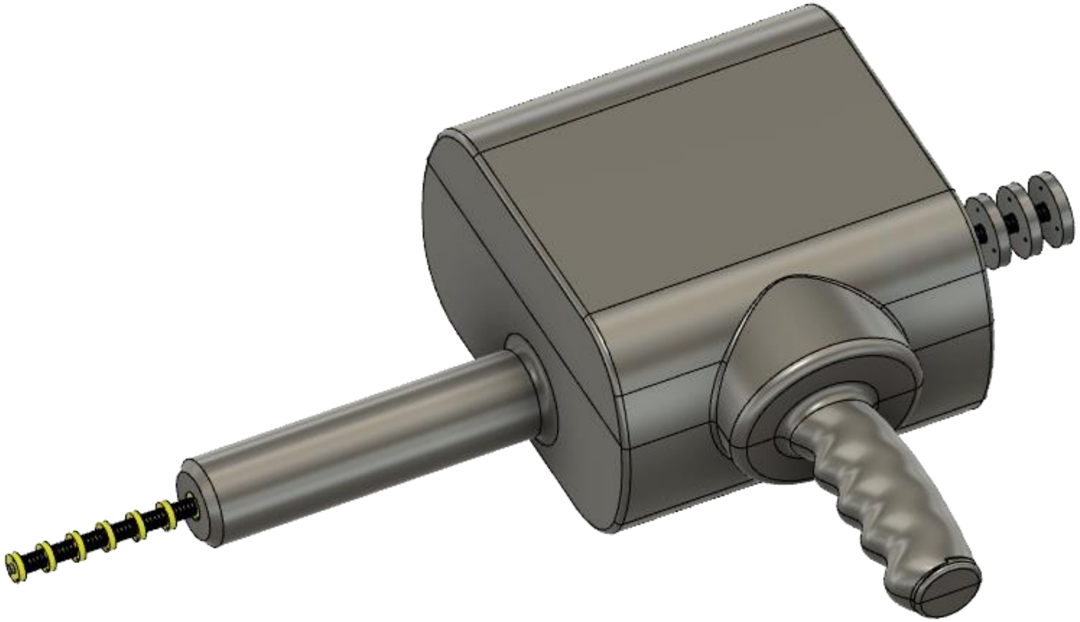
continuum robotics lab

THE TWO PROJECTS

TDCR Learning Kit for OpenCR Project

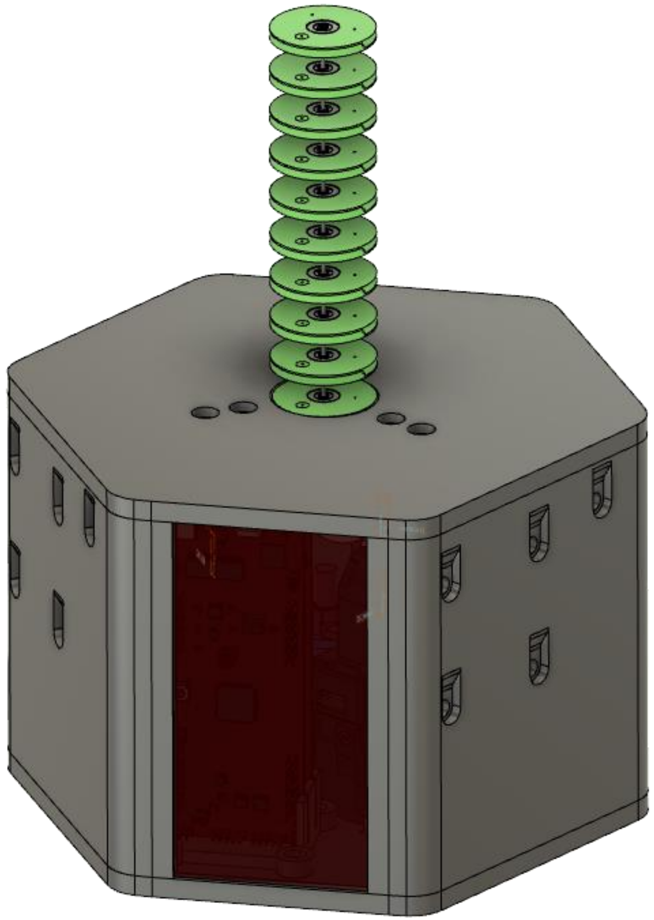


iFAS – FAS as a Manual Input Device

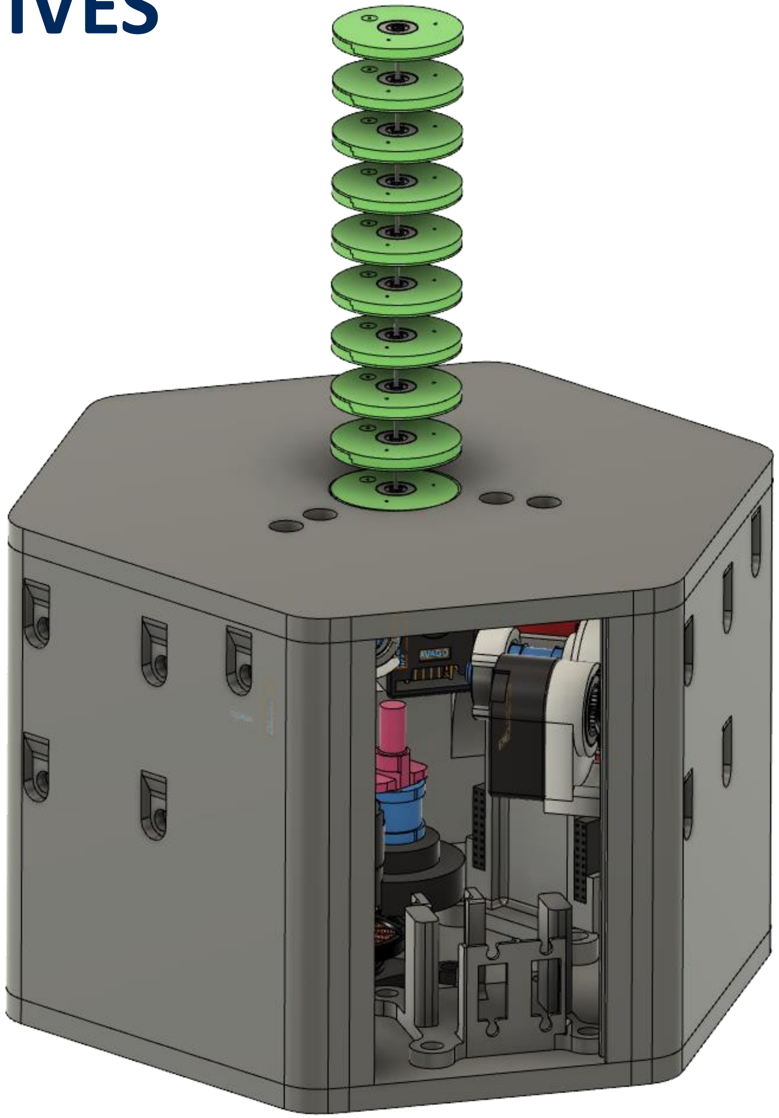


INTRODUCTION TO THE LEARNING KIT

- Aim is to develop a **fully 3D-printable** learning kit for a Tendon Driven Continuum Robot.
- Motivation lies in the fundamental belief of OpenCR, to **empower the world with open hardware**.
- To ensure that the aim is achieved, the design will be tested by being built in an **environment with limited resources**.
- I plan to task students in my home university (in India) to build the design and document their experiences.
- Using their feedback, a new, modified design can be made by **using more widely available resources.**



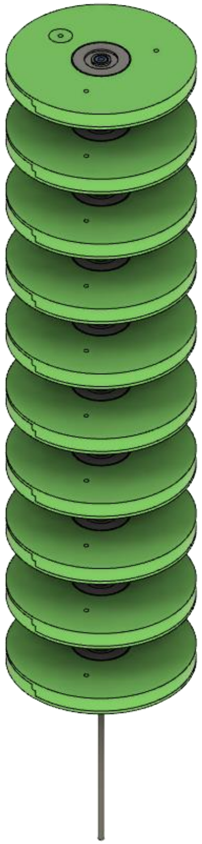
OBJECTIVES

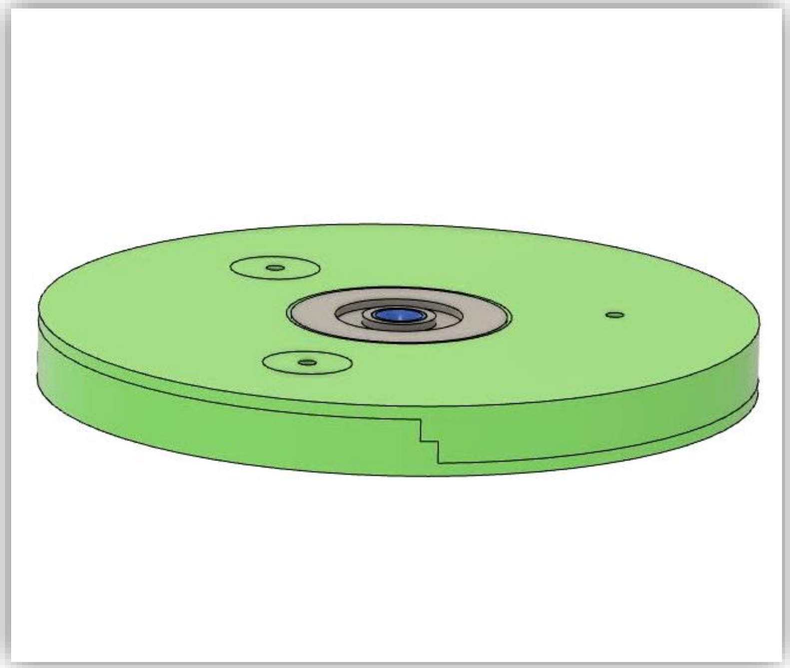


The kit must:

- Be fully 3D Printable using **FDM**
- Use **easily available** off-the-shelf components
- Be **easy to assemble** for all skill levels
- Be **portable** and safe to transport
- Be efficiently designed to be as **compact** as possible
- Allow users to easily understand concepts, design, and implement various algorithms.

THE DESIGN



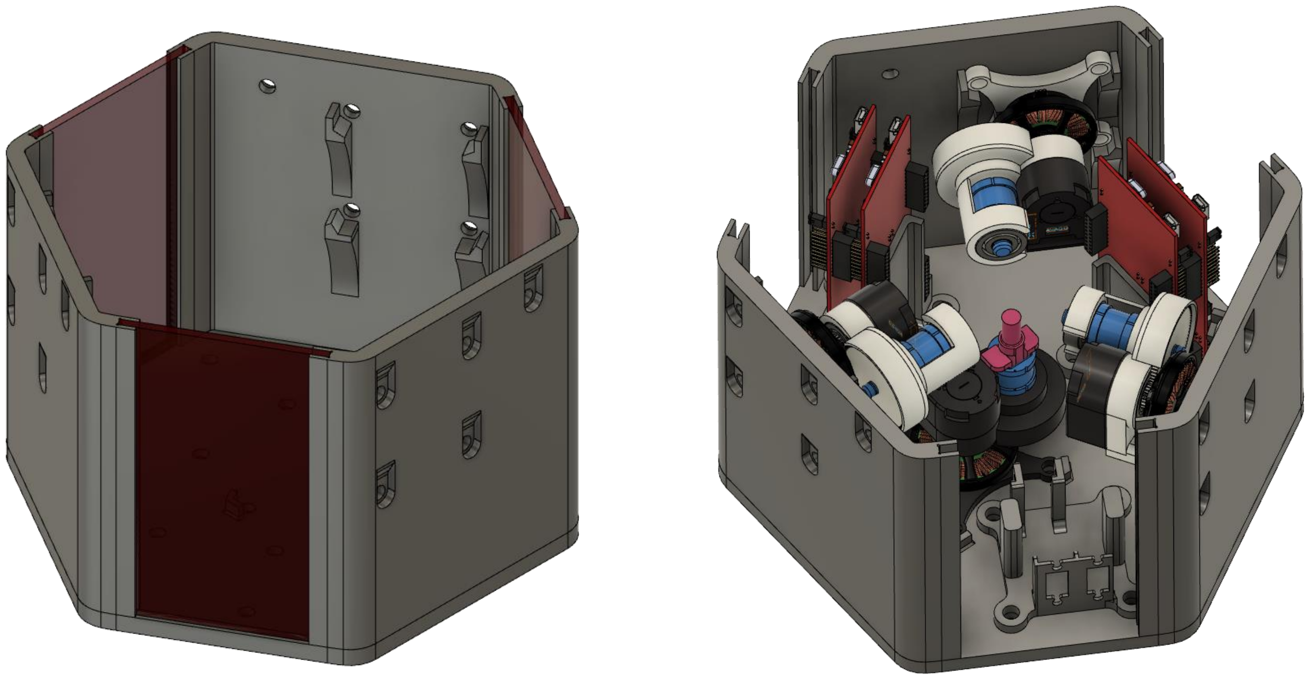


The Tendon Driven Continuum Robot:

- Consists of 10 **Type II Spacer Disks** equally distributed along a Nitinol Backbone
- Is capable of **3 DOFs**, namely bending across two planes and rotation about its axis using 4 actuators

THE DESIGN

- A **specialised hexagonal casing** with windows made of transparent acrylic sheets to view the system's working.
- The 3 tendon actuators are fixed horizontally to **minimise tendon routing**.
- 6 pulleys are placed inside to help **reduce the tendon offset.**
- The backbone actuator is placed at the bottom and controls backbone rotation.
- Specialised mounts have been designed for electronic components.

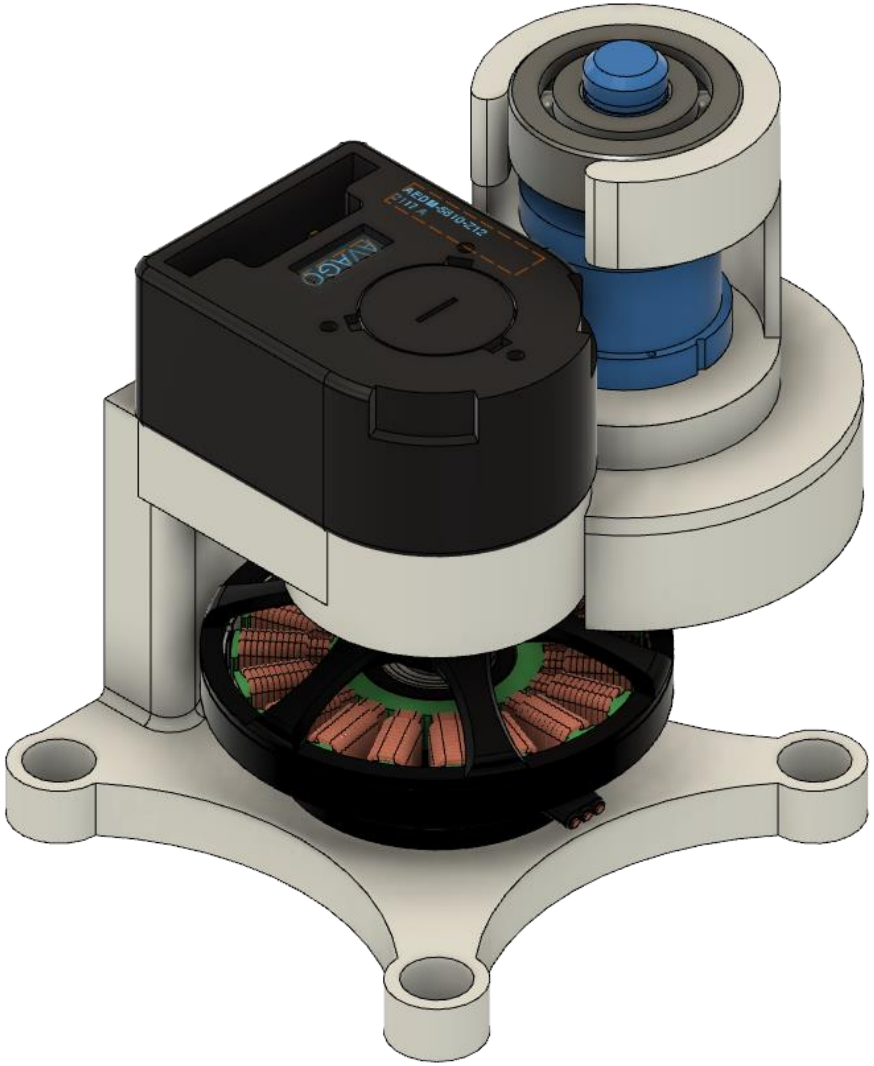


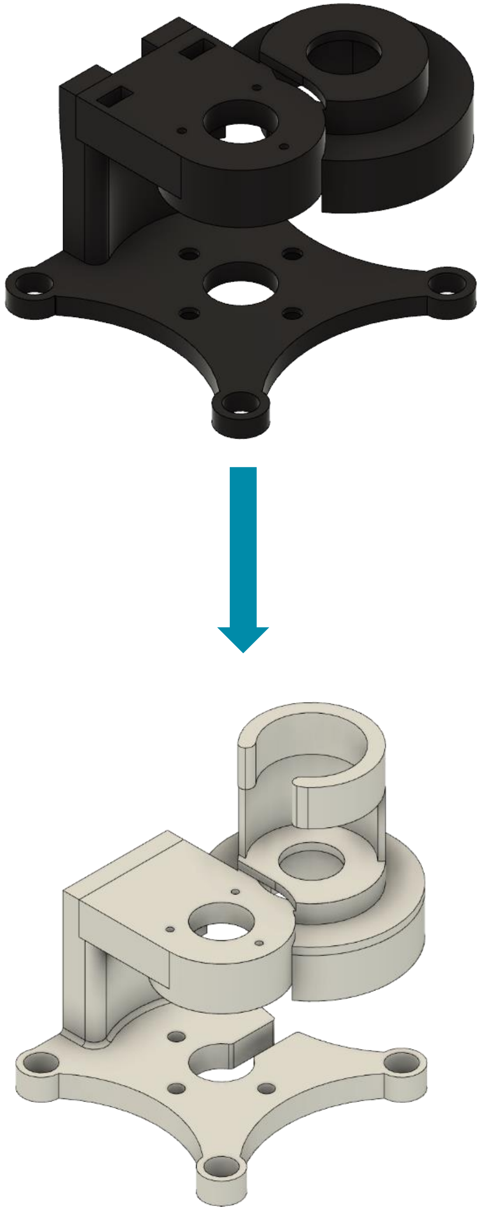
Single Part Hexagonal Base with Slots for Acrylic Sheets, acting as windows

IMPROVEMENTS FROM EXISTING DESIGNS

Actuation Module

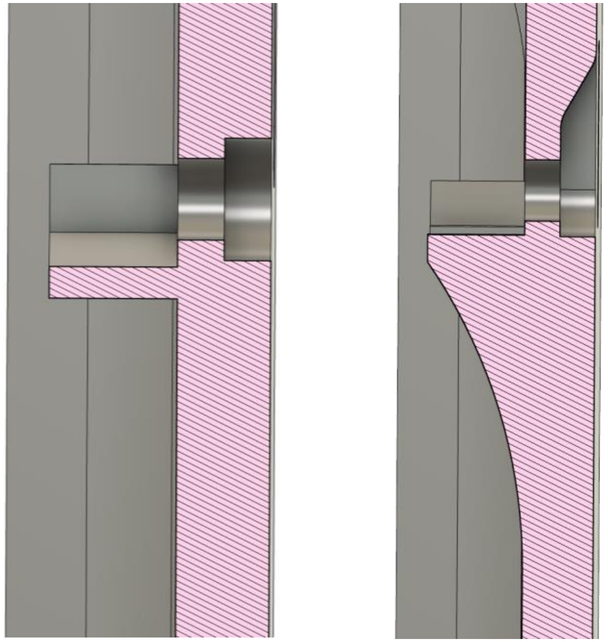
- The multi-part casing is replaced with a **single unit**, optimised to make manufacturing easier.
- This simplifies the assembly process and **eliminates shaft misalignment**.
- The motor and the gears can easily fit into **designated spaces** using **dedicated slots.**
- Since the actuator will only actuate tendons, an extra bearing is introduced at the output shaft to **handle the increased radial tension and eliminate shaft eccentricity.**





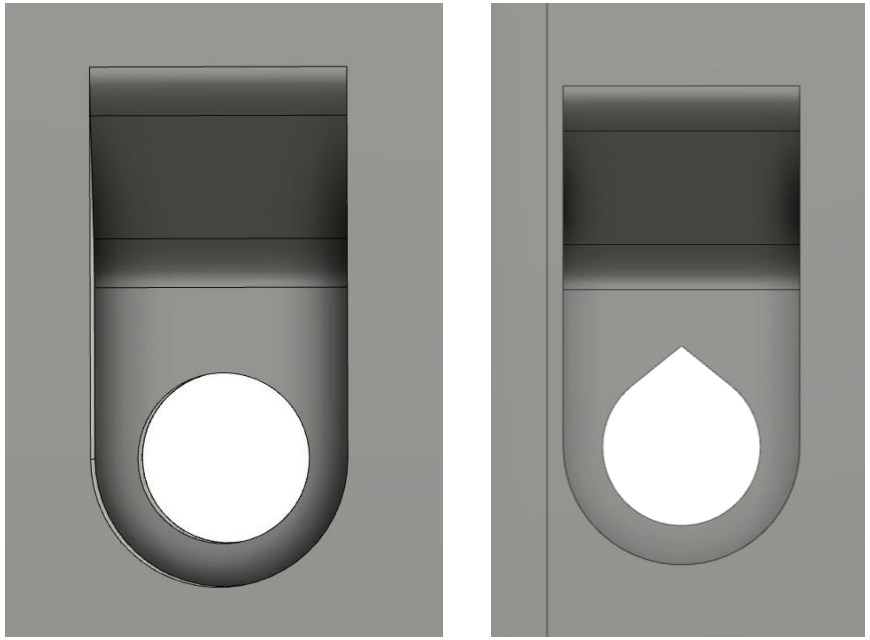
TO REDUCE SUPPORT MATERIAL FOR 3D PRINTING

BEFORE **AFTER**



Horizontal overhangs were eliminated by gradually reducing the overhang angle, thereby reducing support material

BEFORE **AFTER**



Teardrops were used to ensure optimal vertical holes with minimal support

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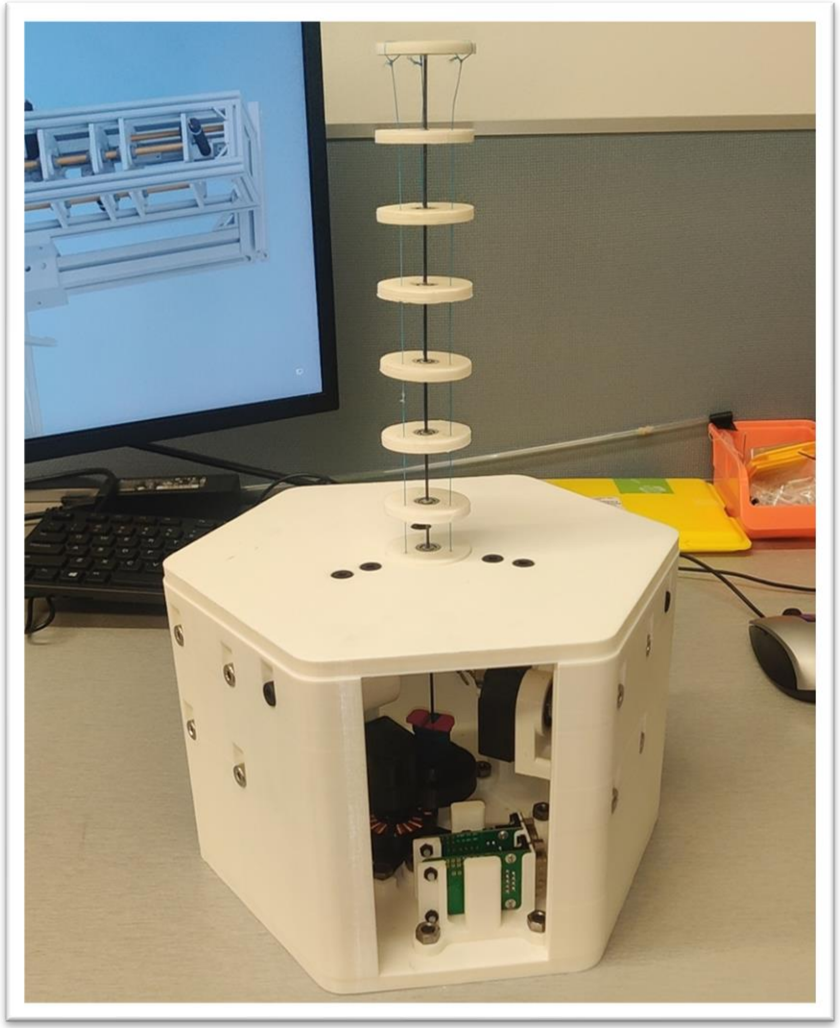
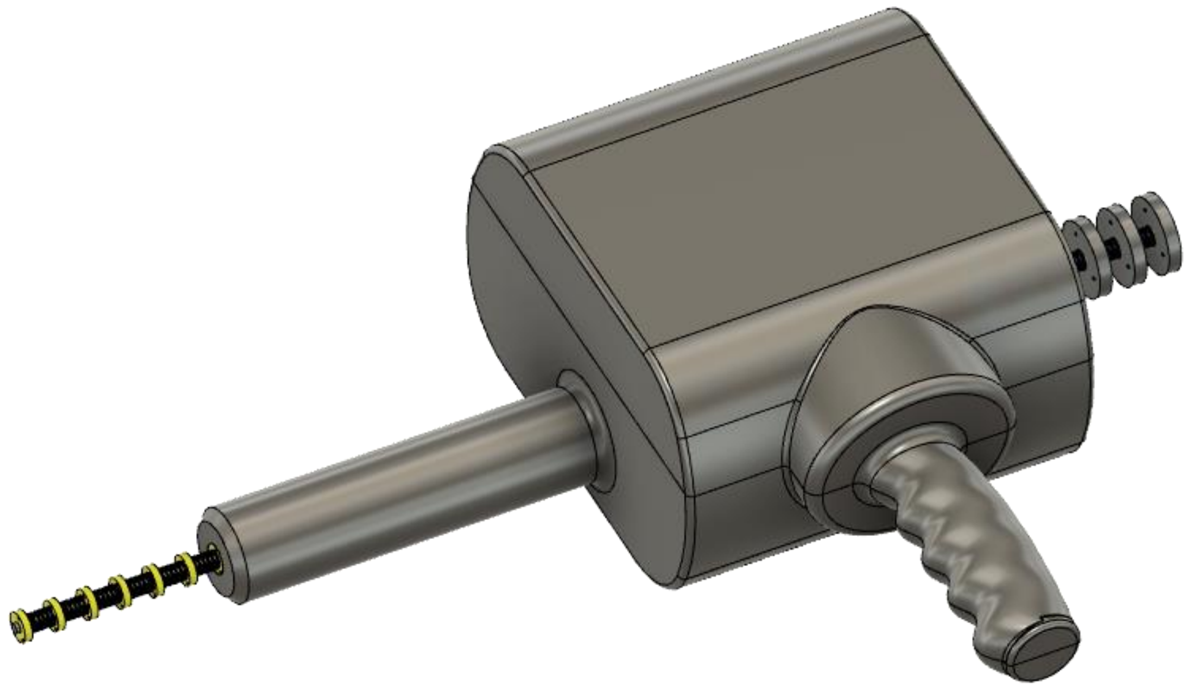
NEXT STEPS FOR THE LEARNING KIT



- Finish **editing the blog post** along with detailed manufacturing and assembly plans.
- Finish up the **hardware connections** to allow for the windows to be inserted.
- **Task students in India to create the design** using locally sourced components and document their experience
- Create a **new Bill of Materials** based on their prototype, ideally cheaper and less expensive.
- Make required changes to the designed parts to suit all calibre of 3D Printers.

IFAS – INPUT FULLY ACTUATED SEGMENT



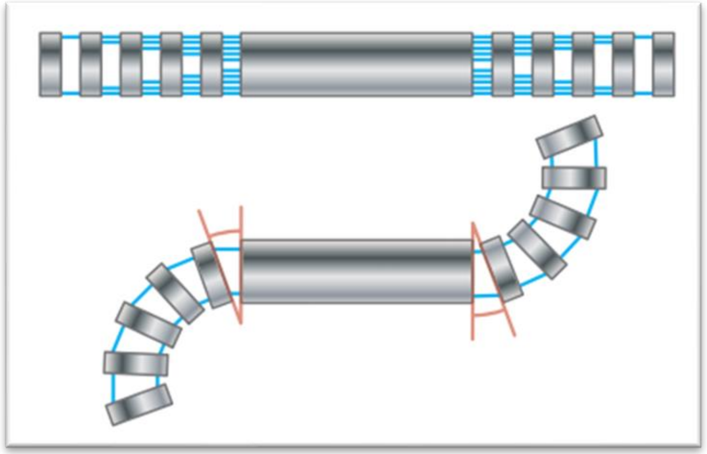
- Completely **manual hand-held device** with applications in surgery and inspection operations.
- Consists of an input and an output FAS segment.
- **The output segment mirrors the movement of the input segment**.
- Works using common tendons between the two segments.
- **Novelty** is introduced by adding **rotation using helical tendon routing** and **extension** DOFs.
- Includes a **working channel** to allow for the placement of a camera or forceps.

PREVIOUS WORKS

Henselmans PW, Smit G, Breedveld P. Mechanical Follow-the-Leader motion of a hyper-redundant surgical instrument

MEMOFLEX

The MemoFlex 1 contains a 12 cm long, Ø5 mm multi-steerable tip with 14 segments that can be controlled individually in 28 Degrees of Freedom.



Giada Gerboni *et al* 2015 *Bioinspir. Biomim.* **10** 066013

ADVANTAGES	LIMITATIONS
Individual actuation of each segment	High Mechanical Complexity
Reliable FTL Motion is achieved	No Extension DOF (pseudo-DOF, achieved using sliding the whole robot on a rail)
Precise replication of input motion using shape memory and compliant helicoid inserts	No Rotational DOF

VISION

Objective	Solution	Limitation
To create a device that **reduces the mechanical complexity** of the MemoFlex while keeping the bending functionality	A **consistent number of tendons** throughout the robot.	Removes the individual control of each disc, leading to **less precise FTL motion**.
To **include the rotational DOF** through helical tendon routing	**Custom mechanism** to compensate for the extension in tendon length	**Limited rotational capacity**, currently at 270°
To add a mirrored **extension DOF**	**Custom mechanism** to mirror the movement of the backbones	Very **Limited Extension** in Length
To make a **hand-held** and lightweight device	Custom casing with an ergonomic handle	**Limited space** to work with, influences the extents of the other DOFs

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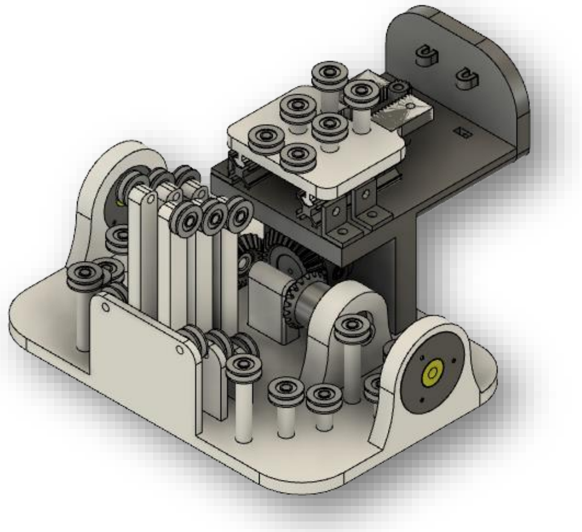
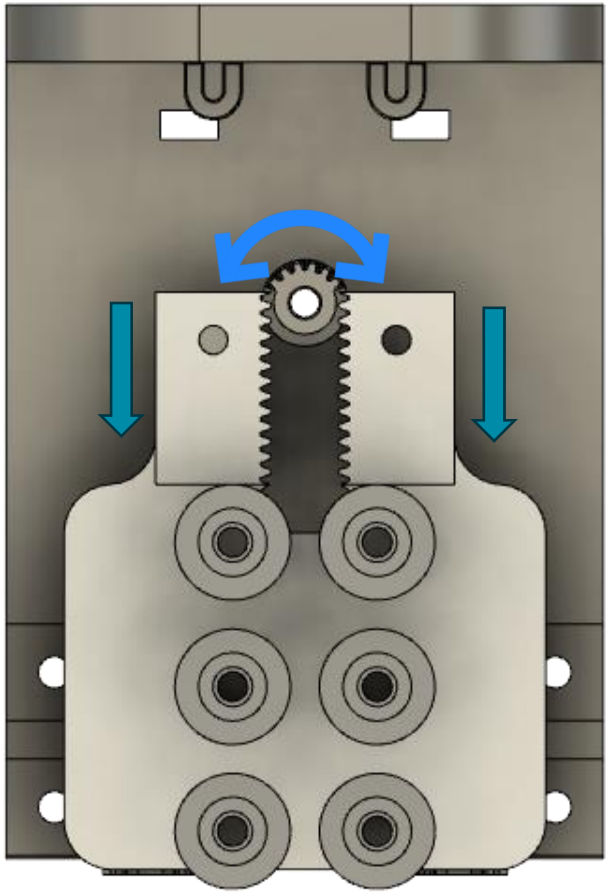
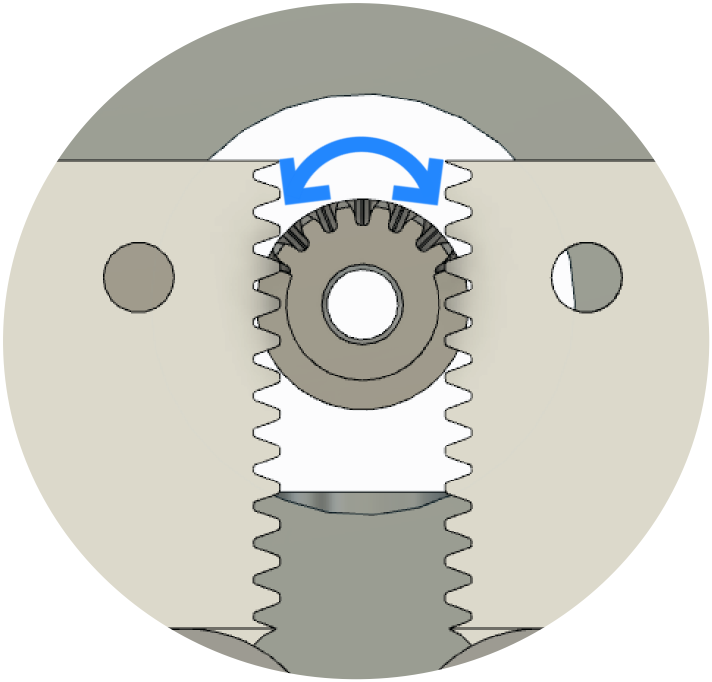
THE DESIGN

- To introduce **helical tendon routing**, a mechanism to **account for change in tendon length** was needed.
- The mechanism uses a combination of **bevel gears, racks and pinions** to change the tendon length available to the robot.
- The **sector-shaped gear** and the two **parallel racks** ensure that the mechanism actuates **regardless of the direction of rotation.**
- Due to limited space, the mechanism only allows 270 degrees of rotation on either side.







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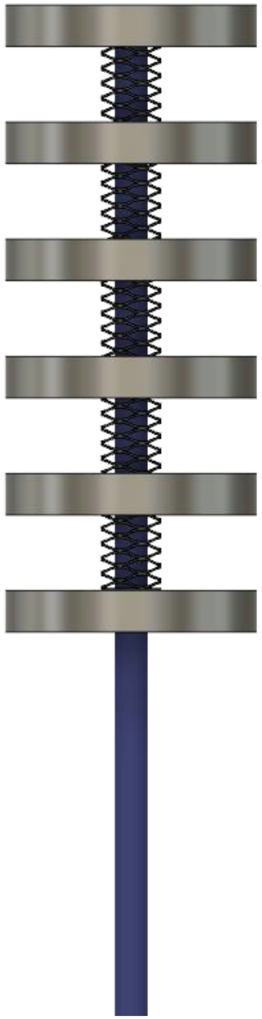
THE DESIGN

- Being a medical device, the TDCR **cannot have magnets** as the mechanism to keep the FSDs equally spaced during extension and retraction.

- To combat this, **stacked helical wave springs** are used.

- With a maximum length of 12mm and a working length of 6.86mm, they provide ample room for extension



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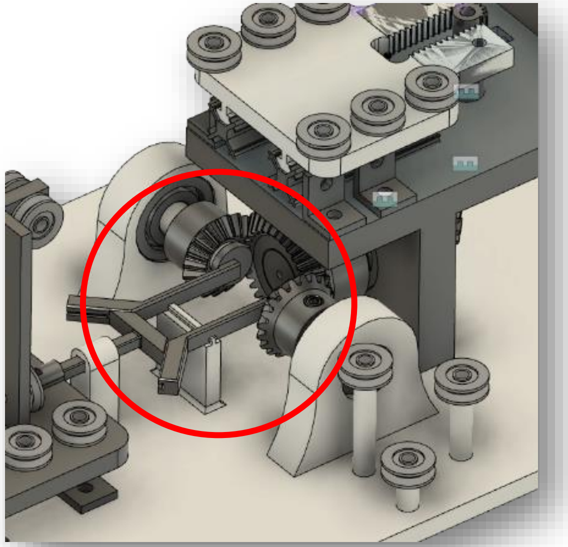
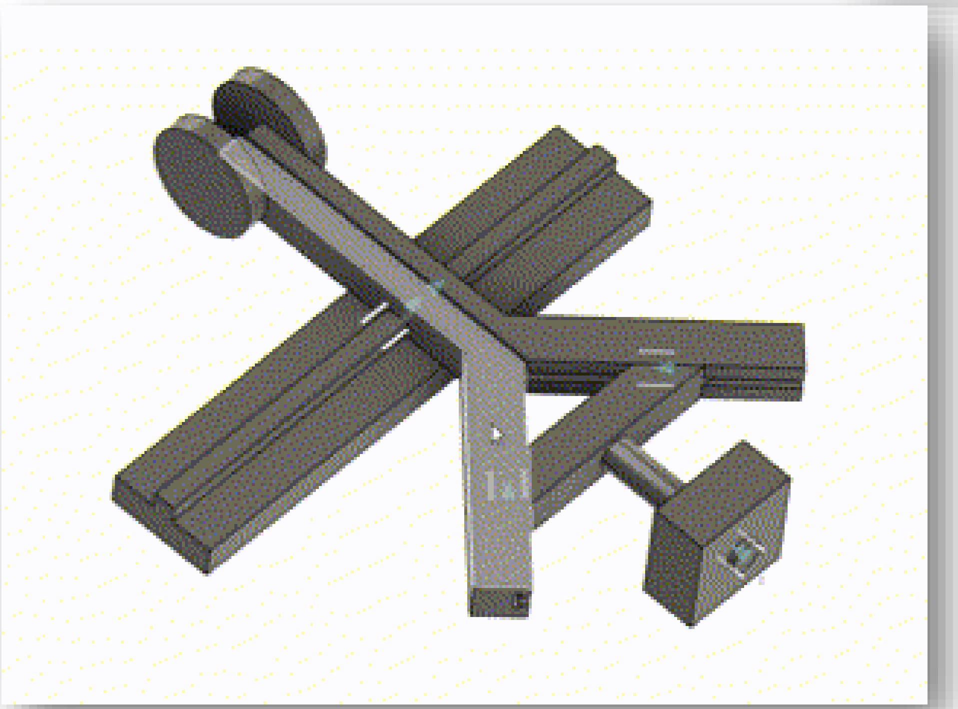
THE DESIGN

- To enable the **mirrored** extension, a four-bar mechanism was designed.
- It uses **4 prismatic joints** and **specifically shaped links** to enable the required motion.
- This idea was dropped as it **did not allow adequate extension** in the length of the robot.
- To get a realisable change in the length of the robot, a different mechanism must be used, as the current one cannot accomplish it, given the space requirements.





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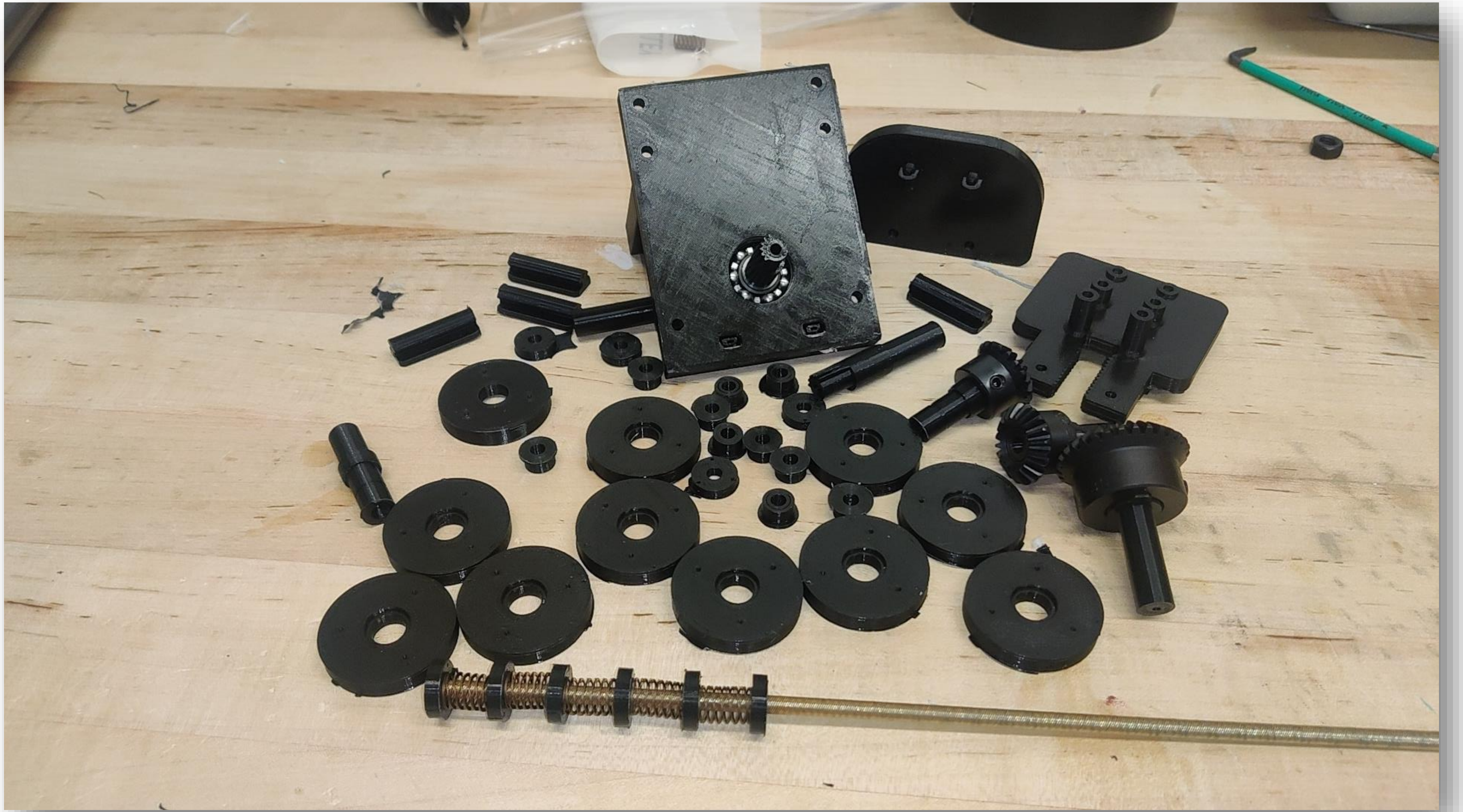
CURRENT PROGRESS



EXPERIMENT PLAN

- Use the **Laparo Advance** in the MEDCVR Lab to create the environment for the experiment.
- Create a **crowded maze**. Aim to see certain positions marked by stickers using the **camera**. Demonstrates inspection capabilities.
- Use the **forceps** to play the **string through-the-hole game** inside the Laparo to demonstrate manipulation capabilities.
- Use the **spring balance** in the lab to create a measure for the amount of force that can be applied. It can be used to see how much of the input force is translated to the output force.

Source: Laparo - Advance Portable - Laparo Medical Simulators (laparosimulators.com)

NEXT STEPS

Current Team Location: Toronto
Objective: Finish building First Prototype

Overall Project Goals

- New or modified mechanism to enable the extension DOF.
- Improve the limitations on the rotational DOF
- Make the assembly lighter and more compact for easier usage
- Aim for a publication

Ankit's Location: Manipal, India
Objective: Work on design enhancements and optimisations

Reinhard's and Puspita's Location: Toronto
Objective: Build successive prototypes and carry out the experiment plan

THANK YOU

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