



Showcase Presentation: Blade Grinding Device

May 2020

Patrick Bodine-Ellison
Peter Booras
Sam Brown
Jake Geraci
Zhenhua Lu
Daniel Llorca

Project Manager
CAD Engineer
Test Engineer/Financial Manager
Logistics Manager
Systems Engineer
Manufacturing Engineer

Overview

Introduction

- [Turbine Blade Damage](#)
- [Manual Blade Repair](#)

Device Design

- [Design Intent](#)
- [Rendering of Device](#)

Hardware Functionality

- [Vertical Navigation](#)
- [Suction Leg Assembly](#)
- [Three-Axis Gantry and Grinding Head Functionality](#)

Software Functionality

- [Control Concepts](#)
- [Control Flowline](#)
- [LabVIEW GUI](#)
- [OpenBuilds Control Software GUI](#)



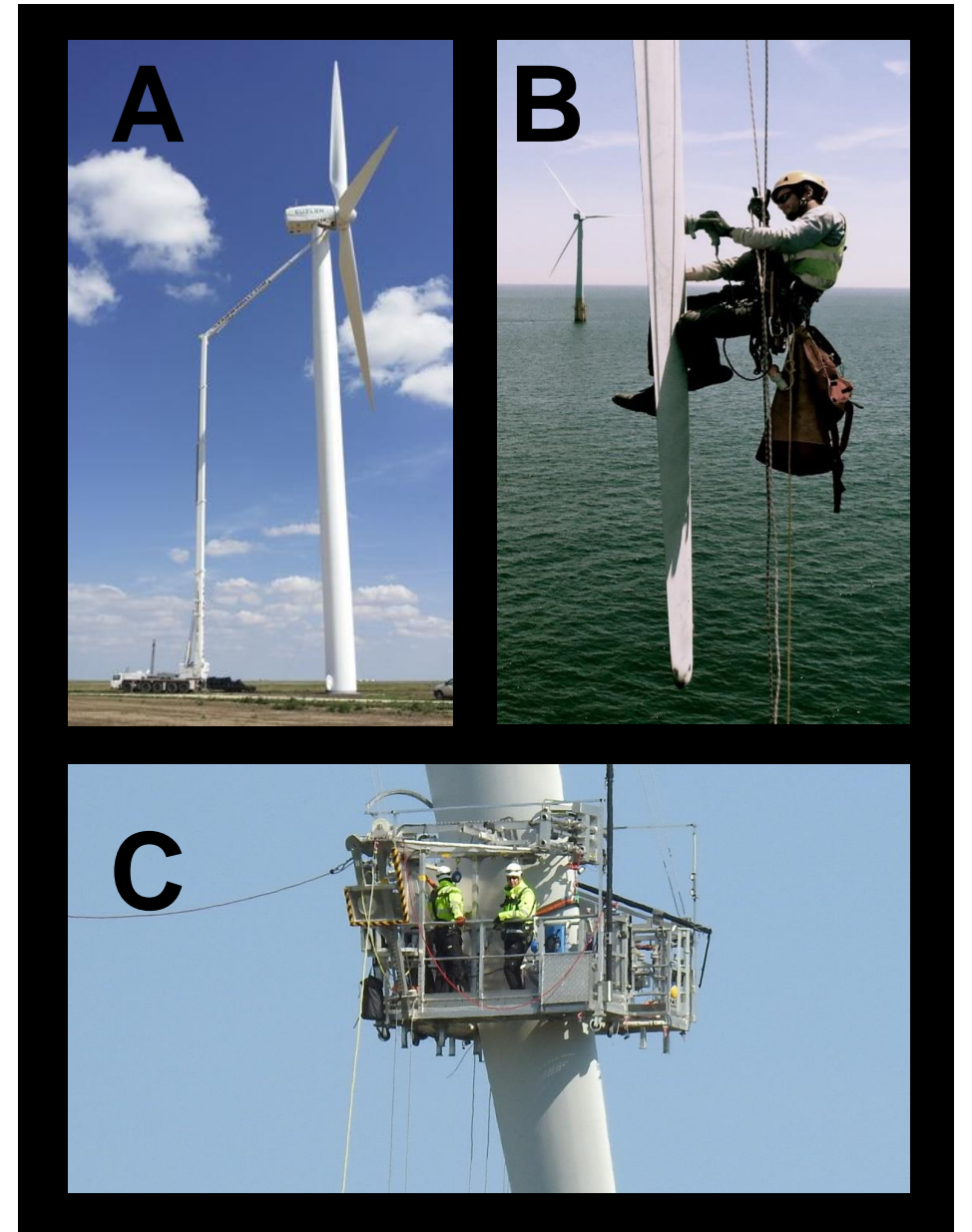
Turbine Blade Damage

- Wind turbine blades are responsible for harnessing kinetic energy to convert this into usable energy.
- Turbine blades are not invulnerable to the elements. The integrity of the blade can be compromised by lightning, rain, and airborne debris.
- If a turbine blade becomes damaged, its effectiveness is reduced and may require repair.



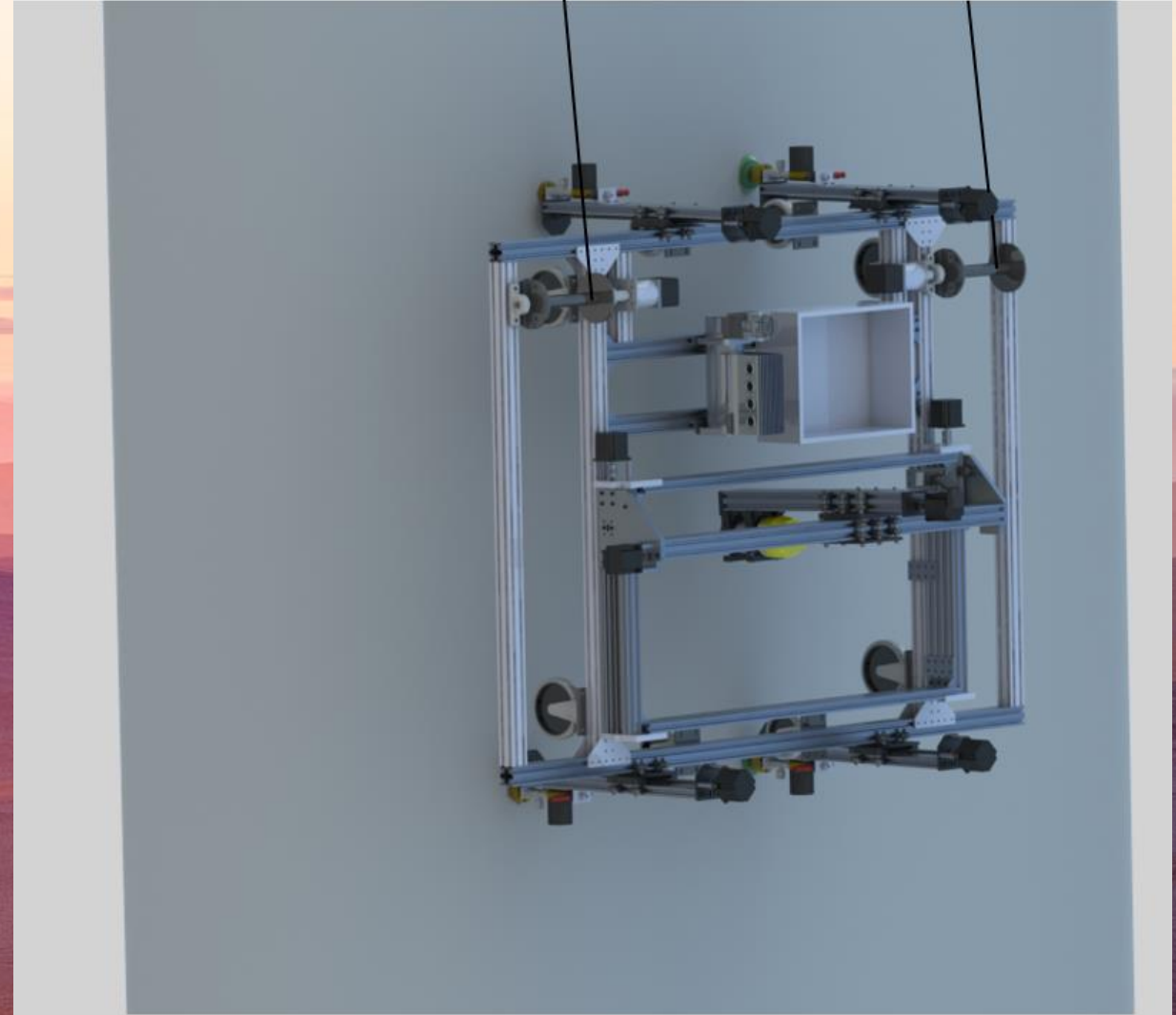
Manual Blade Repair

- Technicians access the blade to be repaired typically in one of three ways; using a boom lift to bring technicians directly to blade damage **(A)**, by accessing the blade with ropes tied to the nacelle **(B)**, or with a blade-climbing platform mounted via cables from the nacelle **(C)**
- Once the technician reaches the damaged location, they must assess the damage
- They then begin grinding through the surface paint, contour filler, fiberglass and balsa core. This process is completed with an angle grinder
- After up to 12 hours of grinding the technician can begin to replace each layer by hand

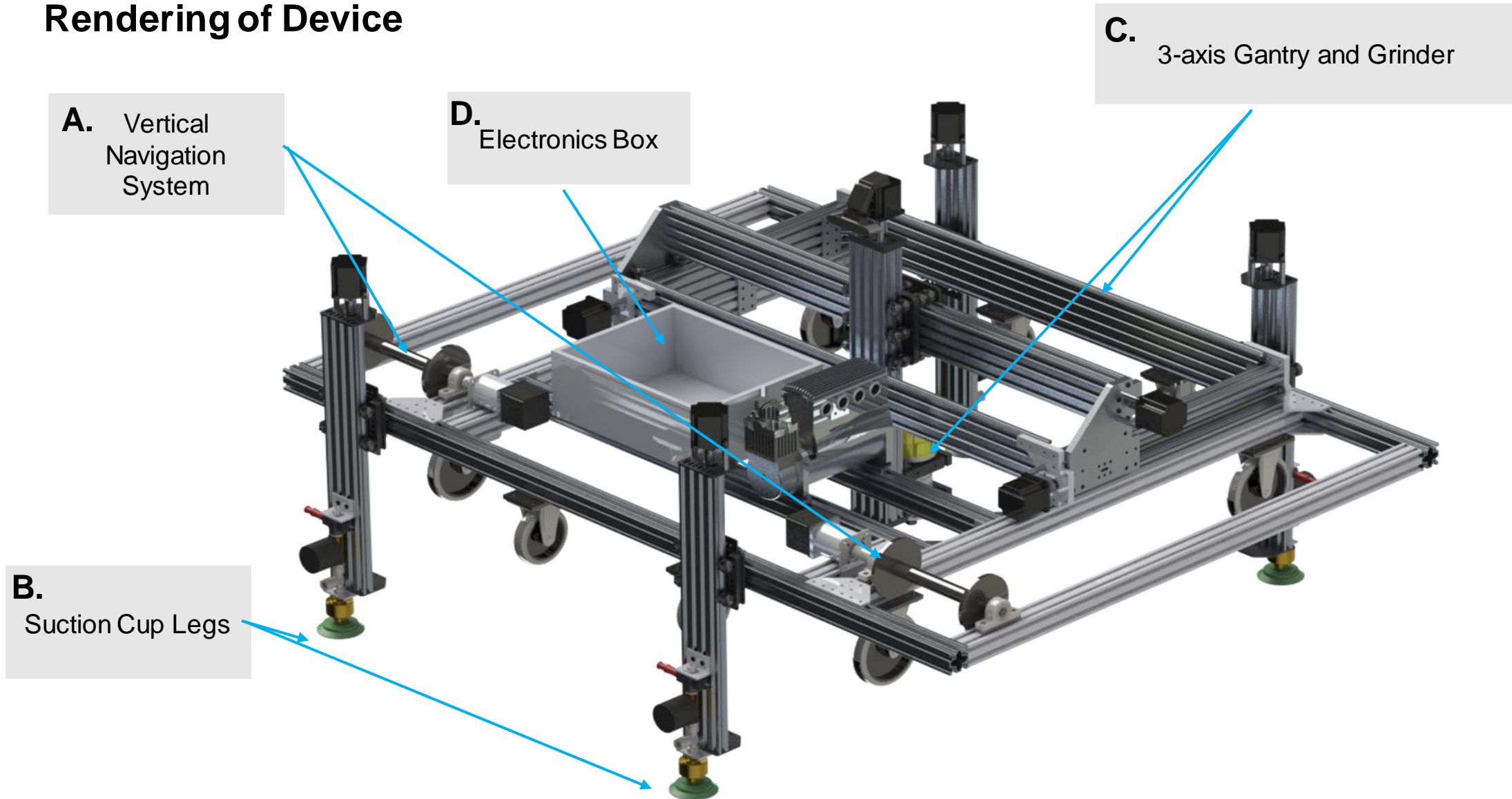


Design Intent

- The purpose of this project was to design a device that could carry out the grinding portion of a blade repair consistently and automatically
- The device that the team has designed and created is able to relieve the technician of grinding. The device allows for a technician to conduct a repair from a safe distance, limiting exposure to irritants and reducing the difficulty of a grind as well as ensuring consistent and accurate results

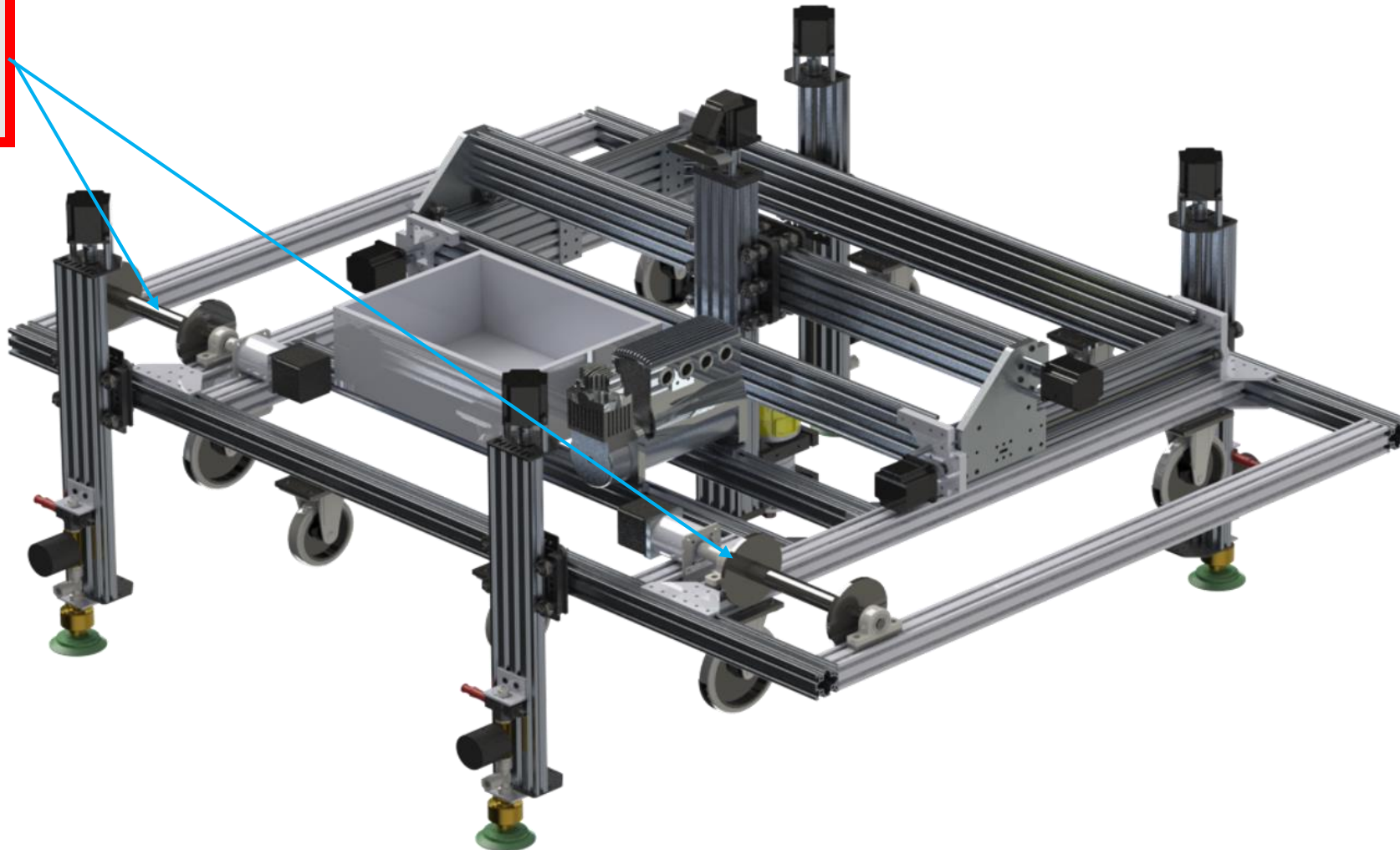


Rendering of Device



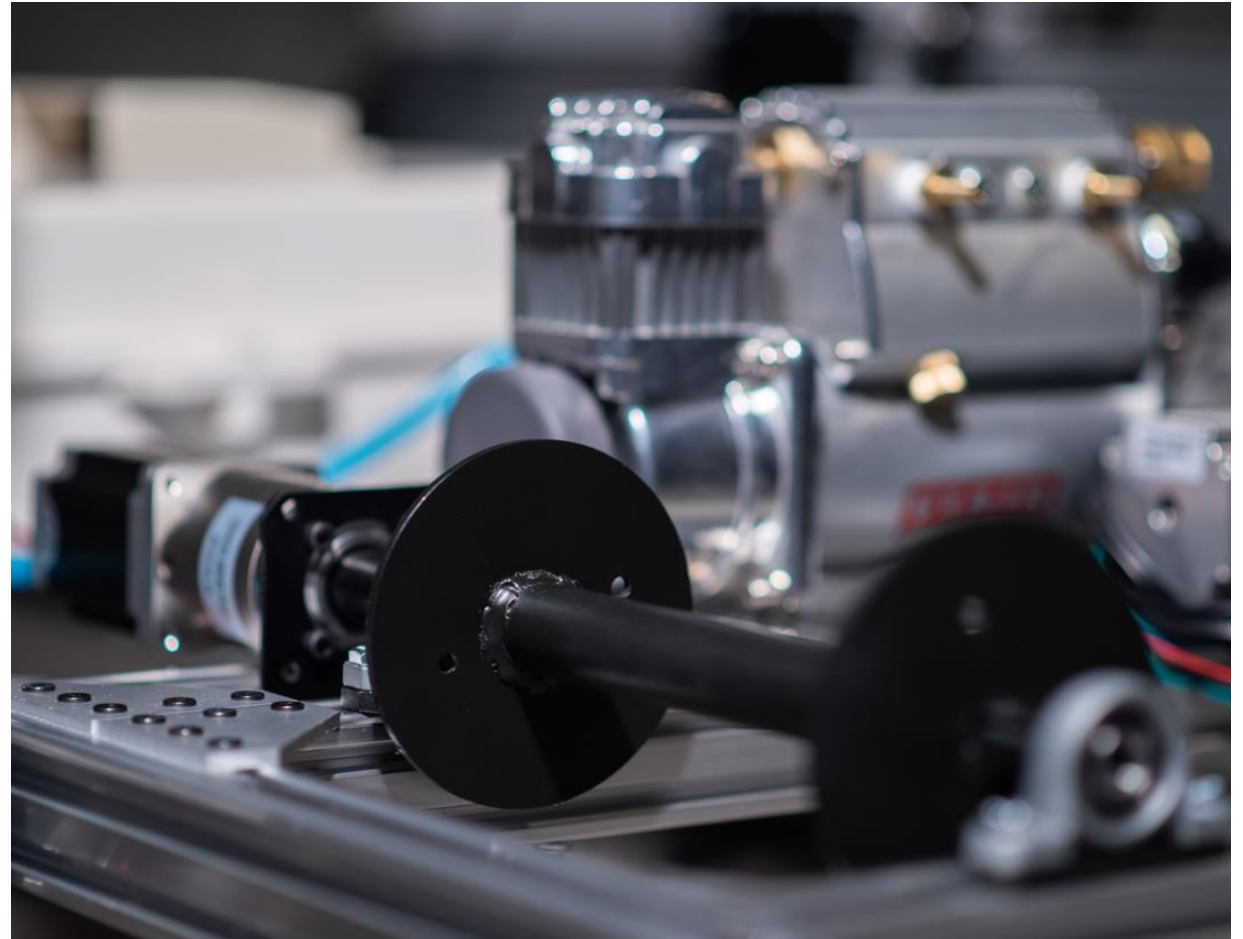
Rendering of Device

A. Vertical
Navigation
System



Vertical Navigation

- The two winches on board, carry the device up and down the length of the turbine blade
- This allows for damage to be reached at any position along the blade

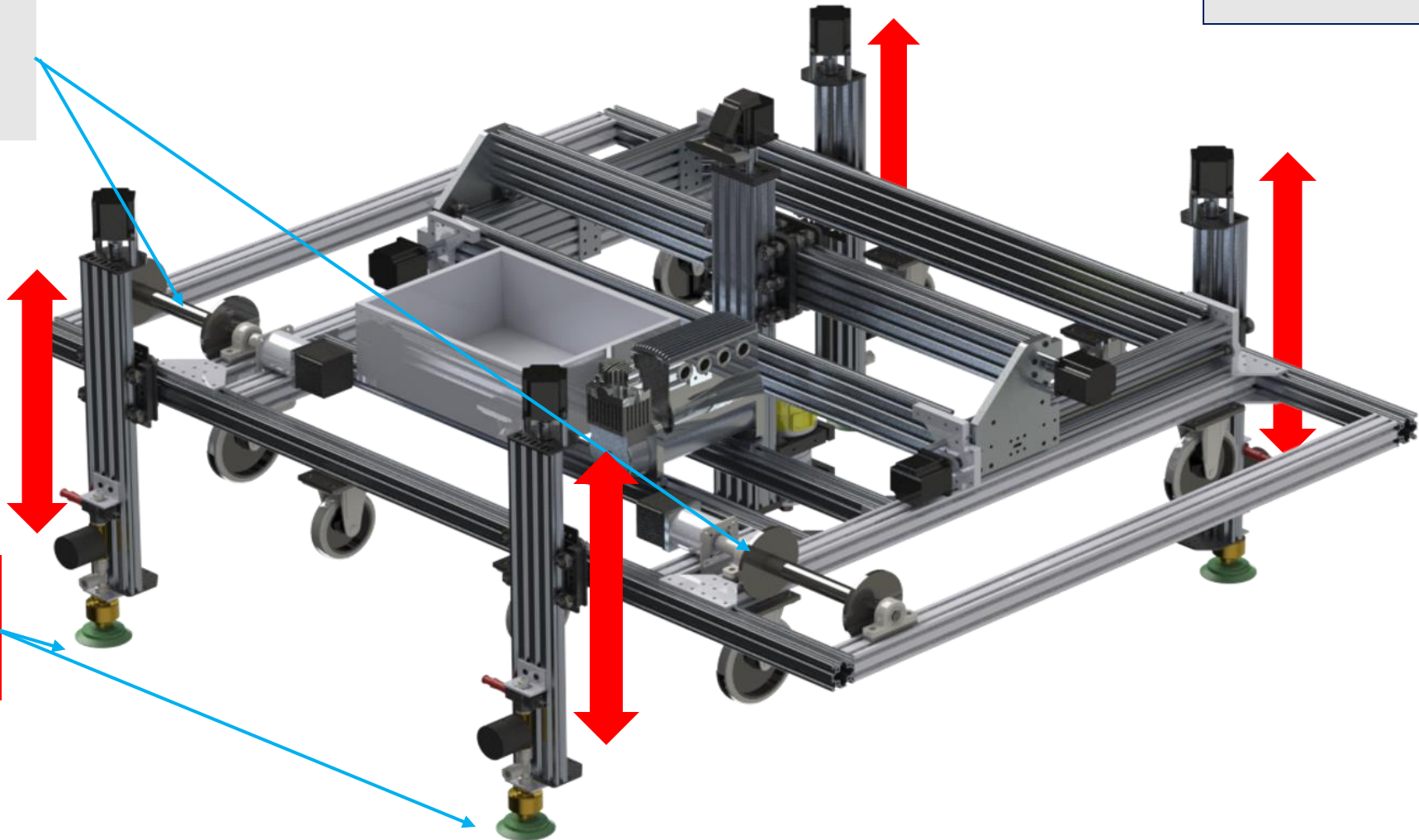


Rendering of Device

↑↓ Indicates Motion

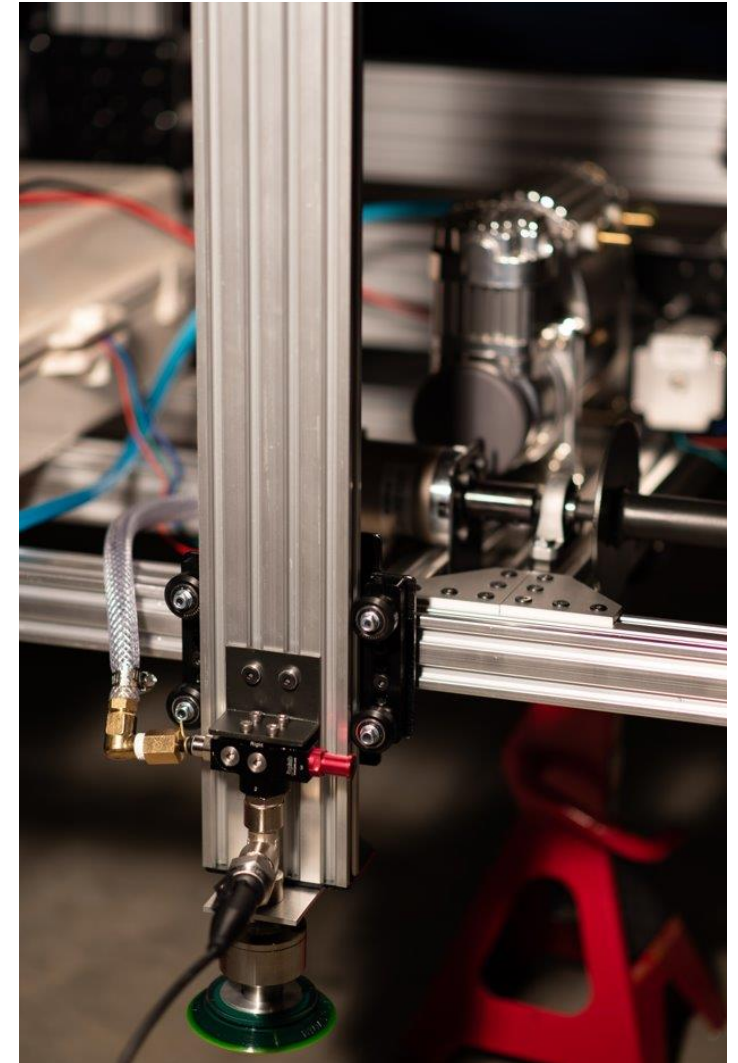
A. Vertical Navigation System

B. Suction Cup Legs

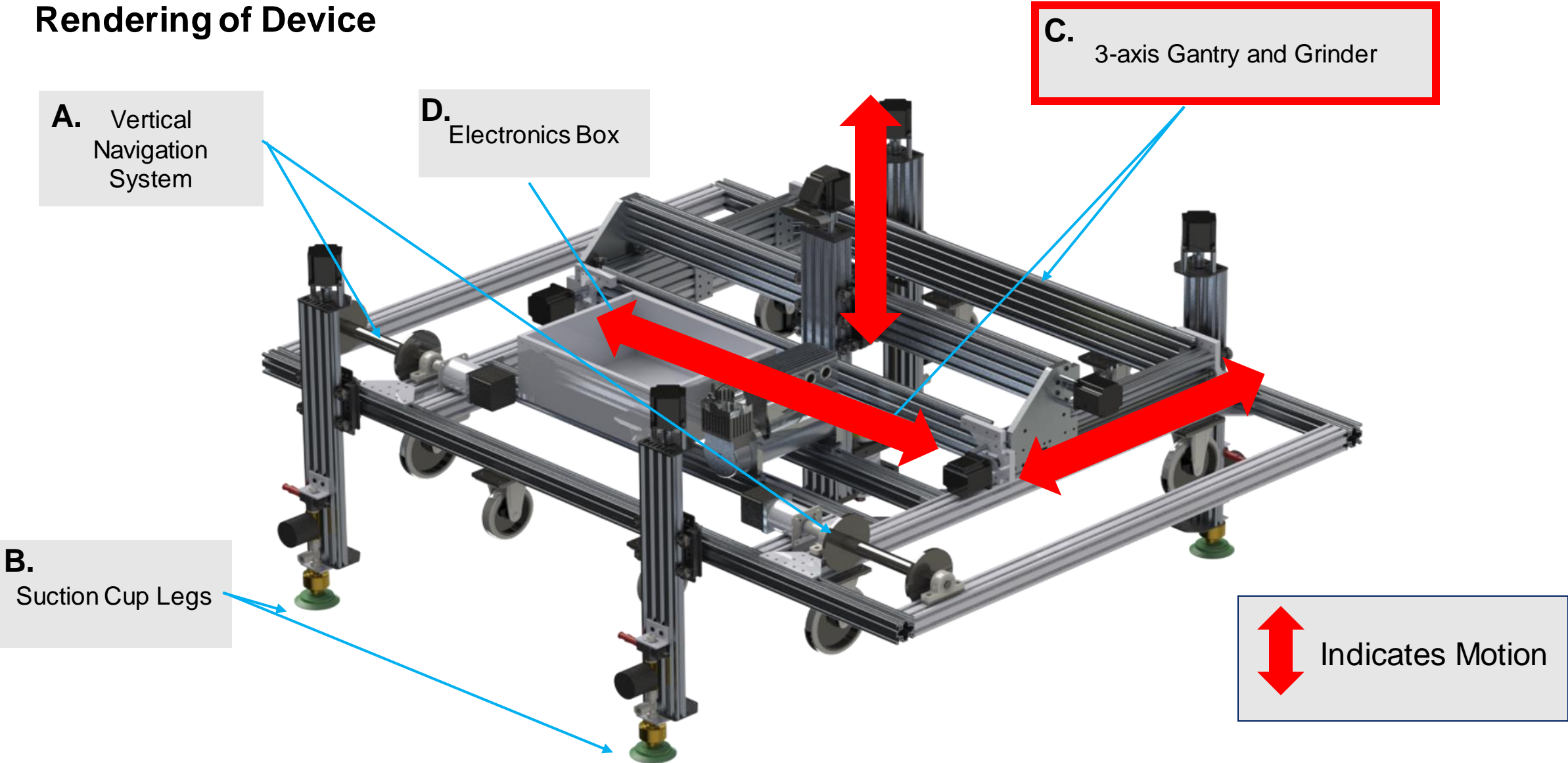


Suction Leg Assembly

- The legs are attached, one on each of the four corners of the device. (shown to right)
- The legs move vertically via the LabVIEW interface. The legs can be adjusted to match the varying widths of the blade
- Suction cups allow for the device to attach to the surface of the blade when conducting a grind

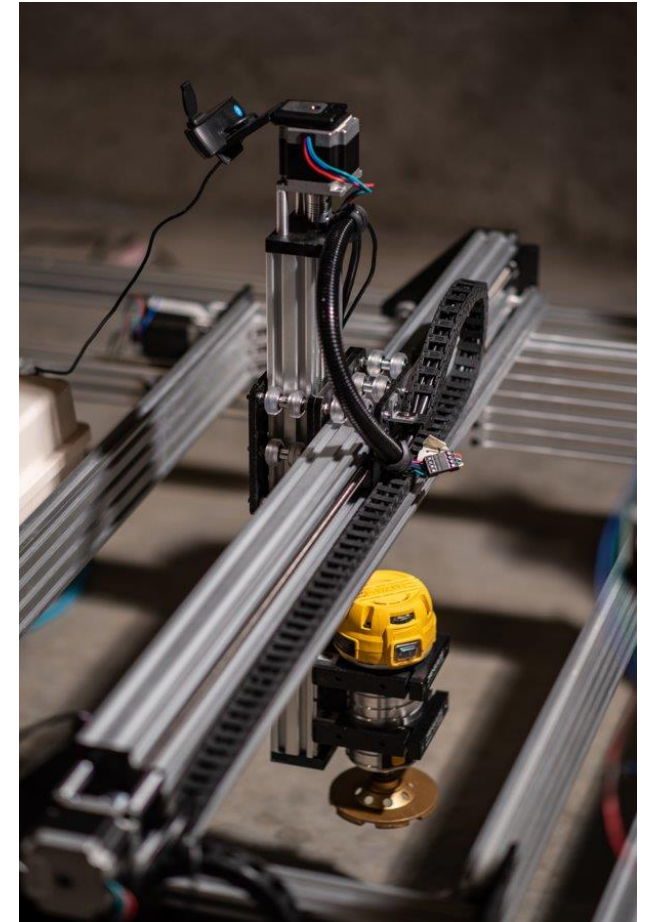


Rendering of Device



Three-Axis Gantry and Grinding Head Functionality

- The diamond cup grinding tool is attached to a router that is controlled by the three-axis gantry
- The gantry is controlled by OpenBuilds control software. This affords the user control of the grinding head in three dimensions in order to ensure an accurate grind that removes damage with adequate margins

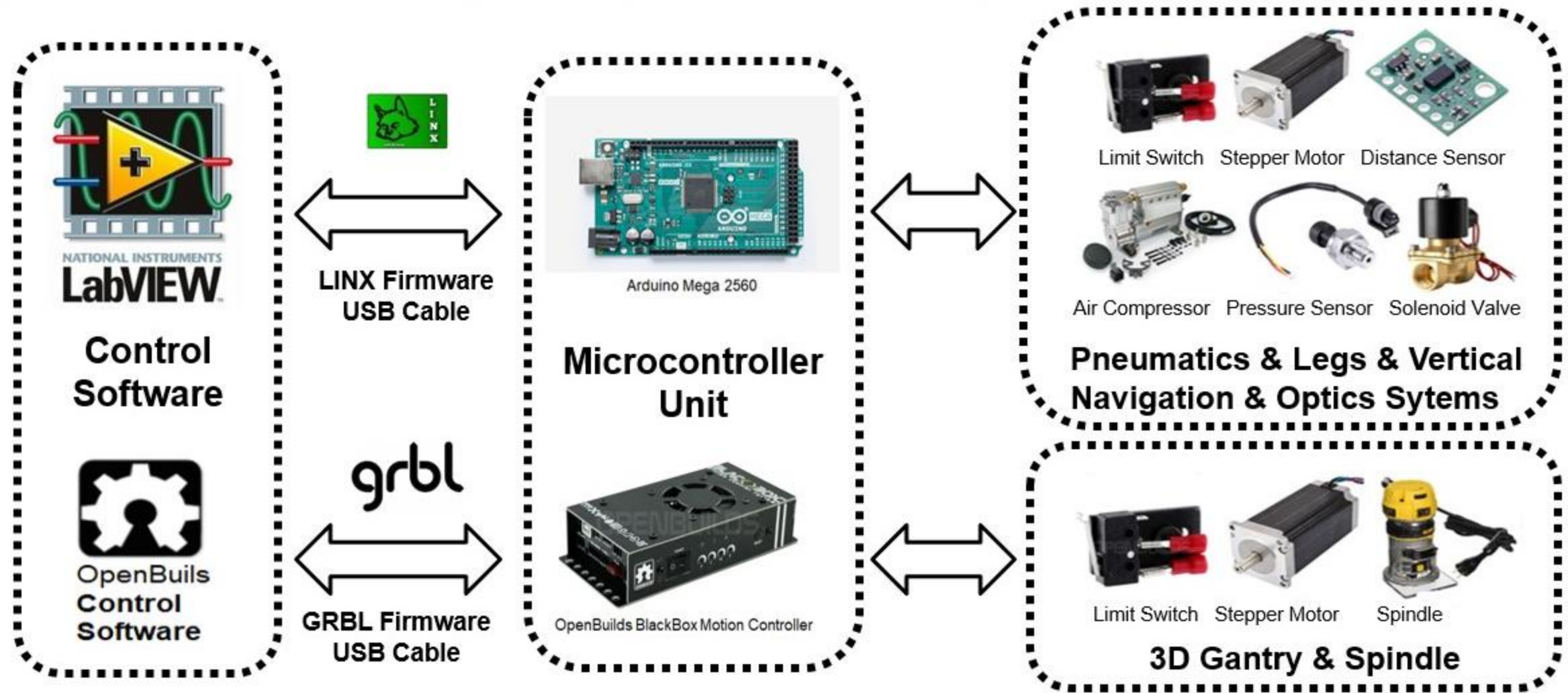


Control Concepts

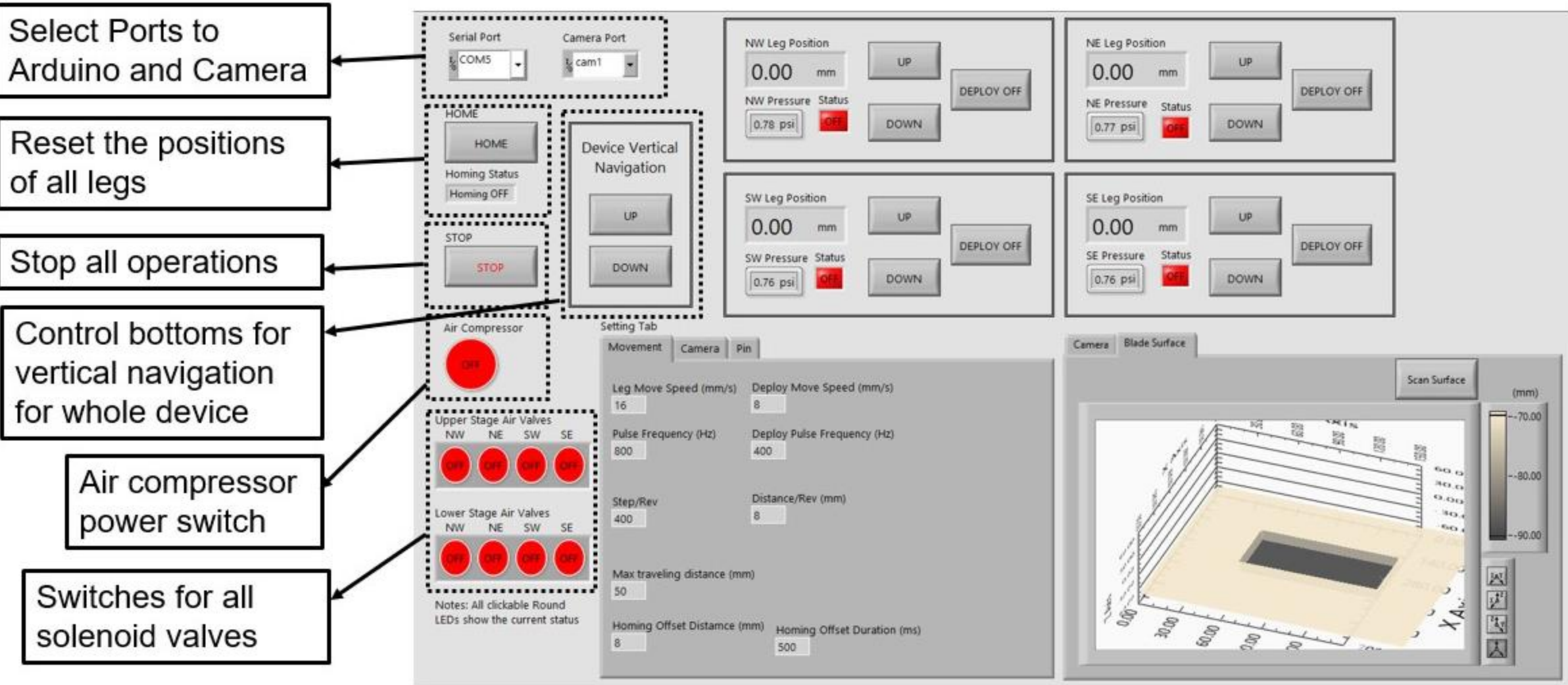
- **Two computer programs are developed for a technician on site to properly control the automated grinding device and monitor the grinding process**
- **The main controlling program, LabVIEW, is used to control Vertical Navigation, Pneumatics, Suction Cups positioning, and the Optics Systems**
- **The CNC machine controlling program, OpenBuilds Control, is used to control the 3D Gantry and Grinder**



Control Flowline



LabVIEW GUI – Used By The Technician During Operation



LabVIEW GUI – Used By The Technician During Operation

Serial Port
COM5

Camera Port
cam1

HOME
HOME

Homing Status
Homing OFF

STOP
STOP

Device Vertical Navigation

UP

DOWN

Air Compressor
OFF

Upper Stage Air Valves
NW NE SW SE
OFF OFF OFF OFF

Lower Stage Air Valves
NW NE SW SE
OFF OFF OFF OFF

Notes: All clickable Round LEDs show the current status

NW Leg Position
0.00 mm
NW Pressure Status
0.78 psi OFF
UP
DOWN
DEPLOY OFF

NE Leg Position
0.00 mm
NE Pressure Status
0.77 psi OFF
UP
DOWN
DEPLOY OFF

SW Leg Position
0.00 mm
SW Pressure Status
0.76 psi OFF
UP
DOWN
DEPLOY OFF

SE Leg Position
0.00 mm
SE Pressure Status
0.76 psi OFF
UP
DOWN
DEPLOY OFF

Setting Tab

Movement

Camera

Pin

Leg Move Speed (mm/s)
16

Deploy Move Speed (mm/s)
8

Pulse Frequency (Hz)
800

Deploy Pulse Frequency (Hz)
400

Step/Rev
400

Distance/Rev (mm)
8

Max traveling distance (mm)
50

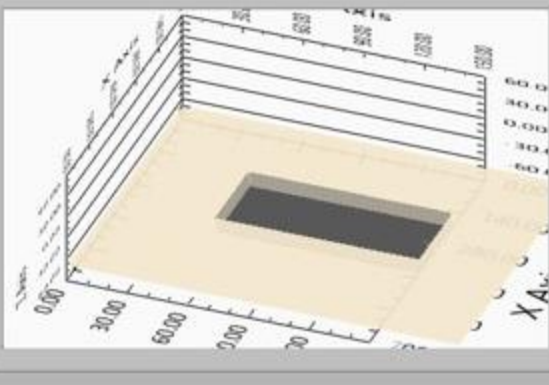
Homing Offset Distance (mm)
8

Homing Offset Duration (ms)
500

Camera

Blade Surface

Scan Surface



(mm)

--70.00

--80.00

--90.00

Control panel for legs that shows leg position, suction cup pressure and control bottoms

Camera feedback and blade surface mapping from laser sensor

Setting tab for motor movement, camera and pin

The screenshot displays the OpenBuilds CONTROL v1.0.234 software interface, which is connected to a COM3 port. The interface is divided into several sections:

- Top Bar:** Includes tabs for Control, Gribl Settings, and Troubleshooting. The main title bar shows "OpenBuilds CONTROL v1.0.234 / connected to COM3".
- Machine Interface:** Contains a "Disconnect" button, a "Restart Gribl" button, and a row of icons for Open G-CODE, Run Job, Stop Job, Probe, Check Size, Tool On, Tool Off, Home All, Wizards & Tools, Unlock Alarm, and Abort. The OpenBuilds.com logo is also present.
- Position Indicators:** A section labeled "mm-mode" and "inch-mode" showing coordinates for X, Y, and Z axes. The X-axis is at 695mm, Y-axis at 195mm, and Z-axis at 53.11mm. Each axis has a "setzero" button and a "gotozero" button.
- Manual Controls:** A section with directional buttons (X+, X-, Y+, Y-, Z+, Z-) and a "Jog" section with buttons for 0.1mm, 1mm, 10mm, and 100mm. The "Jog" value is currently set to 4999.99 mm/min.
- Serial Console:** A section showing a log of messages, including "WebGL Support found! success: this application will work optimally on this device!", "Websocket: Bidirectional Websocket Interface Started", and "You are already running OpenBuilds CONTROL 1.0.234".
- 3D View:** A section showing a 3D model of the grinder head position and pathway.
- Bottom Bar:** Includes a "Send" button, a "Port: Connected" status indicator, a "Controller: Idle" status indicator, and a "Job Queue: 0" indicator.

Annotations on the left side of the image point to specific features:

- "Connection with gantry control box, operational bottoms and emergency stop" points to the top bar and Machine Interface.
- "Grinder head position indicator in XYZ" points to the Position Indicators section.
- "Manual controls for moving the grinder head in XYZ" points to the Manual Controls section.
- "Serial console and 3D view of the grinder head position and pathway" points to the Serial Console and 3D View sections.

Autonomous Blade Grinding Device

- The team invested countless hours into designing, programming, manufacturing, and assembling this device. It was an interdisciplinary endeavor that sought to solve a complex problem. Ultimately, this device is extremely versatile in that it can tackle any sort of damage effectively, though designed with a minimalistic approach in mind. Though this prototype still requires testing to further iterate and improve the design, the team has laid a baseline with which to design an even more effective device. The team would like to extend a sincere thank you to all parties involved, as without their support, this project would not have been possible.

