INFLATION APPARATUS

OPERATING INSTRUCTIONS

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1 Introduction

The Inflation Apparatus is a novel test apparatus used to analyze the mechanical response of aortic rings to internal pressure. The apparatus features an inflatable silicone tube connected to an airflow control system consisting of an air inflow valve and an air outflow valve. The air inflow valve is set to a constant rate during testing. The air inflow goes to a T-connector. From the T-connector one tube goes to the silicone tube. The other tube goes to ball valve and then to the lab air. The air outflow ball valve is controlled by a servo. When the servo closes the valve, the air is trapped inside the airflow system, thus causing the silicone tube to inflate. Opening the outflow valve allows the air to escape into the lab and the silicone tube to deflate. An aortic ring is fitted onto the silicone tube so as to inflate with the silicone tube. A force sensor, placed between the silicone tube and the aortic ring, measures the internal pressure acting on the aortic ring. An edge-detecting camera is aimed at the aortic ring to measure the outer diameter of the aortic ring throughout the test.

Before activating the app, open the orange air valve in the lab wall one-quarter of a turn. Also, turn on the power supply to the servo and set it to 6 volts. The power supply should already be set to this value when you turn it on.

An application developed with LabVIEW 2020 32-bit on a Windows 10 Enterprise Operating System (OS) is used to interface with the test operator. The LabVIEW application also interfaces with a National Instruments (NI) multi-function Data Acquisition (DAQ) device and the USB camera. The NI DAQ device is a USB-6211 and it both controls the servo through Pulse-Width Modulation (PWM) and acquires data from the force sensor. An additional LED light is controlled by the NI DAQ device to alert the test operator of test initiation and completion.

The operating instructions of the Inflation Apparatus application are described herein along with installation instructions for the application. Please direct any questions or bug reports to the application developer, Jason Harwerth (jharwert@umd.edu), or Dr. Haslach

(haslach@umd.edu).

2 Installation

The application requires the use of a Windows 10 Enterprise OS. The application is not guaranteed to work on other Windows editions (see `https://knowledge.ni.com/KnowledgeArticleDetails?id=kA00Z0000019MeUSAU&l=en-US`). An installer is used to install all necessary runtime drivers to run the application along with the application itself. The installer is the only necessary file needed to obtain a running application. NI Vision Assistant may also be downloaded to debug camera operation, but it is not required to run the application.

2.1 The Installer

The Inflation Apparatus installer is packaged in a zip file titled ”InflationApparatusInstall.zip”. Currently, the zip file is not set up to be self-extracting, so the following steps need to be taken to run the installer:

1. After obtaining the zip file, right click on the zip file and press ”Extract All..” in the windows explorer menu.
2. Select the extraction location and extract the files.
3. Once the files are extracted, open the created folder and double click on ”InflationApparatusInstall.exe” to run the installer.

Completing this process will launch the installer wherein the process listed below should be followed:

1. A dialog asking permission to allow the installer from an unknown publisher will appear. Press ”Yes”.
2. The installer prompt will appear and display the destination directory. Press ”Next”.
3. An installer initialization prompt will appear and display the programs to be installed. Press ”Next”.
4. The installer will begin installing all programs. Do not interrupt this process.
5. When the installer finishes, an installation complete prompt will be displayed. Press

"Finish".

At the end of this process, the Inflation Apparatus is installed to the PC and the executable will be located in the "C: \Program Files (x86) \Inflation Apparatus" directory. A shortcut to the application automatically appears in the Windows Start Menu. Additional shortcuts to the application can be created and placed anywhere on the PC.

2.2 Vision Assistant

Vision Assistant is obtained through downloading NI's Vision Development Module (linked below). An installation walkthrough will not be laid out here because the installation process is standardized. However, NI often prompts users to download more than what is necessary, so it is recommended to ensure that only the Vision Development Module is downloaded. A development license will be required to use Vision Assistant (free with UMD-NI accounts).

https://www.ni.com/en-us/support/downloads/software-products/download.vision-development-module.html

3 The Inflation Apparatus

If the installer has completed without errors, the Inflation Apparatus application is executable with or without hardware components. This section overviews through all components of the application and how to use them.

3.1 Initialization

Upon opening the application, a hardware and control initialization prompt appears before entering the main application (Fig. 1a). The operator selects the physical channels on the USB-6211 and PC that correspond to the force sensor, servo, LED, and camera along with the sampling rates for the channels. The camera has an additional color pane that can be changed to decrease noise, however, blue is the suggested color pane. The controller type and parameters are also selected in this prompt. At the time of writing, only the PID controller has been implemented into the application. The operator presses the continue button when they are ready to move onto the main application.

If there is an error with the hardware selections, the application notifies the operator with the hardware components that have errors (Fig. 1b). The application will only continue when there are no hardware errors. If the operator wishes to run the application without physical hardware interfaces, simulated hardware can be selected. Simulated hardware will generate random data for testing modes in the application.

Past the hardware and control initialization prompt, the acquisition hardware (ie. the camera and force sensor) run continuously at the defined frequencies. The application will always retrieve latest value of the acquired data when the operator requests the data through the various features of the application. The servo and the LED will also be in a running state, but they will wait for commands from the application.

3.2 The Main Window

Once the hardware is selected, the application moves onto main window. Several Graphical User Interface (GUI) components comprise the main window (Fig. 2) including:

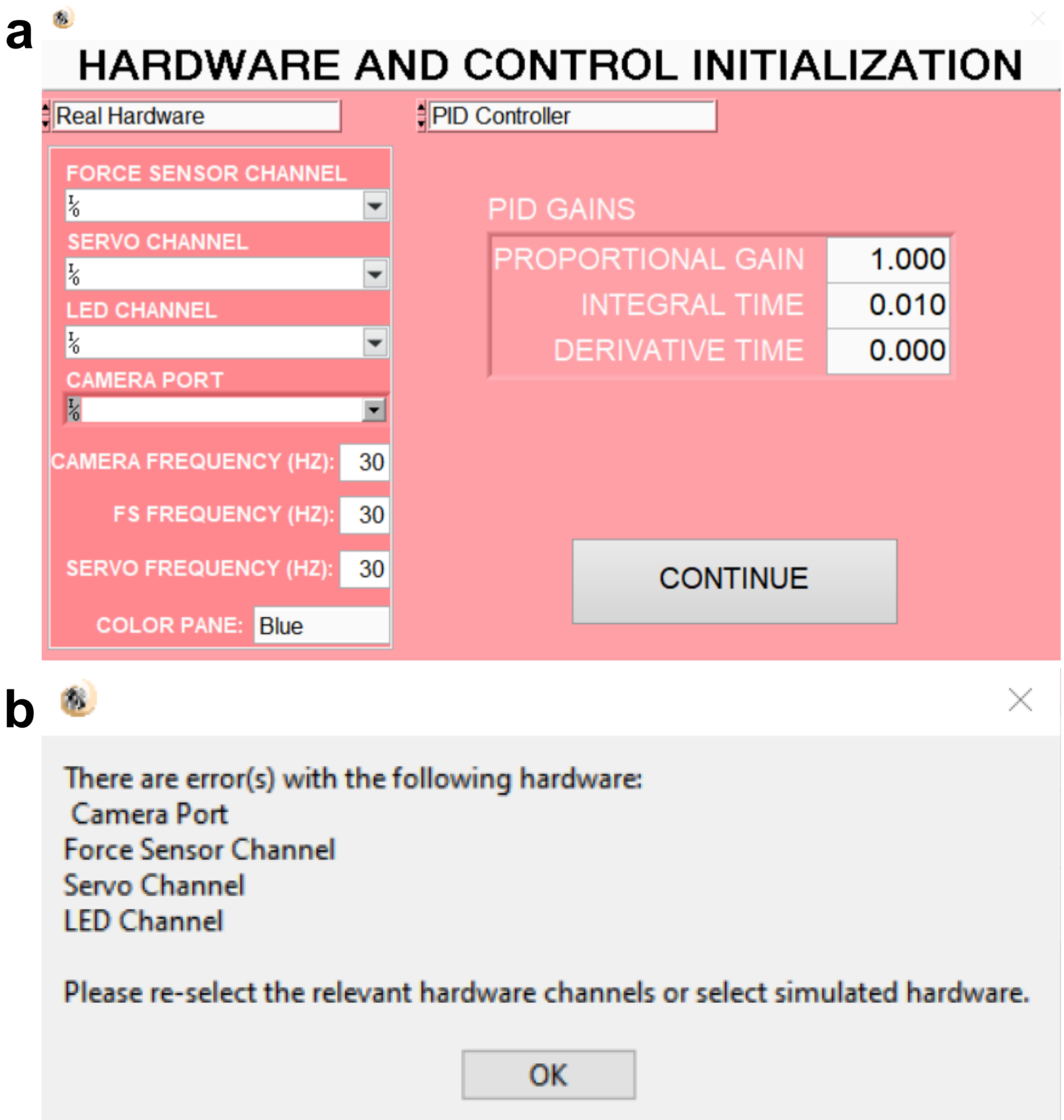

Figure 1: (a) The initial prompt that appears when opening the Inflation Apparatus application. (b) The error prompt that appears if there are issues with the hardware selection.

1. The menu (Fig. 2a). General application features are located in the menu such as exiting the application, loading a camera calibration, or accessing help. Additionally, an option to change the controller used for the inflation test is available in the drop-down menu.
2. The banner (Fig. 2b). The banner controls the state of the application. Currently, the operator can switch between inflation testing, force calibration, camera calibration, and equipment testing. Switching between these states determines which GUI elements appear on dynamic panels.
3. The static inflation test controls (Fig. 2c). Inflation test controls relating to setpoints, timing, and abort parameters are located here. These controls will always be displayed regardless of the selected banner state.
4. The static hardware controls (Fig. 2d). Hardware parameters are located here. A scroll bar will appear when the mouse enters this panel. When the parameters

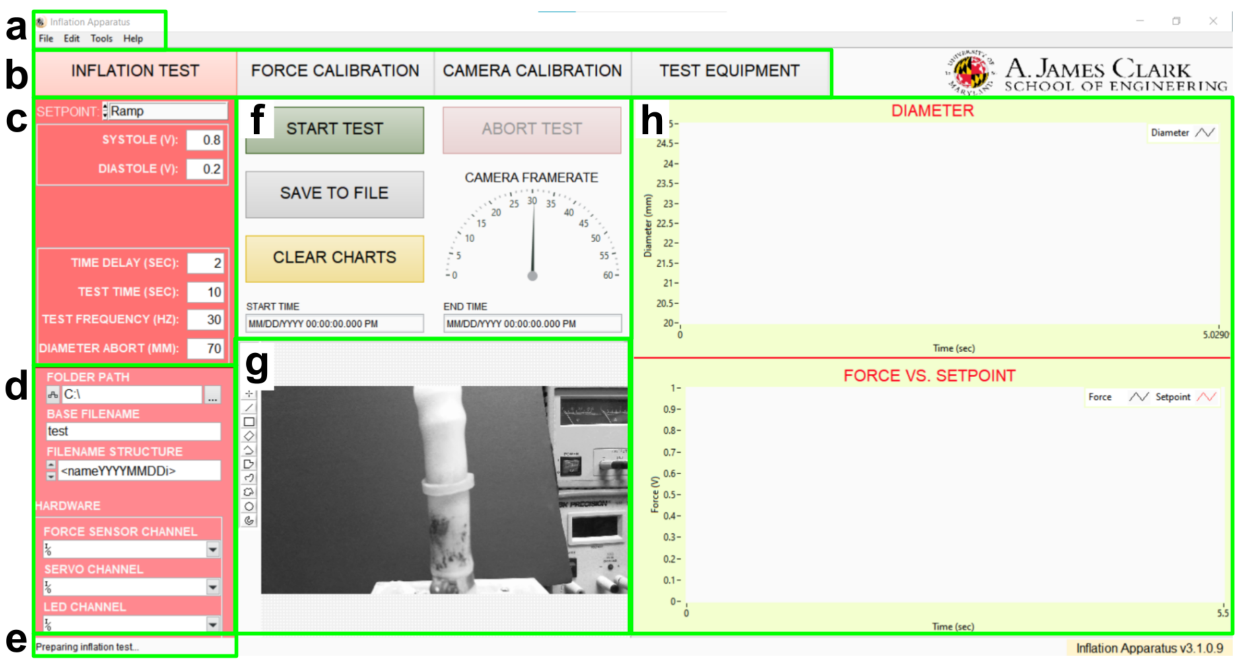

Figure 2: The components of the main window, including the (a) menu, (b) banner, (c) static inflation test controls, (d) static hardware controls, (e) status bar, (f) dynamic controls, (g) dynamic indicators, and (h) dynamic panel display.

are changed, a ”Refresh HW?” button will appear above the hardware parameters. Pressing the refresh button will re-initialize all hardware with the selected parameters.

5. The status bar (Fig. 2e). The last application status will appear here. It is intended to give the operator information on any actions performed by the application.
6. The dynamic controls (Fig. 2f). Controls that differ between banner selections are located here. Additional indicators are also placed here when relevant.
7. The dynamic indicators (Fig. 2g). Indicators that differ between banner selections are located here. Additional controls are also placed here when relevant.
8. The dynamic panel display (Fig. 2h). Panels that differ between banner selections are located here. Graphs most commonly appear in the dynamic panel display.

The entire main window is resizable to fit most window sizes. When resizing, the static hardware controls, dynamic indicators, and dynamic panel display will resize with the main window. All other components will remain static. The sizes of text, buttons, and tables will not scale with the main window.

3.3 Inflation Testing

The force sensor and camera need to be calibrated prior to inflation testing. Details on calibration processes are found in the *Force Calibration* and *Camera Calibration* sections. A live video feed of the inflation apparatus is displayed in the dynamic indicators panel. The current camera framerate is also displayed in the dynamic controls panel. To begin inflation testing, several controls need to be defined prior to testing. The controls immediately relevant to the inflation test are defined below:

1. The setpoint. Options for different setpoints are available and added as needed. For each setpoint, there are relevant controls to define the specific function. For example, a ramp setpoint has systolic and diastolic voltage values (obtained from force sensor calibration) to define the beginning and end points of the ramp setpoint.
2. The time delay. The time delay specifies an amount of time to wait before beginning

the test after starting the test. During this time, the setpoint is equal to the defined diastolic value. The time delay gives the inflation apparatus time to level out at the specified low value of the setpoint.

3. The test time. The test time defines the amount of time that the test runs for. If ”in vivo” is chosen, the test time sets the time to increase from diastole to systole. The test shuts down at end of the test time. If ”fracture” is chosen, the test time is the time to increase from diastole to systole. The app does not shut down at end of test time, but shuts down when the maximum outer diameter is reached. Under “fracture”, the test time controls the rate to go from the voltage chosen for diastole to the voltage chosen for systole.
4. The sampling rate. The sampling rate defines the sampling frequency of the test. If the sampling rate is greater than the frequency of hardware components, the application will disregard the hardware components that have not acquired data new data within the specified sampling rate.
5. The diameter abort. The diameter abort specifies the maximum allowable diameter in the inflation test. If the camera reads a diameter value greater than the diameter abort value, the test will be aborted.
6. The folder path, base filename, and filename structure. The folder path specifies the location to save test data. The base filename specifies the main name for the test data txt file. The filename structure specifies filename saving structure for the test data txt file. Select the form ¡nameYYYYMMDi¿ to avoid the app overwriting the data file on the next test (and losing the test data). The other form writes over the file the next time the app is run. In other words, “filename structure” does not write over the previous file, but “name” does.

After the inflation test parameters have been set, an inflation test can be started by pressing the ”Start Test” button. After starting the test, all controls will be disabled other than the ”Abort Test” button (Fig. 3a). The recorded diameter, force, and setpoint values are displayed on the dynamic panel display charts. The start and end times of the inflation test are updated on the dynamic controls panel. The test will run uninterrupted unless the abort button is pressed or the diameter abort condition is met.

When the test is finished, a test comment prompt will appear requesting the operator

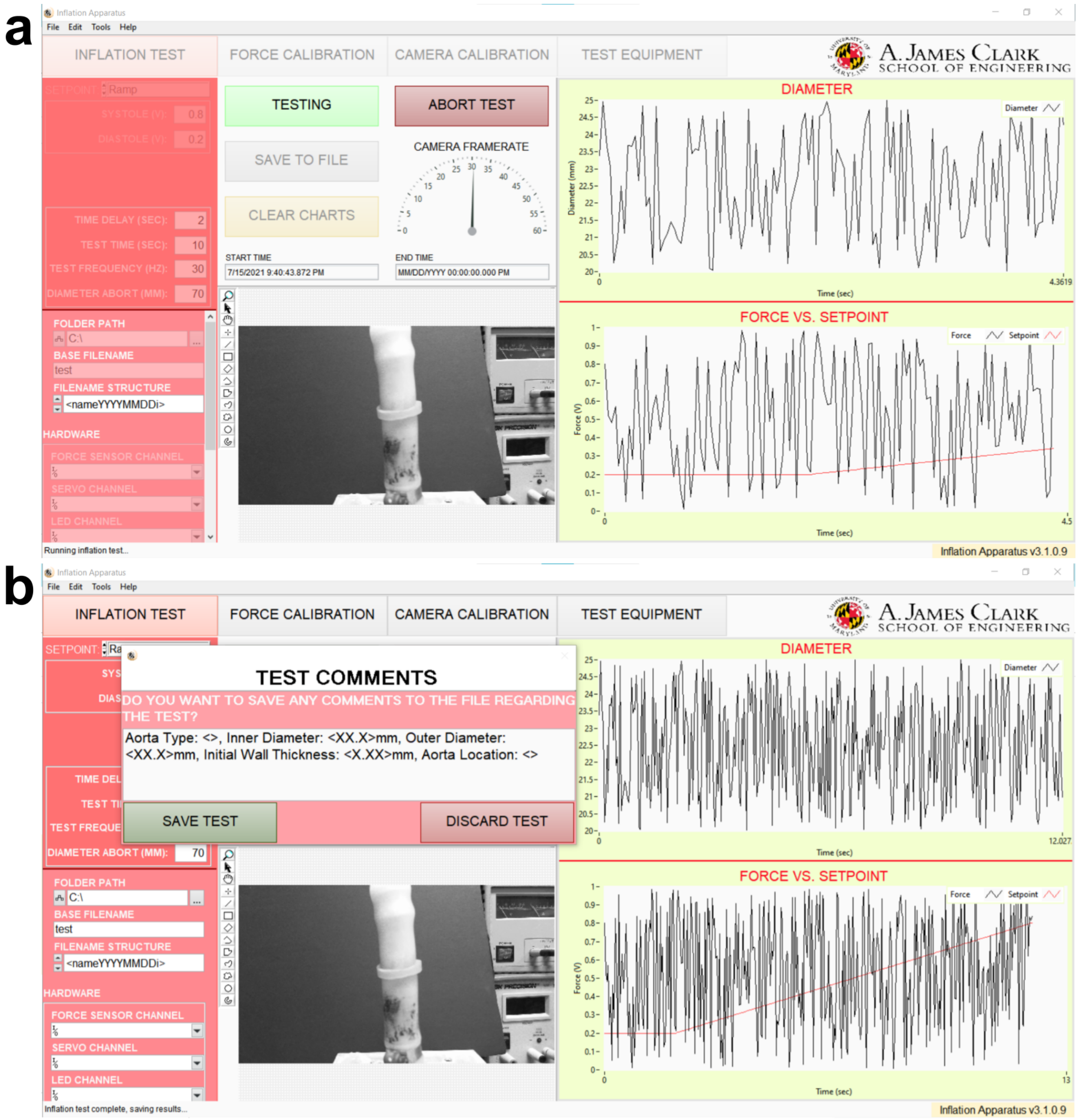

Figure 3: (a) The inflation testing window when running an inflation test. (b) The prompt that appears after a completed test.

to save any relevant information with the inflation test (Fig. 3b). The operator can input the suggested information or any other information that is deemed to be more relevant to the test. This prompt will not appear if the test is aborted. The operator can also choose to discard the test, in which case the test data will not be saved. When the operator is satisfied with the test comments, pressing ”Save Test” will save the test data to the specified folder location with the specified filename and structure.

If the test is not saved because the test was aborted or the operator chose to discard the test, the operator can press ”Save to File” to manually save any data displayed on the charts. The test comment prompt will appear for the operator to save comments. When the operator is satisfied with the test comments, pressing ”Save Test” will save the test data to the specified folder location with the specified filename and structure.

The operator can also press the ”Clear Charts” button to clear any data from the dynamic panel display charts at anytime. The charts will also be cleared automatically at the start of tests.

3.4 Force Calibration

Before inflation testing, the force sensor needs to be calibrated to obtain force units from voltage values. The force sensor needs to be calibrated for each testing session, not each test. When the Force Calibration banner state is selected, the main window will display controls and indicators relevant to force calibration (Fig. 4). The latest acquired force sensor data will automatically display on the force chart. To calibrate the force sensor, follow the process listed below:

1. Tape the force sensor flat on the benchtop surface.
2. Line up the wooden calibration block with the force sensor such that the calibration pencil is centered with the force sensor.
3. Load the calibration pencil with 50g of weight.
4. Wait for the force sensor voltage to level out (approximately 10 seconds) and record the voltage by pressing the ”Log Calibration Point” button. The voltage value will

a b

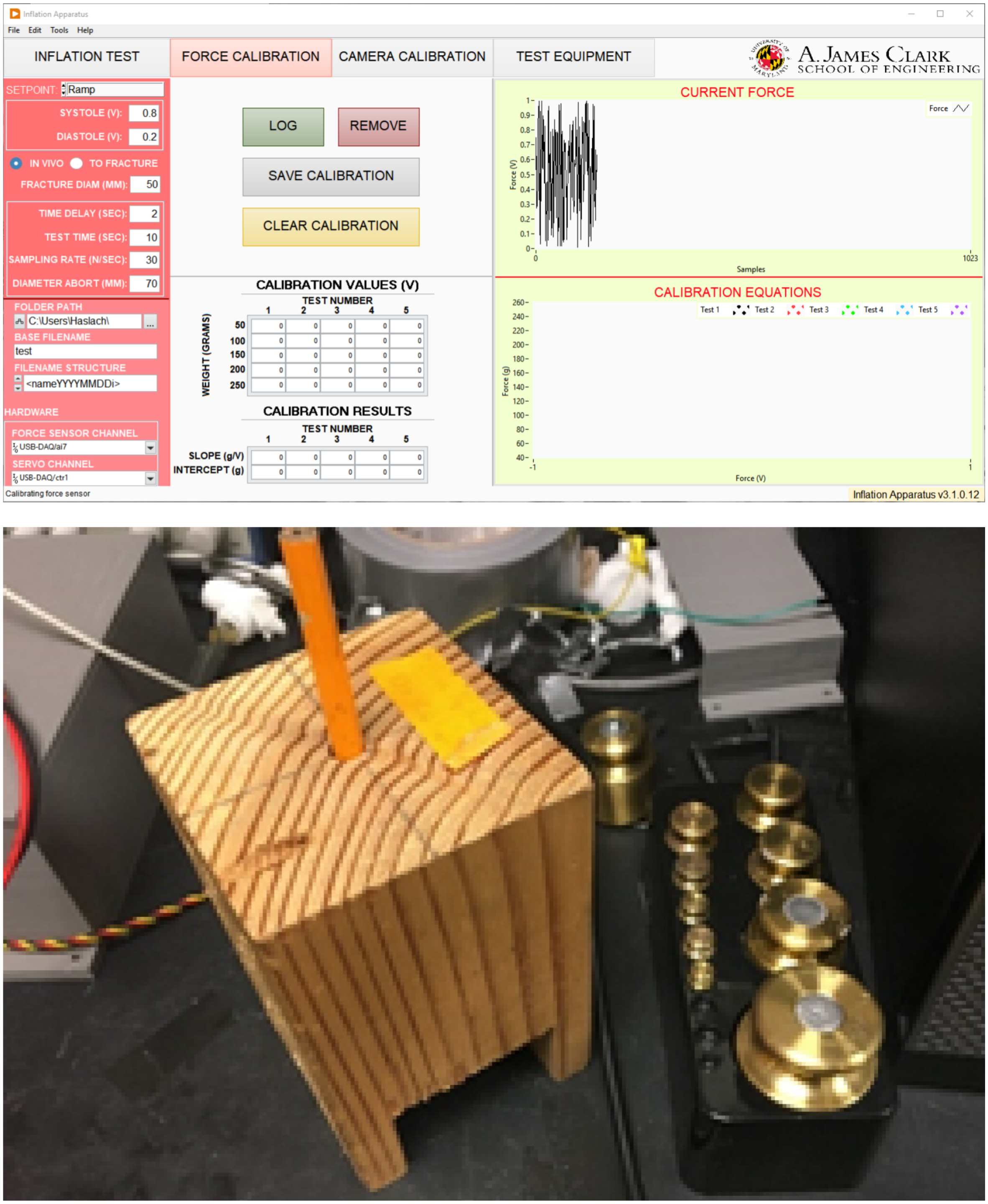

Figure 4: (a) The force calibration window. (b) The force calibration block and masses.

appear in the ”Calibration Values” table.

5. Successively repeat steps 3 and 4 with 100g, 150, 200g, and 250g of weight. After each weight has a voltage, the linear fit for the data is automatically calculated and displayed in both the ”Calibration Results” table and the ”Calibration Equations” chart.
6. Repeat steps 3, 4, and 5 to complete four total calibration tests prior to inflation testing. The fifth and final calibration test is completed after inflation testing.

The calibration can be saved at any time by pressing the ”Save Calibration” button. A prompt will appear asking the operator to choose a folder location and a filename for the calibration txt file. The slope and intercept value for the five tests are averaged upon saving the calibration. The average slope and intercept should be used for data analyses and determining the desired voltage values to be used for testing. The entire calibration table can also be cleared by pressing the ”Clear Calibration” button.

After completion of the calibration, use Excel to make graphs of the obtained data. The horizontal axis of the graph should be the Weight (force) of the gram weights put on the end of the pencil during calibration because the voltage is controlled by the weights. The graph displayed in the app reverses the axes.

Transferring data from txt file to excel file: MAC: Data ¿ Get external text ¿ commas ¿ general Windows: Data ¿ Get data ¿ from text/CSV. Then, open the text file in the window that comes up. A sequence of windows appears. Select ¿ commas ¿ general (so the data is inserted in numerical and not text form).

The measured and known values are fit by a linear curve on Microsoft Excel from where a linear equation can be obtained to relate voltage readings into values of force. Linear equations are returned in the form $y = Mx + B$, where M is the slope and B is the offset, and a voltage value x (in V) is converted into a force value y (in N). Linearity may not be constant throughout different voltages, so an offset is necessary to fit the data onto a linear model. An example set of calibration data from a single test is given in Table 1.

Trend line equations from the second to fourth calibration tests are averaged to calculate the actual governing equation that is used to convert the obtained voltage values into force values. To average the tests, the average of the slopes and the average of the offsets are used for a new linear equation $y = Mx + B$. The first and the last trial are used for comparing whether there is a difference in sensor response right after conditioning and right after finishing inflation trials each day. Therefore they are not used for the slopes used to calculate the force on the rings. Percent error between the used equation and the equations from the first calibration and the calibration done after testing is recorded. These measurements are used to determine the reliability of the sensor during testing,and to see if a degree of consistency can be expected from the sensor. Errors are taken for both the slopes and the offsets in relation to the average relation found from trials 2 to 4.

The R^2 value is also recorded for each calibration trial to see how well the line fits the relation. Since a linear relation is expected for the voltage and force, the correlation is expected to be high.

3.5 Camera Calibration

Before inflation testing, the camera needs to be calibrated to obtain diameter values in mm from the camera feed. When the Camera Calibration banner state is selected, the main window will display controls and indicators relevant to camera calibration (Fig. 5a). The last logged camera picture will be displayed in the dynamic panel display. The

Table 1: Sample force calibration table.

Mass (g)	Voltage	Force (N)
50	0.5678	0.4905
100	1.0500	0.9810
150	1.5283	1.4715
200	2.2461	1.9623
250	2.9297	2.4525

camera picture can be updated by pressing the "Update Image" button. To calibrate the camera, follow the process listed below:

1. Begin the camera calibration by pressing the "Start" button on the Camera Calibration tab. This will disable the top banner to prevent the user from accidentally

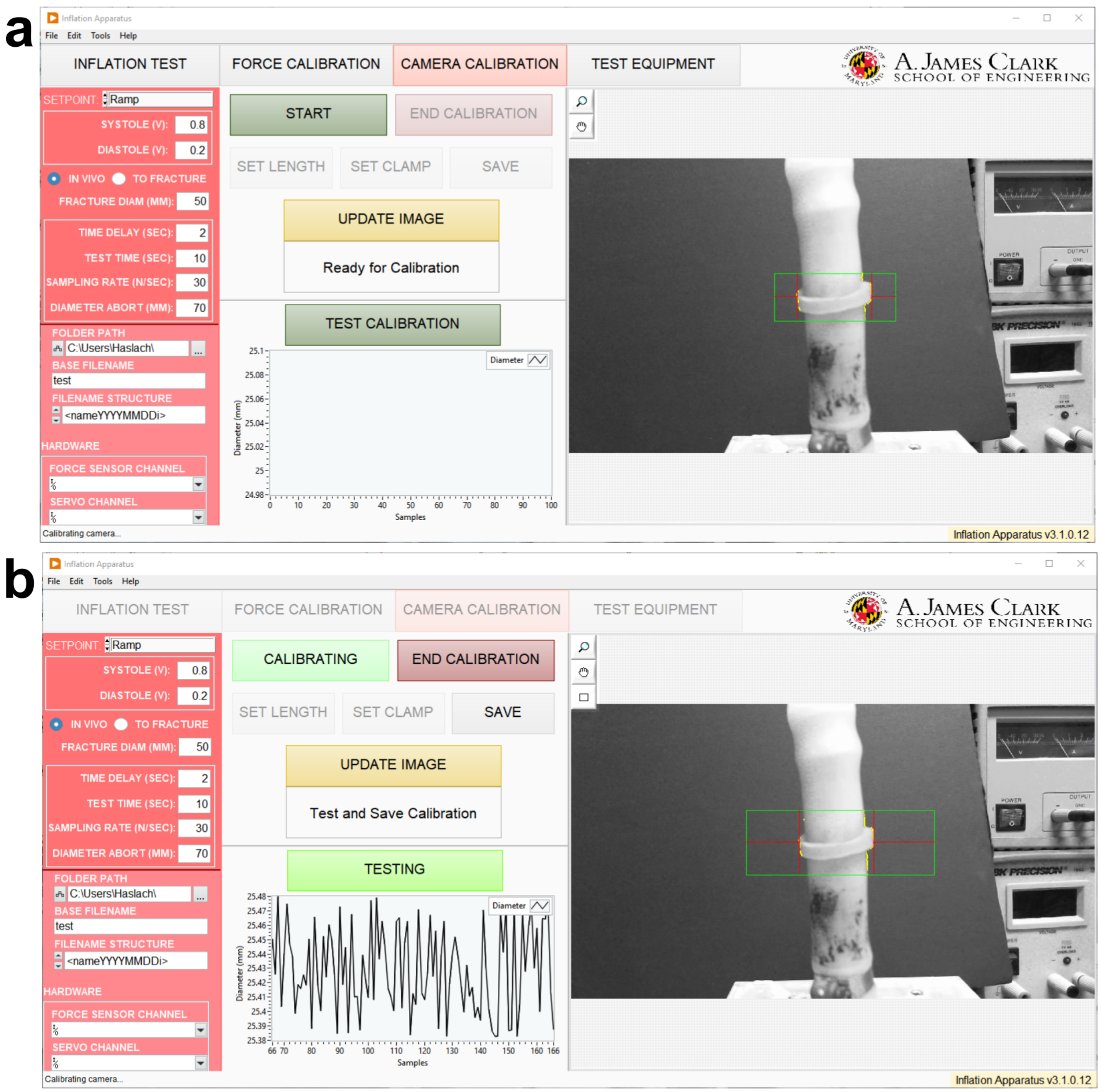

Figure 5: (a) The camera calibration window. (b) The camera calibration testing graph.

aborting the camera calibration. Pressing the ”End Calibration” button will stop the camera calibration. Progress up to the stopping point will be saved.

2. Slide the camera in front of the ruler.
3. Make sure the ruler is aligned with the silicone tube (ie. in the same plane). Keep the ruler aligned with the cross-section of the silicone tube (where the aorta will be placed). The ruler should be about 10 cm away from the camera.
4. Update the camera image. This will update the image with a line tool.
5. Select the line tool and draw a 10 mm line based on the ruler image. Zoom in if necessary.
6. Once the line is drawn, the ”Set Length” button will be enabled. Press the ”Set Length” button when satisfied with the line.
7. A prompt will appear asking for the distance that the line corresponds to. Enter the millimeter distance of the line (ie. 10 mm).
8. Slide the camera in front of the inflation apparatus and update the image.
9. Select the clamp tool that appears. Draw the clamp over the region that the aorta will be inflated to (see Fig. 5b as an example). The clamp rectangular area must be large enough to always capture the outer diameter of the aortic ring during inflation.
10. Once the clamp is drawn, the ”Set Clamp” button will be enabled. Press the ”Set Clamp” button when satisfied with the clamp.
11. The camera parameters have now been defined and the ”Save” button will be enabled. Test the calibration prior to saving by pressing the ”Test Calibration” button (Fig. 5b). Verify that the diameter measurements are correct. If the diameter data has significant noise, change the color plane to different colors to try to reduce noise. The most accurate color plane will most likely be blue.
12. If you are satisfied with the calibration, press the ”Save” button. A prompt will appear asking for the filename and location. A txt file with the calibration data will be saved to this location.
13. The camera is now calibrated with a specified mm to pixel distance and clamp re-

gion.

Saved calibration files should not be altered in any way. The purpose of the camera calibration file is to be able to load a saved calibration to the application to save time. Calibrations can be loaded in the menu bar under Edit > Camera Calibration > Load.

3.6 Equipment Testing

If the operator wishes to test equipment, the equipment testing window allows the operator to test the various hardware used in the inflation test. The LED can be tested by using the switch control. A live camera feed of the camera picture is displayed in the dynamic indicators panel. The force sensor measurement is displayed on the dynamic panel display. The servo can be sent any desired PWM signal within the defined range on the slider.

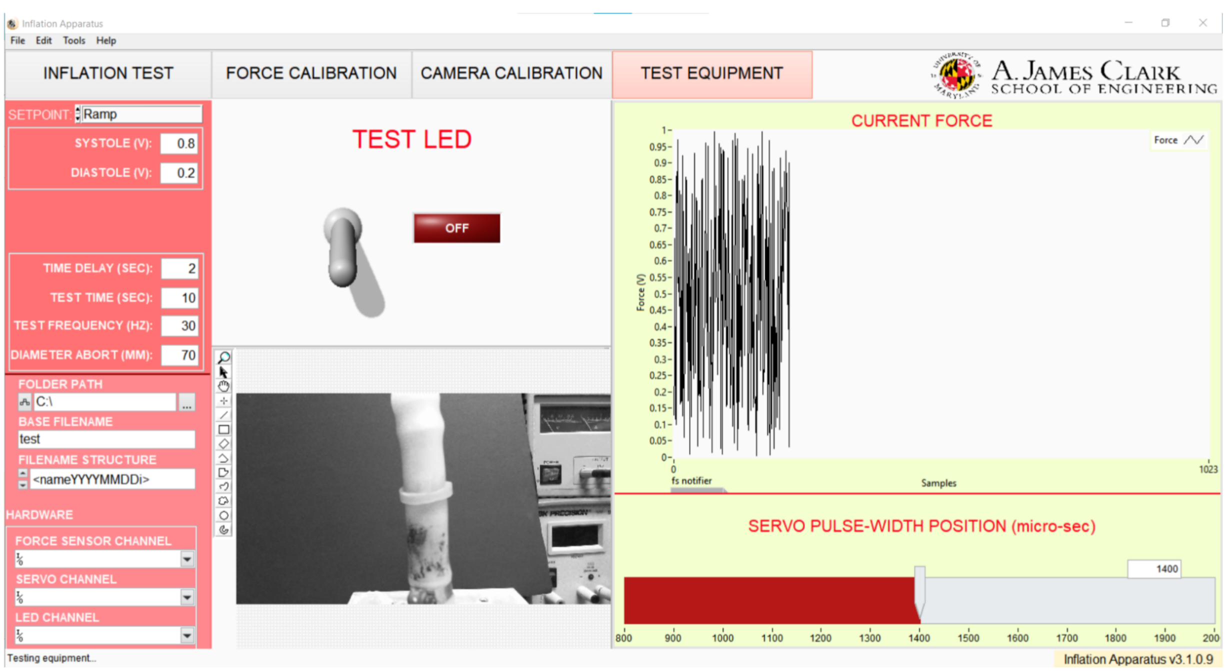

Figure 6: The equipment testing window.

3.7 Menu Options

The menu, located at the top of the application window (above the banner), currently has the following options:

1. File > Exit: Exit the application. The application will prompt the operator to confirm the exit request and then continue on with closing the application.
2. Edit > Choose Controller: Choose a new controller for the inflation test. A window will be displayed and request the user to input controller parameters (Fig. 7).
3. Edit > Camera Calibration > Load: Load a saved camera calibration. The application will ask for a saved camera calibration to load. Select a previously saved txt file to send to the camera.
4. Edit > Camera Calibration > Save: Save the current camera calibration. The application will ask for a filename and location to save the camera calibration. A txt file with the current calibration data will be saved to this location.
5. Tools > Vision Assistant: Open Vision Assistant. Vision Assistant will be opened for the user to interact with camera settings and interfaces.
6. Help > Inflation Apparatus: Open the inflation apparatus operating instructions. This pdf will be opened for the user to access help.
7. Help > LabVIEW: LabVIEW information will be displayed.

3.8 Exiting and Error Handling

To exit the application, the user can either use the exit option in the menu or the close panel button in the top right corner. In either case, the application will open a window asking the operator to confirm the exit request. If confirmed, the application shuts down all hardware and closes the application window. Otherwise, the application continues running.

In the case that there is an error, a prompt telling the operator the error message and source appears. The operator has three options: Stop, Continue, or Hard Shutdown.

If stop is selected, the application will go through the normal exit application case. If continue is selected, the application will disregard the error and attempt to continue on with the running the application. If Hard Shutdown is selected, the application will close without going through the normal exit application case. This action is not recommended because the hardware will not be shutdown in the correct manner.

Shut off the power supply to the force sensor when done testing for the day.

Note: After a test is run, make a screen shot of the two graphs on the main window of the app: force versus set point function and outer diameter versus time.

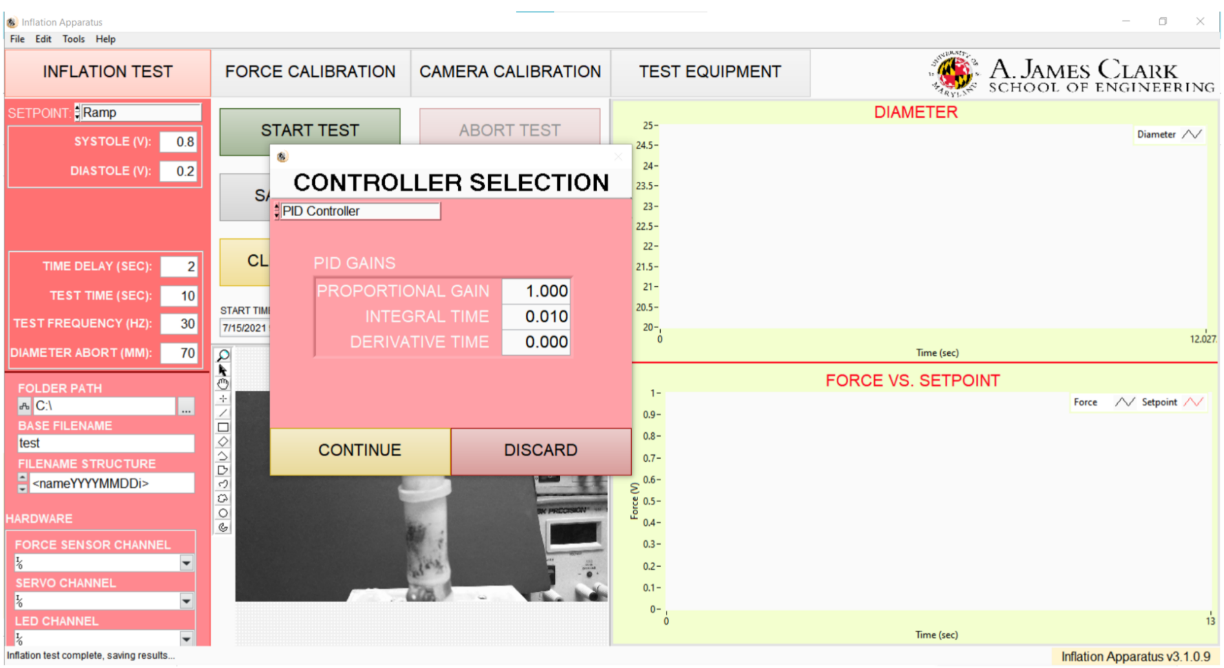

Figure 7: The controller choice window.