



UStretch

Mechanical Test System

User Manual
version 6.3



Mechanical measurement and analysis of biomedical materials

CellScale provides scientific and medical researchers with turn-key systems for measuring the mechanical properties of biomaterials.

Our focus is soft tissue – including skin, ligaments, blood vessels, heart valves, sclera, membranes and scaffolds. We provide user-friendly software, an easy-to-use patented attachment system and effective data analysis tools.

Our foundation was laid at one of the world's leading research institutions – the University of Waterloo. We understand research and aim to provide effective solutions at a reasonable price.

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1. General Information

The UStretch is a precision test instrument specifically designed for the measurement and analysis of biological specimens. The system includes a test station and an integrated software interface to run and analyze test results.

Environmental and Electrical Specifications

Electrical Input	100-240VAC, 50-60Hz
Current Rating	2.5 Amp
Environmental Conditions	Maximum Operating Temperature 25°C 0% - 95% Relative Humidity
Installation Category	Category II
Pollution Degree	Degree 2
Data Connections	1 – USB for controller/PC communication 1 – USB for camera/PC communication

System Assembly

Some basic assembly and setup is required. An unboxing and setup guide can be found in Appendix A. Camera setup (Section 8: System Calibration), software installation (Appendix B), and load cell/gooseneck installation (Appendix C) are required before use.

Connections to Supply

Connect power cord into properly grounded 100-240VAC power source to ensure safe operation. Ensure that the power cord is easily accessible at all times. The use of an Uninterruptible Power Supply (UPS) is recommended to protect against data loss.

The mains supply voltage fluctuations should not exceed 10% of the nominal supply voltage.

Safety Warnings

This equipment must be used in accordance with the procedures outlined in this manual and operators of this equipment must be instructed in safe operating procedures to prevent injury and/or damage.

Ensure that the area around the moving bracket is clear before commencing test protocols.

Keep hands clear of moving parts for the duration of the test.

System Alert

This equipment must not be disassembled by the user or modified in any way.

Manual Operating Controls

There are a few manual controls on the unit. The camera lens has a focus, zoom, and iris ring which can be set by the user.

UStretch Tip: Setting Camera Controls

The iris is usually left 100% open; the brightness of the images is better adjusted by changing the camera gain and exposure.

There are two switches on the front of the control unit, one for powering the control board and another for powering the heating element for the fluid bath.

General Maintenance

Clean the system as needed with mild soap and water or alcohol based cleaning solutions.

Approvals and Certification

This product conforms to applicable CE standards.

2. Testing Terminology

The UStretch is designed to apply uniaxial forces to soft material specimens (deforms by more than 1% *in vivo*) with a test axis dimension of 3 - 60 mm. This includes biological material such as eye tissue, heart valves, pericardium, joint capsules, and large blood vessels.

Multiphase Test Cycles

In order to properly characterize and test a specimen, it is often necessary to load it to different degrees and at different rates. There are three main reasons for doing this:

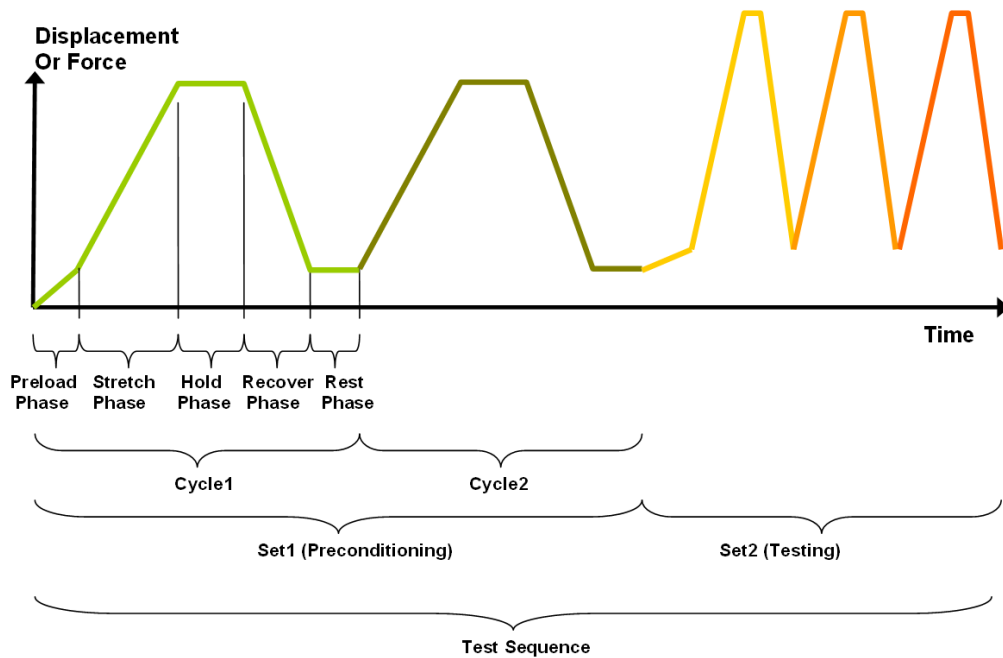
Preconditioning - The goal of preconditioning is to restore a specimen to its physiological or *in vivo* state. During the process of specimen storage and preparation, a specimen may swell, dry out, have its material fibers realign, or its molecules reorganize. It may take multiple preconditioning cycles for a specimen to be restored to its natural state.

Reproducing Physiological Conditions During Testing - By applying various loads and load rates, natural expansion and contraction of a specimen can be reproduced (for example, the pulse pressure in an organ). In as much as the physiological conditions can be recreated, the specimen can be tested in a more realistic state.

Varying Test Conditions - Variable loads and rates allow you to create a variety of test profiles to best study your specimen.

Phases, Cycles, and Test Sequences

As the following diagram demonstrates, each application and release of load on the specimen is called a **test cycle**. The same test cycle can be repeated multiple times to achieve a certain goal (preconditioning, physiological conditioning, or testing); this is called a **test set**. Finally, a **test sequence** is made up of multiple test sets.



The above example describes the following:

- The entire diagram presents a full *test sequence*.
- Within that sequence, there are two *test sets*: the first set applies preconditioning to the specimen; the second set executes the actual test on the specimen.
- Within the first set (preconditioning), two identical *test cycles* are implemented to bring the sample to a satisfactory in vivo state.
- Finally, the second set (testing) is made up of three cycles.

Test Phases: The Smallest Unit of Testing

The test phase is the smallest unit of the test specification. There are five phases within a cycle. Each phase serves a specific purpose:

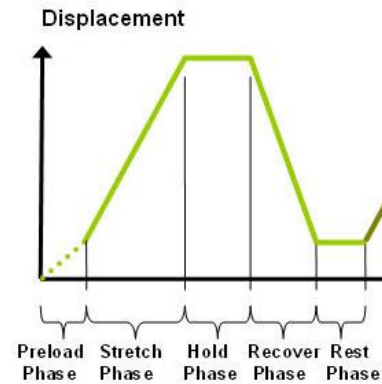
Preloading- Preloads are applied to bring a test to a well-defined starting point. Because the dimensions of a specimen may change as a result of a loading cycle (stretching of fibers, viscoelastic effects, plastic deformation, or localized material failure at the attachment points), the preload adjustment compensates for any of these changes in specimen geometry.

Stretching - During the stretch phase, a deformation is applied to the specimen. The deformation can be specified either in terms of force applied or displacement achieved.

Holding - The deformation can be held for a given duration. The duration for which it is held is dependent on the nature of the testing.

Recovering - The recovery phase is the time during which the force being applied to the specimen is removed. The duration of the recovery time is configurable and dependent on the nature of the testing.

Resting - Finally, the rest phase is the time between the end of one cycle and the beginning of the next. Some tests may specify a short recover time, while others may specify a longer time. The duration is configurable and dependent on the nature of the testing.



Control Modes

There are two control modes which define the basic approach to a given test: displacement control and force control:

Under **displacement control**, the displacement of the specimen is predefined. The UStretch stretches the specimen until the predefined displacement is achieved. The force required to achieve the displacement is an output of the test.

Under **force control**, the force applied to the specimen is predefined. The UStretch stretches the specimen until the predefined force is achieved. The displacement required to achieve the force is an output of the test.

Control Functions

The UStretch makes it possible to test specimens under several control functions:

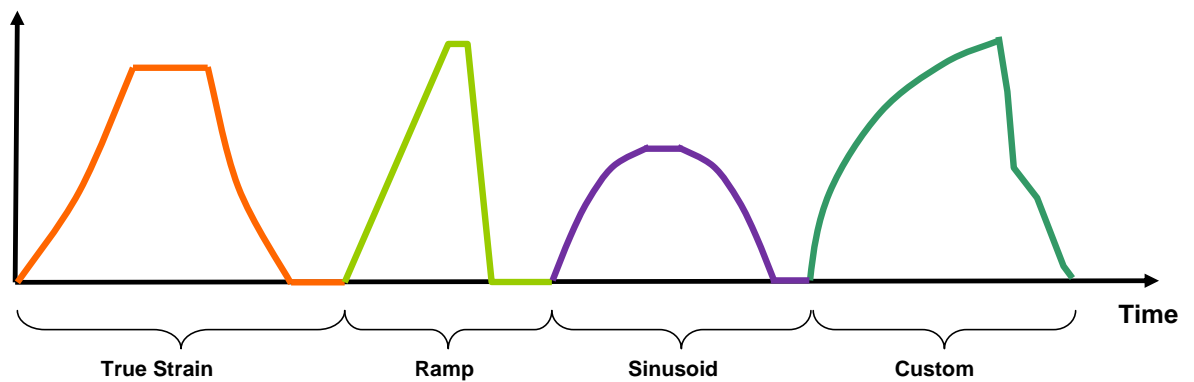
Under displacement control:

The **true strain function** applies the displacement at a true strain rate, which accounts for the current specimen length while the specimen is being stretched. The UStretch system approximates this with a series of linear segments (default = 10).

The **ramp function** applies the displacement at a constant nominal rate. This is equivalent to a constant engineering strain or constant velocity.

The **sine function** applies the displacement according to a sinusoid with the desired displacement magnitude and duration. The UStretch system approximates this with a series of linear segments.

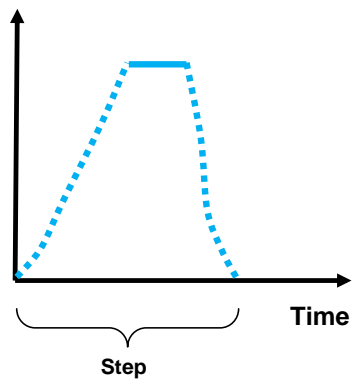
Displacement



Under force control:

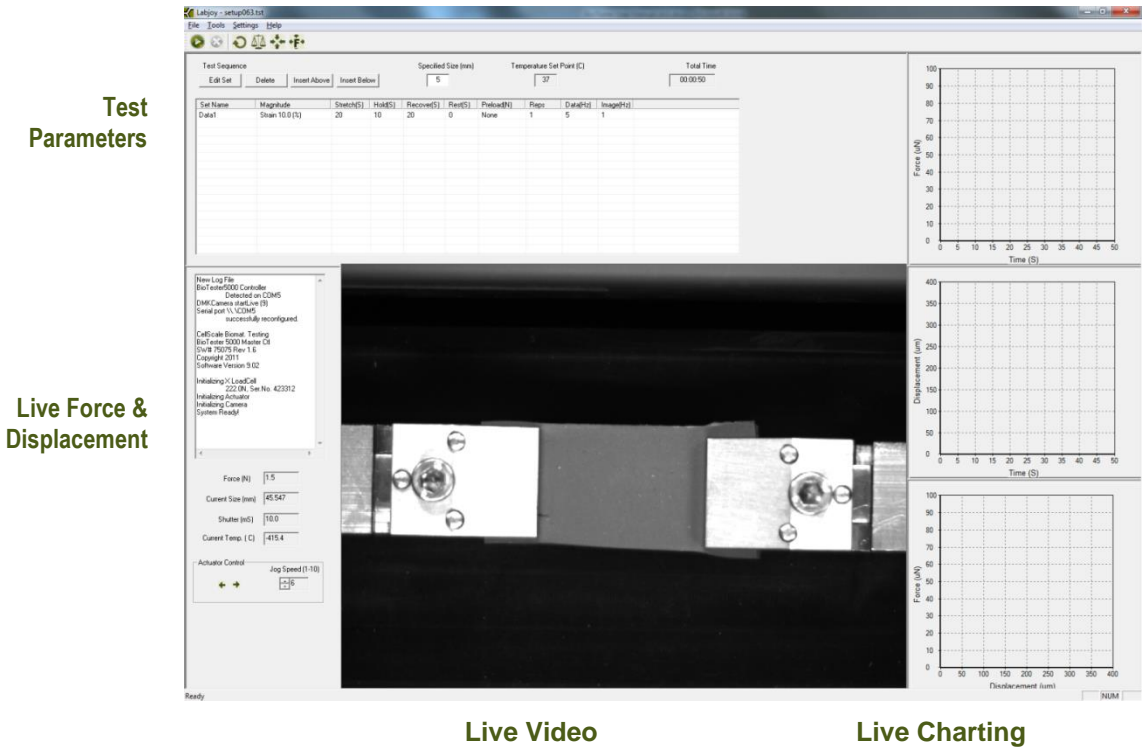
The **step function** achieves and maintains the desired force as quickly as possible. The amount of time it takes to achieve the desired force depends on the material being tested and the force control settings.

Force



3. Software Overview

The software included with the UStretch device is called UStretch. It is divided into two modules, a data collection module and a review and analysis module. The data collection module is used to set test parameters, enable specimen loading and testing, and monitor test progress. The screen layout for this module is shown below:



The review and analysis module is used to playback accelerated or decelerated test images, perform image analysis and tracking, and output movie files for presentation purposes. The screen layout for this module is shown below:



Output Files and Data Structures

For each test, the UStretch creates and saves three file types. The following table describes the three file types for a project named “Sample1”. Output from this test would be found in a “Sample1” output directory (a sub directory of the user specified data directory).

File Type	Description
.tst file	The Sample1.tst file that contains the exact protocol and settings used for the test.
.csv file	The Sample1Data.csv file that contains comma separated numerical data such as time, force and displacement values.
.jpg files	Captured images such as Sample1.000010.3.jpg, which would correspond to an image captured at 10.3 seconds from the start of the test.

Each test folder will also contain 2 subfolders. The “Logs” subfolder contains a text file of the content of the text dialogue portion of the main screen. It is useful as reference to troubleshoot problems with your system, should they occur.

The “Tracking” subfolder is initially empty. If tracking is done on any of the images in the test folder using the “Analyze and Review” software module, there will be data files that contain the tracking information stored in this directory.

While using the “Analyze and Review” software module, you may create additional data files such as text files (*.csv) containing tracking results, images with force data or tracking results overlaid (*.wmf), or movie files (*.avi). These additional files can be stored in the test directory or elsewhere on your computer’s hard drive without interfering with the software application (once created, they cannot be opened by the UStretch application).

When working with the data, you should be aware of a few details regarding the data output:

1. The output specimen sizes are based on the spacing between the grips or BioRake tines and do not account for the specimen material outside of the test region.
2. The software cannot calculate stresses since the thickness of the specimen is not known. To calculate stress, you will have to manually measure the thickness of the material before or after the test is performed.
3. Strains can be calculated using the output displacement values (which are based on the grip or BioRake tine motions). The specimen may actually be subjected to less strain than the calculated values due to attachment site effects and tissue tearing. The image tracking module is useful for determining the actual strain values and variations within the specimen.

4. Setting Up & Starting a Test

Overview

Setting up and running a new test is a simple process made up of both mandatory and optional steps. The following list presents all of the steps, while the rest of this chapter describes each of the steps in detail.

- Step 1: Start a New Test
- Step 2: Reset the Actuator (occasional)
- Step 3: Move the Actuator to a Specified Size
- Step 4: Zero the Load Cell (occasional)
- Step 5: Modify the Test Parameters (optional)
- Step 6: Mount the Specimen
- Step 7: Execute the Test
- Step 8: Terminate the Test Prematurely (optional)

Step 1: Start a New Test

Launch the UStretch software, and then select Collect New from the File menu. In the Create Test From Template dialogue, perform the following steps:

1. Select a template that matches the type of test you wish to perform. See the *UStretch Tip* on how to select and use a template. You can modify the template parameters in Step 5, below.
2. Name your test. The dialogue will have a default test name. You can use the default or rename the test. Each time you start a new test, the default name will continue to increment the number at the end of the name.
3. If desired, you can change the location of the output data. The location of your output data and images is determined by specifying a Test Name and Data Directory. The template and data directories are user specific (computer login name). Each system user can store their files to a different default location. The system uses the last location selected as the default.

UStretch Tip: Selecting and Using Templates

How to select a template: Designing an appropriate test sequence is an art that depends on both the type of material being tested and the specific material properties you are interested in measuring. When first testing a new material, you should expect to have to experiment with the settings until the test yields meaningful data.

The system comes loaded with example templates to help you get started. Selecting a template does not lock you into a specific test sequence or protocol – rather a template defines a test sequence and settings, all of which can be changed before a test is run. Once you have developed a test sequence and settings that are appropriate for the material you are testing, you should save these settings using “Save As Template” from the file menu. You can then select your template the next time you initiate a test.

Step 2: Reset the Actuator (occasionally)

While it is not necessary to reset the actuator with every test sequence, we suggest performing a reset at the start of a new test session. If you have stopped the previous test in mid cycle, then you should reset the actuator. By resetting the actuator, you are ensuring that the displacement measurements taken by the UStretch are accurate.


To reset the actuator, select Reset Actuator from the tools menu, or press  on the toolbar.

System Alert

*You should **NOT** reset the actuator if the specimen is already loaded. Doing so will damage your specimen and/or the load cell.*

Step 3: Move the Actuator to a Specified Size

After the actuator has been reset, it will remain in the fully retracted position and must be moved to a specified (reference or starting) position.

To move the actuator to the specified position, select Move Actuator to Specified Size from the Tools menu, or press  on the toolbar.

Step 4: Zero the Load Cell (occasionally)

While it is not necessary to zero the load cell with every test sequence, we suggest zeroing the load cell at the start of a new test session. With repeated use, the zero point of the load cell can drift. By zeroing the load cell, you are ensuring that the force measurements are accurate.

To zero the load cell, select Zero Load Cell from the tools menu or press  on the toolbar.

System Alert

You should zero the load cell after attaching a BioRake or clamp but before mounting a sample. If a specimen is already loaded when the load cell is zeroed, the force reading will include an offset load.

UStretch Tip: Zeroing the Load Cell

The gooseneck attached to the load cell weighs a certain amount and will introduce forces on the load cell. In the horizontal orientation, this is a bending force which will introduce a small negative offset in the force reading which must be zeroed out after the gooseneck is attached and the load cell is mounted to the frame. Additional bending forces are introduced when a clamp is attached to the load cell gooseneck and must be zeroed out before mounting a sample in the clamp.

In the vertical orientation (for instance, during calibration) an in-line force is produced by the gooseneck which introduces an offset proportional to the mass of the gooseneck. This must also be zeroed out beforehand to achieve an accurate calibration factor or accurate force reading during a test.

Step 5: Modify Testing Parameters (optional)

You can select and modify parameter sets by clicking on a row in the Test Parameter Specification table and then pressing the Edit Set button (or by double clicking on the desired row). When you do so, the Set Parameter Editor Dialogue will appear.

Note that displacements are specified in either % strain, or mm. Force loads are specified in N, and durations are specified in seconds.

The following table describes each of the parameters.

The Set Parameter Editor dialog box is used to configure testing parameters. It includes the following sections:

- Name:** A text field containing "Data1" with a hint "(Example: 'Precon1', 'HoldA', 'TestData1')".
- Magnitude:**
 - Control Mode:** A dropdown menu set to "Displacement".
 - Control Function:** A dropdown menu set to "True Strain".
 - Stretch Magnitude:** A text field with "10" and a unit dropdown set to "%".
- Preload:**
 - Three radio buttons: "Not Applied" (selected), "Applied on 1st Repetition Only", and "ReApply On Every Repetition".
 - Preload Magnitude (N):** A text field with "0".
- Cycle:**
 - Stretch Duration (S):** 20
 - Hold Duration (S):** 10
 - Recovery Duration (S):** 20
 - Rest Duration (S):** 0
 - Repetitions:** 1
 - Data Output Frequency (Hz):** 5
 - Image Output Frequency (Hz):** 1
 - Edit Custom Load Function:** A button.

At the bottom are "OK" and "Cancel" buttons.

Test Parameter	Description
Control Mode	Tests are typically performed under displacement control, however, you can select the following control modes to achieve specific testing objectives: <ul style="list-style-type: none"> For creep testing, use force control with a long hold duration. For relaxation testing, use displacement control with a long hold duration.
Control Function	True Strain or Ramp is typically selected for tests performed in displacement control mode. For tests performed in force control mode, step controls are selected.
Stretch Magnitude (Load Magnitude when in Force Control mode)	Selecting a stretch magnitude is dependent on the material you are testing. A sound approach is to begin with a small magnitude and iteratively move up to larger magnitudes. If you are using Displacement control mode, you can specify the displacement in either μm or as a percentage. For example, the displacement on a 5mm specimen can be expressed as either 0.5mm or 10%. If you are using Force control mode, you can only specify the force in N. Watch the test results carefully to determine which magnitude setting best achieves your test goals.
Preload	Preload is typically reapplied on every repetition during a preconditioning set as well as on the first repetition of a testing set. Specimen size is adjusted after a preload adjustment. Strain calculations are based on the specimen size after the last preload adjustment. If you are working with a material for which preload values have been suggested, you can set the value accordingly. Otherwise, zero is a good initial choice.
Preload Magnitude	As with stretch magnitude, the preload magnitude settings depend on the material you are testing. While Preload can be set at zero, typically you would set the preload magnitude somewhere between zero and 10% of the peak load you expect to achieve.
Stretch Duration	For evenly spaced images, it is recommended to choose a number that is an integer multiple of the Image Output Frequency.
Hold Duration	Hold Duration is typically set to 0, however it is useful for creep or relaxation testing.
Recovery Duration	Recovery Duration is typically set to the same value as the Stretch Duration.
Rest Duration	Rest duration is typically set to 0, however a non-zero value may be used to mimic <i>in vivo</i> conditions or for specialized testing.
Repetitions	Apply enough repetitions until the force deformation curves from one repetition to the next start to overlap each other.
Data Output Frequency	Typically set to the same frequency as the image output frequency.
Image Output Frequency	Typically set to 1Hz for cycles > 5 seconds and 10 Hz for cycles < 5 seconds.

UStretch Tip: Idle Current


Idle current (holding current) can be applied to the motors. The motors have a holding force in the de-energized state of approximately 10N. If forces in excess of 5N are expected it is recommended that idle current is used to prevent position loss during velocity and direction changes when the motors are de-energized for a very short time. When idle current is activated the motors will produce **more noise**, even when the actuator is at rest.

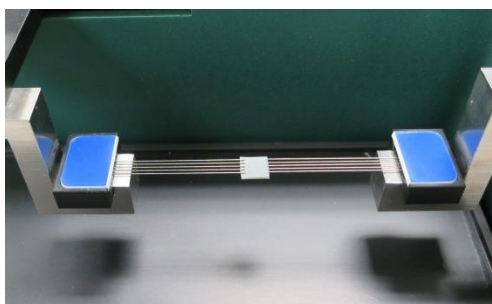
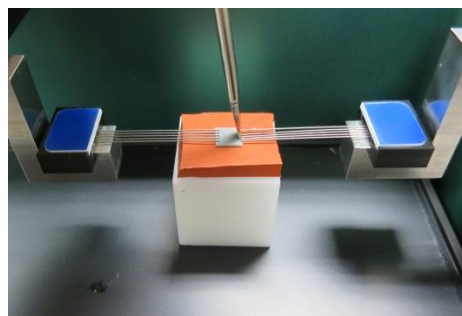
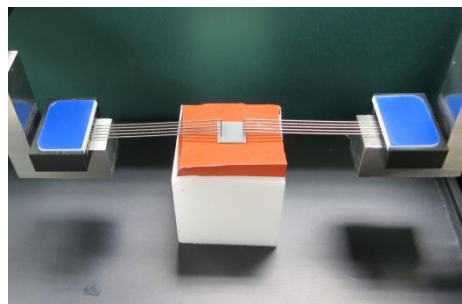
Step 6: Mount the Specimen

BioRake Mounted Specimens

Proper specimen mounting is critical to ensuring accurate and repeatable results. It is best to have the tines spaced evenly across the edge of the specimen and as closely to the edges as possible.

To mount the specimen, follow these steps:

1. Input a specimen size, and from the tools menu, select Move Actuators to Specified Size, or press  on the toolbar.
2. Place the specimen on the rake mounting block on top of a backing material such as soft silicone or foam.
3. Partially raise the UStretch main unit.
4. Place the mounting block underneath the BioRake tips.
5. Centre the specimen between the rakes using a small implement, such as forceps, and the live video window as feedback. Adjustment of the actuators may be necessary to ensure the rake tines are positioned correctly for non-ideally sized specimens.
6. Gently lower the UStretch main unit so that the rake tips are in contact with the specimen. It may be necessary to prop up the main unit slightly based on the thickness of the backing material and sample.
7. Push all 10 tines into the specimen, either all at once using a press block or one at a time using a small implement such as a precision screwdriver.
8. Partially raise the main unit and remove the backing material.
9. Put the fluid bath in place, if desired. Typically, you will want to match a specimen's physiological state, which for most biological materials is in a saline solution heated to the organism's body temperature.
10. Fully lower the main unit.




UStretch Tip: Ideal Specimen Size

The UStretch is designed for small specimen sizes. For our Standard BioRakes (5 tines spaced at 1 mm) the ideal specimen size has ends with lengths of 5.5 - 6 mm. If a specimen is not in the ideal range, it may still be mounted, but the placement of the rake tips will need to be adjusted.

Manual adjustment of rake positions during specimen loading may be necessary to ensure that the rakes puncture the tissue correctly.


These manual adjustments result in a change in specimen size, which in turn results in a change in actuator displacement profiles. The specified specimen size is displayed at the top of the screen while the current specimen size is displayed on the left of the screen just below the force output.

At any point before the test has started, specimen size can be changed using one of the following methods:

- Press  on the tool bar, or from the Tools menu select Move Actuators to Specified Size
- Use the Actuator Control jog button arrows.

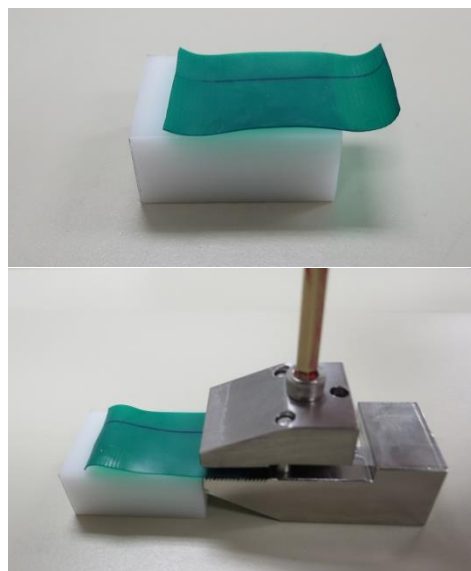
**Clamp Mounted Specimens**

To mount the specimen, follow these steps:

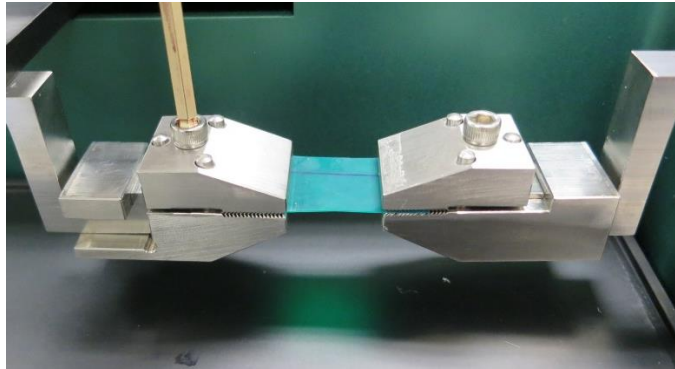
1. Input a specimen size, and from the tools menu, select Move Actuators to Specified Size, or press  on the toolbar.
2. Place the specimen on the clamp mounting block.
3. Slide the jaws of the clamp onto the specimen, tighten the clamp using the appropriate hex key
4. Place the clamp on the load cell gooseneck

The clamp being placed on the force-measuring side should **not** be tightened when in place on the gooseneck to prevent off-axis loads and subsequent **damage** to the load cell.

5. Place the other clamp on the actuator gooseneck.
6. Slide the specimen between the jaws of the clamp and tighten the clamp using the appropriate hex key. It may be necessary to jog the actuator to the appropriate size.




7. Partially raise the main unit and put the fluid bath in place, if desired.
8. Fully lower the main unit.




UStretch Tip: Zeroing the Load Cell

Additional bending forces are introduced on the load cell when a clamp is attached to the load cell gooseneck and result in a force offset which must be zeroed out before mounting a sample and starting a test.

Step 7: Execute the Test

Select Execute from the File menu, or press  button on the toolbar.

Step 8: Terminate the Test Prematurely (optional)

You can stop a test at any time by pressing  on the toolbar, or by selecting Stop from the File menu. This is preferred over powering down the equipment, as it allows the software to store the current actuator position and eliminates the need to reset the actuators on subsequent tests.

At the end of the completed test (both normally or prematurely terminated) the actuators will maintain their current position.

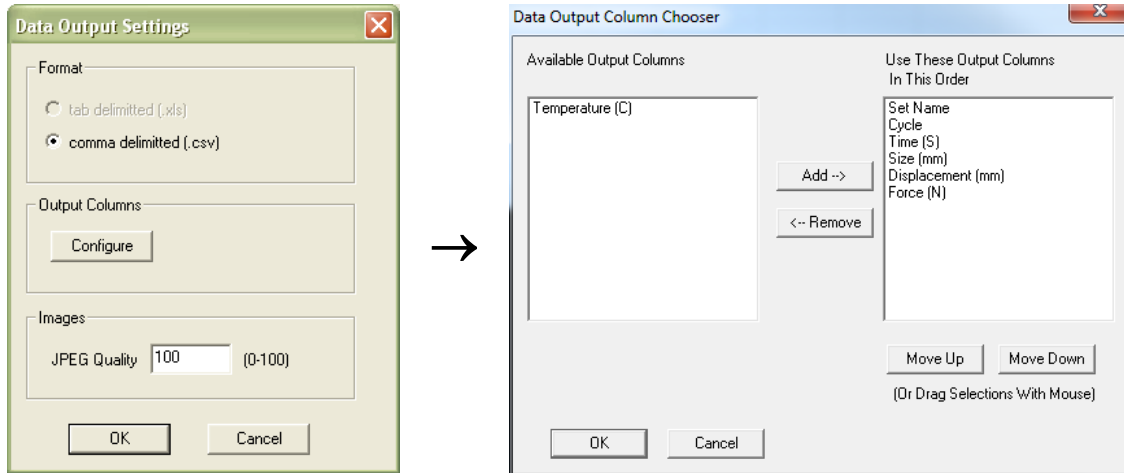
UStretch Tip: Specimen Thickness

Measuring the specimen thickness before and/or after a test is performed will allow stress calculations to be made from your output data.

5. Additional Settings

Configuring Output Data Files

From the Settings menu, select Data Output to display the dialogue shown on the left. Click the Configure button to select which of the following columns to output.



Output Column	Description
Set Name	User defined name of each set
Cycle	Cycle and Phase information
Time (S)	Time in seconds
Size (mm)	Specimen Gage Length
Force (N)	Load Cell reading
Displacement (mm)	Reports the change in size relative to the initial size
Set Name	Name specified for each set
Temperature (°C)	Current temperature

Advanced System Settings Dialogue

Advanced settings are available by selecting Advanced from the Settings menu. All of these settings are template specific.

True Strain Rate

Unlike nominal or engineering strain rate, a plot of velocity versus time for a true strain rate test would be non-linear. The degree of non-linearity increases with increasing strain. The UStretch approximates this non-linear curve with a series of linear segments. Typically, 10 line segments is a sufficiently close approximation. More segments can be used, but you should bear in mind that the actuator velocity can only be updated every 250ms.

Data Averaging

The load cells are sampled at 100Hz with hardware using a central moving average of 8 samples. Further data averaging can be applied to smooth noisy data.

Force Control Settings

Force Control Settings affect the rate and stability at which forces are achieved. These settings apply to preloading as well as Force Control Modes.

Advanced Settings

True Strain Rates
 Number of Linear Segments Approximating a True Strain Rate

Data Averaging
☐ Apply Averaging to Force Data
 Number of data points (central moving average)

Force Control Settings
 Kx
 Tolerance (N)
 Settling Frames
 Velocity (1-10)

Warning:
 Incorrect Force Control Settings
 May Result in Unstable Behavior.

Force and Displacement Control
 Acceleration (1-10)

Reset Actuators
☒ Show Warning Before Resetting Actuators

Note: To Save these settings to a Template
 Select Save As Template from the File Menu

OK Cancel

Kx (Default = 100, integer values) is a proportional gain tuning parameter. It controls the sensitivity or the amount of corrective action that is applied to the difference between the current and target force values. At low gain values the system may be safe and stable but may be sluggish in response to changing conditions. If the proportional gain is increased the system becomes more responsive and loads are achieved more quickly. If Kx is set too high, an unstable oscillating system may result and forces may never be achieved. The optimal value for these settings depends on the properties of the material being testing. For stiff tissues values may range between 1 and 10. For soft tissues values may range between 50 and 200.

Tolerance (N) (Default = 0.01) controls how close to the specified force the actual load values need to be. For example, a specified force of 0.1N with a Tolerance of 0.003 N will be considered achieved when the loads are between 0.097 and 0.103 N. Keep in mind the tolerance of the load cell being used when choosing the value for this parameter. The load cells typically fluctuate by about 0.1% of their full scale during the course of a test. For a 1N load cell this is about 0.001N but for a 23N load cell, this is about 0.023N. This value should usually be 0.2-0.5% of full scale to ensure stable operation.


Settling Frames (Default = 5) controls how many successive load samples (sampled at 100 Hz) need to be within the Tolerance criteria for the force to be considered achieved. For example, a specified force of 0.1 N with a Tolerance of 0.003 N and Settling Frames = 5 will be considered achieved when the loads are between 0.097 and 0.103 N for 5 successive data samples at 100 Hz.

Velocity (1-10 integer values) matches actuator jog speed. Typically for harder tissues, this value should be between 4 and 6 and for soft tissues, this value should be between 6 and 10.

Acceleration (1-10 integer values). Typically, this should be set to the default value of 10 (maximum acceleration). Changes made to the acceleration will affect tests under both force and displacement control. Reducing this value may help smooth force controlled tests under low loads or displacement controlled tests at high speeds. Tests run with lower accelerations will have softer transitions at direction or speed changes but may take longer than specified to achieve testing cycles.

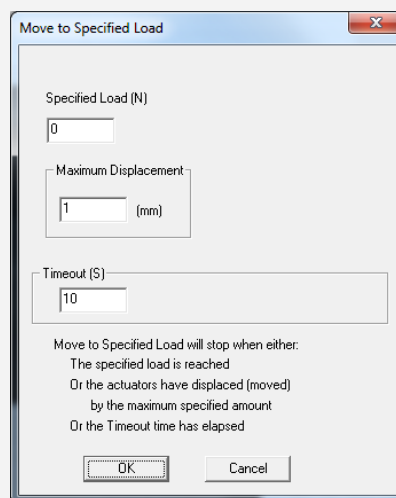
UStretch Tip: Testing Force Control Settings

It is important to have appropriate Force Control Settings that match the materials you are testing.

To safely test Force Control Settings: press  on the tool bar, or from the Tools menu select Move Actuators to Specified Load. The dialogue shown on the right will appear. The UStretch will attempt to achieve the specified load (force) but will stop when the specified load is reached, the actuator has displaced by the maximum specified amount, or the timeout time has elapsed.

If the actuator oscillates around the specified loads but never achieves them try reducing Kx and/or decreasing the velocity.

If the actuator reaches the specified load too slowly, try increasing Kx and/or increasing the velocity.



Reset Actuators

Resetting the actuators with a sample attached may damage the specimen, BioRakes, and/or load cells. To avoid resetting the actuators with a sample attached, a warning dialogue will appear after "Reset Actuators" is selected, prompting the user to proceed. This feature can be disabled by de-selecting "Show Warning Before Resetting Actuators".

Range Limits

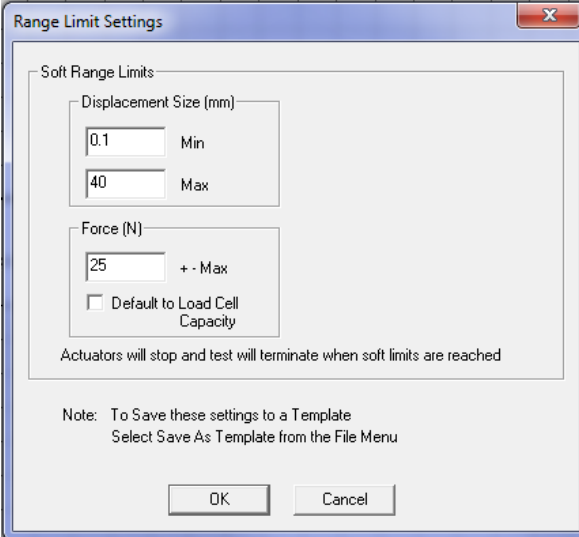
Range limits can be accessed by selecting *Range Limits* from the Settings menu.

Soft Limits

To avoid rake collisions or sample destruction, it is useful to assign reasonable travel limits to the actuators. This is especially important during force control or preloading, where if specified loads cannot be reached, the actuators will keep moving until they reach the soft limits.

Min and Max Displacement, in mm, set the minimum and maximum positions to which the rakes are allowed to move.

Max Force, in N, sets the maximum value of force at which a test will be automatically stopped. The default value is set to the capacity of the load cells. Setting this value may be useful to prevent sample destruction or overloading of the load cells.



The image shows a 'Range Limit Settings' dialog box with a title bar containing a close button. The main area is titled 'Soft Range Limits' and contains two sections. The first section, 'Displacement Size (mm)', has two input fields: 'Min' with the value '0.1' and 'Max' with the value '40'. The second section, 'Force (N)', has an input field with the value '25' and a label '+ - Max'. Below this is a checkbox labeled 'Default to Load Cell Capacity' which is currently unchecked. A note at the bottom of the main area states: 'Actuators will stop and test will terminate when soft limits are reached'. At the very bottom of the dialog, there is a note: 'Note: To Save these settings to a Template Select Save As Template from the File Menu'. At the bottom right are 'OK' and 'Cancel' buttons.

Soft Range Limits	
Displacement Size (mm)	
0.1	Min
40	Max
Force (N)	
25	+ - Max
<input type="checkbox"/> Default to Load Cell Capacity	

Actuators will stop and test will terminate when soft limits are reached

Note: To Save these settings to a Template
Select Save As Template from the File Menu

OK Cancel

Configuring the Live Charting Graphs

The three graphs on the right side of the screen provide real-time user feedback during a test. These graphs are intended to be used for qualitative feedback, not for detailed analysis.

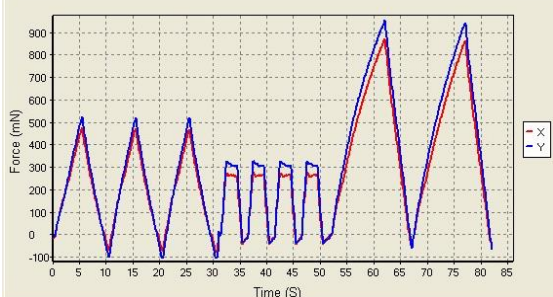
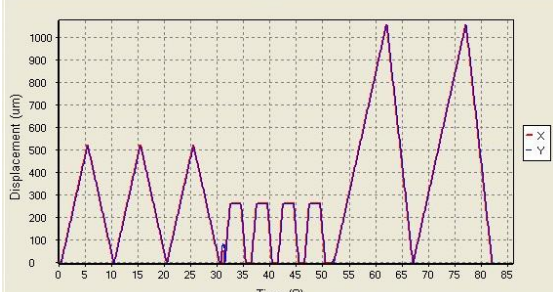
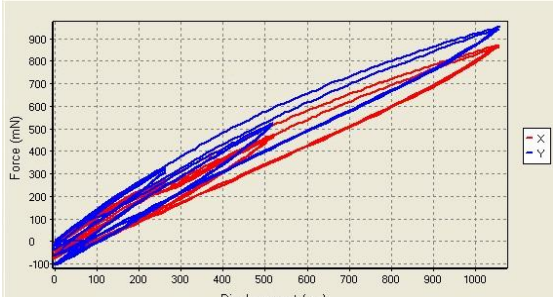
The graphs are updated at a maximum frequency of 10Hz; certain short-duration tests may not show all the detail that is actually present.

The graph settings can be specified by selecting Graphs from the Settings menu. Auto scaling allows the axis min and max to start at the specified values but expand if the data values are larger or smaller than the initial limits.

The **Graph Settings** dialog box contains three sections for configuring individual graphs. Each section includes an X-axis and Y-axis configuration area with dropdown menus for units and values, and a checkbox for 'Clear Graph Between Sets'.

- Graph 1:**
 - XAxis: Time (S), Auto, Min 0, Max 40
 - YAxis: Force (mN), Auto, Min 0, Max 500
 - ☐ Clear Graph Between Sets
- Graph 2:**
 - XAxis: Time (S), Auto, Min 0, Max 40
 - YAxis: Displacement (um), Auto, Min 0, Max 400
 - ☐ Clear Graph Between Sets
- Graph 3:**
 - XAxis: Displacement (um), Auto, Min 0, Max 400
 - YAxis: Force (mN), Auto, Min 0, Max 500
 - ☒ Clear Graph Between Sets

At the bottom of the dialog are **OK** and **Cancel** buttons.

Graph	Data
<p>Force versus Time</p> <p>This graph shows how the measured forces are changing with time. Peak loads per cycle and force relaxation are all easily seen in this type of graph. Force is proportional to nominal (engineering) stress.</p>	
<p>Displacement versus Time</p> <p>This graph shows how the rakes are moving with time. The phases of the test sequence and size adjustments due to preloading are readily apparent in this type of graph.</p>	
<p>Force versus Displacement</p> <p>This graph displays a qualitative representation of the material behavior. Viscoelastic effects (like hysteresis) and material response to different loading phases are apparent in this graph. This graph is proportional to a nominal (engineering) stress-strain graph.</p>	

6.Reviewing Test Results

Overview

The UStretch software has an integrated image analysis module which can be accessed by selecting Analyze and Review Images from the file menu, then selecting the appropriate test file. The test file is a text file with a .tst extension that contains information about the test parameters so that the software can display the images and data in a useful fashion.



Selecting Images

The Images are shown in a tree structure on the top left panel. The tree structure organizes the images by:

Set (line on the test parameter window)

Cycle (iteration of a given Set)

Phase (Preload/Stretch/Hold/Recovery/Rest of each Cycle)

Image (the one or more individual images from each Phase)

You can select which images to include in a playback set in one of several ways:

- hold down the shift key and click on individual images
- select entire sets, cycles, or phases (will playback all contained images)
- select images which have data associated with a particular tracking set

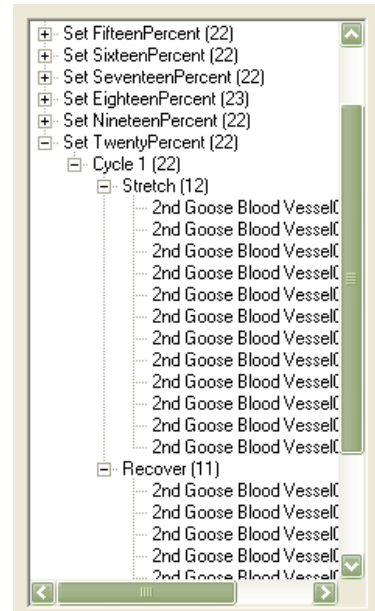


Image Playback Options

The controls on the left of the screen are broken into 2 sections: Playback and Tracking.

The playback buttons allow the user to review the images taken during a test.

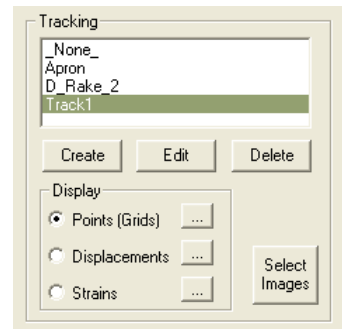


Next/Prev	Display next or previous image (as dictated by "Play Every" parameter).
Play/Stop	Start and stop the playback.
Prev/Next Cycle	Jumps to a corresponding image and phase in the next or previous cycle. Useful when reviewing sets that have multiple cycles.
Loop	Sequences can be played continuously in a loop or only once.
Playback Rate	+/- changes the speed of the playback. A playback rate can also be manually entered in the display box.
Play Every	Allows the users to skip some frames to expedite playback.

Image Tracking: Overview

Image tracking is a function that can be used to quantify the motions of image features (rake lines, specimen texture and fiducial markers). This can be useful for studying localized specimen deformations, determining or verifying strain magnitudes, and comparing the results of one test to another.

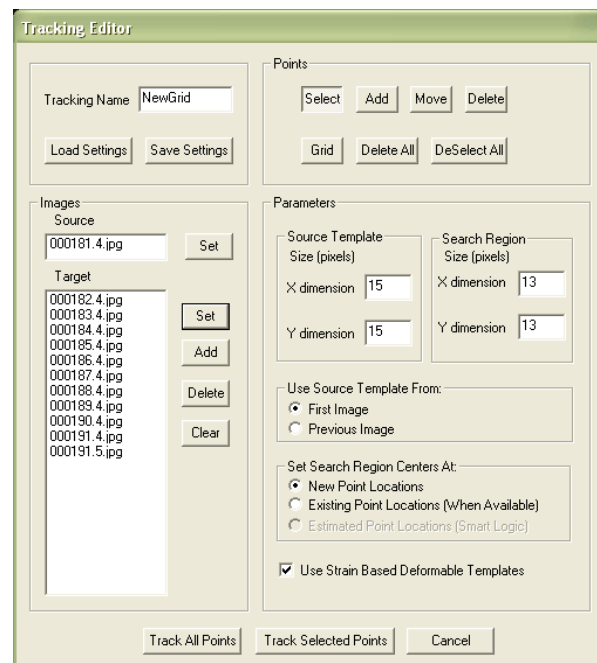
The image tracking engine is based on a template matching algorithm. This algorithm starts by defining a “patch” of pixels (called a template) surrounding the selected source point on the source image. It then determines the optimal location for this template on a target image within a specified search region.



The algorithm defines the location of the tracked point on the target image as the center of the optimally located template.

To track an image, follow these steps:

1. Click the Create button in the tracking window, shown above. This brings up the Tracking Editor dialogue box.
2. Enter a Tracking Name.
3. Select the Source Image in the test image list tree, and click Set to the left of the Source box.
4. Select the Target Images in the test image list tree, and click Set to the left of the Target box. The target image list will automatically be sorted to remove duplicates and be put in sequential order.
5. Generate source points on the source image by performing the following steps:
 - a. Manually click source point locations on the source image with the Add button depressed.
 - b. Draw a box on the source image with the Select button depressed, then click the Grid button and define a grid of points.



The displayed image will automatically change to the source image when either the Add or Grid buttons are depressed.

6. Modify search parameters:

Source Template	The optimal source template is difficult to predict, but in general it is advantageous for the template to be large enough that it contains at least one feature, but not so large that it contains multiple features. Typical values for this parameter are between 15 and 55, with 35 being a good starting point for most situations.
Search Region	The search region needs to be large enough that the optimal location for the template is found. In general, no part of the specimen moves more than the rake tines, so the motion of the rake tines is a good guideline for how large the template needs to be. For example, if the rake tines move 50 pixels over the 10 frames you are interested in, it is unlikely that any part of the specimen is moving more than 5 pixels/frame and so a good value for the search region parameter would be 11 (5 pixels each way, plus the center pixel).
Use Source Template From	<p>First Image tracks all images against the first in the series (1→2, 1→3, 1→4...).</p> <p>Previous Image tracks each subsequent image against the image before it (1→2, 2→3, 3→4...).</p> <p>First Image Tracking tends to have poorer correlation than Previous Image Tracking because the current image is usually closer in content to the previous image than it is to the first image in the sequence. Previous Image Tracking tends to have good correlation for each individual step, but is prone to error accumulation since each step is independent. The best method for a given data set will depend on the number of images and the content of the images. Sometimes it is best to use Previous Image Tracking but to only use every other image or every n'th image rather than all the images available. Sometimes it is best to use First Image Tracking and use every image but set the source image in the middle of the image series rather than at the beginning.</p>
Set Search Region Centre	<p>New Point Locations The location of the center of the search region is set to the same location of that point in the previous image (even when the source template is from the first image).</p> <p>Existing Point Locations The search region center location is set to the previously tracked location of that point. When no previously tracked point exists, the location is chosen in the same way as New Point Locations.</p>
Use Strain Based Deformable Templates	When this option is checked, the source template will be scaled (resized) according to strains calculated from the test XSize parameters. Best tracking results are often obtained when using this option. This option may not be the best for tests where the specimen deformation is non-uniform.

7. Perform tracking with either Track All Points or Track Selected Points.

Image Tracking: The Points Display Option

The Points Option displays the points in their current location (i.e. their location on the currently displayed image) with or without gridline connecting points that were generated using the grid function.

Clicking the details icon brings up the window shown to the right. Options include changing the point radius or color, showing ID numbers and showing gridlines with or without ID numbers.

Gridline ID numbers are associated with each grid square (cell), while Point ID numbers are associated with the points themselves.

Tracking display settings default to the last used settings.

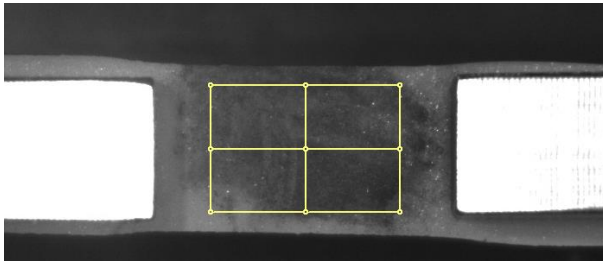
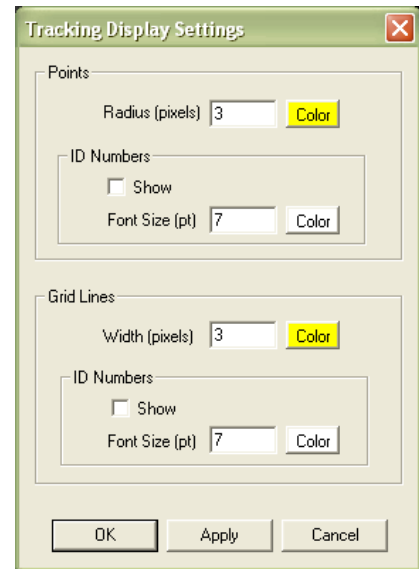


Figure 1: Initial tracking grid displayed as points.

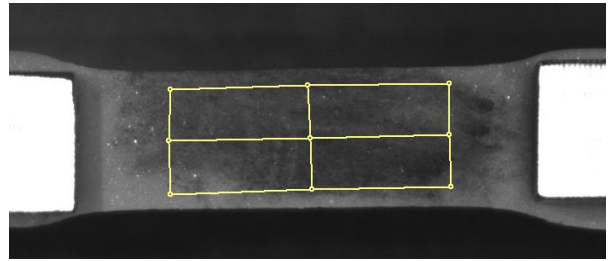


Figure 2: Tracking to 50% strain displayed as points.

Image Tracking: The Displacement Option

The Displacement Option displays the points in their current location as well as graphically representing their motion through time.

Clicking the details icon brings up the window shown to the right. This dialogue allows the user to change the reference image, change the type of connecting line, and change the line appearance.

Displacement connecting lines directly connect the reference and current points via a vector or a path. The path option provides more information but can result in slow playback speeds for sets with many points and/or many images.

The Flow option generates a direction vector based at the current location and oriented in the direction of motion relative to the reference image. This can be useful because the length of this vector can be scaled to better visualize small displacements.

Tracking displacement settings default to the last used settings.

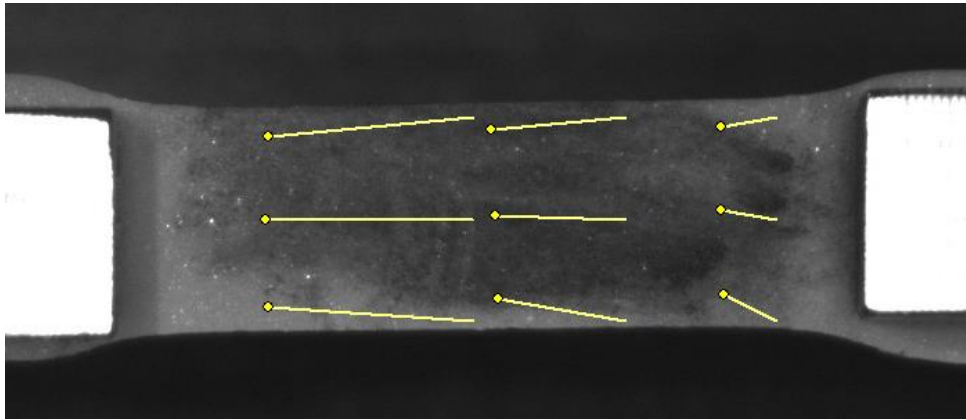
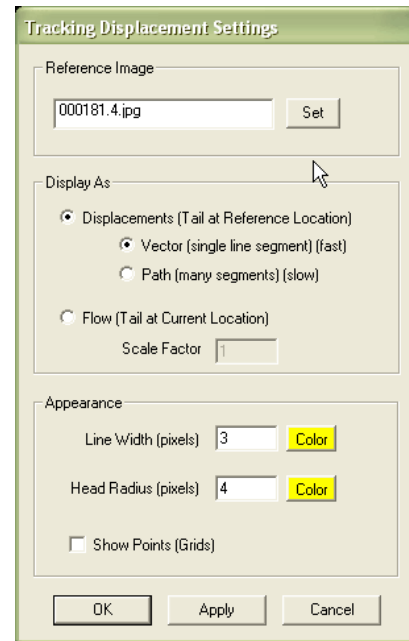


Figure 3: Tracking to 50% strain displayed as displacement.

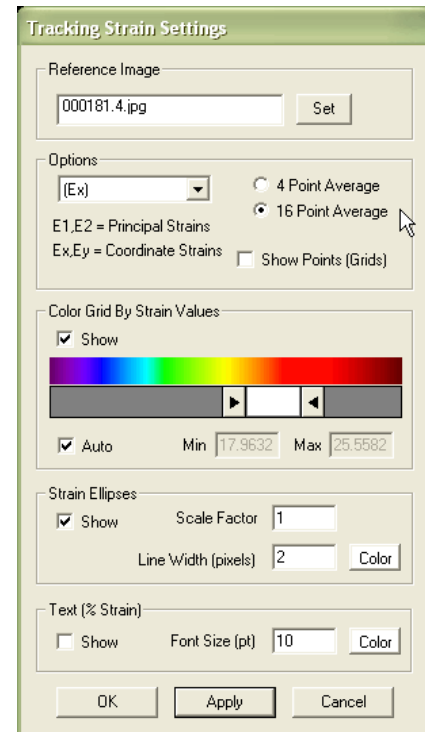
Image Tracking: The Strains Option

The Strains Option can only be used in conjunction with a grid of points (as opposed to individually placed points). This option calculates the regional strains inside every grid box and displays this data as an ellipse. One can imagine this is what would happen to a grid of circles drawn on the surface of the specimen at the beginning of the test.

Clicking the details icon brings up the window shown to the right. This dialogue allows the user to change the reference image as well as the appearance of the circles and text.

Showing text for E1, E2 (principal strains) will result in the text showing the strains along the major and minor axis of the ellipse. Showing text for Ex, Ey will result in text showing the strains along the X and Y directions regardless of the ellipse orientation.

Tracking strain settings default to the last used settings.



The 'Tracking Strain Settings' dialog box contains the following sections:

- Reference Image:** A text field with '000181.4.jpg' and a 'Set' button.
- Options:**
 - A dropdown menu showing '(Ex)'.
 - Radio buttons for '4 Point Average' and '16 Point Average' (selected).
 - Text: 'E1,E2 = Principal Strains'.
 - Text: 'Ex,Ey = Coordinate Strains'.
 - Checkbox for 'Show Points (Grids)' (unchecked).
- Color Grid By Strain Values:**
 - Checkbox for 'Show' (checked).
 - A color gradient bar from blue to red.
 - Buttons for 'Auto', 'Min', and 'Max'.
 - Min value: 17.9632, Max value: 25.5582.
- Strain Ellipses:**
 - Checkbox for 'Show' (checked).
 - Scale Factor: 1.
 - Line Width (pixels): 2.
 - Color button.
- Text (% Strain):**
 - Checkbox for 'Show' (unchecked).
 - Font Size (pt): 10.
 - Color button.
- Buttons: OK, Apply, Cancel.

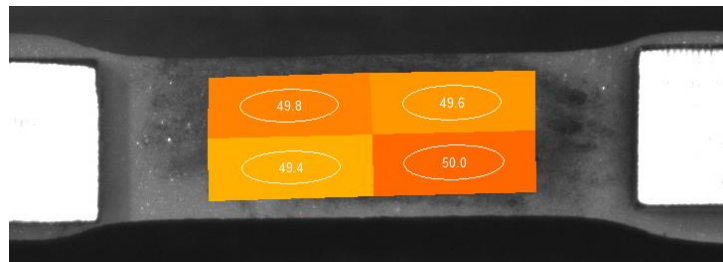
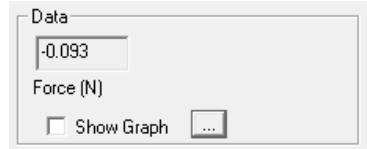


Figure 4: Tracking to 50% strain displayed as strain ellipses with text showing x% strain.

Data Overlay

Data associated with each image is displayed below the tracking controls on the left side of the main window. Checking the Show Graph box displays this data as a graph overlaid on the images



Clicking the details icon displays the window shown to the right. The dialogue allows the user to change the size and appearance of the overlaid graph. The data points associated with the current image are marked on the graph with green circles. The overlaid data graph will be drawn on top of any image tracking displays (when they overlap).

Data Overlay settings default to the last used settings.

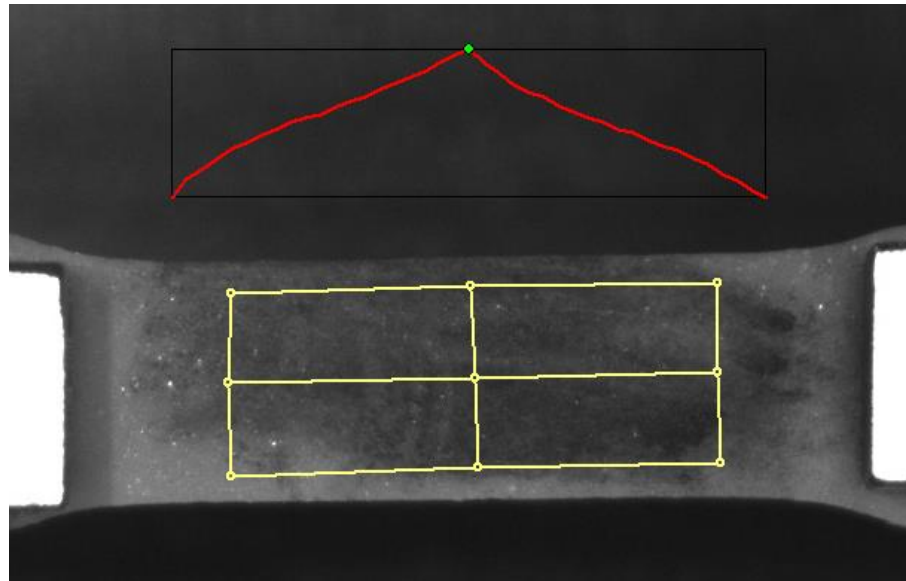
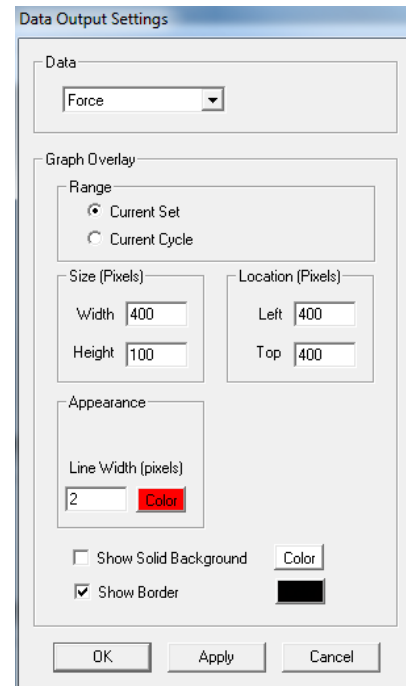


Figure 5: Tracking to 50% strain with overlaid force graph.

Exporting Tracked Data

Tracked grid point coordinates and calculated grid strains can be exported to a .csv file. From the Export menu, select Data Points to display the dialogue shown on the right. The image list is automatically set to the currently selected images in the test image list tree. This image list can be changed by selecting new images in the test image list tree and pressing the set button. When exporting Strains data from Selected Tracking Points, all four points of a grid cell need to be selected for data from that cell to be exported.

Exported data is labeled with associated ID numbers (grid point ID numbers for exported coordinates and grid cell ID numbers for exported strain values). To display ID numbers on tracking grids see Image Tracking: The Points Display Option. In the following example (Figure 9), grid point ID numbers are shown in yellow and grid cell ID numbers are shown in white. When exporting data for the selected points as shown in red (see below image), coordinates are exported for points with ID numbers 5, 6, 7, 8, 9, 10, 11 and 12, and strains are exported for grid cells with ID numbers 4, 5, and 6.

The exported .csv file is written to the test directory.

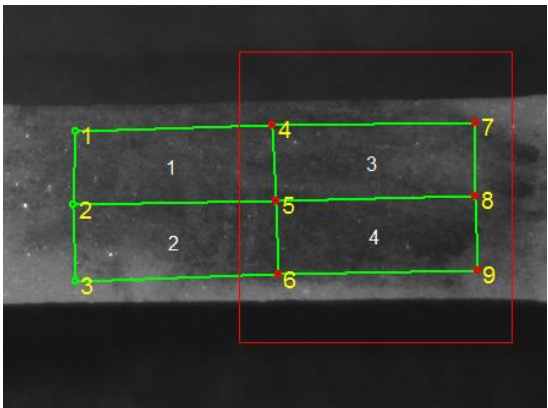
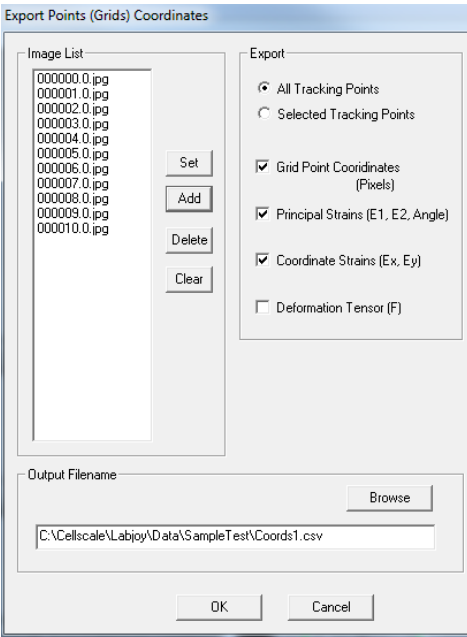


Figure 6: Tracking Grid showing ID Numbers.

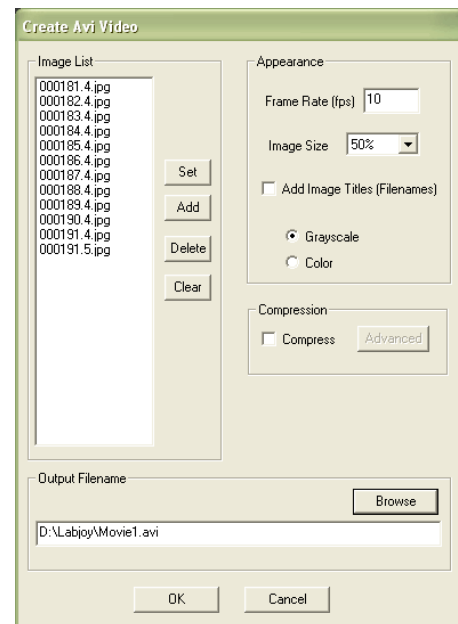
Grid Point	Coordinates (pixels)										
FileName	Time(S)	X5	Y5	X6	Y6	X7	Y7	X8	Y8	X9	
2nd Goos	181.4	588	323	588	426.667	588	530.333	588	634	69	
2nd Goos	182.4	587.125	318.75	586.75	424.75	586.875	531.625	586.625	636.875	692.62	
2nd Goos	183.4	586.5	314.75	586.25	423.5	586.125	532.375	585.375	639.25	693.62	
2nd Goos	184.4	585.375	310.5	585.25	421.625	585.375	532.625	584.375	642	694.37	
2nd Goos	185.4	584.375	306.875	584.125	420	584.125	533.125	583.125	645.625	695.12	
2nd Goos	186.4	583.625	303.125	583.125	418.875	583.25	534.75	582.5	649	695.87	
2nd Goos	187.4	582.5	299.125	582.5	417.5	582.125	535.75	581.25	652	696.7	
2nd Goos	188.4	581.5	295.25	581	416	581	536.25	578.625	655.875	697.62	
2nd Goos	189.4	580.5	291.125	579.875	414.875	579.75	537.5	577.375	658.875	698.62	
2nd Goos	190.4	579.375	286.625	578.75	413.25	578	539	576.5	662	699	
2nd Goos	191.4	578.25	283.5	577.5	412	577.25	539.75	574.25	665.75	700	
2nd Goos	191.5	578.25	283	577.5	412	577.125	540.125	576.875	665.125	700.62	
Coordinate Strain X - Values (16 point least squares average) (Grid Cells are numbered from the top left corner -											
FileName	Time(S)	StrainX_4	StrainX_5	StrainX_6							
2nd Goos	181.4	0	0	0							
2nd Goos	182.4	0.02448	0.02443	0.02512							
2nd Goos	183.4	0.04696	0.04739	0.0492							
2nd Goos	184.4	0.06915	0.06983	0.07204							
2nd Goos	185.4	0.08994	0.09044	0.09307							
2nd Goos	186.4	0.10994	0.11052	0.11394							
2nd Goos	187.4	0.13117	0.13203	0.13574							
2nd Goos	188.4	0.15236	0.15373	0.15853							
2nd Goos	189.4	0.17472	0.17701	0.18233							
2nd Goos	190.4	0.19704	0.19955	0.20549							
2nd Goos	191.4	0.21951	0.222	0.22825							
2nd Goos	191.5	0.22055	0.2223	0.22813							
Coordinate Strain Y - Values (16 point least squares average) (Grid Cells are numbered from the top left corner -											
FileName	Time(S)	StrainY_4	StrainY_5	StrainY_6							
2nd Goos	181.4	0	0	0							
2nd Goos	182.4	0.01942	0.02171	0.02187							
2nd Goos	183.4	0.04246	0.04261	0.03932							

Figure 5: Sample Exported Data.

Exporting Images and Movies

The current Image view, including all displayed tracking grids, tracking data and overlaid data can be exported as a metafile by selecting Current Image from the Export menu. Alternately, the current image view can be copied to the clipboard by selecting Ctrl-C from the keyboard.

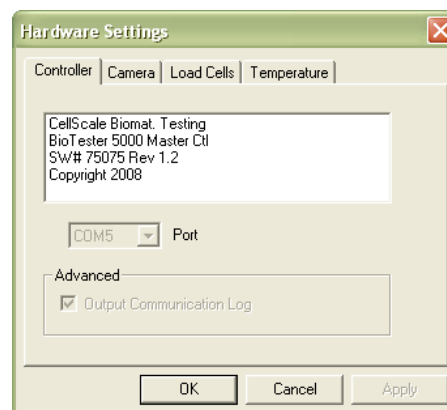
To export a series of image views, including all displayed tracking grids, tracking data and overlaid data as a .avi movie, select Movie from the Export menu. The dialogue shown on the right will be displayed. The image list is automatically set to the currently selected images in the test image list tree. This image list can be changed by selecting new images in the test image list tree and pressing the set button. Options are available for setting the frame rate or image size (resolution), adding filenames, and choosing color or grayscale output. Compression options are also available.



7. System Hardware Settings

Controller

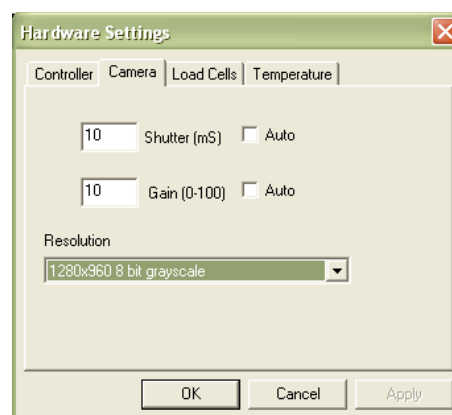
The UStretch uses an integrated control board rather than a group of PC controlled device drivers. This minimizes communication lag and allows the device to operate asynchronously with the PC. The control board details can be seen by selecting Hardware from the Settings menu, which brings up the window shown to the right.



Camera

The camera uses a 1/2" monochrome CCD sensor to obtain a resolution of 1280 pixels by 960 pixels. The camera shutter can be controlled during the setup phase of the test.

The camera captures images at 15 frames per second during every test and writes these images to a buffer. The test controller extracts images from this buffer at the frequency specified in the Set Parameter Editor (15Hz, 5Hz, 1Hz, 0.1Hz, 0.01Hz, or 0.001Hz). These images are written to the output directory. The file name is the ideal capture time. The actual capture time may differ from the ideal capture time by as much as 1/30 of a second since the images are extracted from a buffer.




The test software creates an image capture log file in the output directory should this difference be significant. This log stores the actual capture time and the idealized capture time.

The camera default shutter and gain are specific to each test template and can be set by selecting Hardware from the Settings menu. The recommended maximum shutter speed is 10mS. Typically, the camera iris is left fully open and the shutter and gain are adjusted to achieve the desired image brightness.

Load Cell

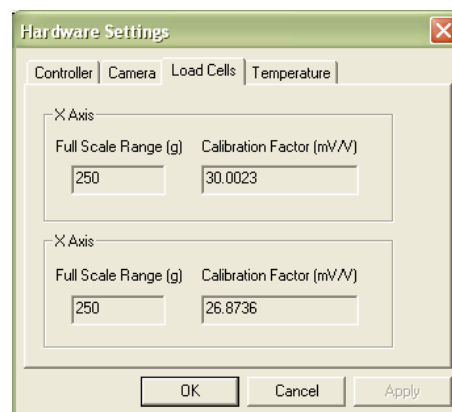
The load cell is semiconductor strain gage-based with high overload capacity. It has an accuracy equal to 0.2% of the rated full scale load. The load cells are available in 0.5N, 1N, 2.5N, 5N, 10N, 23N, and 45N sizes. Each load cell has a unique calibration factor which is stored in a chip attached to the load cell connector.

While the load cells should not have significant hysteresis or thermal drift, temperature changes or prolonged loading can introduce small offsets. In addition, the bending force from the weight of the gooseneck and clamp can introduce a small offset in the load cell reading. It is recommended that the zero load state be redefined before beginning a test. This can be done by selecting Zero Load Cells from the Tools menu

or pressing .

The load cells are sampled at 100Hz, with hardware providing 8 sample averaging to reduce noise in the data. Further sample averaging can be implemented by selecting Advanced from the Settings menu.

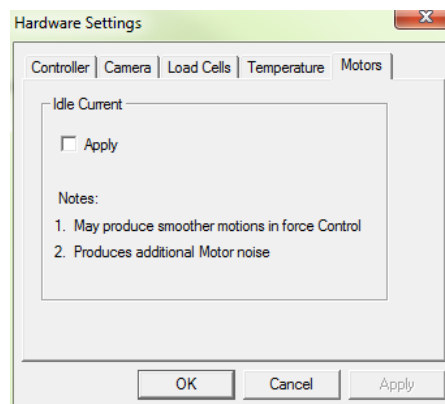
Each load cell is calibrated and has a specific calibration factor which is stored on a chip in the load cell connector. Field calibration using the provided test weights is recommended (see Section 8). The range and calibration factor can be viewed by selecting Hardware from the Settings menu, but are not user controlled.



Actuator and Motor

The actuator is driven by a stepper motor under open loop control. The motor drives a lead screw attached to a stage that the gooseneck is mounted to. The stage has a peak velocity of 50mm/s. Provided that the actuator is not driven beyond its rated velocity and thrust load, the stepper motor is very unlikely to lose steps. To prevent excessive velocities and accelerations, the control software will issue warnings if entries in the Set Parameter Editor result in accelerations or velocities that are out of range. Excessive thrust loads should only occur if mechanical interference from the fluid chamber or a foreign object obstructs the movement of the actuator. It is advisable to reset the actuators occasionally.

Idle current (holding current) can be applied to the motors. The motors have a holding force in the de-energized state of approximately 10N. If forces in excess of 5N are expected it is recommended that idle current is used to prevent position loss during velocity and direction changes when the motor is de-energized for a very short time duration. Turning idle current on may produce smoother motions in force control (since the motors are frequently stopping and starting). When idle current is activated the motors will **produce more noise**, even when the actuator is at rest.

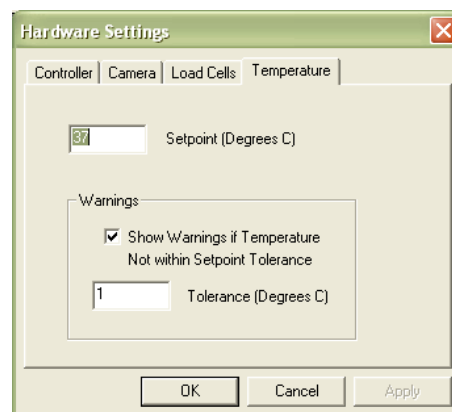


Temperature

To activate the fluid chamber heater, both power switches on the front of the UStretch control box need to be in the On position (the computer and software do not need to be on yet). At this point, the heater will warm the fluid to the last used temperature set point. The temperature set point can be changed by selecting Hardware from the Settings menu.

Typically, the heater will take 30-60 minutes to warm a full fluid chamber from room temperature to 37°C.

When Show Temperature Warnings is enabled and the Current Temperature is not at the Temperature Set Point plus or minus the specified tolerance -- a red indicator button will be displayed next to the Current Temperature live output and a warning dialogue will appear when you execute the test.



System Alert

In the event of a dislodged or faulty temperature sensor, or if there is a lack of fluid in the fluid chamber, the system is designed to reach a maximum temperature of 70°C.



Caution: Avoid touching the base plate surface below the fluid chamber when the heater is on, it can become very hot!

UStretch Tip: Preheat Fluid

You can add preheated fluid to the fluid chamber to reduce warm up time.



8. System Calibration and Advanced Tools

Load Cell Calibration

If the load cells are changed or moved, it is advisable to perform the load cell calibration routine.

Before installing a load cell, select the appropriate gooseneck. Use the stainless steel gooseneck for the 1N, 2.5N, 4.5N, 8.9N, 22N, and 44N load cells. Use the **black plastic** gooseneck for the **0.5N** load cell. Do not use the stainless steel gooseneck with a 0.5N load cell as the weight of the gooseneck alone will overload the load cell. After selecting the appropriate hardware, proceed with these steps to calibrate the load cell:

This calibration can be performed in the following steps:

1. Reset the actuator 
2. Place the unit in the vertical orientation.
3. **Zero the load cell**  to remove the weight of the gooseneck from the calibration values measured.
4. From the *Tools* menu select *Advanced* then select *Load Cell Calibration*

Load Cell Calibration (Free Weights)

1. Attach Weights

a. Enter Weight (g)

b. Read Load Cell

FullScale Load (g)

For best results
Apply at least 2 different weights
Covering most of the load cell range

Weight(g)	LoadCell(g)
0	0.020394
200	210.665851

2. Calibrate

a.

Relative Calibration Factor

Absolute Calibration Factor

3. Apply Calibration Factor

a.

5. Measure the zero load condition for the first calibration point (no calibration weight)
 - a. Enter “0” in the “Enter Weight” dialogue
 - b. Click “Read”
6. Measure one or more known weights in the same manner as above. Hang the weights from the upper gooseneck using the supplied calibration test weights. Centre them on the load-bearing surface to ensure in-line loads and use weights corresponding to the load cell capacity range. **Do not overload the load cell.**



7. Click "Run".
8. Click "Apply"
9. Click "Done"

Note: *Only take one reading per calibration weight used. Multiple readings of a single load value can cause an error in the calibration algorithm*

Be sure to re-zero the load cell in the horizontal testing position before running a test in this orientation

UStretch Tip: Calibration Factor

The relative calibration factor that is displayed in the main dialogue box at the end of the calibration procedure is the ratio of the current calibration value to the previous calibration value. If there has been no change to the load cell, this should be between 0.99 and 1.01.


The absolute calibration factor is the actual calibration factor in mV/V. This is typically between 20-40. If this is not the case, perform the calibration again or call the manufacturer for assistance.

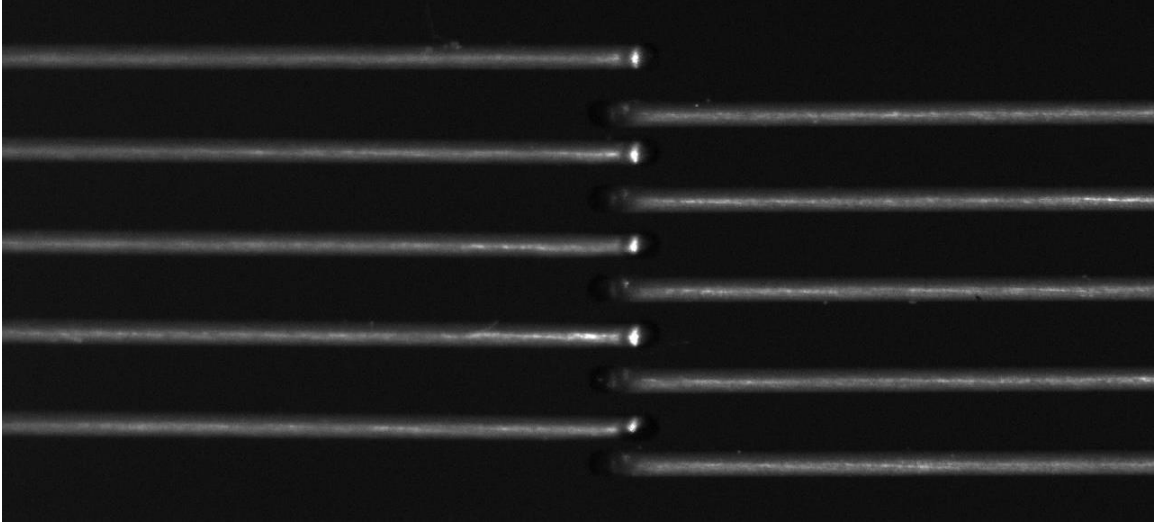
Zero Position Calibration

The actuator position is indicated in the “Current Size” dialogue on the left-hand side of the screen. This is the current separation of the BioRake tips or the front edge of the clamps. In order for this measurement to have meaning, a zero position must be defined. This is a position where the BioRake tips just overlap or the clamp tips would just touch each other.

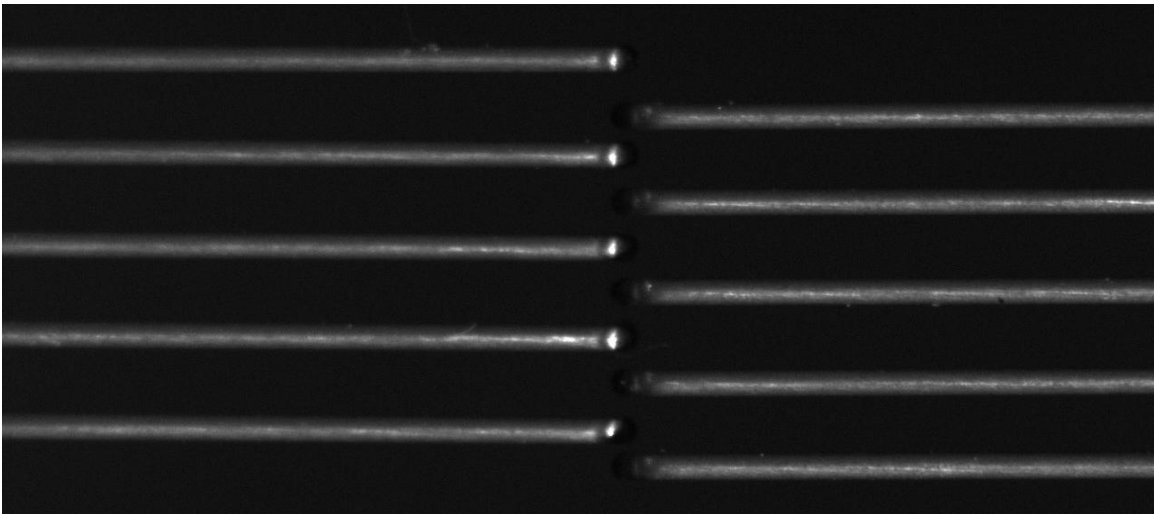
The “Move to Size” command is also dependent on a correctly defined zero position.

The actuator zero position is preset at the production facility before the UStretch unit is shipped. However, if the actuator zero position has been incorrectly reset or if the goosenecks or load cell has been changed, a zero position calibration must be performed.

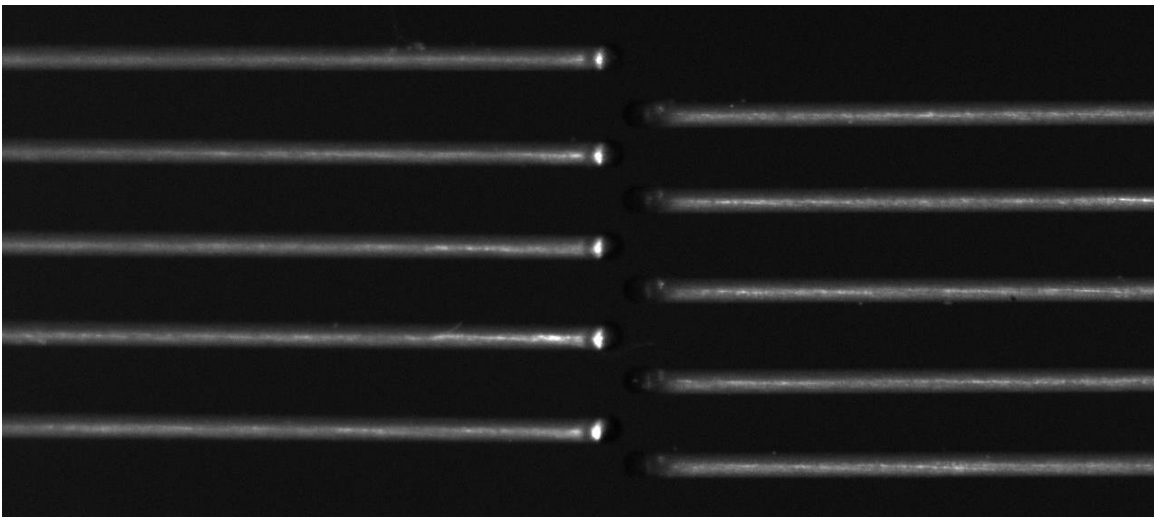
1. Select the reset actuators button  (or use *Tools>Reset Actuators*).
2. Place a BioRake on each gooseneck.
3. Using the actuator jog control arrows at the lower left of the screen, manually move the actuators until all 10 BioRake tips are collinear. The camera view can be used to provide a close-up of the rake tips for this procedure. Note that it is the tips of the BioRakes that should be collinear and not the outside edge. Because the tips are underneath the BioRakes and cannot be seen on screen, it is necessary to estimate their position. Please use the images below as a reference:



Example 1: BioRakes have too much overlap.

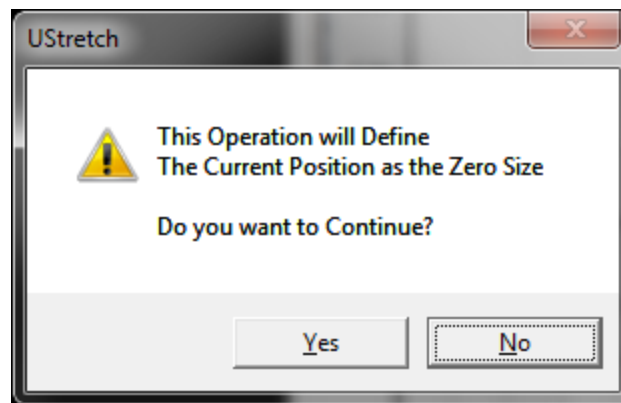


Example 2: BioRakes are correctly positioned.




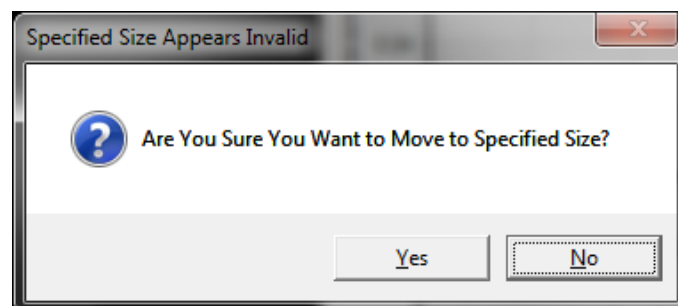
Example 3: BioRakes do not have any overlap so tips are not collinear.

4. From the *Tools* menu select *Advanced* and select *Zero Position Calibration*. This should bring up this dialogue box:



5. Press YES.
6. Select the reset actuators button  (or use *Tools>Reset Actuators*).

To check the zero position calibration, use the Move to Specified Size command . Enter Specified Size = 0mm for this step.



A warning dialogue will appear. Select YES.

Place a BioRake on each gooseneck and compare the position of the rakes to the image in step 3 above.

After a successful zero position calibration, the actuator can be successfully moved to a given sample size before beginning a test (for example, 5mm).

Snap Image Feature

Located under >Tools>Snap Image

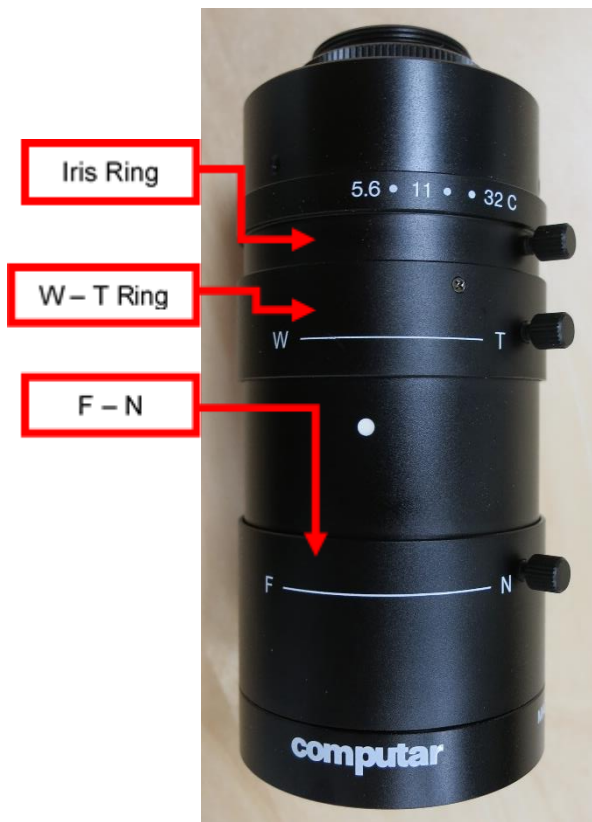
This feature allows the user to capture a single image during the setup phase. This can be useful for documenting specimen loading activity and neutral (non-contact) beam position.

Adjusting the Camera Position and Image Magnification

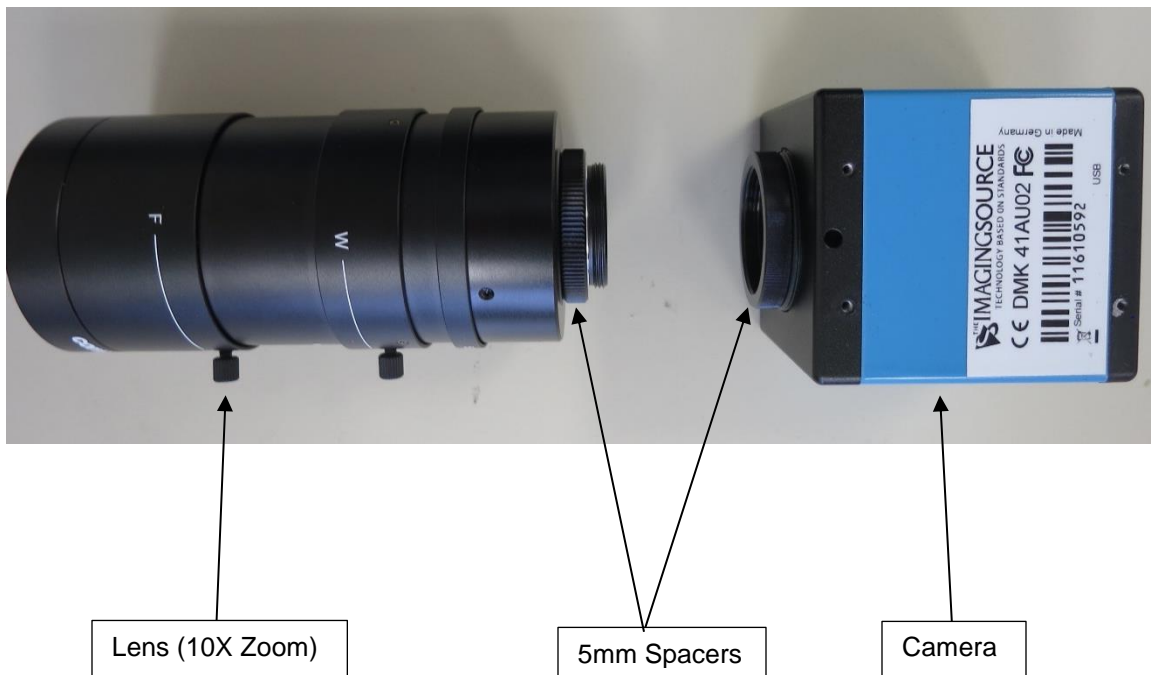
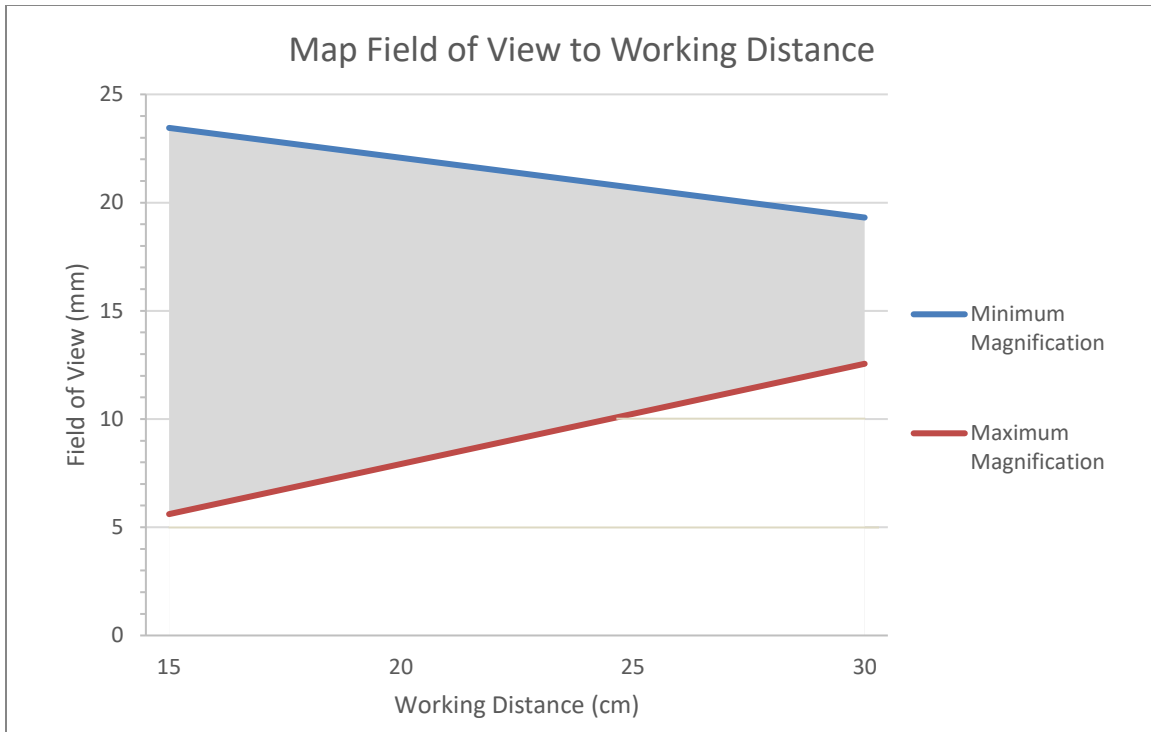
The UStretch comes equipped with a 10X zoom lens as shown below. Other versions of the UStretch may be equipped with a fixed magnification 50mm or 75mm focal length lens (see Appendix D instead).

The image magnification and focus can be changed by rotating the adjustable rings found on the lens. Once the rings are adjusted to the desired settings, they can be locked using the thumb screws. Adjusting the three rings have the following effect:

1. The iris ring changes the brightness of the image. It is recommended to leave this ring fully open and control image brightness by adjusting the camera shutter and gain in the Camera tab of the Hardware Settings.
2. The W – T ring changes the magnification of the lens.
3. The F – N ring changes focus of the lens.

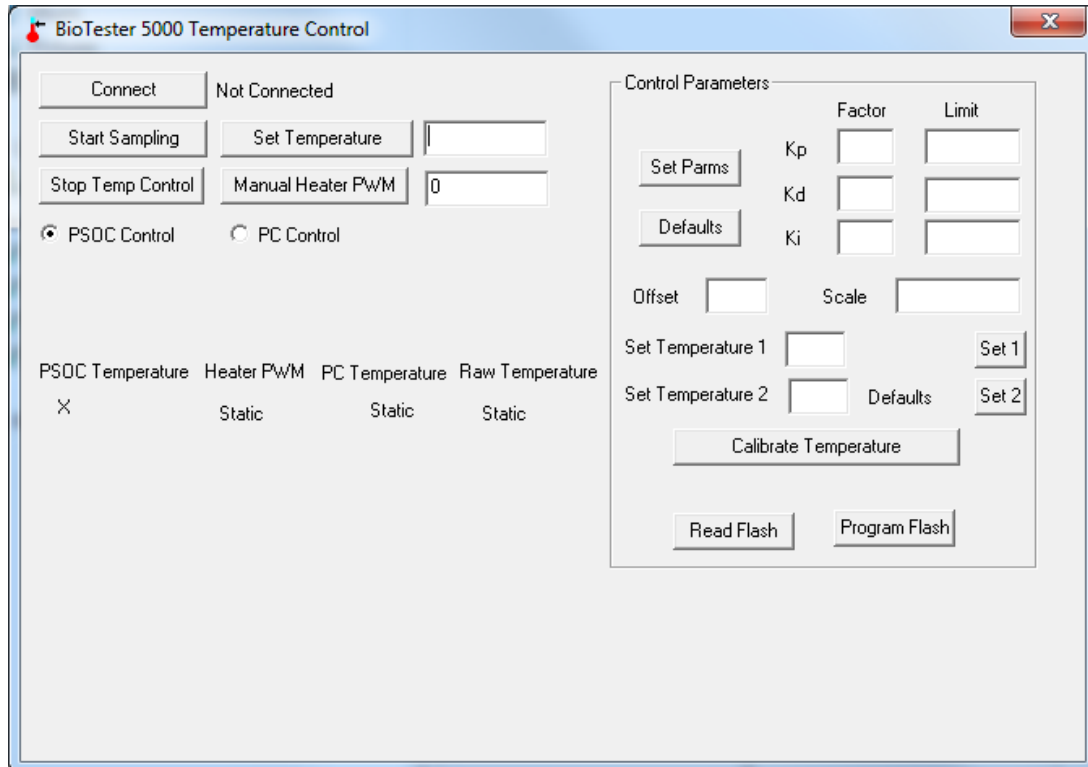


Using this lens, it is possible to achieve a wide range in the field of view as shown in the graph below. Possible values for field of view are shown by the shaded gray region of this graph and can range from 5.5mm to 24mm. The smallest fields of view are achieved at shorter working distances (that is, the camera is closer to the specimen). To adjust the camera position, adjust the screws on the camera mounting brackets. The ideal distance from the specimen to the lens is 15cm. It is not recommended to have the lens any closer than this.



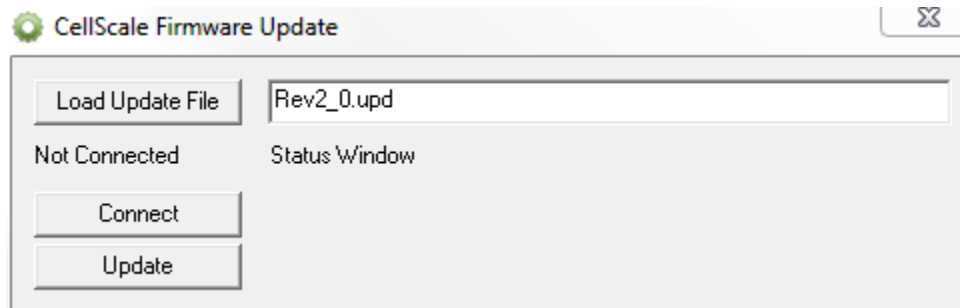
Temperature Sensor Calibration

1. With the UStretch connected to the PC and turned on, launch the temperature calibration software located in the Windows start menu under UStretch>Utilities.
2. Click the “Connect” button to establish communication between the software and the temperature controller. The dialogue box should read “Digital temperature sensor in use”.
3. Click the “Defaults” button to load the default control parameters from the temperature controller.
4. Click the “Set Parm’s” button to assign the on screen parameters.
5. Click the “Program Flash” button.
6. The digital temperature sensor and temperature control parameters are now calibrated.



Update Firmware

1. With the UStretch connected to the PC and turned on, launch the firmware update software located in the Windows start menu under UStretch>Utilities.
2. Load the desired firmware file using the “Load Update File” button.
3. Click the “Connect” button.
4. Execute the update using the “Update” button. This process can take many minutes to complete.



9. Troubleshooting

Image Appears Out of Focus

With the live image on the screen, adjust the lens focus until the image appears to be in focus.

Whenever you adjust the focus, the image magnification may change slightly. If you want to know the absolute scale of your Images you can snap an image of a calibrated target (such as a precision graticule or ruler) by selecting Snap Image from the Tools menu. You can estimate the image scale by comparing the number of pixels between rake tips in the images with their known μm spacing (size) in the data output files.

Communication Errors: ReadFile failed with error 6.

When communication errors occur the live message window will display a ReadFile failed message. Communication errors can occur if:

- The UStretch is not powered up.
- USB cables between the computer and UStretch are disconnected.
- The supply power surges or is interrupted.

When a communication error occurs, close UStretch software, check connections, power cycle the UStretch Device, and restart the UStretch software.

UStretch Tip: Preventing Power Disruptions

We recommend plugging the UStretch (and host computer) into an uninterruptable power supply (UPS) or battery back-up.

10. Appendix A: Unpacking and Initial Setup

Step 1: Unpack all components and have them ready for assembly.



Step 2: Remove the cover from the main unit.

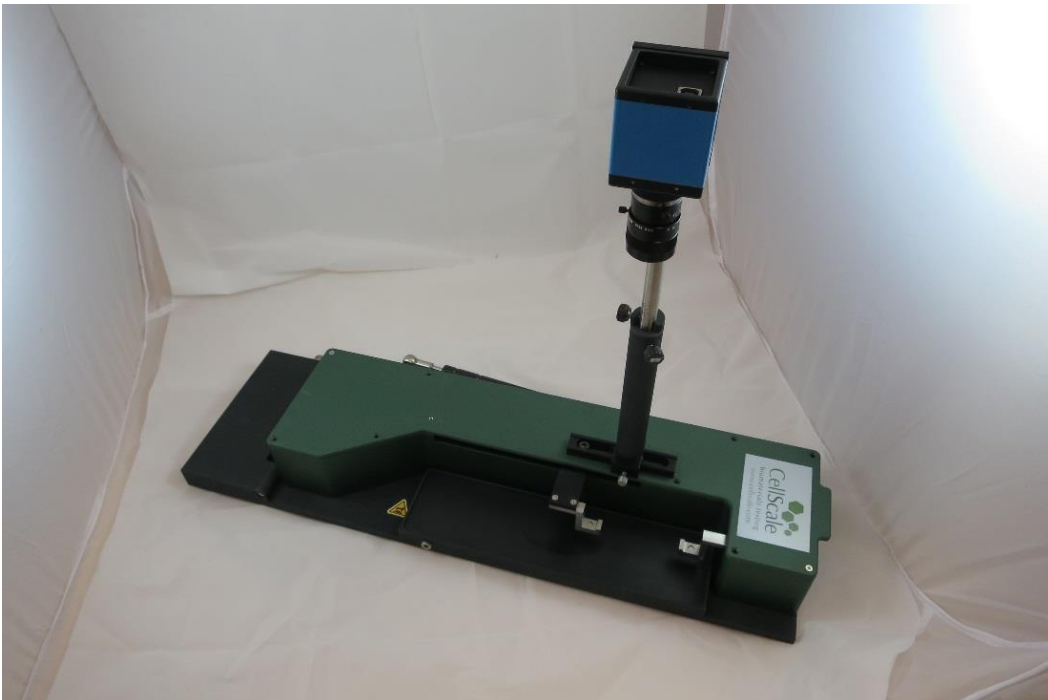


Step 3: Attach the load cell and replace the cover.

Refer to **Appendix C** for more details on this procedure.

**Step 4: Attach the imaging system.**

Slide the main post holder over the positioning rail and tighten with the finger screw. Attach the post riser to the camera bracket and slide the post in the post holder. More information on adjusting the camera position and magnification can be found in Section 8 of the User's Manual. Two different post sizes are included to accommodate various camera offsets.



Step 5: Position the fluid bath and temperature sensor.

Put the fluid bath in place. Insert the temperature sensor in the sensor pocket. Excess cable can be fastened with the included plastic C-clamp.



Step 6: Attach the light source.

An LED lamp is included for specimen imaging. It is USB powered and can be clamped to the UStretch base or lab bench.



Step 7: Connect the controller to the test unit.

3 connections are required: one for the main unit (large circular connector to the main unit), one for the heater (small circular connector to the black base plate), and one click connector for the temperature sensor.

***Step 8: Install the UStretch software.***

See **Appendix B** of the User's Manual for more information.

Step 9: Connect the UStretch controller and camera USB cables to the PC, connect the power cable

A 48V brick power supply powers the UStretch system via a barrel connector on the front of the control box. The UStretch controller and camera are connected to the PC via individual USB connections. A third USB connection may be needed to power the LED lighting system. Connect the USB cables and power on the UStretch unit.

Step 10: Launch the software and begin a test to ensure the device loads up normally.***Step 11: Calibrate the Load Cell***

See **Section 8** of the User's Manual for more information.

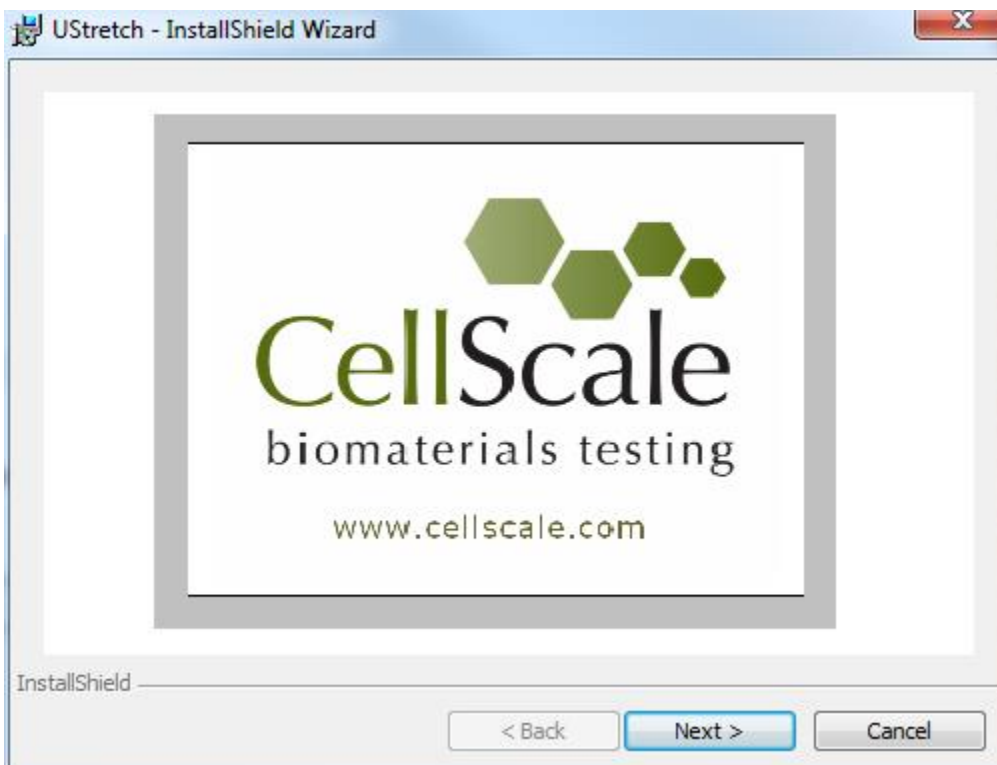
Step 12: Begin Testing

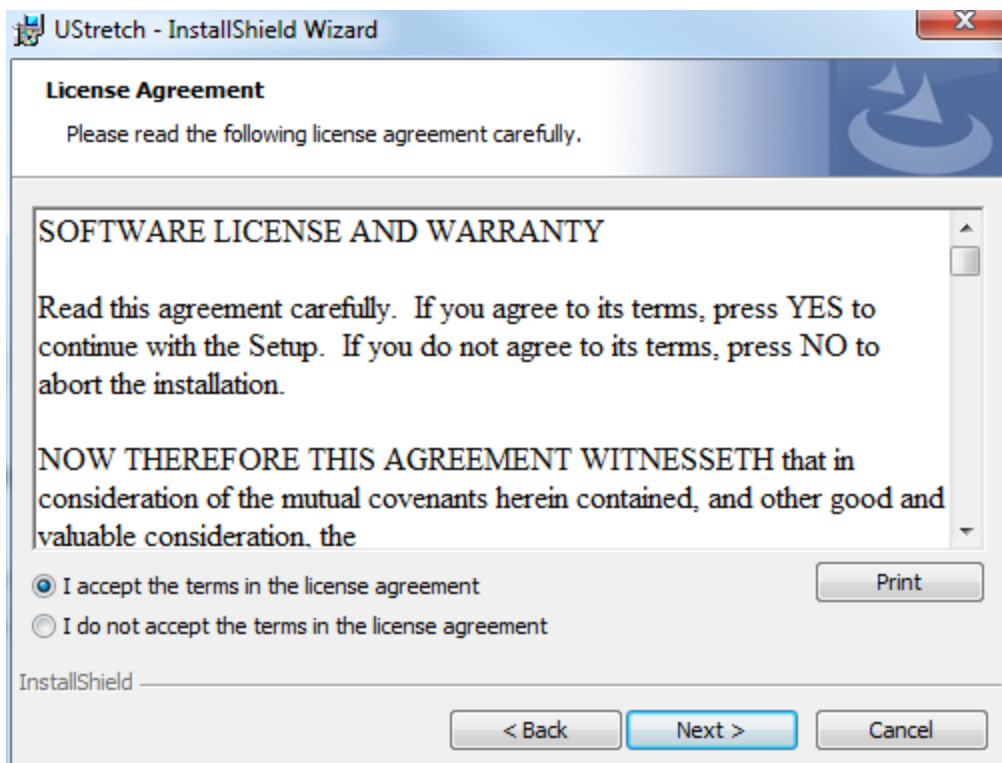
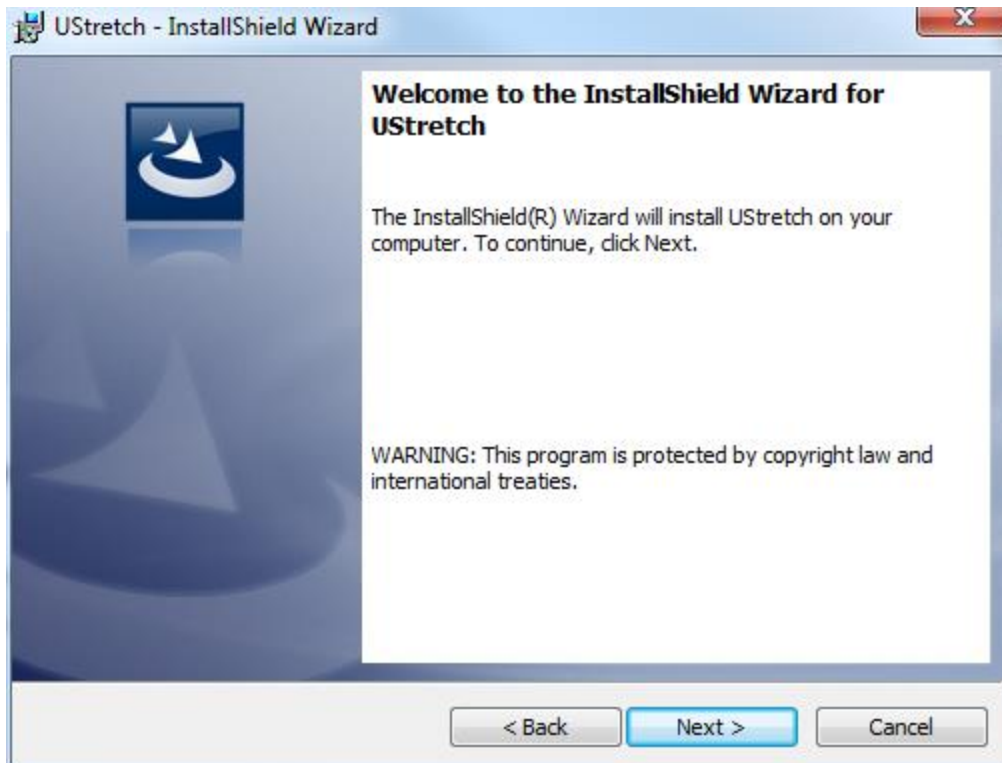
It is recommended that the User's Manual be thoroughly reviewed before beginning testing using the UStretch system. Procedures for loading samples, setting up tests, carrying out tests, and reviewing results are described in detail.

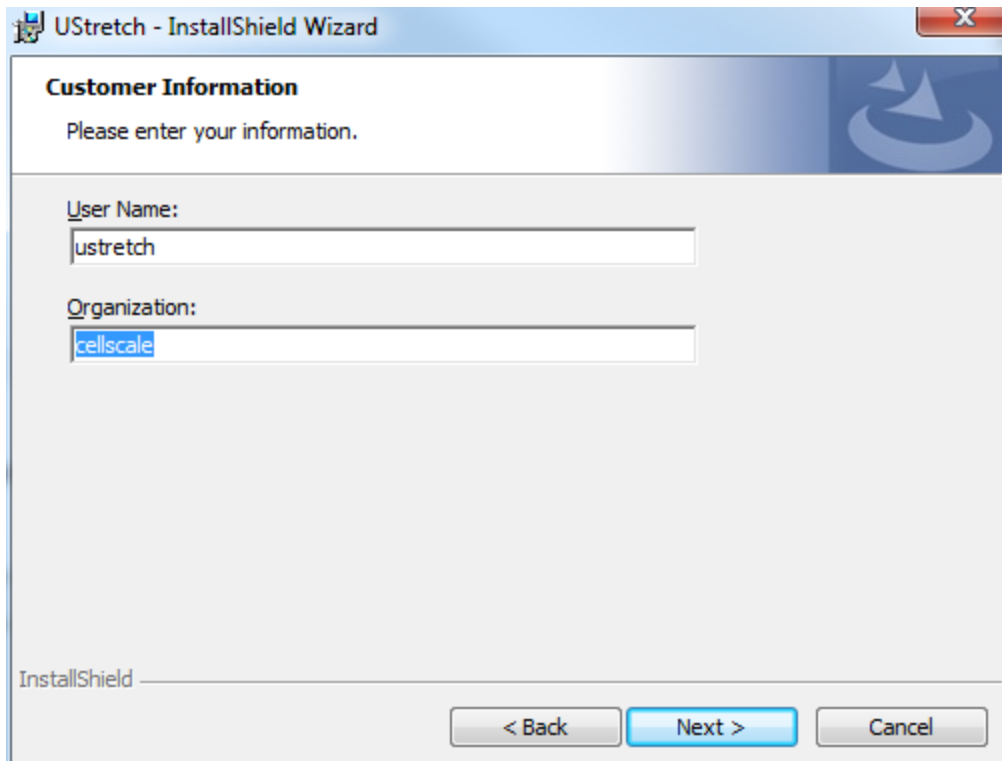
11. Appendix B: Software Installation

A Windows based PC (Windows 7 or above) with at least 2 USB ports is required to operate the UStretch. A label on the cover of the manual contains a web address to download the UStretch software installation package. These files contain the software installer for the user interface and control software for the UStretch.

To install the software, go to the provided web address and download the compressed installation package. Transfer this file to the computer which will be running the UStretch. Right click on the file and select "Extract All..." to unzip. After this is complete, go to the uncompressed installation folder and select "setup.exe". Details of typical dialogue boxes are shown below.







UStretch - InstallShield Wizard

Customer Information

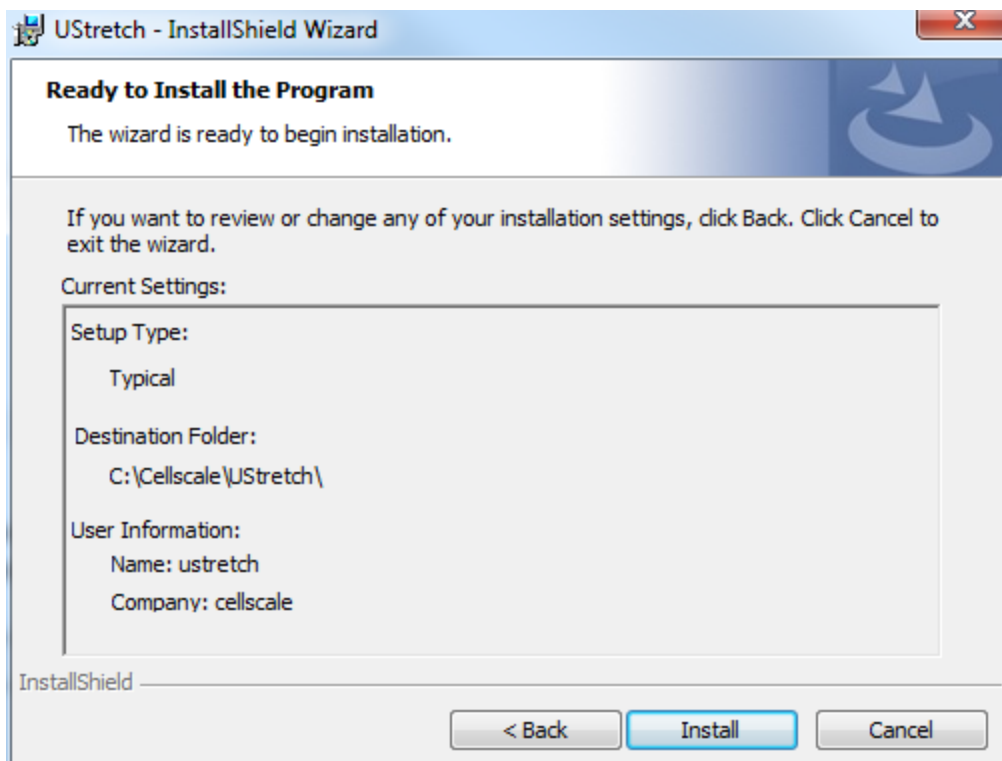
Please enter your information.

User Name:
ustretch

Organization:
cellscale

InstallShield

< Back Next > Cancel



UStretch - InstallShield Wizard

Ready to Install the Program

The wizard is ready to begin installation.

If you want to review or change any of your installation settings, click Back. Click Cancel to exit the wizard.

Current Settings:

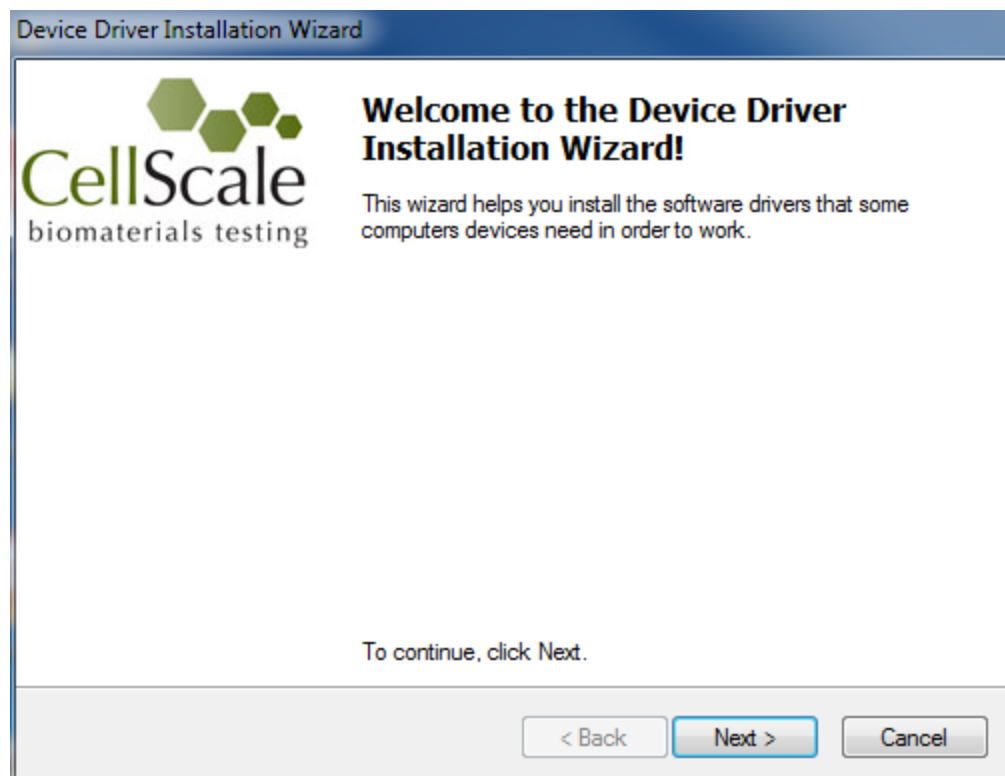
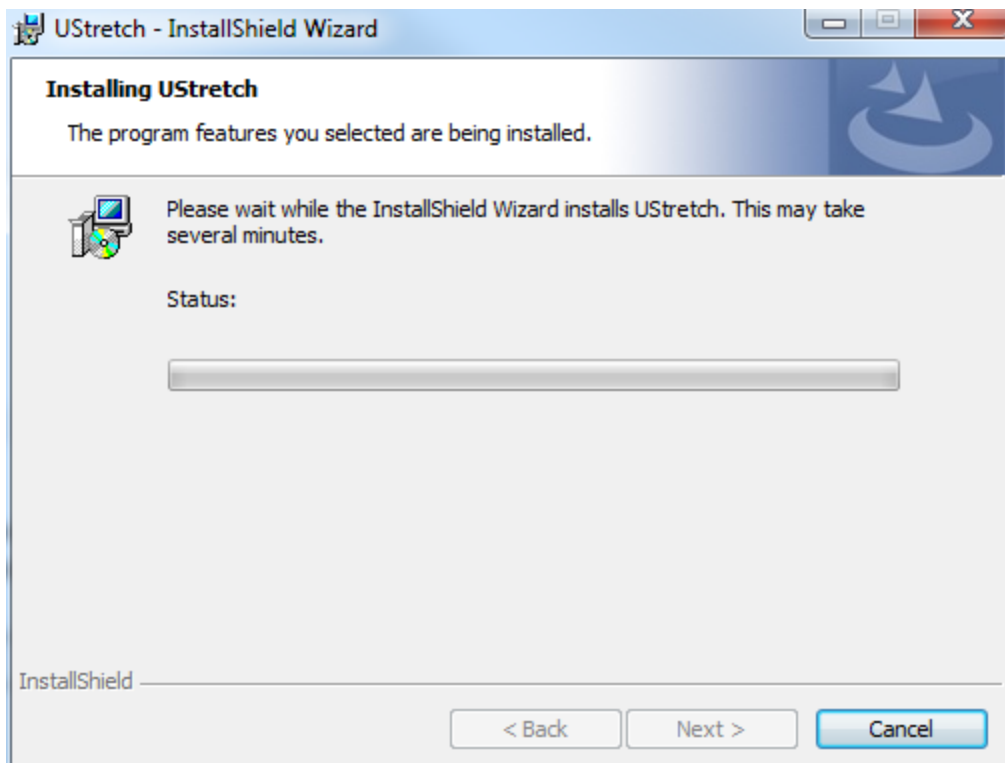
Setup Type:
Typical

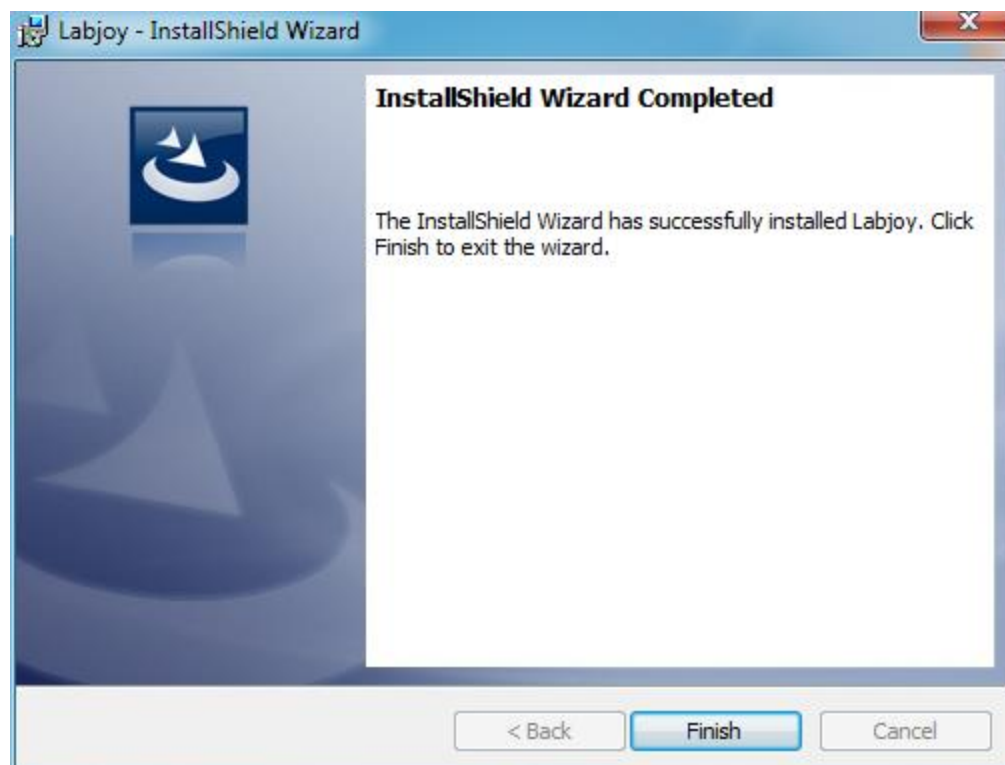
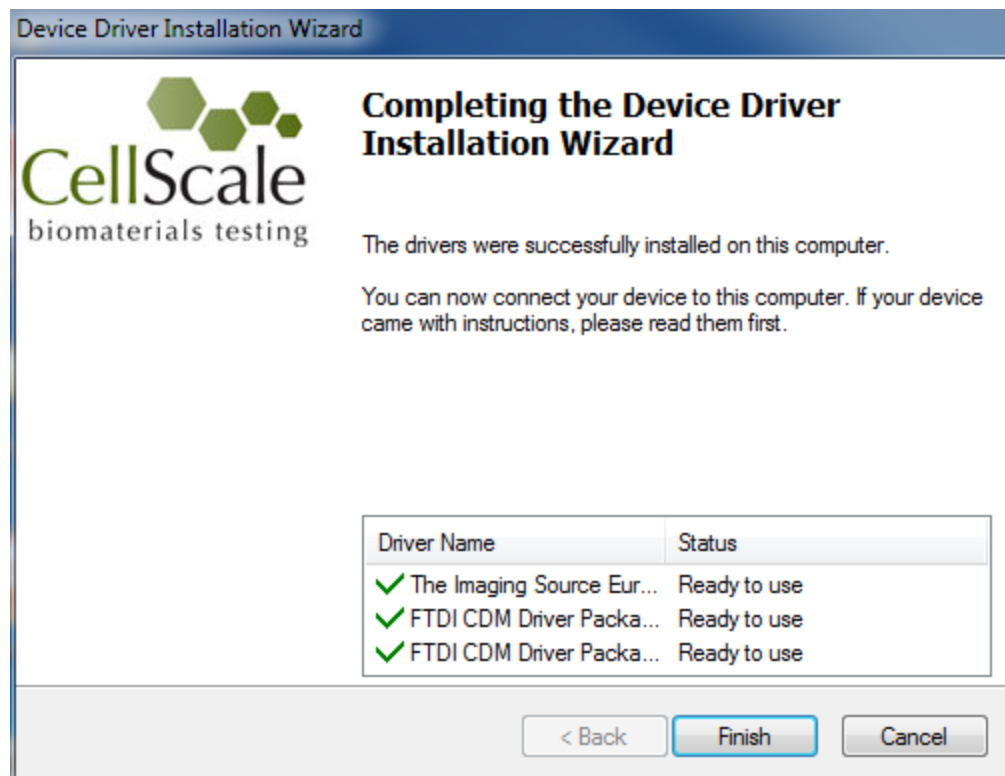
Destination Folder:
C:\Cellscale\UStretch\

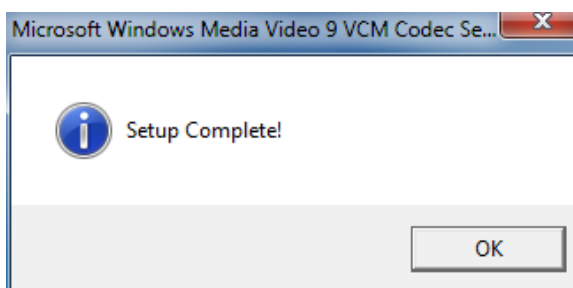
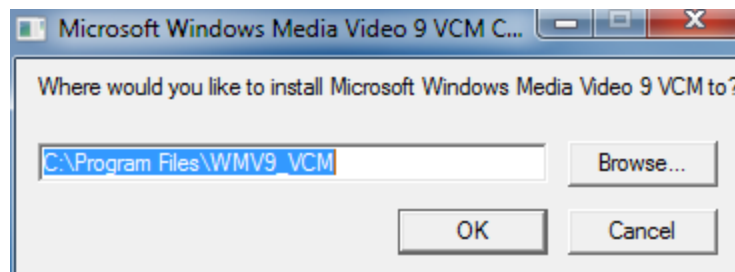
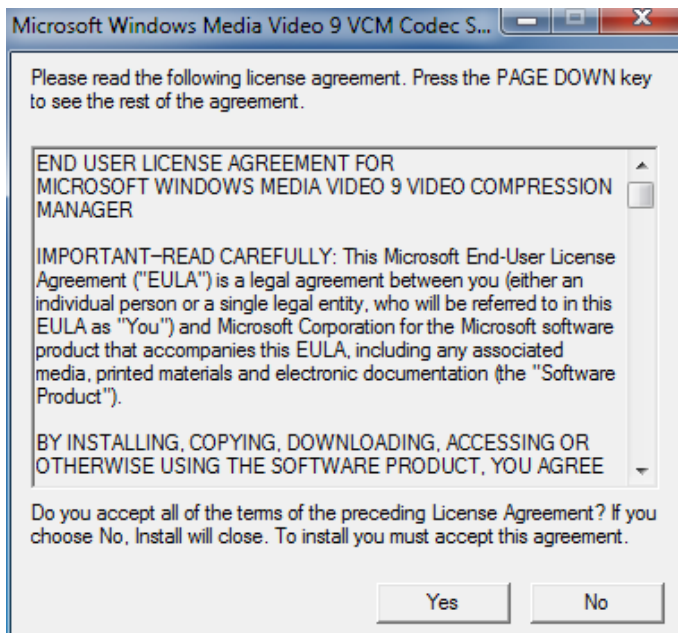
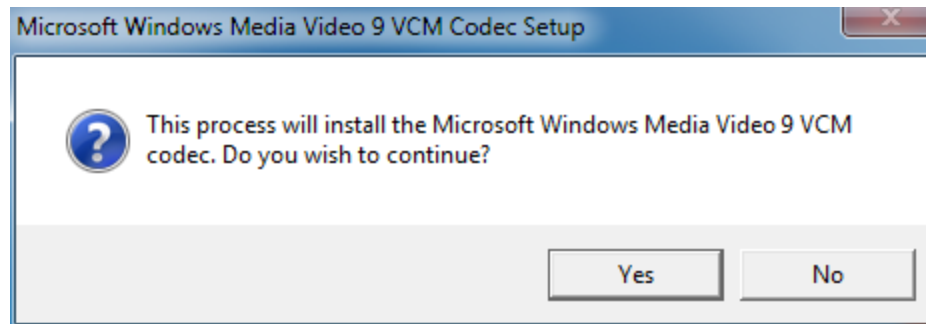
User Information:
Name: ustretch
Company: cellscale

InstallShield

< Back Install Cancel





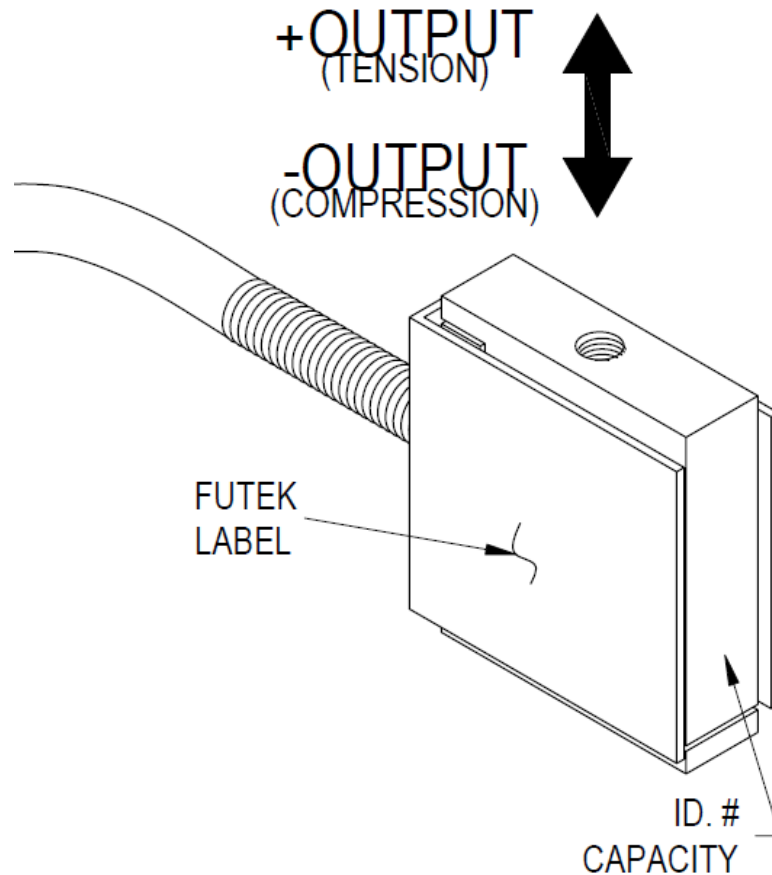


12. Appendix C: Load Cell and Gooseneck Installation

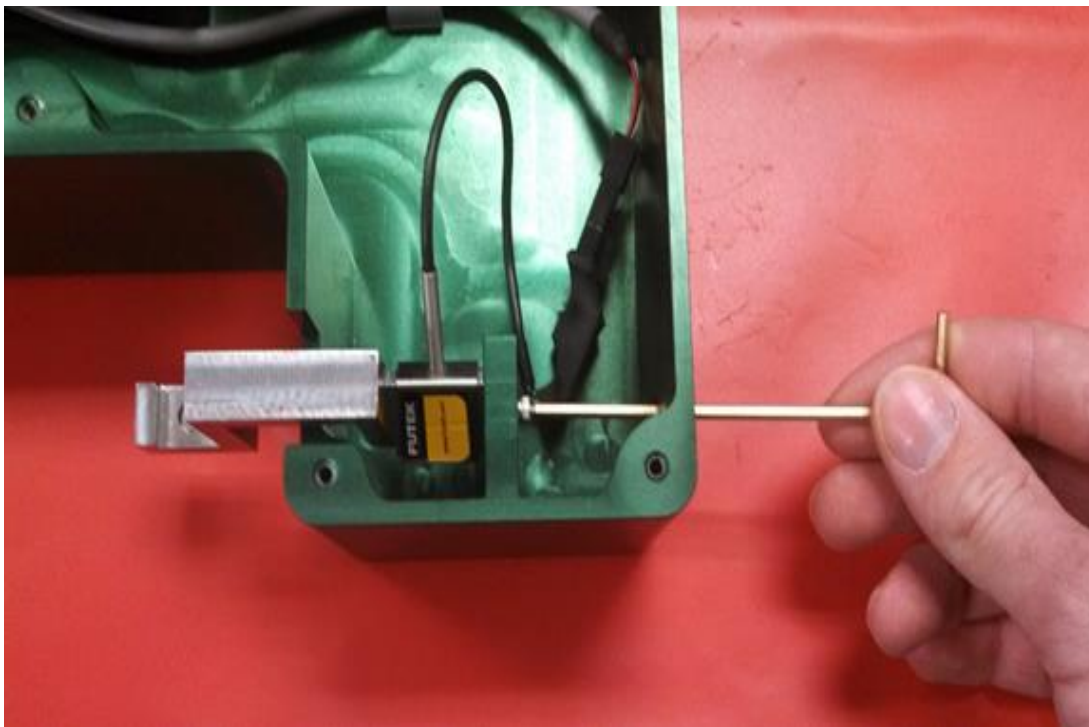
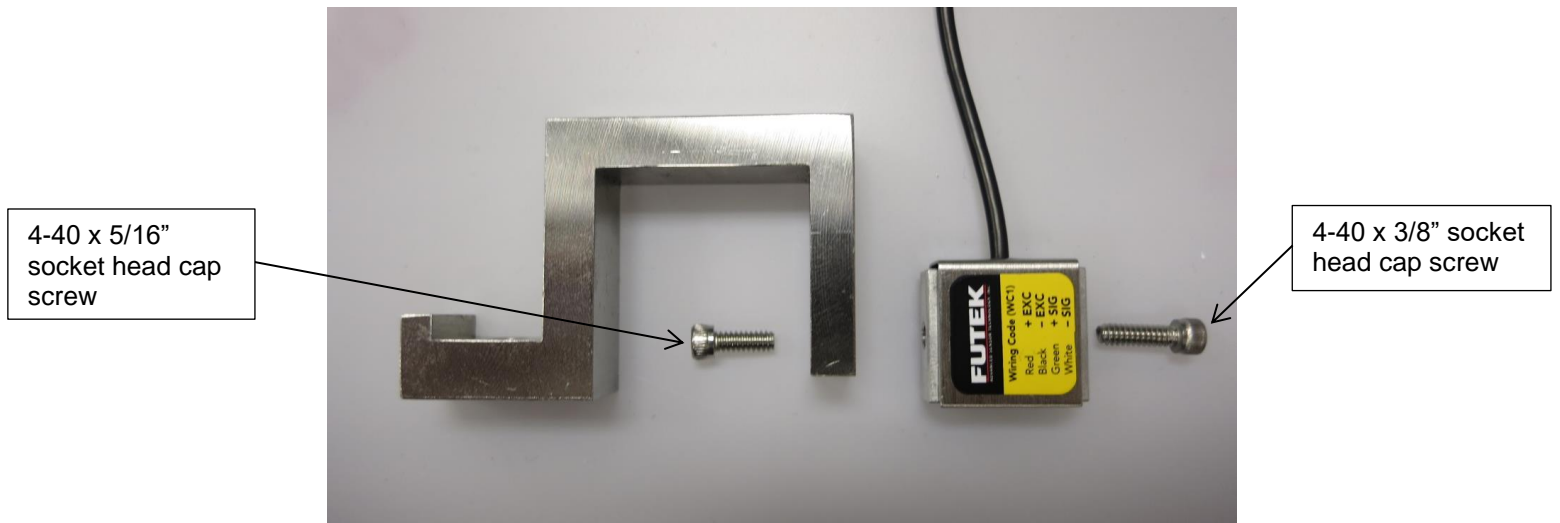
Start by removing the main cover (9 x M3 counter-sunk screws)

Attach the Load Cell to the Gooseneck and the Main Body

Ensure the correct orientation of the load cell and tighten the screws gently to avoid damaging the load cell (a bit tighter than finger tight). Ensure the load cell is angled as shown, the “measuring end” is connected to the gooseneck, and the fasteners attached in the correct order and position (see below images). Use the appropriate gooseneck the load cell being used (black plastic for the 0.5N load cell, stainless steel gooseneck for 1N, 2.5N, 4.5N, 8.9N, 22N, 44N load cells.)



Load cell female threads are 2.8mm deep



First select an appropriate gooseneck. Use the stainless steel gooseneck for the 1N, 2.5N, 4.5N, 9N, 22N and 44N load cells. Use the lighter **black plastic** gooseneck for the **0.5N** load cell.

The load cell should be rotated about 30° away from the user (see above) to properly stabilize the gooseneck yet avoid interference with the cable from the UStretch cover. Also, the **Futek** symbol (black background) on the load cell label is the “**measuring end**” and should be **attached to the gooseneck and not the main body**. Reversing the orientation can introduce offsets in the force data.

Attach the gooseneck to the load cell using the 4-40 x 5/16" fastener and the 3/32" hex key. Insert the hex key through the access hole to tighten the load cell to the UStretch main body using the 4-40 x 3/8" fastener. Ensure that the gooseneck is level. Attach the load cell connector to the cable and neatly tuck away any excess cable. Replace the main cover.

System Alert

*The load cell is designed for in-line loads only. An excessive transverse load or bending moment applied to the gooseneck can **permanently damage the load cell**. Care should be taken, especially when installing the load cell and attaching samples.*

13. Appendix D: Fixed Focal Length Lens

In addition to the 10X zoom lens described in Section 8, the UStretch system can also use fixed focal length lenses. Other UStretch models may have a 50mm or 75mm focal length lens and a set of lens spacers. Other focal lengths are available and are compatible with the BioTester system.

Adjusting the Camera Position and Image Magnification

The camera position can be adjusted using the screws on the camera mounting brackets.

Using the 50 or 75mm focal length lens and lens spacers, it is possible to achieve a field of view ranging from 9mm to 30mm. The details of the appropriate number of spacers and the required standoff are shown in the table below. The image magnification can be changed by adding or removing spacer tubes located between the camera body and the lens. Increasing the total spacer tube length will result in higher magnification while reducing the tube length will result in lower magnification. Changing the tube length will also change the working distance of the lens. To adjust the vertical position of the lens and camera assembly, loosen the locking screw on the camera post and raise or lower the camera until the image is in focus. It is helpful to make sure the lens focus ring is in the middle of its rotation so that fine tuning the image focus can be done once the camera position is fixed using the camera post locking screw.

NOTE: INCREASING THE TOTAL LENGTH OF THE SPACER TUBES WILL INCREASE MAGNIFICATION (DECREASE FIELD OF VIEW) AND DECREASE WORKING DISTANCE (STAND-OFF).

The camera lens has two adjustable rings: a focus ring and an iris ring. The iris adjusts camera brightness and is typically left at the brightest possible setting. Further adjustments to brightness can be made in the software (shutter and gain setting). As mentioned above, the focus ring is used to make fine adjustments to the camera focus.

As the table and graph also show, it is also possible to swap in a lens with a different focal length to achieve a different range of magnifications. This data was collected using the family of fixed focal length lenses available from Edmund Optics (the part numbers are shown in the table). The camera has a C-mount connection, making it possible to mount a wide variety of optical components to best suit any application. Currently, only the standard camera is supported.

	25mm (NT56-529)			35mm (NT56-530)			50mm (NT56-531)			75mm (NT56-532)			100mm (NT56-675)		
Spacer (mm)	Stand off (mm)	pix/c m	FOV (mm)	Stand off (mm)	pix/c m	FOV (mm)	Stand off (mm)	pix/c m	FOV (mm)	Stand off (mm)	pix/c m	FOV (mm)	Stand off (mm)	pix/c m	FOV (mm)
0	685	78.6	162.8	1070	71	179.3	930	121	105.9						
5	100	520	24.6	215	373	34.3	370	329	38.9	820	206	62.2	1540	147	86.8
10	53	935	13.7	125	682	18.8	235	560	22.9	450	404	31.7	950	258	49.6
15				90	993	12.9	185	779	16.4	350	534	24.0	675	366	34.9
20				73	1273	10.1	160	978	13.1	285	711	18.0	535	473	27.0
25							135	1186	10.8	245	859	14.9	455	578	22.1
30							125	1410	9.1	220	959	13.3	400	687	18.6
35							115	1630	7.9	200	1111	11.5	355	797	16.1
40							105	1842	6.9	185	1260	10.2	320	897	14.3
45							100	2068	6.2	170	1392	9.2	295	1003	12.8

